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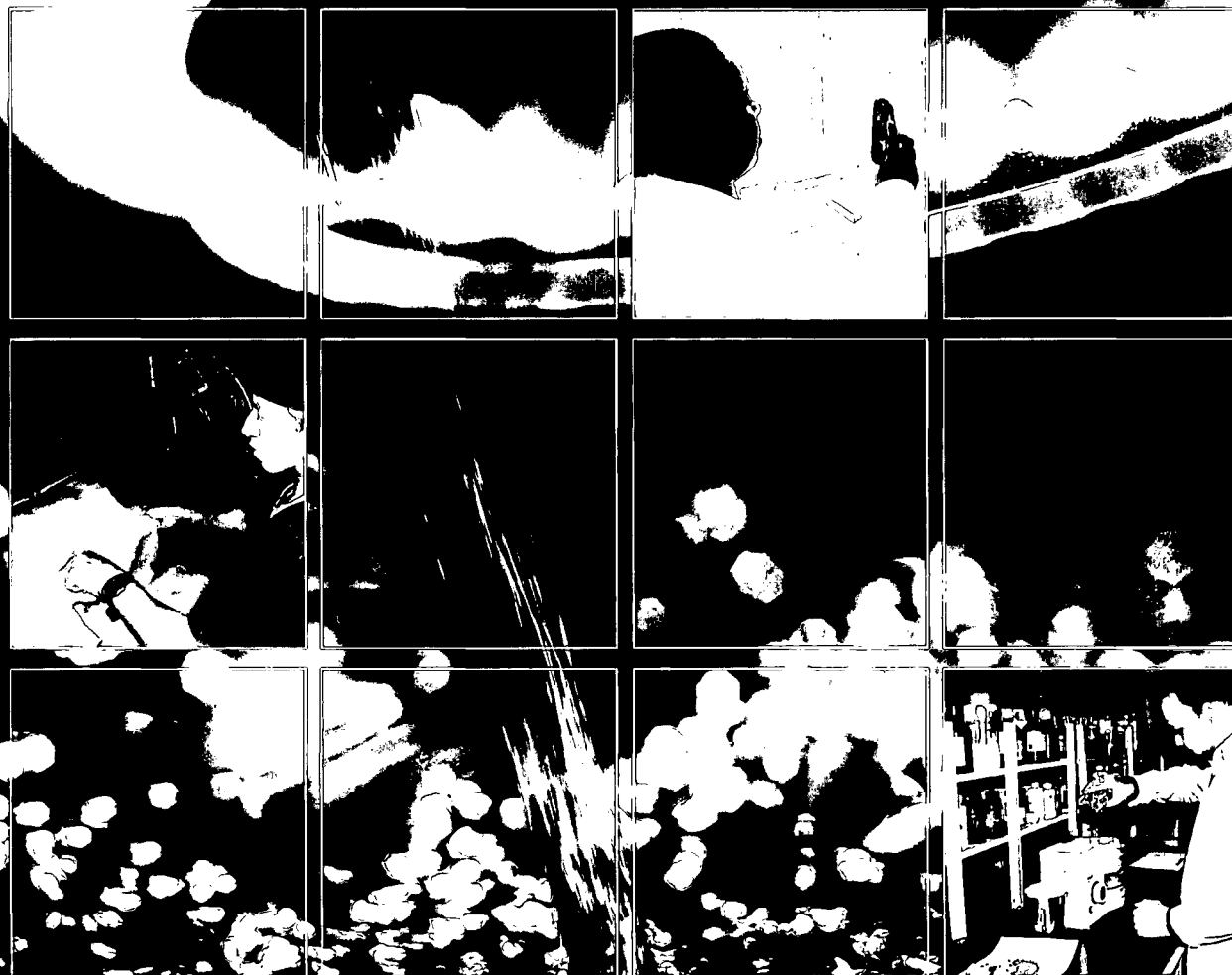
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Assessing the Uptake of Environmentally Sound Technology

Highlights from a UNIDO Survey in Nine Developing Countries



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

economy environment employment

UNIDO and the World Summit on Sustainable Development

*Assessing the Uptake
of Environmentally Sound
Technology*

Highlights from a UNIDO Survey in
Nine Developing Countries



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2002

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Introduction

Technological change is key for achieving sustainable development. Economic growth—the condition *sine qua non* for poverty reduction—crucially depends on it as does the preservation of environmental quality.

UNIDO fully underscores the importance of firm-level technological change for initiating a path of sustainable development. The Organization actively works with relevant national and international stakeholders to foster productivity growth in developing countries and economies in transition. Productivity growth results from producing goods more efficiently, producing goods of better quality and producing new goods. This attribute of newness precisely relates to innovation and technological change.

In broad terms, technological change can be defined as "any change in the way in which inputs are transformed into outputs". Undertaking such a change requires information, knowledge and skills on the part of the firm as well as a conducive business environment. The importance of understanding this change process and its determinants is obviously crucial for stimulating the growth of higher value production in developing countries. Moreover, an improved understanding of this process is instrumental in defining how public policy can shape technological change towards more environmentally benign directions. While the recent study of technological change in developing countries has greatly advanced our insight into this phenomenon, more theoretical and empirical work is still needed—particularly in terms of the environmental aspects of this process.

It is for this reason that UNIDO has undertaken a research project with the objective of determining the factors that govern the uptake of environmentally sound technology (EST), which includes a variety of cleaner technology measures as well as pollution control solutions, in a variety of circumstances. The project thus aims to contribute to the debate on the subject and further the understanding of how environmentally-sound technological change can best be stimulated in developing countries. The project once more underscores UNIDO's commitment to sustainable industrial development and builds upon the insights gained from years of technological assistance in the areas of technology development and cleaner production. Results of this research project will feed into the Organization's policy advisory services and technological cooperation interventions.

Objective of the research project

The aim of the project is to gain a better understanding of the factors that govern the uptake of EST. In full recognition of the fact that a host of reasons cause firms to utilize EST, the project not only aims to document factors influencing EST uptake, broadly classified as both motivating factors (drivers) and enabling factors (conditions), but also to assess their relative importance according to firm- and country-specific circumstances. Motivating factors are drivers such as supply chain and regulatory pressures. Examples of enabling factors are financial capacity and technological capability.

Conceptual framework

The conceptual framework for this research draws on evolutionary economic theory¹ and more specifically on a system of innovation approach² to technological change. Thus, the framework is based on a system-view of technology and economic activity and emphasizes the importance of learning and adaptation. It looks at ways in which institutions (economic, social and political) shape and limit economic decisions and technology choices. It also considers the interactive learning processes between different agents (suppliers and users) with respect to technological change. Seen from this perspective, a firm's decision to adopt a technology/undertake technological change is considered a function of many variables/determinants, both internal and external to the firm. In this way the framework departs from neoclassical economic thinking with its explicit recognition of firm heterogeneity—particularly in terms of a firm's response capacity to regulatory pressures and to incentives, such as changes in the price and demand structure. Firms in developing countries, in particular, are often constrained by cognitive limitations, by their technological capabilities or by institutional constraints.

Figure 1 illustrates the systemic view adopted in this research. It is a stylized representation of the determinants of environmentally-sound technological change at firm level.

The determinants of technological change, including introduction of various types of EST, vary from firm to firm and eventually depend on a firm's strategy, management and resources (including technological capability). Indeed, the variety of firm responses to external incentives and pressures could, broadly speaking, be explained in terms of firm differences in these three dimensions. At the same time, these firm dimensions are a function of the overall economic and social environment in which a firm operates.

A firm's business environment is a reflection of complex interactions among incentives, factor markets, institutions and societal environmental pressures. Incentives are the

signals emanating from the market (competitive pressures at home and abroad, changing demand conditions, growth prospects and the like) and the policies that influence these signals. Institutions are both the rules of the game (legal, e.g. environmental standards and operating conditions) and a range of organizations. This range encompasses organizations that design policies, set regulations and oversee their enforcement; intermediary agencies (providing technological support services, R&D, standards, quality, training, finance) which supplement factor markets; and private sector associations. Factor markets include all the inputs that enterprises need, from material inputs and infrastructure services (e.g. energy and water) to finance, labour, technology and information.

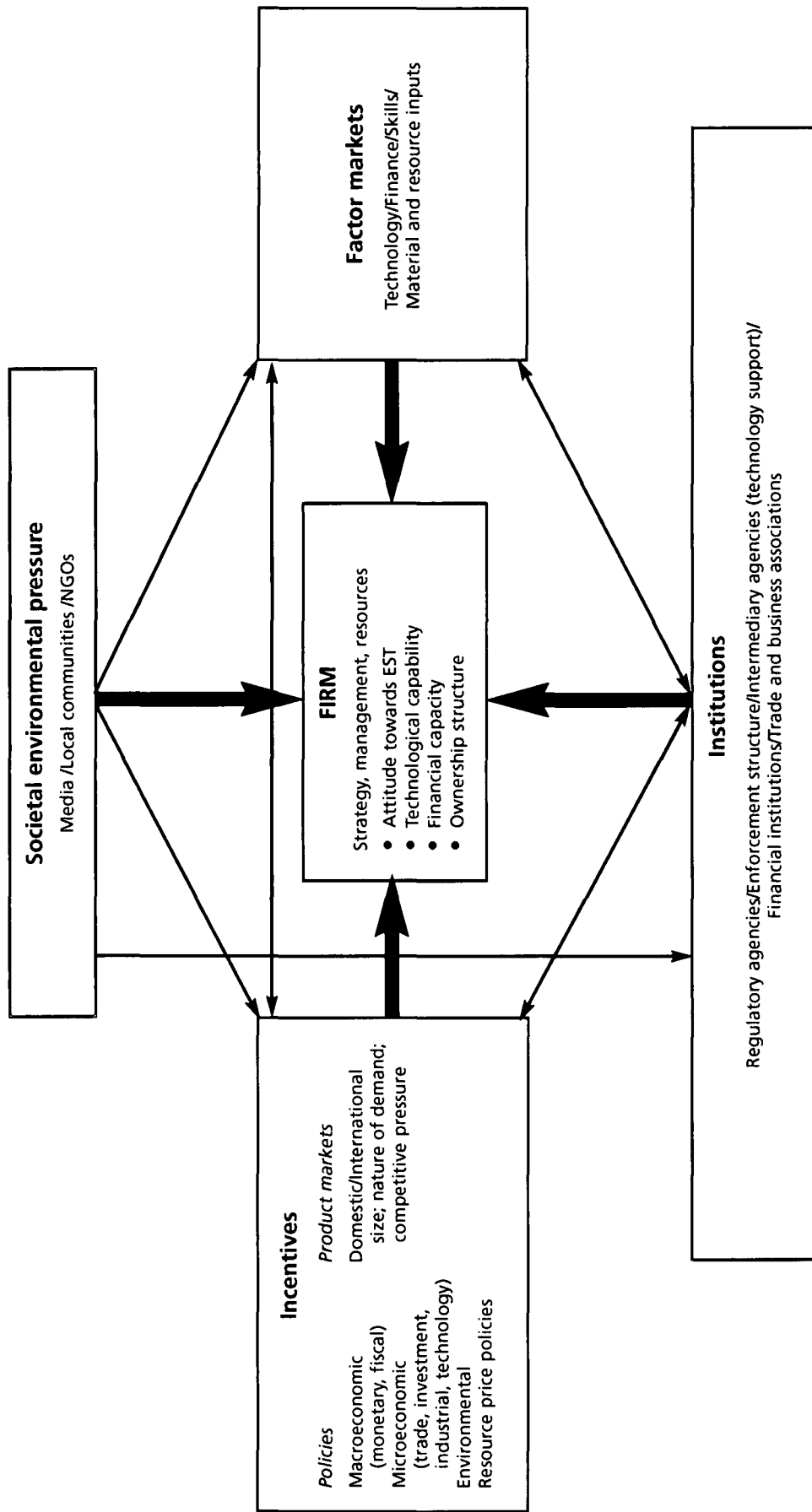
The interacting triad of incentives, institutions and factor markets constitute, what is termed an "industrial learning system". It conceptualizes the economic environment in which firms undertake technological change and emphasizes the learning aspects in adopting new technology. As the successful adoption of new technologies depends on a firm's technological capabilities, developing these capabilities is considered crucial for responding to opportunities and pressures and undertaking technological change at various levels of complexity. Technological change, and the underlying learning processes, work best in a dense network of efficient enterprises, institutions and markets. Complementing this system are social forces with the potential to influence the direction of technological change, namely the environmental pressure exerted by civil society, local communities and the media. A firm's technological effort, including the type and degree of EST response, depends vitally on this system. The effectiveness of the system in promoting, supporting and directing firm-level technological efforts depends on how effectively each of these sets of factors operate and interact.

Within this conceptual framework a firm's technological choices and environmental responses are seen in terms of the specific external and internal conditions facing the enterprise. A firm's strategy and management decisions are considered to be a reflection of its efforts to match external pressures and opportunities with its own internal characteristics (notably its resources). Companies within the same industry, struggling with the same type of environmental problems, may choose different technological trajectories and environmental responses depending on their internal resources.

¹Nelson, R. R. and Winter, S. G. (2002), "Evolutionary Theorizing in Economics" *Journal of Economic Perspectives*, vol.16, No.2, Spring, pp. 23-46.

²Edquist, C. and M. McKelvey, eds. (2001) *Systems of Innovation: Growth, Competitiveness and Employment*, Cheltenham, U.K., Edward Elgar. UNIDO (2002), *Competing Through Innovation and Learning*, Industrial Development Report 2002/2003, Vienna, Austria.

Figure 1. Determinants of the uptake of EST at firm level





The survey

Scope

The main features of the survey can be summarized as follows:

- The survey was conducted in nine countries, representing a broad range of levels of economic/industrial development (Brazil, China, India, Kenya, Mexico, Thailand, Tunisia, Viet Nam, Zimbabwe) by teams of national experts (annex I);
- Four highly-polluting industrial subsectors were studied, representing a broad technological spectrum, namely textile dyeing and finishing, leather tanning, pulp and paper and iron and steel;
- A large number of firms were interviewed (a total of 105 enterprises, stratified according to a number of dimensions: scale, ownership, market orientation and environmental performance);
- A variety of "other key informants" were consulted, namely business associations, technology centres, raw material/equipment suppliers, NGOs and regulatory authorities (in total, 130 other key informants have been interviewed); and
- Enterprise data were collected for a ten year period (1991–2000)

Annex II summarizes the number and type of informants interviewed per country.

Methodology

Developing a better understanding of the determinants of EST adoption requires one to "go inside the firm" and

investigate the external and internal factors which influence a firm's management to undertake EST-related technological changes. The methodology adopted in this project, therefore, comprised face-to-face interviews with managers to probe into firm-level decision-making. Interviews with business associations, environmental regulatory agencies, technology centres, raw material/equipment suppliers and NGOs were undertaken to complement and confirm the insights directly derived from firm interviews.

Based upon the conceptual framework, semi-structured firm questionnaires were developed. The analytical variables that were examined in the questionnaire covered the main variables, which have been identified by theory and empirical studies as determinants of firm/plant-level environmental behaviour—and more generally, of EST related technological change.

In addition to collecting data on a number of general firm characteristics (such as size, number of plants, level of technology, age of production equipment, type of products, market orientation, ownership), managers were interviewed on a variety of enterprise and business aspects. The latter included questions related to:

- Market developments (degree and nature of competition, importance of environmental aspects) and the determinants of profitability;
- Environmental regulation (type of regulation: command and control or win/win approach);
- Environmental pressure (regulators, buyers, financial intermediaries, business associations and local communities);

- Technological change (sources of technology, linkages with technology institutions, cooperation with other enterprises, availability of technological resources); and
- Environmental performance and barriers to EST adoption.

Two main techniques were used to identify the influence of different factors on the adoption of EST. First, firms were asked to identify the main reasons for implementing EST projects and subsequently rate the importance of a number of potential drivers. These drivers can be circumscribed as:

- *Improving conformance to regulatory environmental requirements:* Three specific drivers are of relevance: "Regulatory pressure, high pollution charges and fines"; "Expectations that in the future regulations will become more stringent and charges will be higher"; and "Environmental norms and standards for selling goods in foreign markets". Pollution charges and fines work as a deterrent, driving firms to reduce pollution loads and comply with set standards. However, the actual "cost of non-compliance" for a firm (or the degree of regulatory pressure) is not only determined by the level of charges, but importantly by the way regulation is being enforced. While current regulation might not exert much pressure on firms in certain countries, an anticipated increase in the stringency of such regulations might nevertheless motivate firms to start improving environmental performance. Lastly, to access foreign markets, firms in developing countries often need to comply with stricter environmental regulatory requirements than at home. Environmental standards of foreign countries therefore can effectively stimulate firms to adopt ESTs;
- *Reducing operating costs:* Achieving or maintaining competitiveness often means reducing operating costs, particularly in markets characterized by stiff price competition. Cleaner technology can be an effective route to improving production efficiency by cutting down the cost of wasteful energy, water and material input use (including chemicals). A country's resource price policies clearly affect the overall cost of resource inputs, and often act as a main stimulant to adopt ESTs;
- *Supply chain pressure:* Environmental requirements of a firm's business partners (primarily supply chain

buyers/customers, but also suppliers) increasingly act as a driver for EST uptake in firms that are active in certain value chains;

- *"Informal" regulation:* The influence exerted by local communities, NGOs, the media and the public at large on polluting firms can act as an effective complement to formal regulation. This type of public pressure has been confirmed by a number of recent studies;
- *Peer pressure:* Anecdotal evidence exists of the influence of trade and business associations on firm's environmental behaviour;
- *Goal not to lag behind competitors who have achieved good results in waste reduction:* Good environmental performance by competitors may stimulate firms to adopt ESTs and improve their environmental reputation;
- *Policy incentives:* Economic incentives such as loans, grants, tax exemptions for capital investments, and related consultancy services are examples of public policy measures that are often used to improve the adoption rate of ESTs; and
- *Environmental requirements imposed by owners and shareholders of the firm:* Several studies have confirmed the influence of investors (owners/shareholders) on the firm's management decisions with regard to EST uptake.

Second, statistical analysis on collected data was used to determine the underlying trends in firm behaviour. Only the results from a test of statistical association, Chi Square, are presented in this highlights report. The test was used to explore the relationship between a firm's EST related technological change ("EST response" as a dependent variable) and other factors of firm behaviour or context (as independent variables). Independent variables included: technological capability, dependency on—and quality of—institutional technological support, inter-firm cooperation, formal (command and control, win/win) and informal (community and NGO) regulation, buyer pressure and business association pressure.

The dependent variable, EST response, and the two more complex independent variables are briefly described below. The other and more straight forward ones are only described in the full report for the project.

EST response

The distinction between different types of environmentally sound technology is not always clear. Nevertheless, a basic distinction can be made between pollution control measures (the so called "end of pipe" measures) and pollution prevention or Cleaner Technology (CT). In terms of the latter, a variety of measures can be distinguished. Annex III contains an elaboration of the categories (e.g. better process control, on-site recovery and reuse, and major technology change) that were used to classify particular CT projects. In turn, these CT categories were classified as per their level of technological complexity into "low", "medium" and "high". The idea behind the categorization is one of a "continuum of technological change", which sets out firm's EST responses on a sloping scale, from pollution control (in most cases, add-on technologies and usually basic in terms of technological complexity) to pollution prevention/CT (with the highest level of CT being a major technology change or product modification). The categorization thus takes account of two dimensions: the "technological complexity" of EST projects as well as the degree to which firms are moving away from control measures and changing wasteful and pollution-intensive production methods.

Technological capability

Firm-level technological capability (TC) refers broadly to the ability of productive enterprises to handle industrial technologies and cope with technological change. The

literature identifies a variety of TC components, commonly categorized as investment, production and technology functions.³ TC underpins many pre- and post investment tasks which include: the search for sources of technology, the selection and purchasing of equipment (and material inputs), the implementation of the technology (including adaptation of inputs), process changes and product modifications. The ability to effectively link up with external suppliers of technology (including links with technology institutions) is considered an important element of technological capability (among others). Firms generally vary in their mastery of the various functions involved. Indices were constructed to measure TC in its totality and split between TC internal and TC external.

Regulatory approach

This is an indication of how firms perceive regulatory regimes imposed by government bodies. The regulatory index was divided into two types. One was a "win/win" regulatory index meant to show the impacts of a generally "positive" and "cooperative" regulatory attitude by the government. The other, a "command and control" regulatory index, indicates the degree to which regulation is imposed rather than negotiated. The latter index also captures the extent to which firms considered regulation negative for business performance.

³Sanjay Lall (1992) "Technological Capabilities and Industrialization," *World Development*, vol. 20, No. 2, pp. 165-186.



Global overview

In reporting highlights from the survey, this section describes quantitative findings for all nine countries i.e., a global overview. These are tentative results, based upon the data currently available. The next section extracts selected qualitative findings from each country report (see annex I for a list of all country reports).

Factors influencing the uptake of EST

Two main techniques were used to identify the influence of different factors on the adoption of EST. First, firms were asked to identify reasons themselves and to attribute importance to different drivers. Their responses are the consciously stated reasons. Second, the underlying trends in firm behaviour were analysed using statistical techniques. The purpose of this analysis is to identify what driving forces may exist for the adoption of EST regardless of what firms consciously identified as important drivers.

Consciously stated reasons

Firms were asked to rate on a scale of one to five with five being most important what they considered the reasons for their overall EST response over the past ten years. As can be seen in table 1, the three most important reasons in descending order aggregated across all countries are reducing the costs of energy and raw material (3.9), regulatory pressure (3.5) and anticipation of future regulations (3.3). This overall result varies from other similar assessments which suggest that regulatory pressure is the dominant driver.⁴ Our findings suggest that there are a mix of

important drivers that need to be taken into account to understand firm-level behaviour in regard to EST-related technological changes.

The differences among the three sectors are consistent with what one might have anticipated given their different technological configurations and market structures. The pulp and paper sector is one of the most energy and material intensive industrial sectors and deals at arms length with consumers. The textile sector is one of the most competitive sectors. The leather sector (two African countries) is primarily an export activity that is beginning to be influenced by environmental considerations.

The differences in descriptive findings amongst the countries certainly invites speculation. The most important reason for pulp and paper firms operating in free market economies, Brazil (3.7) and India (4.4), is regulatory pressure whereas the most important reason for pulp and paper firms operating in socialist economies, China (4.4) and Viet Nam (4.6), is reduction in the costs of energy and raw material. Interestingly enough, one should note that cost reductions are an important driver for firms in Brazil and almost the second most important driver for firms in India. On a similar note, the second most important driver for both China and Viet Nam is anticipation of future regulation, which suggests that environmental regulation is beginning to be effective in these two countries. The most important reason for the two textile producing countries is different, cost reductions in the case of Thailand (4.3) and the requirements of business partners in the global supply chain in the case of Tunisia (4.5). This difference is not surprising in that most of the firms surveyed in Tunisia are exporting to Europe whereas most of the

⁴A summary of the literature in this regard is World Bank, 1999. *Greening Industry: new roles for communities, markets and governments*. Washington, D.C. World Bank.

Table 1. Reasons for implementing EST projects

Reasons for implementing the EST Projects	Pulp and paper			Textile			Leather		Iron and steel		Total
	Brazil	China		Viet Nam	Tunisia		Kenya	Zimbabwe		Mexico	
		India	Viet Nam		Thailand	Tunisia		Kenya	Zimbabwe		
Regulatory pressure	3.7	3.7	4.4	3.6	4.0	2.8	3.5	2.4	3.9	3.8	3.5
Environmental norms and standards in foreign markets	2.0	2.8	1.1	3.0	3.3	2.6	2.0	1.9	2.2	3.4	2.5
Requirements of the business partners	1.3	2.4	1.1	2.1	3.1	3.1	2.6	1.4	1.7	3.8	2.4
Requirement of the owners and shareholders	2.7	2.5	1.1	3.0	3.1	4.4	3.3	2.9	2.3	3.1	2.9
Future regulations	2.3	4.1	1.4	3.9	3.8	3.9	4.0	3.0	2.9	3.8	3.3
Reductions in cost of energy and material	2.3	4.4	3.1	4.6	4.3	3.6	3.4	4.6	3.6	4.4	3.9
Public pressure	2.2	2.8	3.2	3.3	2.3	2.9	2.5	1.0	2.9	2.3	2.5
Peer pressure	1.2	2.8	1.4	3.1	2.1	1.8	2.0	1.0	2.1	2.1	1.9
Incentives	1.0	3.3	1.5	3.0	2.1	2.5	1.1	1.4	2.2	2.1	2.0
Keep up with competitors	1.8	3.3	1.4	2.7	3.4	2.8	2.9	1.6	2.3	3.4	2.5
Other: cost reductions, pro-activity	2.8	-	-	-	-	-	-	-	-	-	-

firms surveyed in Thailand are producing for the domestic or regional markets. The most important reason for the two leather producing countries in Africa is different requirements of owners in the case of Kenya (4.4) and anticipation of future regulation in the case of Zimbabwe (4.0). The response in Kenya is best understood when one knows the situation there. Most tanneries are privately owned and these owners have been under community pressure to reduce pollution. The low rating assigned to public pressure in this case is perhaps the result of some confusion in the firm response, but the low rating assigned to regulatory pressure is consistent with the fact that owners and communities have been primarily responsible for the installation of pollution control equipment. The highest and second highest ratings for Zimbabwe, anticipation of regulation and regulatory pressure itself, is consistent with the qualitative presentation later in the report that the cooperative regulatory activities of local authorities are effective in bringing about pollution reduction.

In trying to refine our understanding of the importance of the various drivers for changes in EST, we looked at disaggregated project data for the EST-related changes for each country and then summed them for the three sectors. (Iron and steel in Mexico is excluded because there is only one country for the sector and only seven plants surveyed in the country). The country team asked the firms to describe each EST-related action, classified into one of four categories (pollution control, on-site recovery and reuse, better process controls and major technology/product change) and then to identify the most important driver associated with each change. For example in the case of the pulp and paper sector in Brazil, the seven mills identified 27 EST related technology changes over the past ten years and assigned a dominant driver to that change from the list of 10 potential drivers provided for describing the reasons for the overall EST response (annex IV).

In the case of the pulp and paper sector, regulatory pressure was the dominant driver for investments in pollution control measures whereas cost reductions/savings was the dominant driver for on-site recovery and reuse (figure II). A more interesting finding is that regulatory pressure rather than cost reductions was the primary driver for better process controls, a result strongly influenced by the Brazilian data. This finding suggests that at least in some circumstances firms and perhaps environmental regulators recognized the importance of pollution prevention measures as

a way to comply with environmental standards. To more fully understand these findings one would have to look at individual country data, which would allow one to distinguish between command and control and win-win environmental regulatory approaches to industry and to take into account the technological capability of firms.

In the case of the textile sector, regulatory pressure was the dominant driver for investments in pollution control whereas cost reduction was the dominant driver for both on-site recovery and reuse and better process controls (figure III). The difference from the pulp and paper sector in regard to process controls perhaps reflects the fact that the textile sector operates in buyer-driven rather than a global supply chain.

In the case of the leather sector, regulatory pressure was again the dominant driver for investments in pollution control, but requirements of owners was also a significant driver compared to the other two sectors/country situations (figure IV). For better process controls, the pattern also differed in that requirements of buyers was the dominant driver and public pressure was a noticeable driver. For technology change (only three cases/ one in Kenya and two in Zimbabwe), the dominant driver was regulatory pressure, but again public pressure was also a noticeable driver. The role of public pressure is consistent with the importance of owner/community interaction in Kenya and enterprise perception that public pressure needs to be taken into account in Zimbabwe.

Underlying trends

The purpose of the statistical analysis is to identify trends in firm behaviour that may not be apparent from consciously stated reasons. The statistical analysis required the use of indices to characterize both the dependent variable, EST response, and independent variables, such as technological capability and regulatory approach.

The findings from the statistical analysis are based on a Chi Square test applied to the entire data set except for the cases referred to in the notes to table 2. Strong relationships are shown by high percentages. A high percentage shows that there is a statistically significant influence between the values for the EST response and the underlying causes. Usually, figures higher than 90 per cent are considered a strong relationship.

Figure II. Pulp and paper: major drivers for implementing EST projects

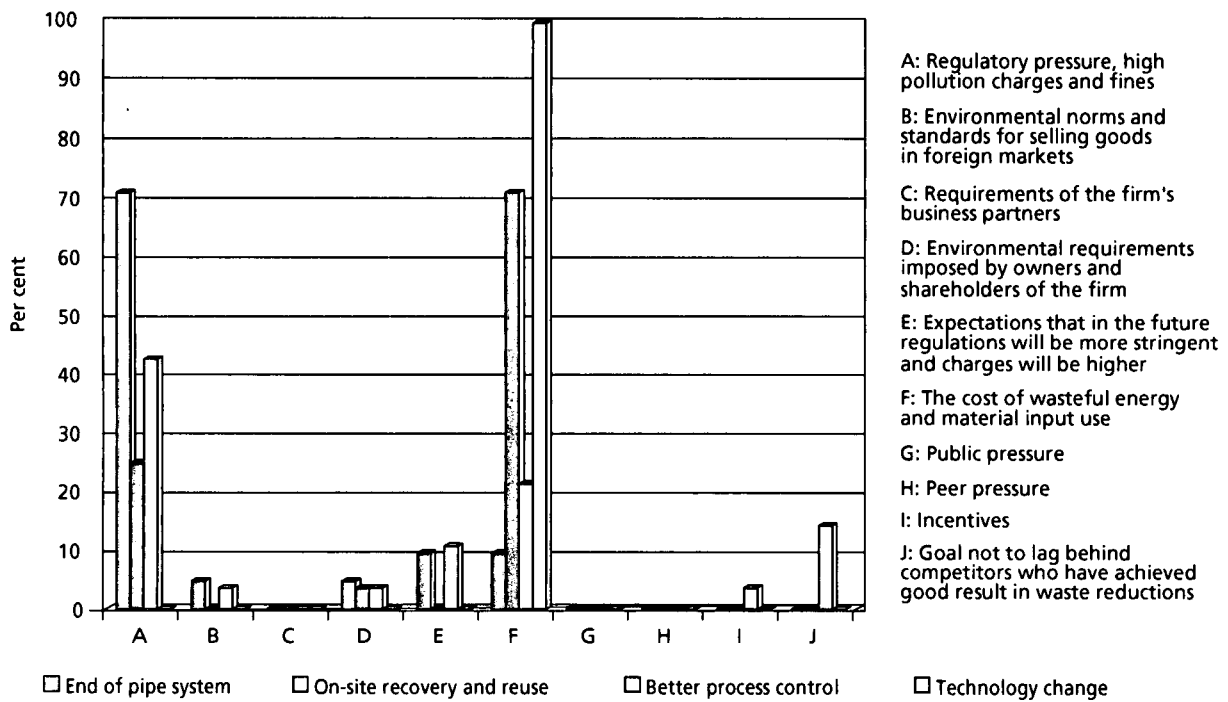


Figure III. Textile: major drivers for implementing EST projects

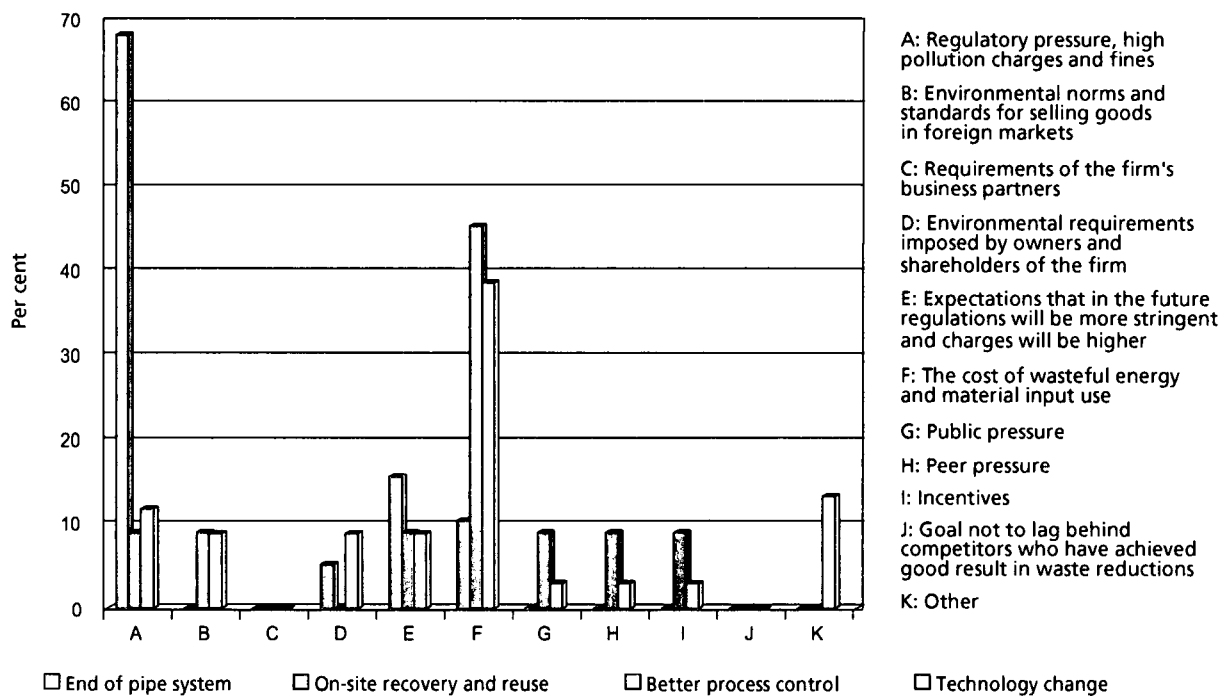


Figure IV. Leather: major drivers for implementing EST projects

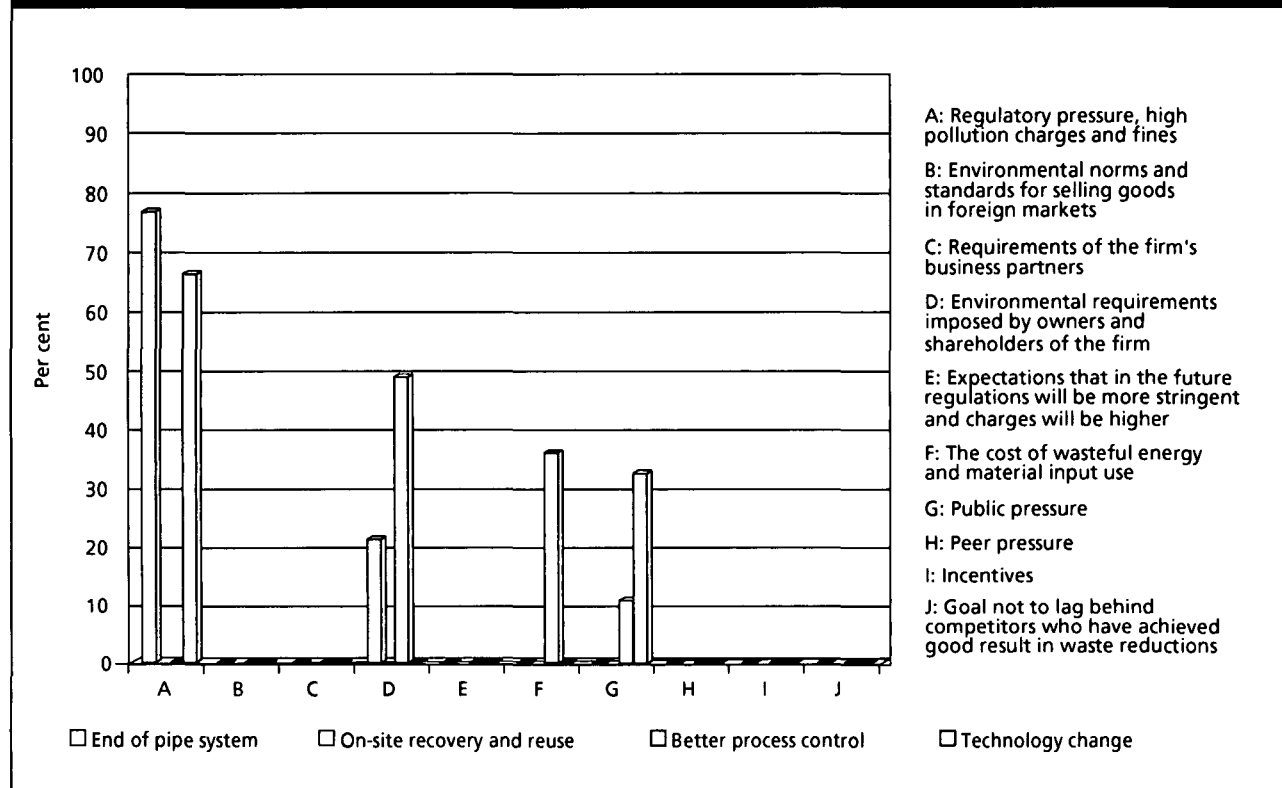


Table 2. Statistical analysis of overall EST response (strength of association in percentage)

Factor	Pulp and paper	Textiles	Leather	Steel	Total sectors
Number in sample	<i>n</i> = 41	<i>n</i> = 28 ^{a, b}	<i>n</i> = 19 ^b	<i>n</i> = 7 ^b	<i>n</i> = 95 ^b
TC internal	18.8	97.0	30.0	54.1	12.9
TC external	43.0	79.8	7.9	32.5	99.7
TC total	89.9	47.6	22.2	51.2	31.0
Institutional techn. support	7.4	17.6	61.0	90.0	17.8
Perceived quality of inst. support	57.6	42.0	58.4	54.1	20.0
Inter firm cooperation	1.9	82.0	79.8	67.1	52.0
C+C regulation	97.0	36.0	90.0	41.3	34.9
Win-win regulation	93.1	40.4	99.2	32.5	95.9
Bus assoc. pressure	99.0	49.7 ^c	82.9	84.5	99.3
Community pressure	87.9	9.9 ^c	55.4	86.4	85.7
Firm size	86.5	58.5 ^c	91.1	^d	93.7

^aFigures based on Thailand alone (Tunisia not included).

^bUsual strict rules for Chi Square not followed (i.e. some matrix boxes had less than 5 expected occurrences).

^cIncludes Tunisia (total *n* = 38).

^dSize for steel firms is a constant (all are large, 2), hence the values do not compute.

The data analysis across all firms suggests that the following factors are important:

- External technological capability seems to be the most prominent factor in EST adoption;
- Regulation, of both command-and-control, and "win-win" varieties scores highly. Business association pressure also seems strongly related to EST adoption; and
- Community pressure is also prominent, although less strongly. Some caution has to be applied here, as the index was highly variable between countries and some firms in specific countries (e.g. Thailand) claimed that no such community pressure existed in spite of studies that have documented the importance of community pressure.

Concerning the individual sectors, pulp and paper seems to exhibit greater influence from a higher variety of factors than other sectors. But again, some concern has to be expressed here because the other sectors have generally small sample sizes, and consequently, it is possible that they too would reveal such trends with larger samples. There also seems to be some level of predictability in the factors influencing EST response in leather tanning. Some trends also come out in the accumulation of all sectors, but this may be due in part to the high dependency of this accumulation on the pulp and paper sector.

Restrictions on the adoption of cleaner technologies

Firms were asked to rate on a scale of one to five, with five being most important, several barriers to adopting cleaner technologies/pollution prevention measures. The firm responses are summarized in table 3 by country, sector and globally. Not surprisingly the global and sectoral findings all reveal the high implementation costs of cleaner technologies as the most important barrier. The country level findings show some interesting variations. In the case of Thailand, the lack of information and lack of skills are equally weighted as the most important variables. In the case of Kenya, uncertainty about performance is clearly the most important variable.

Clearly the dominance of high implementation costs needs additional exploration given that the majority of the firms

interviewed had varying degrees of association with cleaner production programmes. One would have anticipated that firms with some knowledge of cleaner production would have responded in a way similar to the firms in Thailand.

Importance of technological capability

As apparent from table 2, technological capability is a prominent factor for EST uptake. Aggregated across all sectors, the measure of external technological capability (TC external) displays the strongest statistical association with the measure of EST adoption (EST response). In sectoral terms, internal technological capability (TC internal) is a clear factor for EST uptake in the textile sector, while total technological capability (TC total) also shows a significant relationship with EST uptake in the pulp and paper sector. These findings support the view that EST adoption (particularly CT) depends to a great extent on a firm's technological capabilities.

The strong overall statistical association between EST-related technological change and external technological capabilities (which measures the extent to which firms draw on external technological resources when undertaking change) deserves further exploration. Generally speaking, this finding lends support to the argument that firm-level technological change works best in an environment which is characterized by a dense network of interacting enterprises, support institutions, consultancy companies and technology suppliers. The characteristics of these networks however differ by country. Indeed, while virtually all companies draw on external technological resources, the picture for each country differs with regard to the type of external resources that are used, the degree of reliance on external resources and the perceived quality of these resources.

Within the pulp and paper sector, companies in the two open, market-based economies (Brazil and India) rely to a much larger degree on private consultants than companies in China and Viet Nam. Virtually all of the sampled firms in China and Viet Nam indicated a reliance on public sector technology institutions. The perceived quality of this support was however low. Poor access to up-to-date technological information, in particular, causes concern. The Brazilian firms generally expressed satisfaction with available external support. The interviewed Brazilian firms are

Table 3. The main barriers to adopting cleaner technology

<i>What are the main barriers to adopting cleaner technologies/pollution prevention measures?</i>	<i>Pulp and paper</i>				<i>Textile</i>		<i>Leather</i>		<i>Iron and steel</i>	<i>Pulp and paper</i>			<i>Total</i>
	<i>Brazil</i>	<i>China</i>	<i>India</i>	<i>Viet Nam</i>	<i>Thailand</i>	<i>Tunisia</i>	<i>Kenya</i>	<i>Zimbabwe</i>	<i>Mexico</i>	<i>Pulp and paper</i>	<i>Textile</i>	<i>Leather</i>	
	Lack of information	1.5	3.0	1.1	2.4	3.7	2.2	3.1	2.4	2.4	2.0	3.0	
High implementation cost	2.8	4.5	4.1	4.2	3.6	4.2	2.8	3.7	3.1	3.9	3.9	3.3	3.7
No alternative chemical/raw material input	1.2	3.7	1.0	2.0	3.1	1.0	2.2	2.1	2.0	2.0	2.1	2.2	2.0
No alternative process technology	1.6	3.7	2.4	2.7	2.9	3.3	2.9	2.3	2.9	2.6	3.1	2.6	2.7
Uncertainly about performance impact	1.7	3.5	1.5	2.2	3.4	1.5	4.1	2.5	2.7	2.2	2.5	3.3	2.6
Lack of tradition/skills	2.0	3.7	1.4	2.7	3.7	3.5	2.9	2.4	2.1	2.5	3.6	2.7	2.7

able to draw on—what appears to be—well functioning factor markets complemented by a good institutional support system. The two Brazilian trade associations seem to provide good guidance in terms of EST matters. In comparison with Brazil, the Indian firms expressed a lower degree of satisfaction with available technological support. This was notably the case for some smaller paper mills which complained that the competence to develop ESTs suitable for small and medium-sized plants is very small in India. More generally, public sector research institutions were criticized for not focusing on the needs of industry.

Within the leather tanning sector, firms generally relied to a larger degree on external resources than in other sectors. A comparatively lower level of in-house capabilities partly explains this. The perceived quality of support differed in the two countries. In Kenya, firms generally

expressed satisfaction, while remarking that local capacity of technological services is still low. Support is mainly provided by public sector institutions and UNIDO. Foreign consultancy services are inaccessible for most firms. As stated in the Kenya country report, the development of local technological capabilities is perceived as a clear need. In Zimbabwe, firms generally indicated a limited access to technological information. Zimbabwean firms also rely to a greater degree on private sector sources.

With regard to the textile dyeing and finishing subsector, the majority of firms interviewed in Thailand—small and large firms alike—indicated a reliance on public sector technology institutions. The quality of this support—as well as of national consultancy companies—was rated as satisfactory. Nevertheless, firms stressed the need for improved services so as to effectively support them in future technological upgrading programmes.



Observations from country reports

Brazil

1. *Sector description:* In 2001, pulp production reached 7.4 million tonnes, a growth of 38.7 per cent over the past 10 years, and paper production reached 7.3 million tonnes, a 48.6 per cent growth for the same period. The sector is an important world player, ranking number seven in the world for pulp manufacturing and number 12 in paper-making. The sector accounts for about 4 per cent of industrial output and claims to generate over 100,000 direct jobs. The sector consists of 220 manufacturers with roughly 255 production units. Of this number, 30 account for 93 per cent of pulp production.
2. *Technological characterization:* Most of the Brazilian pulp mills are based on the Kraft manufacturing process. For the most part, the best known pulpmaking technologies are in place. The process is very efficient in chemical recovery (over 95 per cent) and energy.
3. *Technological support institutions:* Institutional support comes from two business associations: ABTCP (Brazilian Technical Association of Pulp and Paper), and BRACELPA (Brazilian Association of Pulp and Paper Manufacturers). Both associations have environmental committees with voluntary participation of members to discuss relevant subjects about environmental performance and upgrading. The ABTCP committee is more technical; it discusses technologies, equipment, performance, benchmarking, compliance parameters, permits, targets, etc. The BRACELPA taskforce is a healthy blend of political, legislation, and benchmarking issues. Both complement each other. In some cases, the member representing the company participates in both committees.
4. *Environmental policy:* The country has strict environmental legislation and an efficient environmental management system. In addition to the federal apparatus, there are state and municipal regulatory bodies, which in some cases impose environmental limits more stringent than those recommended by the federal government. For the most part, the enforcement system serves as a warning rather than a punishment for an environmental offender. Penalties are modest and regulators, before they apply a penalty, offer opportunities for correction. In the light of water and energy constraints, the government is experimenting with incentives to reduce their use.
5. *Quality considerations:* One of the main factors influencing EST uptake was the quality programme implemented in most pulp and paper mills. Total quality management, quality circles, total productive maintenance, 5 Sigma's and ISO 9000 encouraged firms to reduced wastes of inputs that cut down on pollutant loads. Companies with good quality programmess and excellent housekeeping were easily converted to a cleaner production approach to environmental management. Several EST projects were implemented, although in many cases without knowing the concept of EST or cleaner production.
6. *Industry perception of environmental regulators:* The regulators were not considered a factor in guiding technological development because of the lack of information and knowledge they have about the sector technologies. They were reported as more concerned with standards and limits. However, the strict limits they impose were strong drivers for innovation and the use of EST. It was even said that globalization may have an impact on Brazilian environmental norms because regulators will be able to more easily identify new restrictions.



7. *Market forces:* One market force is pressure from customers demanding ISO 14001, forest certification and environmental labelling. This situation particularly characterizes exporting companies. A second market force is the possibility of selling environmentally friendly products (chlorine free paper) in niche markets that are found primarily in Europe. A third market force is firm image. Firms, particularly multinationals, do not want to be seen as destroying the environment.

Brazil: pulp and paper—pollution control

Cambara S/A Produtos Florestais is the sole producer of fluff paper in Cambara do Sul. In the early 1990s it was cited by the State of Rio Grande do Sul for violations of environmental norms. It invested US\$900,000 in improving its activated sludge wastewater treatment plant as well as several cleaner technology measures. Today it is in compliance with environmental norms and has reduced water use by 90 per cent.

China

1. *Sector description:* The Chinese paper industry has suffered frequent difficulties in spite of which it has contributed a great deal to the country. Initially, the production of paper and board in 1949 was only 108,000 tonnes throughout the country. In 1998, the production of pulp was 17 million tonnes, and of paper and board 27 million tonnes. The pulp and paper industry consists of more than 10,000 plants. More than half of the plants are small and use locally made technologies, which are old and not of sufficient size for efficient production or utilization of black liquor recovery. The latter is essential for efficient operations and a reasonable cost for pollution control.

2. *Technological characterization:* The current five year plan for the sector stresses the need to prohibit small plants, sets a lower limit on the size of new plants or plant expansion and proposes building several larger capacity plants.

3. *Technological support infrastructure:* The State Environmental Protection Agency production (which is the host institution for the UNIDO/UNEP national cleaner production centre), has set up 15 extension centres for environmental protection technologies and is active in

promoting cleaner production and certification of products with environmental labels. SEPA together with the State Light Industry Agency issues guidelines and provides support for wastewater prevention and treatment technology in the non-wood based pulp sector. The Centre for Environmentally Sound Technology Transfer provides integrated intermediary services for the emerging EST needs of China's small and medium-sized enterprises (SMEs) by providing information about ESTs. The Environmental Protection Committee under the Industrial Association focuses on wastewater treatment for non-wood based pulp production.

4. *Environmental policy:* There is insufficient enforcement of environmental laws and regulations, thus reducing demand for EST. Many environmental standards are based on end-of-pipe treatment rather than the pollution prevention principle. Economic incentives, such as taxes on pollutants, are still not widely used and those in use have become ineffective because of rapid inflation.

5. *Integrated technology and economic policy to promote EST:* Both five year plans and many specific technology policies, particularly in the area of energy savings, encourage the use of ESTs.

6. *Barriers in management:* Many decision makers in enterprises are not familiar with modern management practices concerning environmental policy. Few of them consider getting more profit through improving production processes and increasing the quality of products or using EST as a strategic tool to increase their profit. They know little or nothing about EST, so it is impossible for them to be aware of the effectiveness of its potential benefits.

7. *Barriers to adaptation:* Some enterprises have little protection against risks, due to their small scale. When using Cleaner Technology, the enterprises always worry that if an accident occurs, the whole production may be affected. Additionally, the traditional end of pipe (EOP) technologies, which are normally separated from the existing production line, have proved useful in achieving compliance with environmental norms. So it is quite difficult to persuade enterprises to substitute Cleaner Technology for EOP technology.

8. *Barriers to information:* EST is normally a combination of various technologies. However many enterprises believe that technological change is only equal to modification of

hardware, which restricts the uptake of EST. There is insufficient information about alternative ESTs. Often the only known process technologies are those out-dated ones that are energy, water and material intensive.

China: Pulp and paper—on site recovery and reuse

Guanxy Guitang No.1 Paper Co. Ltd produces mechanically made paper with a capacity of 100,000 tonnes located in Guigang. It invested US\$1,000,000 in advanced alkali recycle boiler. As a result of this investment the mill recovers 85 per cent of active alkali and reduced Chemical Oxygen Demand discharge about 70 per cent.

India

1. *Sector description:* The Indian pulp and paper industry is extremely fragmented. In 1990 the production of pulp was 1.9 million tonnes and the paper and board production was 2.2 million tonnes. By 1998 the production of pulp increased to 2.6 million tonnes and the production of paper and board to 3.3 million tonnes. Presently, there are more than 400 registered pulp and paper mills with a total installed capacity of approximately 4.3 million tonnes per annum. There are 34 large mills, 120 medium-sized mills and 252 small mills. Mills can be categorized by their use of raw materials—28 wood-based, 111 agro-based and 241 waste paper-based.
2. *Technological characterization:* Most Indian mills use obsolete and inefficient technology and equipment. Compared to international norms, these mills consume large amounts of energy, water and raw materials and the quality of paper is poor. They also produce comparably large amounts of pollutants.
3. *Technological support infrastructure:* The demand for technology by Indian mills is primarily met through two sources, consultants and installation of new machines. The consultants advise on the economics of new technology, while the machine manufacturers, both subsidiaries of leading international companies and wholly owned Indian companies, advise on the choice of technology. The machine producers also provide training when necessary.
4. *Environmental policy:* The enforcement of environmental standards is very lax. Although there are variations in the different states, the general thinking is that the state pollution control boards lack the resources and political support to carry out their job efficiently and honestly. Moreover, the role of these boards is largely punitive; they do not provide industry with advice and information (or other support) on how to reduce pollution.
5. *Environmental performance:* Although most mills have installed EOP equipment, many are not in compliance with environmental norms. On the whole, the industry's environmental performance is poor.
6. *Financial situation:* The industry is experiencing a serious recession. The increase in import of paper has worsened the problem of over capacity faced by the sector. This problem is particularly serious in the case of cultural (printing and writing) and industrial (packaging) paper. Most mills are reportedly faced by a shortage of capital, making it difficult to invest in modern technology. The problem has been made more difficult by the fact that the banks and financial institutions are reluctant to provide loans for technological upgrading of the industry. The industry thinks that it needs to be provided with subsidized loans to carry out technological up-grading in general and the use of ESTs in particular.
7. *Risk aversion:* Large-scale adoption of EST is limited to those technologies that provide assured and immediate financial return. The most common example of this is the adoption of chemical recovery technology. As this technology leads to significant saving of raw materials, most large mills have installed it. However, mills are reluctant to invest in EST, such as environmentally friendly bleaching, whose benefits are considered to be uncertain.
8. *Effectiveness of technology support:* By and large Indian mills do not have serious in-house R&D facilities. Even in the largest mills, R&D activities are confined to the testing of raw material and paper products. The lack of technical expertise limits Indian mills' ability to improve their efficiency and environmental performance through incremental technological changes. In addition, the contribution of research centres to the technological upgrading of the industry appears to be small. Even the Central Paper and Pulp Research Institute, which is reported to be one of the largest of its kind in the world, has made little contribution to the technology modernization of the industry.

Kenya

1. *Sector description:* The production status of the leather sector has changed considerably for the worse over the past ten years with a production of 11,500 tonnes in 1990 and 2,300 tonnes in 2000. At the beginning of the 1990s, 16 tanneries were in operation at an average capacity utilization of 80 per cent. Out of total production, 95 per cent was processed for export as value added product, either as wet blue, crust or finished. At the beginning of 2000, only eight tanneries were in operation at an average capacity utilization of 20 per cent. Of the total production of hides and skins, only 15 per cent were processed for export.

2. *Technological characterization:* The tanning industry in Kenya consists of eight medium to large-scale registered commercial tanneries ranging from semi-mechanized, fully mechanized to the most ultra modern. Six have installed crust leather and finished-stage leather technology. Most of the tanneries have purchased reconditioned technologies from Europe to upgrade their processes. Only a few of them have the capacity to procure new machines and equipment and support well equipped and staffed engineering maintenance units.

3. *Technological support infrastructure:* The Kenya Industrial Research and Development Institute, which is a government parastatal in the Ministry of Trade and Industry, offers technological advisory services to the leather sector and also hosts a leather quality control laboratory. Within this Institute, there are also the Leather Development Centre, the Engineering and Design Centre and the National Cleaner Production Centre, all of which are offering services to the leather sector in their area of expertise. The survey revealed that there are no locally based technology developers associated with the leather sector. Two tanneries have had some of their tanning drums fabricated by local entrepreneurs, but there is no formal linkage between these fabricators and the tanneries.

4. *Economic policy:* The leather sector thinks that there is a lack of coherent and appropriate government policies. In particular the Government should impose restrictions on the export of raw hides and skins, liberalize the importation of hides and skins, impose deterring taxes on the importation of second-hand leather products, allow customs waivers upon the importation of cleaner technology

and enact a government procurement policy from local leather manufacturers.

5. *Environmental policy:* In 1999, the Government adopted the Environmental Management and Coordination Act to consolidate 77 sectoral laws relating to the environment. The Act combines both incentives and disincentives to modify environmental behaviour and requires an annual environmental audit for all industrial establishments. However, there continues to be uneven enforcement of the law regarding discharge standards, leading to a situation where some tanneries operate without effluent treatment plants while others have had to install them. When enforcement takes place, the main driver is community pressure on the environmental authority to do its job.

6. *Technological capabilities:* Increased technology acquisition and transfer to Kenya has so far not adequately been matched by the development of local technological capabilities. This has made it difficult to service the machines even when the machine parts can be fabricated locally. At one tannery for example, the hair-saving machine and submersible pumps are not functioning, as the parts have taken a long time to be sourced from Europe. Thus, technology developers and suppliers continue to be overseas based and therefore not readily accessible and for many leather and leather products manufacturers, expensive.

Kenya: leather tanning—EOP

Sagana Tanners is a large-scale, locally-owned tannery, which exports 90 per cent of its production of high-quality semi-processed leather. In 1993, the tannery invested US\$1 million in a physical-chemical waste treatment system as a result of the positive environmental attitude of its directors. While this significant investment already brings the company into compliance with existing regulations, company management has plans to install an additional biological treatment system out of "societal obligation".

Mexico

1. *Sector description:* Privatization of the Mexican steel making industry that began in 1992 has had an important impact on the production of the sector. Production increased from 8.7 million tonnes in 1990 to 15.3 million

tonnes in 2000, and the place of the Mexican steel industry in the world changed from the 20th place to the 15th place. The exports also increased from 1 million tonnes in 1991 to 4.3 million tonnes in 2000, which is 28 per cent of the annual production. There are 191 mills that comprise the iron- and steel-making sector. Four of these mills, which were included in this survey, account for about 80 per cent of the total steel production in the country.

2. *Technological characterization:* About two thirds of the firms in this survey perceive that they have best available technology and one third perceives that they have modern-standard technology. Clearly these mills do not fully represent the country situation, but do account for most of the production. Due to technical and economic characteristics, as well as management and administrative matters, it is not always possible to maintain the expected performance of the technological configurations. This is particularly so for semi-integrated and non-integrated mills.

3. *Technological support institutions:* There are two technology centres that support the firms: Laboratorio de Metalurgia (metallurgy laboratory) and Corporacion Mexicana de Investigacion en Materiales S.A de C.V. (COMIMSA). COMIMSA has a high impact at the regional level and directs its services primarily to the steel-making sector. Both centres offer information on new production technologies, evaluation and selection of product technologies, implementation of new technologies and testing and analysis services. COMIMSA also offers solutions to environmental problems and assistance in quality management systems.

4. *Environmental policy:* Environmental policies encourage end-of-pipe measures in most instances for all industrial sectors. The Ministry of Environment and Natural Resources is in charge of environmental protection. The most important regulation is the "General Law on Ecological Equilibrium and Environmental Protection".

5. *Technological investments:* Some firms undertake R&D investigations for improving their technological configurations. These investigations focus on incremental improvements in the efficiency of production processes. However, the global steel market is very competitive and the high costs of construction do not permit undertaking major investments in technological modification.

6. *Environmental investments:* Approximately 25 per cent of the investments of the sector in the past 10 years have been motivated primarily by environmental concerns. Due to an increasingly competitive market in the 1990s compared to the 1980s, most of these environmental investments do the minimum to achieve compliance with environmental regulations.

7. *Technology diffusion within the country:* The largest firms transmit their experiences and knowledge to the smaller ones through the Commission of Ecology and the iron and steel association, CANACERO. But still, the SMEs suffer from lack of information, technology and capital, and generally cannot invest in cleaner technologies.

8. *Price changes:* Due to rapidly rising prices, the greater part of modernization projects have focused on the better use of energy. As a result, the consumption of energy was reduced by about 20 per cent over the past five years. The sector now recycles nearly 80 per cent of its water intake.

Thailand

1. *Sector description:* The textile sector's rapid growth over the past two decades has catapulted it into the nation's largest manufacturing sector, accounting for 14.5 per cent of manufacturing output. The domestic market consumes around 60 per cent of total production. The textile sector exports declined markedly between 1995 and 2000 (from US\$6.4 billion to US\$5.5 billion), reflecting a loss of competitiveness in the labour-intensive part of the industry, specifically in garments, with a drop from US\$4.1 billion to US\$3.1 billion. There are approximately 4,500 textile mills in Thailand, of which 412 are engaged in dyeing and finishing operations.

2. *Technological characterization:* Obsolete textile machines present a hurdle for the textile industry. Approximately 80 per cent of weaving machines, 70 per cent of spindles and most dyeing and finishing units (the latter category are aged from 10 to 30 years) need to be upgraded to improve product quality and value addition. The dyeing, printing and finishing subsector is a capital intensive industry. Thus, the larger scale companies, 8 per cent of total, use high technological equipment and produce high quality products. The remaining 92 per cent produce low- to medium-quality products. In this subsector,

the technology level depends directly on the scale of the factory. However, the medium-scale firms are using a suitable technology.

3. *Technological support infrastructure:* The technological infrastructure relevant to the firms in the subsector consists of two major players. The Textile Industry Division of the Department of Industrial Promotion promotes the textile industry by means of technical training, consulting services, quality-testing services as well as carrying out research in the textile field. The Thailand Textile Institute, an initiative of the textile sector, aims to upgrade the textile sector to enable it to become a higher-quality textile manufacturer.

4. *Environmental policy:* The Factory Act of 1969 and its 1992 Amendment are the most important of eight major laws that affect industrial environmental management practices. The Act provides the legal basis for regulating industrial plants; the 1992 amendment increased the levels of fines. There is still a need for more regular monitoring of firms particularly those with known high levels of effluents. The penalty system still needs improvement in terms of penal provisions and an increase in the monetary value of fines.

5. *Environmental performance:* Most textile dyeing and finishing operations take place in firms that either have their own wastewater treatment systems or discharge into a collection system on an industrial estate or city with a wastewater treatment system. There is said to be a reasonably high level of compliance with environmental norms, but this is impossible to verify with regular monitoring data.

6. *Price changes:* There are divergent opinions regarding the influence of upward price trends for water, energy and raw materials on technological changes. Some suppliers claim that as there has been only a moderate increase in such prices and they have not influenced technological changes. Other suppliers claim that the increased prices for water, electricity and raw materials have been significant enough to influence investment decisions particularly those resulting in energy savings.

7. *Technology centres:* The technology centres recognize that their services need to change in order to help firms with the product/process improvements needed to create

a higher value added-product and to find more cost-effective environmental solutions to increasingly stringent environmental regulations at a time when the sector is faced with increased losses in market share.

Thailand: textile dyeing and finishing—process control

Sinsaene Co. Ltd. is a producer of knitted fabric and dyed and finished fabric located in Samutprakan. It invested US\$37,000 in several energy conservation options including replacement and insulation of steam pipes, heat recovery and boiler efficiency. These options all contributed to fuel savings. The investment paid for itself in 15 months.

Tunisia

1. *Sector description:* The textile sector accounts for 27 per cent of industrial output and is the leading export sector, accounting for 65 per cent of exports. The exports more than doubled between 1992 and 1998 to US\$3.7 billion with 94 per cent exported to Europe. In the textile and garment sector there are about 1,800 production units with about 250,000 employees. Within this number are 85 units for dyeing and finishing; the ten firms interviewed for this study account for over 50 per cent of the output of this subsector.

2. *Technological characterization:* More than half of the dyeing and finishing units consider that they have standard modern technologies, which reflect a generally good technological level of the sector. Major technological changes were made because of the need to modernization equipment (60 per cent of the firms), then to reduce water and energy (50 per cent), and lastly to increase productivity (50 per cent).

3. *Technological support infrastructure:* There is an intensive network of institutions supporting the textile sector. Of particular importance are the Technical Centre for Textiles and the Tunis International Centre for Environmental Technology in which is located the National Cleaner Production Centre. The main programme for supporting technological modernization is the National Programme for Industry Upgrading (Programme de Mise a Niveau-PMN), launched in 1996 with support from the European

Union. Approximately 4,000 key industrial enterprises have been prioritized for support over a 10-year period.

4. *Environmental policy:* The development of a strong environmental institutional framework by the establishment of the pollution control body in 1988 and the Ministry of the Environment and Land Planning in 1991 increased the pressure on companies to take measures for the prevention and abatement of industrial pollution. A national clean-up fund provided the financial support needed for promoting ESTs. In addition, the Government has recognized the importance of water pricing on an escalating scale as an essential economic instrument for improving environmental performance.

5. *Environmental performance:* Protection of the environment in the textile dyeing and finishing subsector is related to a great extent to its equipment and to the use of dyestuffs and auxiliary inputs. Over the last decade, the enterprises have bought new finishing machines that operate using considerably less water and energy than the previous ones. These efforts have contributed to more environmental improvements than those obtained from direct pollution-reduction measures undertaken by firms. In addition, the use of most environmentally objectionable chemicals appears to have ceased and these chemicals are apparently no longer available from chemical suppliers.

6. *Export orientation:* It is noteworthy that the uptake of ESTs was faster in those companies with either an international partner or export orientation than those firms working only for the local market.

7. *SME constraints:* The lack of financial resources and qualified professionals employed in SMEs remain constraints against the uptake of ESTs.

8. *Industrial modernization:* Concerning the dyeing and finishing operations, the situation in Tunisia seems rather good. The PMN is playing a catalytic role and providing incentives for adopting innovative approaches and technologies geared toward improving the competitiveness and integration of the textile sector in the global economy. The holistic approach of the PMN includes improvement of environmental performance as an essential element in improved competitiveness and access to international markets.

Viet Nam

1. *Sector description:* The pulp and paper sector is one of the most important sectors in Viet Nam. In 2000, it produced 370,000 tonnes of paper, which satisfied only 70 per cent of domestic market requirements. The annual average growth rate of production over the period 1996 to 2000 was 3.6 per cent with a growth rate of only 2.9 per cent in mills owned by the Ministry of Industry. The significant growth took place in Town and Village Enterprises. There are approximately 100 operating pulp and paper mills of which only three have a production capacity of over 20,000 tonnes per year.

2. *Technological characterization:* The overall technological level and the quality of the enterprises are still very low. Even the two biggest and most modern mills view their technological configuration as backward compared to international standards. To improve the technological level comprehensively involves many factors, such as improving the structure of raw materials, reforming enterprise structure, changing the technological structure, revising the product structure and reforming the management system. These steps are much more difficult than increasing the level of production.

3. *Technological support infrastructure:* The major institutions in the infrastructure are the Research Institute of the Pulp and Paper Industry, Viet Nam Paper Corporation, Viet Nam Paper Association and the Viet Nam Paper Import-Export Corporation. The Viet Nam Cleaner Production Centre is becoming an increasingly important source of advice on cleaner technology.

4. *Environmental policy:* Since the Law on Environmental Protection was adopted in 1994, the Government has enacted 14 decrees, decisions and directives related to industrial environmental management. There is the National Environment Agency at the national level of government, Departments of Science, Technology and the Environment at the provincial level of government, and environmental management units in the Ministry of Industry and industrial corporations.

5. *Environmental performance:* Only a few of the larger mills are in reasonable compliance with environmental norms. There is almost no treatment of wastewater from the smaller mills.

6. *Needed changes in environmental policy:* There is a need to formulate detailed procedures for incorporating EST evaluation into the Environmental Impact Assessment process for new industrial investment projects (both technological innovation and capacity expansion) and to generate recommendations on how to integrate the procedures into the existing "Three Simultaneous" policy implementation.

7. *Finance:* There is a need for effective financing mechanisms and institutions to support the adoption of ESTs by SMEs. The costs associated with replacing obsolete, inefficient and polluting technologies with environmentally sound technologies are often very high. In general, there are no effective financial mechanisms or institutions to support the technological transformation activities of SMEs in general, or to facilitate the adoption by SMEs of ESTs in particular.

8. *Information:* There are only a very limited number of sources of technological information as well as technical support for firms. Firms rely on a limited number of technology centres and national experts for advice. Moreover, firms do not consider that these sources have sufficient professional qualifications. International advice is costly, which means that only the Government can afford to pay for it.

9. *Personnel:* The lack of skilled staff in environmental protection in most firms obstructs the progress of EST adoption. However, special environmental staff in the firm may not be an appropriate solution. A better alternative would be technical staff who already understand specific technological processes, trained by attending special courses on cleaner production and environmental performance. Moreover, at least one professional environmental expert in a technical department is essential to the performance of EST in firms.

Zimbabwe

1. *Sector description:* Zimbabwe's leather industry is a significant source of income and among the country's most successful exporters. Exports of leather in the years 1991 to 2000 ranged between 6.5 and 10 thousand tonnes with a sharp decline in 2001 due to a shortage of chemicals. The bulk of the exports are to destinations outside the

southern African region. Currently there are 13 operating tanneries in the country with seven of them established since 1991, indicating a high rate of direct investments in the sector.

2. *Technological characterization:* Some tanneries only produce wet blue leather while others cover the whole range up to finished leather. Only one tannery has the best available technology throughout the production process, while three other tanneries have the best available technology in certain key areas and modern-to-traditional technology in the rest of the plant. The majority of the tanneries are in a transitional phase with a mixture of modern and traditional equipment. In a few cases, the equipment is mainly traditional.

3. *Technological support institutions:* The Scientific and Industrial Research and Development Centre is the main institution for technological development in industry. Other technological support institutions, excluding universities and technical colleges, are the Leather Institute of Zimbabwe (quality and laboratory services and training for the leather sector), Standards Association of Zimbabwe (quality assurance and standards development for industry) and Technological Information and Promotion Services (dissemination of technological and trade information to SMEs).

4. *Environmental policies:* Command-and-control regulations enacted in the 1970s have been the traditional approach to industrial environmental management. The regulations are poorly enforced and fines imposed on violators are too low to be a deterrent. However, the working relationship between firms and regulators in some local areas are well established and beneficial to both parties. Generally, environmental regulations in Zimbabwe do not encourage the assimilation of cleaner technologies as the various environmental acts were enacted before the advent of cleaner technology.

5. *EST utilization:* All the tanneries except one have waste-water treatment works for their process water. An assessment of the processes and equipment in use in Zimbabwean tanneries against the recommended best practices revealed that although not all companies have best practices, most companies are implementing some best practices or have some recommended cleaner technology in use. There is a huge gap between small and



large-scale tanneries in the rate of adoption of ESTs with the large ones having the better production processes. It is clear from the responses given by the firms that environmental regulations and requirements do not have a major impact on their competitive position.

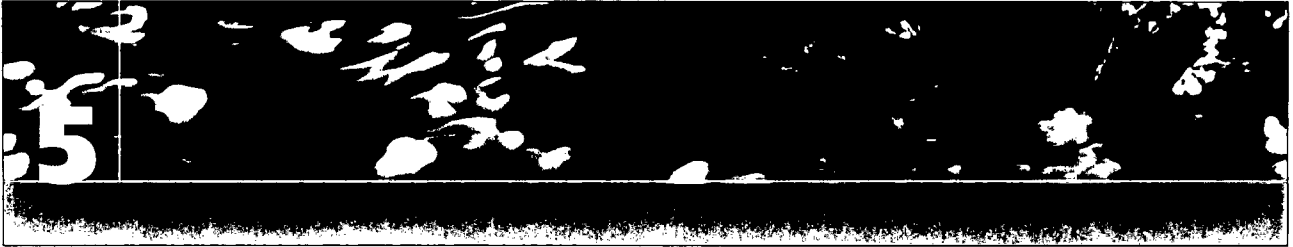
6. *Management perceptions:* Some tanneries that have adopted ESTs have benefited financially through savings in raw material inputs and effluent charges. Only one tannery has actual figures on how much was saved as a result of implementing cleaner process technologies. It emerged from the survey that most companies think that cleaner technologies have high investment costs and for this reason they have not pursued their implementation.

7. *Donor support:* It should be highlighted that the uptake of ESTs by tanneries in Zimbabwe was largely a result of donor assistance programmes, which have made available consultants and finance at either very low or no cost

to the firm. In the case of the one tannery owned by a transnational corporation, their company policy demands that the production process be as environmentally friendly as possible. In the case of the most recently built tannery, it is a completely new plant owned by foreign investors.

Zimbabwe: leather tanning—major technology change

Imponente Tanning Ltd. is a medium-sized tannery in Harare. It invested US\$40,700 in a compacting filter for hair recovery and a change of the chemical recipe for the de-hairing process. The process change reduced chemical oxygen demand discharge by 50 per cent and brought the tannery in compliance with the municipal discharge limits. The investment generates an annual saving of US\$ 13,500 in effluent treatment and disposal costs.



The way forward

The research findings indicate that firm-level EST-related technological responses result from a host of diverse but inter-related factors. Both external factors, categorized as incentives, institutions, factor markets and societal environmental pressure, as well as internal factors, characterized as strategy, management and resources, have motivated firms to make EST-related technological decisions over the past ten years. Seemingly the most important factor for adopting EST, based on the statistical analysis, is the ability of firms to draw on external technological resources.

The research findings are clearly consistent with the literature on general technological change that posits a system view of economic behaviour and emphasizes the importance of firm-level learning and adaptation. The findings also reveal that EST-related technological decisions take place in a more complex situation than normally described by investigations on industrial environmental performance in developing countries. Not only do plant characteristics, economic considerations and obvious external pressures determine environmental performance, but also technology support institutions, such as sector-specific and cleaner production centres play a role. In addition, internal and external technological capabilities of firms influence environmental performance, as well as other firm-specific factors such as the environmental understanding and values of managers and a firm's ownership structure.

The way forward based on this work suggests that countries undertake three sets of inter-related activities (figure V). The first activity is a technology needs (capacity) assessment of the national, sectoral and firm level

priorities for developing expertise to utilize modern technologies.⁵ The national assessment would examine the performance of current policies and mechanisms and propose modifications. It would take into account industrial, technology and environmental management policies and institutions as all three can have a significant influence on firm-level EST related decisions.

The second activity is working within the national Agenda 21 process, which is responsible for preparing national sustainable development strategies that the 1997 Special Session of the United Nations General Assembly requested all countries to prepare by 2002. A UNIDO review of national efforts to integrate an industrial dimension into national sustainable development strategies shows that most have not met the criteria proposed by the OECD.⁶ Successful efforts normally include the following: (a) long-term vision and priorities for industry, including scenario formulation; (b) participation of the industrial sector; (c) integration of industrial, environmental and technology policies; and (d) monitoring and reporting of outcomes.⁷

The third activity is formulation of sectoral and regionally focused (State/Province) technology upgrading programmes for achieving sustainable production as called for at the World Summit on Sustainable Development.

⁵Michael Hobday and John Bessant (2002) "Technology Needs Assessment for Developing Countries," prepared for UNIDO.

⁶UNIDO (2001) "Developing Countries Industrial Source Book", Vienna, Austria.

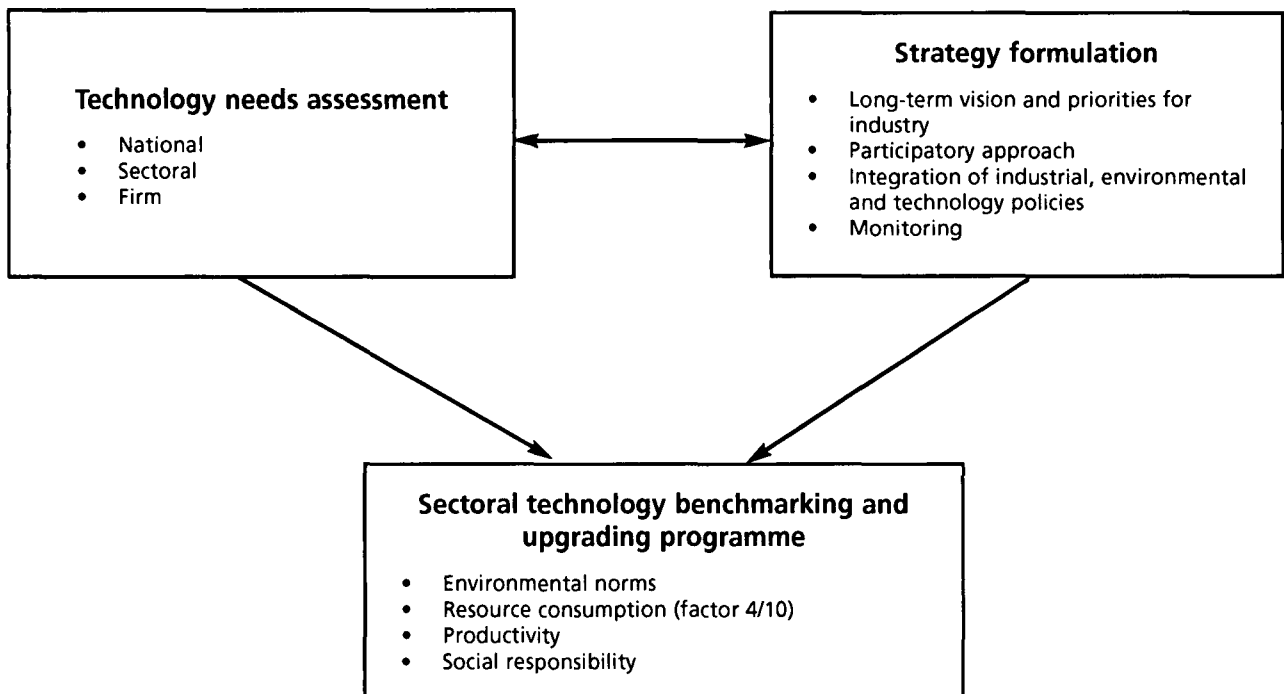
⁷OECD (2001) *Strategies for Sustainable Development: Practical Guidance for Development Cooperation*, Paris, France.

These programmes would align all the factors, both internal and external to a firm, to mitigate the more serious environmental pollution problems and reduce utilization of energy, water and material resources. To be successful, however, these programmes must be undertaken within the challenging task of enhancing the technological

capabilities of firms to compete in domestic and international markets.⁸

⁸The recommendation to focus on firm level upgarding of technological and organizational capabilities is consistent with the findings of others such as David Angel and Michael Rock (2001) "Policy integration: Environment and Development in Asia", paper prepared for the United States Asia Environmental Partnership, Washington, D.C. USA.

Figure V. National EST strategy



Annex I

Country reports

Brazil: CENTRO NACIONAL DE TECNOLOGIAS LIMPAS. *Assessing the Uptake of EST by the Pulp and Paper Industry in the South of Brazil.*

China: CHINA NATIONAL CLEANER PRODUCTION CENTER & CHINESE RESEARCH ACADEMY OF ENVIRONMENTAL SCIENCES. *Assessing the Uptake of ESTs in China.*

Kenya: KENYA NATIONAL CLEANER PRODUCTION CENTER. *A survey on the uptake of environmentally sound technologies in the leather tanning subsector in Kenya.*

India: CENTER FOR TECHNOLOGY STUDIES. *Adoption of ESTs: A study of India's Paper and Pulp Industry.*

Mexico: CENTRO MEXICANO PARA LA PRODUCCIÓN MAS LIMPIA. *Assessing the Uptake of Environmentally Sound Technologies in Selected Developing Countries: Iron and Steel Making Sector.*

Thailand: THAILAND ENVIRONMENT INSTITUTE. *Assessing the Uptake of Environmentally Sound Technology (EST) in Selected Developing Countries.*

Tunisia: CENTRE DE PRODUCTION PLUS PROPRE. *Survey of the Uptake of Environmental Sound Technologies in the Textile Industry in Tunisia.*

Viet Nam: VIETNAM CLEANER PRODUCTION CENTRE. *Assessing the Uptake of Environmental Sound Technology in the Pulp and Paper Industry in Viet Nam.*

Zimbabwe: THE ENVIRONMENT AND SENSING INSTITUTE (ERSI) OF THE SCIENTIFIC AND INDUSTRIAL RESEARCH AND DEVELOPMENT CENTER. *Assessing the uptake of environmentally sound technologies in Zimbabwe's leather and tanning sector.*

Annex II

Number and type of informants interviewed per country

<i>Country</i>	<i>Sector</i>	<i>Firm</i>	<i>Business association</i>	<i>NGOs</i>	<i>Suppliers</i>	<i>Regulators</i>	<i>Technology centres</i>
Brazil	Pulp and paper	7	5	4	4	5	5
China	Pulp and paper	11	2	2	2	4	4
India	Pulp and paper	14	2	1	7	3	4
Kenya	Leather	9	7	1	5	5	3
Mexico	Iron and Steel	7	1	2	2	2	2
Thailand	Textile	28	1	1	10	2	4
Tunisia	Textile	10	1	1	1	1	3
Viet Nam	Pulp and paper	9	1	1	1	1	1
Zimbabwe	Leather	10	4	1	2	6	3
Total		105	24	14	34	29	29

Annex III

Categorization of EST

End-of-pipe measures

Technologies aimed at the treatment of wastes and polluting streams—i.e. water, air, noise and solid wastes.

On-site recovery and reuse

Reuse of the wasted materials in the same process or for another useful application within the company.

Better process control

- *Process modification*: modification of the working procedures, machine instructions and process record keeping in order to run the processes at higher efficiency and lower waste and emission generation rates.
- *Equipment modification*: modification of the existing productive equipment and utilities—for instance by the addition of measuring and controlling devices—in order to run the processes at higher efficiency and lower waste and emission generation rates.
- *Input material change*: substitution of input materials by less toxic or renewable materials or by adjunct materials with a longer service lifetime.

Major technology change

Replacement of the technology, processing sequence and/or synthesis pathway in order to minimize waste and emission generation during production.

Product modification

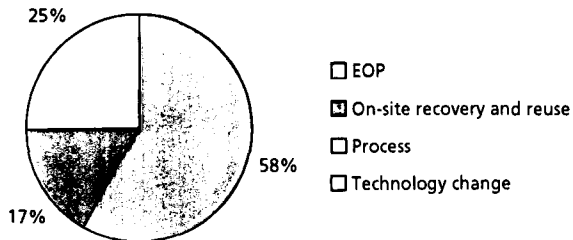
Modification of the product characteristics in order to minimize the environmental impacts of the product during or after its use (disposal) or to minimize the environmental impacts of its production.

Annex IV

Distribution of the different EST projects into the EST categories

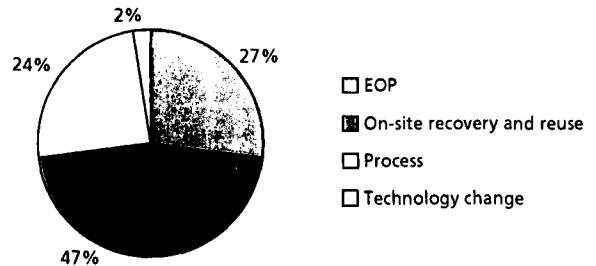
Pulp and paper

Brazil: EST projects



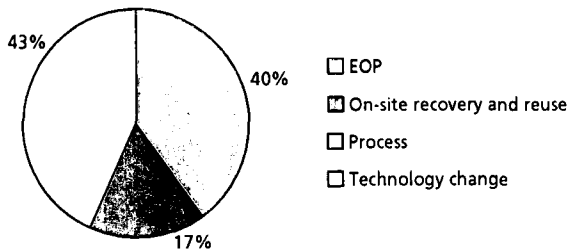
Brazil: 7 firms – 24 projects listed

China: EST projects



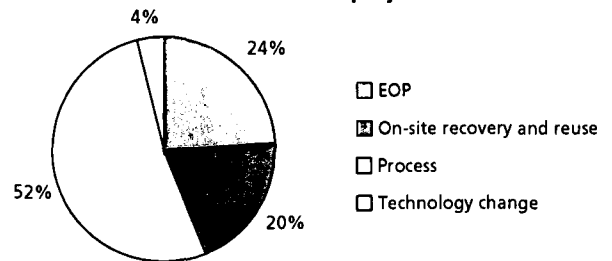
China: 11 firms – 41 projects listed

India: EST projects



India: 14 firms – 47 projects listed

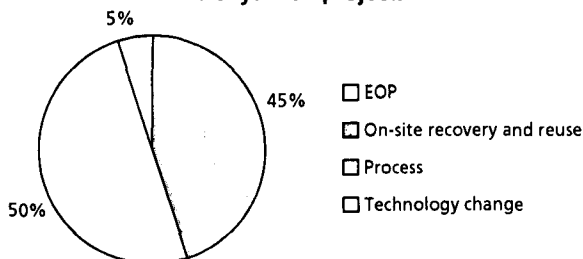
Viet Nam: EST projects



Viet Nam: 9 firms – 25 projects listed

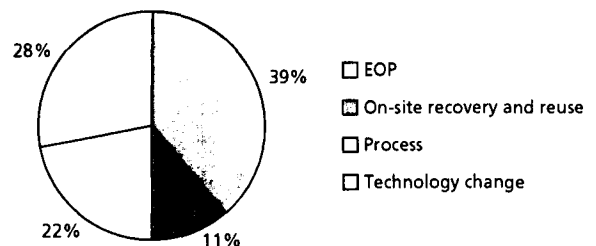
Leather

Kenya: EST projects



Kenya: 9 firms – 20 projects listed

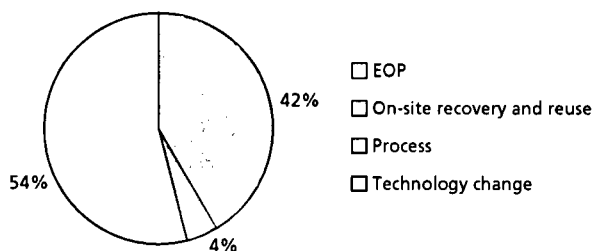
Zimbabwe: EST projects



Zimbabwe: 10 firms – 18 projects listed

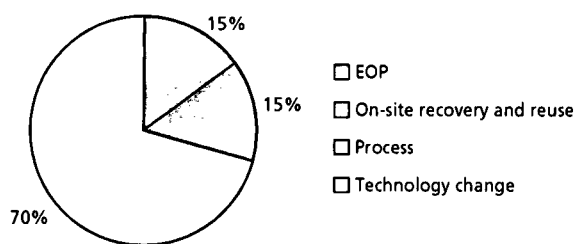
Textile

Tunisia: EST projects



Tunisia: 10 firms – 24 projects listed

Thailand: EST projects



Thailand: 28 firms – 41 projects listed

The United Nations Industrial Development Organization (UNIDO) helps developing countries and countries with economies in transition in their fight against marginalization in today's globalized world. It mobilizes knowledge, skills, information and technology to promote productive employment, a competitive economy and a sound environment.

UNIDO is responding to the challenge of sustainable industrial development by serving as a global forum and providing technical cooperation services. In its global forum function, UNIDO generates and disseminates knowledge relating to industrial matters and provides a platform for the various actors to enhance cooperation, establish dialogue and develop partnerships. As a technical cooperation agency, UNIDO designs and implements programmes to support industrial development efforts.



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