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Assessing and rationalizing the management of a portfolio of clean technologies: experience from a French environmental fund and a World Bank Cleaner Production demonstration project in China

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Abstract

Industrial pollution is intrinsically linked to the adoption and development of technological alternatives. Environmental policies from regulation to economic instruments, in industrialized nations as well as in developing countries and in transition economies, cannot ignore the technological dimension when they aim at controlling or preventing the pollution generated by industrial activities. The implementation of cleaner technologies has been examined here for a French environmental fund (the water agency Agence de l'Eau Rhin-Meuse) and for a World Bank Cleaner Production demonstration project in China. A three-dimensional assessment methodology, including (1) the level of innovation, (2) the type of process targeted, and (3) a process flow-oriented categorization of technologies, has been developed and has identified significant heterogeneity for the two venues. Using Foster's theory on innovation S-curves, three kinds of interpretation are proposed to distinguish what is due to intrinsic differences existing between the various technological choices, from what could be explained by resistance to change inside firms or to policy distortions. Thus, this assessment focuses on evaluating the performance of financial assistance for furthering environmental policy, identifying technological alternatives which should be particularly promoted, and monitoring the evolution of the various technological choices over time.

Keywords: Technological management; Innovation; Cleaner production; Environmental policies assessment

1. Introduction

Environmental policies addressing industrial pollution cannot be separated from technological management. Realistic levels of pollution reduction will be achieved according to both reasonably technically and economically achievable levels of performance for existing technologies and similarly reasonably achievable levels of technological innovation. Moreover, this will require that various possible categories of environmental approaches for technological management are considered: (1) targeting primarily pollution control and the treatment of wastes (the so-called end-of-pipe approach); (2) preventing their generation (cleaner production); (3) considering various types of existing technology alternatives; and (4) taking into account the technological potential for improvement (innovation). An optimal environmental policy will address technological management in such a way that all opportunities for technological improvement are explored, thus becoming an essential component of sustainable development.

Factors influencing technological management have been addressed directly or indirectly by the various categories of existing environmental policies (regulatory instruments, economic incentives and voluntary approaches). For example, traditional regulation is often argued to promote a static diffusion of technologies [1] because it does not give incentives to enterprises to go beyond standards. However, more sophisticated 'command and control' policies, and those that introduce 'innovation waivers', may promote dynamic efficiency as well [2]. In general, technology forcing regulatory instruments directly affects the management of technology, while economic incentives addressing exclusively economic variables influence technological management in a more indirect manner.

In developing countries and transition economies,

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additional considerations have to be raised when assessing existing environmental policies or establishing new ones. One of the most significant factors may be limited capabilities to innovate, which suggests that the focus in these countries should be on the diffusion of existing technologies. However, diffusion should itself be distinguished as either the diffusion of commonly nationally adopted technologies, or the diffusion of new technologies imported from industrialized countries (technology transfer). Requirements for a successful implementation of innovative policies in developing countries and transition economies should include a proper enforcement of regulations when considering the command and control approach, limited market failures for economic instruments, and the extent of social concern for voluntary environmental approaches. In countries with dramatic institutional failures, but progressively opening to a market economy, economic instruments may be preferred at first and be combined with capacity building, before strengthening environmental regulations.

This paper presents some examples of economic instruments in the form of financial assistance designed to promote cleaner production in two different economies: an industrialized country (France) and a developing nation (China). A systematic approach allowing the evaluation of technological and financial management is developed and applied to the various venues. Results are interpreted, considering three schemes for interpretation, and policy recommendations are proposed.

2. Sources of information and research methods

The French water basin agencies are an example of environmental policies which have an indirect influence on the management of technologies. Created in 1964 under the Water Act, they have been at the heart of water policy in France for more than 20 years. As a redistribution mechanism that earmarks revenues from effluent taxation to finance pollution abatement projects, they promote technological change through two types of economic incentives: firstly, they give a negative incentive to pollute through the direct or indirect taxation of wastes that are generated, and secondly, they give enterprises a positive incentive to invest in cleaner technologies by offering subsidies [3]. For the purpose of this research, one of the six French agencies, the Agence de l'Eau Rhin-Meuse, has been studied during a field visit in March 1997. This study has included interviews of managers and an extensive survey of the line of credit (no. 130) dedicated to clean technologies during the sixth strategic plan (1992–1996). A portfolio of implementation projects for 65 technologies was considered in the survey.

The Cleaner Production (CP) Demonstration Project (B-4) initiated by the World Bank, and the Industry and Environment Office of the United Nations Environment Program (UNEP IE), in partnership with the National Environmental Protection Agency (NEPA) of China, included the completion of CP audits in 29 Chinese enterprises during the period 1993–1995 [4]. The project's initial objectives were: (1) to develop and test a Chinese systematic approach to CP; (2) to demonstrate the existence of a large potential for CP in 25–30 Chinese enterprises; (3) to develop adequate CP policies; and (4) to help disseminate the CP approach in China. A total of 22 audit reports were collected during a field visit to UNEP IE in December 1996 which allowed the identification of 39 technological options. Interviews of Chinese stakeholders, as well as managers from the World Bank and UNEP IE, were also conducted. Finally, results from previous evaluations of the projects were reviewed and integrated in the present research—one conducted by the University of Amsterdam [5], one by the Chinese National Cleaner Production Centre [6], and the latest, by UNEP IE [4].

The basis for a three-dimensional technological management assessment was inspired by a methodology developed by Nicholas Ashford at the Massachusetts Institute of Technology [7]. This assessment distinguishes the three following dimensions: (1) end-of-pipe versus CP approaches; (2) diffusion versus innovation of technologies; and (3) targeting primary, secondary or ancillary processes. For the purpose of the present research, the first dimension was refined in the various categories of CP options, following the usual flow of processes: (1) input substitution; (2) process change; (3) waste recovery;[1] and (4) product redesign. The second dimension (the nature of the innovation process) was assessed differently in the case of France and China. In the case of France, three levels of innovation were distinguished: (1) incremental environmental innovation through the diffusion of well-known clean technologies; (2) the transfer of a clean technology commonly adopted in a particular industrial sector, to new industries, or an innovative combination of several incremental innovations (which could be described as an architectural process innovation;[2] and (3) truly new breakthrough innovations (radical or revolutionary innovation).[3] In the case of China, where few technological innovations are taking place in the field of clean technologies, only two

[1] Waste recovery includes both internal recycling and the conversion of wastes into by-products. This typology of CP options differs from the one used by UNEP IE, which distinguishes good housekeeping measures (incremental innovations), thus mixing the innovation dimension and the process flow categorization of options.

[2] This concept has been inspired by the definition of Henderson and Clark [8] for architectural product innovation.

[3] See in particular the definitions of Abernathy and Clark [9] for regular and revolutionary innovations.

levels were distinguished: (1) the diffusion of technologies already known and adopted in the country; and (2) the transfer of clean technologies from industrialized countries. This choice can be justified by the fact that the adoption of a clean technology through technology transfer could take place through radical innovation if sufficient innovation capabilities were present in developing countries. Therefore, similar opportunities should exist for technology transfer and national radical innovation. Finally, the third dimension was assessed by replicating Ashford's definitions: (1) primary processes yield the basic functional form of the product such as forming or casting a part from a material; (2) secondary processes involve the application of a functional finish, such as noncorrosive or aesthetically pleasing finishes; and (3) ancillary processes do not affect the characteristics of the product and are usually less fundamental for the whole manufacturing process.

This technological assessment was completed by a financial one considering the profitability of implementing each technology and the cost of the investment. These financial criteria were related to each of the three technological dimensions previously described in order to identify, for example, if primary process options are more costly but more profitable than those of ancillary processes. In the case of France, the criteria to assess the options' profitability has been the maturity of the loans offered by the water agency. During interviews with managers from the Agence de l'Eau, it was established that the policy of the agency had been to establish a direct correlation between the maturity of the loan and the profitability of the investment. Such a policy is justified, when there is no market failure, by the fact that private funding can be found for profitable investments while a public agency such as the Agence de l'Eau Rhin-Meuse should focus on the internalization of externalities and subsidize investments with high environmental impact and lower profitability [3,10]. Finally, in the case of China, the profitability was assessed by considering the estimation from the audit reports of the investment payback.

3. Results

Table 1 presents the results for the profitability assessment. In the case of France, the usual maturity for loans is nine years, but in the case of more profitable investments, this figure can become seven, five, four or even three years. Each cross ('X') corresponds to a technology with these characteristics. For example, a waste recovery option targeting ancillary processes and with a low level of innovation has been financed with a three-year maturity loan. In the case of China, the figure that is presented corresponds to the average payback of technologies. Results show that for both France and China, waste recovery options tend to be more profitable than process changes.[4] In the case of China, options targeting ancillary processes seem to be more profitable than for primary and secondary processes, but this cannot be established for the French agency (five options out of 48 have a maturity lower than nine months, to be compared to, respectively, one of nine for primary and one of seven for secondary). Finally, while in the case of China nothing can be said about the profitability of technology transfers versus the diffusion of well-known technologies, for France, technologies with low levels of innovation seem to be more profitable than more innovative options.

Figs. 1 and 2 present the three-dimensional technological assessments for the two venues. The radius of the various circles corresponds to the number of technologies with these characteristics that have been funded. In the case of France, a large proportion of technologies are waste recovery options targeting ancillary processes. These are still many in the case of China but less dominant. Certain types of technologies are never, or very rarely, found for the two venues: (1) options other than process changes and targeting primary or secondary processes; and (2) product redesign and input substitution options. Finally, it seems that in the case of France, most innovative options in primary and secondary processes can be found among process changes (and maybe input substitution). In the case of China, results are hardly statistically significant but may suggest that input substitution in ancillary processes and process changes in secondary processes are more innovative, while primary processes include less innovation.

Figs. 3–5 present the cost distribution for the three technological dimensions. In order to be able to compare the two venues, each figure presents the various cost distributions for the two countries (the upper values of the cumulated percentage for France and the lower ones for China). The horizontal axis corresponds to the cost of technologies (in million RMB or FF).[5] Thus, the closer the curve from the horizontal axis, the higher the cost of the corresponding type of technology. Fig. 3 shows that for the two venues, process changes tend to be more costly than waste recovery options.[6] Fig. 4 shows that in the case of France, technologies targeting primary processes are the most costly, then secondary ones and finally ancillary ones. In the case of China, options concerning primary processes are still most costly than for secondary ones but nothing can be said between ancillary and secondary processes. In particular, for the high ranges of cost, options targeting ancillary processes seem

[4] Nothing can be said for the other CP options due to the small number of corresponding technologies.

[5] 1 USD = 8.3, RMB = 5.1 FF (1996).

[6] Other CP options (input substitution or product redesign) are not statistically significant.

Table 1
A three-dimensional profitability assessment of the portfolios of the two venues

		France (maturity of loans)					China (average payback)	
Dimension	Years	3	4	5	7	Total	—	Total
Type of change	Waste recovery	X	XX	X	X	38	3.1	9
	Process change			XX		24	4.7	19
	Other CP					3	4.0	2
Type of process	Primary			X		9	4.4	9
	Secondary			X		7	4.4	8
	Ancillary	X	XX	X	X	48	3.8	13
	+	X	XX	XX	X	32	4.2	23
Type of innovation	+ +					13	—	—
	+ + +			X		10	—	—
	Tech. transfer	—	—	—	—	—	4.3	4
	Total[a]	1	2	3	1	65	—	30

'X' indicates number financed.
[a]In a few cases (10 of 65 in the case of France and three of 30 in the case of China), it was not possible to determine exactly the level of innovation from the documents that were available. In one case for France, it was not possible to determine the type of process targeted.

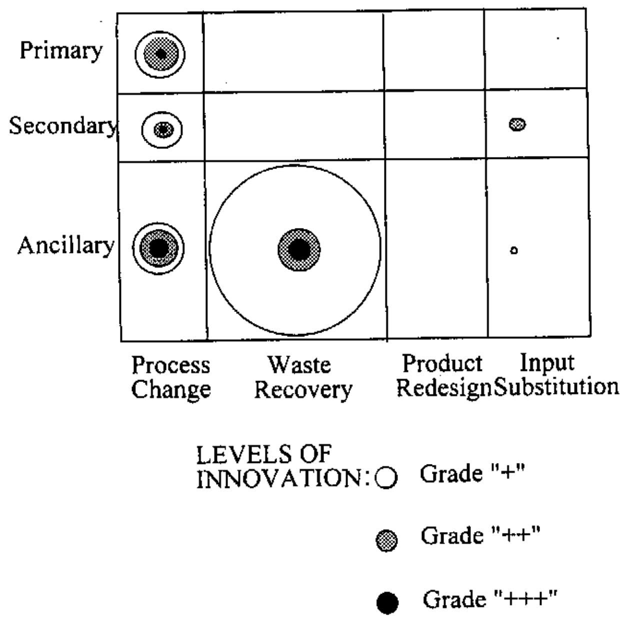

Fig. 1. Technological options assessment of the Agence de l'Eau Rhin-Meuse's portfolio of clean technologies funded during the sixth strategic plan.

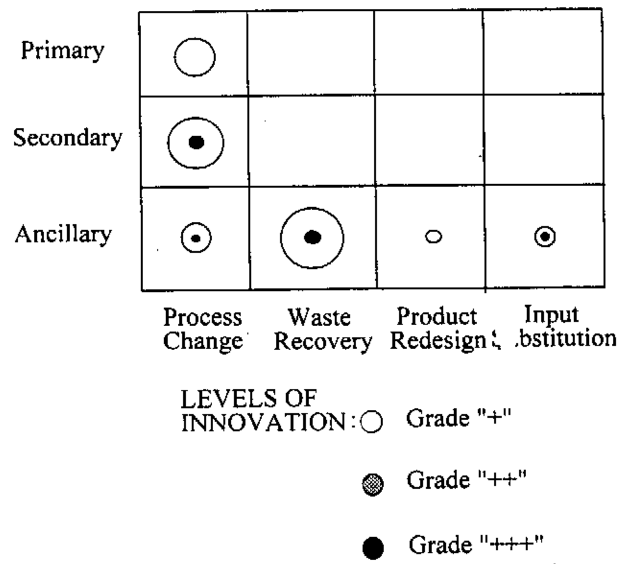

Fig. 2. Technological options assessment of the World Bank subproject B-4's portfolio of CP technologies (China, 1993–1995).

to be more costly than for secondary or even primary ones. Finally, Fig. 5 presents the cost distribution for the various levels of innovation. For the Agence de l'Eau Rhin-Meuse, the diffusion of well-known technologies (rated ' + ') is less costly than for more innovative technologies. Similarly, in the case of China, diffusion is in general less costly than technology transfers. However, for the French venue, technologies for an intermediate level of innovation (rated ' + +') seem to be more costly than radical innovations (rated ' + + + ').

4. Interpretation and discussion

Three different schemes for interpretation can be proposed to explain the various results previously described: (1) interpretations taking into account endogenous factors arising from the typology of technologies that has been proposed; (2) interpretation considering the perception that firms have of the various technology options; and (3) interpretations based on policy distortions in the management of environmental funds.

The first scheme allows, in particular, explanation of why waste recovery options target exclusively ancillary

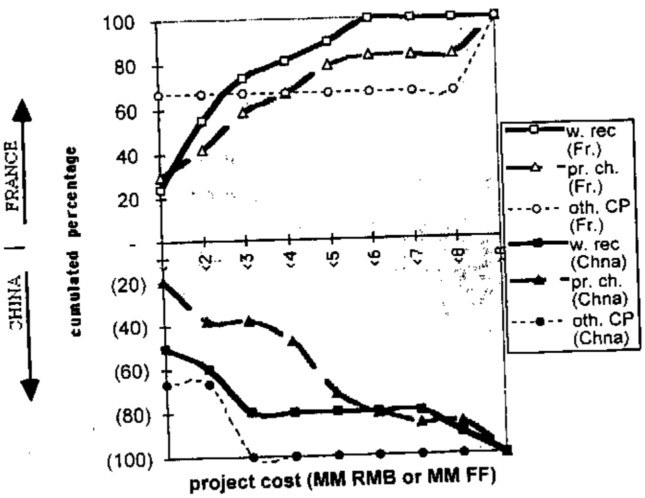

Fig. 3. Cumulated cost distribution of the various CP options categories for the two venues.

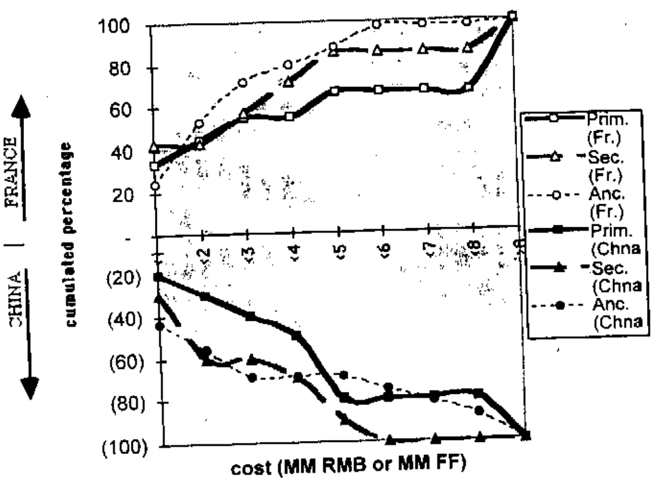

Fig. 4. Cumulated cost distribution of the various process types for the two venues.

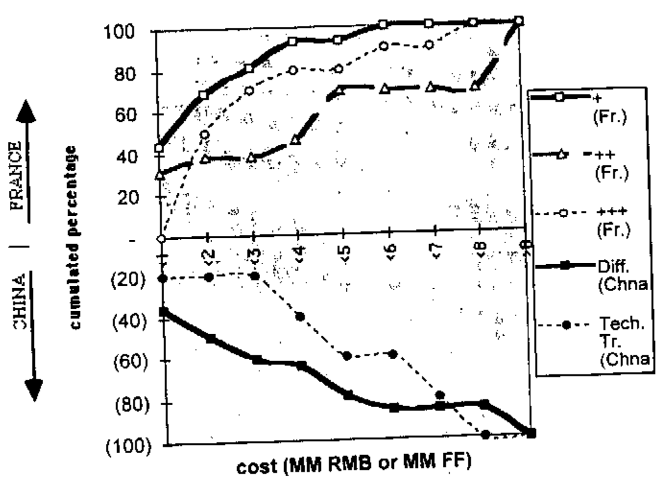

Fig. 5. Cumulated cost distribution of the various levels of innovation for the two venues.

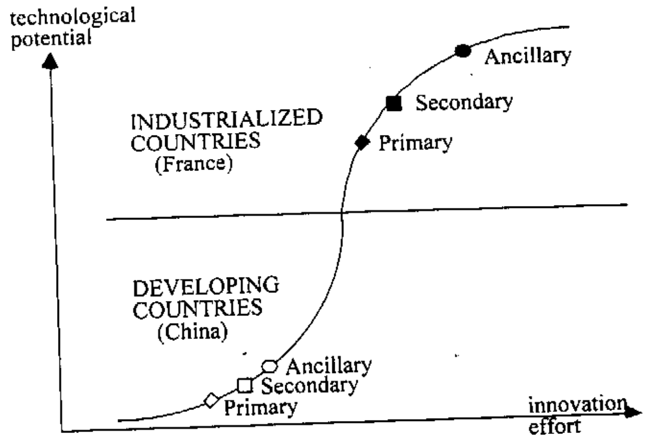

Fig. 6. Possible positioning of the various types of processes for the two venues on Foster's innovation S-curves.

processes. By definition, the recovery of waste does not affect the core of the production process where the fundamental characteristics of products are established, but is rather associated with peripheral good housekeeping practices. Another endogenous interpretation is related to the positioning of the various categories of technological options on their innovation S-curves [11]. Foster's theory on technological innovation states that technical performance evolves as a function of the research effort, following an S-curve pattern. Thus, depending on the positioning of the various technological options for clean technologies on a global aggregated innovation S-curve, less innovative projects should be observed when a category of technological options has been intensively explored and is reaching the upper plateau of the curve. Figs. 6 and 7 propose a possible interpretation of the levels of innovation observed using Foster's S-curves.

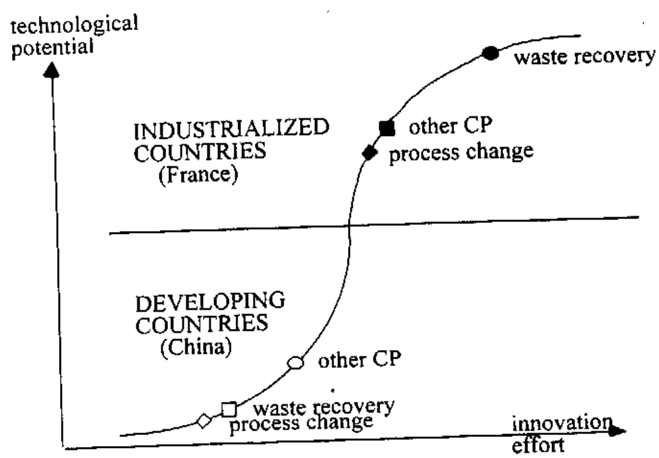

Fig. 7. Possible positioning of the various categories of CP options for the two venues on Foster's innovation S-curves.

To simplify, a single S-curve was considered[7] which allows comparison of the categories of options among themselves more easily. According to this interpretation (which has to be confirmed by further research), technologies in developing countries are located at the bottom of the S-curve while in industrialized countries they are located at the top of the curve. Differences observed for the level of innovation in the case of France would be explained by the fact that options targeting ancillary processes as well as waste recovery ones are reaching the upper plateau of the curve. In other words, more potential for improvement should be found among process changes and other CP options, and among clean technologies targeting primary and secondary processes. Lastly, differences across economies may explain why in China the proportion of process changes is higher than in France due to the large number in this developing country of obsolete equipment and of technologies needing to be updated.

The second scheme of interpretation proposes consideration of the technological management of firms and the perception that they have of the various types of technologies. For example, the profitability and the cost of the various alternatives may explain why waste recovery, ancillary processes, and lower levels of innovation are preferred by enterprises: according to financial criteria, these types of clean technologies are in general less costly and more profitable (but maybe less environmentally friendly). Moreover, rigidities to change and the aversion of firms toward technological risk could explain why process changes are less preferred than waste recovery options (in the case of France) and why options targeting primary and secondary processes are fewer than those targeting ancillary processes. They could also explain why lower levels of innovation are preferred. Finally, another possible explanation could be based on the separation inside the firm of environmental and production competence which may reduce opportunities for finding technological alternatives targeting primary and secondary processes and may limit options to waste recovery ones. In a similar way that no knowledge of the core processes of production is necessary to design end-of-pipe technologies, production competence may not be needed to investigate waste recovery options and ancillary processes. On the contrary, interactions between individuals dealing with production and others dealing with environmental issues, 'who each possess diverse and different knowledge structures, will augment the organization's capacity for making novel linkages and associations' [12] and could promote process changes or other CP options and allow targeting of primary and secondary processes.

Finally, the third scheme of interpretation involves the management of the environmental policy instrument itself. In the case of the French water basin agency, for example, the selection policy has been to focus on the diffusion of successful clean technologies and to avoid technological risks. Similarly, in the case of China, the aim of this CP demonstration project has been to create 'success stories' to advertise the concept of cleaner production in China and, therefore, innovative but risky technologies may have been avoided. Moreover, in the case of France, it appears from interviews conducted with the agency's managers that the decision toward a specific type of technology is taken at the level of field managers named *ingénieurs chargés d'affaires*. As the French water basin agencies have adopted until recently a more 'end-of-pipe-oriented' approach, the capacity of these managers to evolve toward more innovative technologies targeting primary and secondary processes depends on their personal involvement to make this transition and to investigate new technological alternatives. Cleaner technologies other than waste recovery options and those concerning processes other than ancillary ones could perhaps be promoted by educating these field managers.

5. Conclusion

The three-dimensional technological assessment has allowed the identification of significant heterogeneity within the various technological alternatives. Some of them may be explained by intrinsic differences that exist among options, but others may be the result of environmental policy distortions or of resistance existing inside firms—as, for example, for primary processes. Further research should be done to confirm the hypotheses that have been proposed throughout this paper. Foster's innovation S-curves in particular could be determined more precisely for the various alternatives. Correlation should be more rigorously established as well between firms' various types of management and their technological preference, and between the management of environmental policy instruments and the types of technologies they promote.

This research has consciously omitted the discussion of the environmental performance of the various technological alternatives due to lack of reliable data.[8] Further research could be done in that field to determine whether some technological alternatives should be preferred for certain types of pollution. However, such an investi-

[7] In reality, various categories of technological options should have different types of S-curve: a higher environmental performance could, for example, be achieved by using process change options rather than waste recovery ones, but with a higher research effort.

[8] Only partial ex ante estimations of pollution reduction were available.

gation should keep a pollutant-by-pollutant approach and avoid the use of aggregated indexes. The use of an index[9] allows to establish an absolute comparison among technologies but does not allow to identify tradeoffs. For example, the top of the innovation S-curve may have been reached for the recovery of fibers in the black liquors for the pulp and paper industry in Sweden but not for the recovery of heavy metals in the Swedish electroplating plants. Moreover, the use of an index is always controversial from the health-based point of view given the current scientific knowledge of the relative health impacts of the various categories of pollutants. In distinction, a single pollutant approach could allow one to determine, for a specific kind of pollution, if a particular technological approach should be promoted.

For environmental policy makers, the technological assessment methodology could allow the comparison of the performance of various existing policy alternatives. When certain categories of technologies are not sufficiently explored, extra incentives could be found to promote these alternatives. In the case of economic instruments, more favorable technical or financial assistance could be proposed to enterprises. In France for example, another water agency, the Agence de l'Eau Seine-Normandie, offers different types of financial support to enterprises depending on whether cleaner technologies target primary or secondary processes on one hand, or ancillary processes on the other. Changing the financial parameters may be the easiest way to reorient the technological strategy of environmental economic instruments, but other options could be considered as well, such as the education of managers, demonstration projects, databases of technologies, etc. In the case of France, where governmental economic instruments (revolving funds and subsidies) are widely used to promote clean technologies and industrial development in general, the methodology of the three-dimensional technological assessment could prove to be a useful management tool for policy makers and managers.

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[9] Certain World Bank documents (World Bank Asia Information Service Center project files corresponding to the credit no. 2475, 3781, 3966 and 4055) report the use of an equiscalar pollution reduction index by the Chinese NEPA. The principle of this index is to add for various pollutants, the ratio of the pollution reduction obtained divided by the corresponding standard.