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Technological paradigm and innovation of EST of SMEs in China

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Abstract——This article described the change of technological paradigm from environmentally unfriendly technology to environmentally sound technology(EST), and reported results from the investigation made in 1993—1995 of how China's small-medium enterprises (SMEs) have been innovating technology in response to environmental pressures and tried to identify factors affecting China' SMEs to innovate more environmentally sound products and processes.
Keywords: EST; technology management; SMEs.

1 Introduction

In the pursuit of rapid industrialization environmental degradation, especially industrial pollution are witnessed. Now, in China, the current state of the environment is described as deteriorating in general, and improvements in some locality. Higher speed development of small and medium sized enterprises (SMEs), which accounts for 99.9% of enterprises in China, greatly contributes to this situation. There is a serious hidden crises-low economic benefit and high environmental cost. Cleaner production is a main measure to decrease industrial pollution and improve sustainable development. Technological innovation is regarded as "the key to an effective solution" (Orr, 1976). But literature on "EST" is limited. Management of technological innovation responding to environment is still at a relatively early stage of development (Winn, 1993). This paper reports some results from an investigation of how China's SMEs have been responding to environmental pressure.

The questionnaires were sent to 182 sample SMEs (small-sized enterprises are one less than 100 employees, and medium-sized refer to one with 100—500 employee). 104 firms in Zhejiang and Jiangsu Province responded to this, including 62 environmentally sound products and process. All the SMEs are state-owned or collective ownership (Table 1).

We interpreted the result in terms of the theoretical framework of "technological paradigm" and "selection environment" and tried to find factors affecting SMEs to innovate more environmentally sound products and process in China.

Table 1 Structure of investigated enterprises and projects

Industry department	Mechanical	Print-dye	Paper making	Building materials	Other	Total
Enterprise, %	23.1 (24)	30.8 (32)	17.3 (18)	21.1 (22)	7.7 (8)	100 (104)
Project, %	19.4 (12)	38.7 (24)	14.5 (9)	17.7 (11)	9.7 (6)	100 (62)
Include:						
Green product	—	—	—	—	4	4
Cleaning Process	—	4	3	1	2	10
Cleaner technology	12	20	8	8	—	48

2 Technological paradigm and selection environment

2.1 Technological paradigm is shifting

Technological paradigm, which is analogous to Kuhn's "scientific paradigm", is developed by Dosi as a "model" and "pattern" of solution of selected technological problem based on selected principles derived from natural science and on selected material technologies. Technological paradigm determines the paths of technological change which is called a "technological trajectory". Just very recently, the trajectory are environmentally unfriendly technologies with latent scale economies, mechanization of operations, electrification. Natural was regarded as a storehouse containing unlimited resource required for industrial production. Technology is regarded as a means to exploit potential resource and meet people's physical demand. The industrial ecosystem is characterized by linear (Fig. 1).

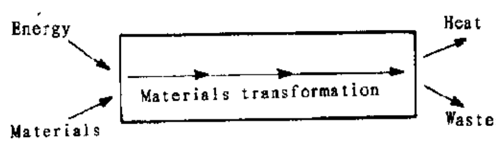

Fig. 1 Type I industrial ecosystem

The paradigm of technology is gradually changed from environmentally unfriendly technology to environmentally sound technology, now nature is regard resource store with limited building capability and limited carrying capability. ESTs became the new development direction. The industrial ecosystem is changed to some internal or complete internal cycling of materials (Fig. 2).

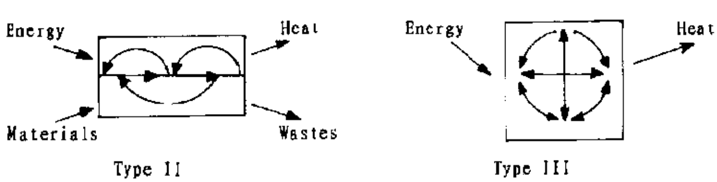

Fig. 2 Industrial ecosystem

ESTs includes:

- Green products: Less emission during production and consumption, easy to recycle and reuse;
- Cleaner technology: Pollution is prevention on the conception of source reduction,

reuse, recycle, and something else with residue;

- Cleaning technology or end-of-pipe techniques: including waste treatment, residue incineration and resourcelization, and so on.

2. 2 Selection environment

The dominance of particular trajectories is to a large extent related to the adaptation of the selection environment which Nelson and Winter (Nelson, 1977; 1982) called. The new green selection environment for EST, in my view, will mainly include: regulation preference; consumer preference; public pressure; cost saving through energy efficiency and waste minimization.

Certainly, "market demand" or "regulation regimes" do not simply impact on a reactive firm. A spur for one firm may be disadvantage another. So, the innovative climate for firms is important too including enterprise cultures, organizational structure, entrepreneurial strategies and so on.

3 Factors affecting innovation of ESTs of SMEs in China

We asked firms to rate, from a list provided, those "factors which might have prompt your enterprise to develop EST". Responses, in terms of average rating, are presented in Table 2.

Table 2 Factors to prompt SMEs to develop EST

	Product innovation	Cleaner process	Cleaning tech.
Existing government regulation	1. 81	2. 10	3. 41
Anticipated regulation	0. 41	1. 03	1. 52
Pressure from environment campaigns	1. 57	1. 43	3. 01
Economic incentive instruments	NA	0. 45	1. 23
Cost savings through better use of materials/energy	0. 87	2. 05	1. 89
Prospect of expanding market share	2. 17	1. 23	1. 47
Personnel commitment to environmental matters	2. 26	1. 38	2. 15
Employee protection	NA	2. 89	1. 76

* Rate their importance on a scale of 1 to 5

Table 2 shows that:

(a) Prospect of expanding market share and personnel commitment to environmental matters are the main factors;

(b) Existing government regulation, cost savings through better use of materials/energy and pressure from workers for safe working condition are the top three factors influencing cleaner process;

(c) Existing government regulation and pressure from environment campaigns play an important role in the application of cleaning technology;

(d) Economic instruments such as emission fee to encourage innovation of EST are still less effective in prompting EST innovation of SMEs because of too low emission charge in China.

The result, to some extent, is similar to K. Green and A. McMeekin's (Green, 1993) conclusion that existing government regulation is significant incentives to EST innovation of UK firms. It is different from the common sense that technological innovation is conceded as "technology push" (Schumpter, 1939) and "market pull" (Schmookler, 1966). Market force is not enough to prompt the development of EST without government regulations and enforcement.

Besides the green selection environment, the internal corporation structure including technological capability, environmental awareness, organization structure and decision-making mechanism is an important factor to prompt or hinder innovation of EST. Technical obstacles to innovation of ESTs of SMEs are shown in Table 3.

Table 3 Technical obstacles to innovation of ESTs of SMEs

Factors	Product innovation	Cleaner process	Cleaning tech.
Restricted R&D capability	3.37	3.19	2.73
Lack of EST information	3.41	2.01	2.15
Lack of practical demonstration	1.48	1.87	1.53
Lack of complementary technology	NA	2.74	1.36
Difficult to integrate with the existing technical infrastructure	2.59	3.36	1.85
Process inflexibilities	2.13	3.02	1.54
Technology risk	2.83	2.94	1.97

* Rate their importance on a scale of 1 to 5

Low technological capability of SMEs is a main obstacle to innovation of EST. SMEs lack of their own core technologies, 91.7% small firms have no R&D department, 85.7% medium firms have no R&D department. Technology experts are also shortage. An investigation on Yixing, a most prosperous area of environmental industry in China, stated that there are averagely only one full-time senior scientific and technological research personnel in 20 firms. In addition, most of the equipment was obsolete, and the resource utilization rate is lower than SMEs (Table 4).

Though there are many kinds of intermediaries such as "productivity promotion center", "industrial park of environmental S&T", and so on to help innovation and adoption of ESTs for SMEs. As Table 3 states, information is not easy for SMEs to access, and capability of SMEs to integrated information is also very low. Only 7.7% SMEs can synthesize the collected information.

Table 4 Technological personnel of environmental industrial firms of Yixing City of Jiangsu Province in 1994

Item	Number	Percentage of employees, %
Firm	738	
Employee	30303	
S&T research personnel*	4753	15.70%
Include: Senior	1265	4.17%
Middle	1496	4.93%
Junior	931	3.07%
Skill worker	803	3.53%

Data source: Lu Yan and Wang Weiqiang (Lu, 1996) * include part-time employees

Besides technical obstacle, the conceptual, organizational, and economic obstacle are also listed in Table 5.

Table 5 Overview obstacles to innovation of ESTs in SMEs except technical one

Item	Factor	Frequency
Economic	No profit to invest in EST	0.92
	Incomplete calculation and allocation of environmental cost	0.97
	Low charge for environmental protection	0.95
	Lack of capital on EST	0.97
	Short-term behavior	0.98
Conceptual	Resistance to change	0.91
	Protecting environment is costly	0.92
	Prevention is only in the long-term	0.91
Organization	Lack of open and innovative climate	0.95
	Lack of internal environmental protection department	0.88
	Lack of trained and motivation of employee	0.91

As Table 5 shown, some factors including "incomplete calculation and allocation of environmental cost", "low charge for environmental protection", "resistance to change", and "lack of open and innovative climate" are rated higher. It states the environmental protection education and environment audit need to be strengthened.

Capital shortage is also an very important obstacle to innovation of ESTs of SMEs. The national investment on EST innovation is only about 12 million RMB Yuan in the last five years including 4.8 million RMB Yuan allocated in hardware technology (accounting for 37% —42% of the total investment). It is also not enough for SMEs to support the innovation of ESTs. Because of small scale and low capital accumulation rate in SMEs as Table 6 shown.

Table 6 Capital accumulation of paper-making industry of SMEs in China

Province	Zhejiang	Henan	Hunan	Sichuan	Whole
Pmax, 10^4 RMB Yuan/a	4.27	3.1	1.34	1.1	3.35

Data source: Wang Jiangming *et al.* (Wang, 1993)

*P*max= sale profit + cost (of paper-making industry in area)/the firms of the industry

4 Implications and conclusions

The paradigm change, from environmental unfriendly technology to environmental sound technology, is slow and evolving. The introduction and diffusion of new technologies not only involves a change in technology, but also quite fundamental changes in organization and social culture. EST innovation is different from common technological innovation, implications and conclusion are as follows:

(a) Government is an important actor within the selection environment as the survey stated because of market failure for environmental protection. Government intervention may be in the form of economic instruments that affect the costs and benefits of pollution control and of R&D; or in the form of emission standards that require the innovation and adoption of ESTs; or in the form of communicative instruments aimed at better understanding and environmental awareness of firms and consumers (Kemp, 1992).

(b) It is necessary to shift attention from assessing risk to identifying technology for risk reduction and change the end-of-pipe technological trajectory to EST (including end-of-pipe technology, green product technology and prevention).

(c) Restrict standards with flexible provision to allow and encourage innovative response of industry are needed.

(d) The current emission charge is too low to give incentive to firms for innovation and adoption of ESTs. It needs to give a time-table to increase emission fee and charge emission fee based on emission and industrial process emission coefficience instead of emission density.

(e) It is also necessary to provide assisstment to the firms that are not in a position to innovation because of low technological capability of SMEs. The support system is needed in order to push innovation and diffusion of ESTs including engineering center, ESTs innovation center, information transfer, demonstration project, the education of consultants and joint venture.

(f) As we know, public pressure is an important source to push innovation and diffusion of EST and protect environment. It is very urgent to educate policy-makers and technological experts to pay more attention to environmental protection during decision-making and products and processes design. In addition, new skills and knowledge are also needed for environmental sound commercial products and processes.

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