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Spin-Off Enterprises in China:

Channelling the Components of R&D Institutions into Innovative Businesses

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1. INTRODUCTION

1.1 China's S&T System.

A huge system for Research and Development (R&D) developed under the centrally-planned regime in China from the 1950s on. It was entirely Government-owned and Government operated. Some basic indicators of this system are shown below.

BASIC INDICATORS OF CHINA'S R&D SYSTEM

1. Expenditure for R&D: usually slightly less than 1% of GNP. In 1990 it was 0.7%;
2. R&D Scientists and Engineers: 653,000 (in full time equivalents, in the fields of natural science and engineering, with secondary and above educational background)
3. The distribution of expenditure in 1990:
   Independent R&D institutes: 70%
   Higher educational institutions: 5%
   Enterprises: 25%
4. The distribution of R&D scientists and engineers in 1990:
   Independent R&D institutes: 59%
   Higher educational institutes: 23% (in full time equivalents)
   Enterprises: 18%
5. Total number of independent R&D institutes in 1990: 5,084
6. The sectoral distribution of independent R&D institutes in 1990:
   1) Agriculture, Forestry, Animal Husbandry, Fishing, and Water Conservancy: 1,552 institutes, 9% of the expenditure by all 'independent' R&D institutes
   2) Industry, Transportation, Post and Telecommunications: 2,109 institutes, 54% of expenditure
   3) Comprehensive Scientific and Engineering R&D: 242 institutes, 14% of expenditure
   4) Medicine and Public Health: 332 institutes, 5% of expenditure
   5) Others (including Geological Survey and Exploration; Construction; Environmental Protection; Measurements; Meteorology etc): slightly more than 10% of expenditure

Source:
Calculated from data in the *China Statistical Yearbook on Science and Technology, 1991* (Chinese version), pp. 1, 31, 70, 118. Richard Conroy provides a similar description of the situation for the early 1980s (Conroy 1992, Chapter 2).

The first significant feature is that the size of the system, as outlined by indicators 1 and 2, is significant in terms of both total manpower and overall expenditure for R&D, though it is moderate in *per capita* terms even as compared to some developing countries.[1]

Second, R&D institutes for industrial technology were separated from the industrial users of their outputs. Those carrying out industrial R&D were organized in, and confined to, their designated departmental administrations according to the institutional rules of the time — as indeed were the end-users of their research. Organizational segmentation was so serious that, until 1990, only about one fourth of R&D activities, in terms of expenditure for instance, were performed by enterprises, as shown by indicators 3 and 4.

This gave rise to serious problems in 'linking' R&D institutes and production enterprises, or 'transferring' R&D output to its industrial users.

Third, the external R&D institutes are numerous and widely dispersed among the levels of the administrative hierarchy, as shown by indicators 5 and 6. This dispersal occurred in parallel with the decentralization of the economy in China from the 1950s to the 1970s. The resulting widespread geographical distribution of R&D institutions facilitated the initiation of development Zones and spin-offs by local governments later on. These phenomena are the subject of this paper.

1.2 Market Reform and Restructuring Responses to the Market Reform.

In China

As in many countries, market-oriented reform of the S&T system in China is being enacted in tandem with market-oriented economic reform, which reached full development in the mid-1980s. The market orientation of the reform of the S&T management system was embodied in the "Decision on the Reform of the Science and Technology Management System" by the Central Committee of the Communist Party of China (promulgated in May 1985, see CCCPC 1985). The Decision announced that government funds granted for R&D institutes were to be gradually diminished, and that a 'technology market' was to be created.[2] Funding reductions were scheduled on the supposition that direct links between R&D institutes and the users could be extended as an add-on to the existing institutional set-up, by introducing a technology market for transactions such as the transfer of product and process technologies, contractual development of production technology, and technological consulting services.

The explosive development of spin-off enterprises from R&D institutions is taking place in this context. It could be seen as an inherent consequence of market reform of both the economic and S&T systems. In fact, the immediate experience of the technological market was not very pleasant, for both buyers and sellers. One of the major options taken by R&D institutions in response was to 'spin off' some of their assets to form new enterprises. There were other responses also. Merging R&D institutes into existing industrial enterprises was strongly promoted under China's reform policy in 1987, but was not very successful at that time. Since entering the 1990s, another type of restructuring — transforming entire R&D institutes into profitable innovative companies — seems to have been successfully carried out in a number of cases. Some consensus regarding the restructuring of industrial R&D institutions has begun to appear, at least as regards the need to integrate R&D with production and marketing. This implies a close interaction between policy-makers and R&D institutions. Indeed, throughout the development of various restructuring phases, reform policy has evolved in response to practical experience, making a continuous adjustment of China's S&T reform programme possible.

Most of the options open to R&D institutions under the technological market were directed towards the internalization of the various functions necessary for the commercialization of technologies, either within the R&D institute, or in the newly created spin-off enterprise, or in existing production entities. This is happening in parallel with the slow but steady strengthening of in-house R&D and of technologically innovative activities within productive enterprises. The 'Technology market' — the new rule and practice for the S&T system, mandating paid transactions for technologies — has served as a complementary way of capitalizing on the value of the output of R&D institutes, secondary to the various internalization options. This points to a basic inference, which the study takes as a starting point, that *market-oriented economic reform calls for the restructuring of the R&D system, rather than simply connecting the old institutions with users by means of the marketing of technologies, while leaving existing institutional bases untouched*.

In some former centrally planned economies

This consideration is reinforced by broader observations. Outside China, more and more literature is reporting *poor sales records* for independent R&D institutions in the former planned economies.[3] Serious problems have been encountered in many countries: a brain drain, crises in R&D organizations, and, most critically, acute disputes regarding reform policy. Reform policy for the R&D sector has in fact been weak and muddled. Serious questions arose: how to re-deploy the scientific resources which had built up within, and were grounded in, the previous institutional framework. Chris Freeman put the problem in these terms:

> ...most of the former Communist countries did actually invest fairly heavily in R&D and related technology activities. But this investment suffered from great distortions such as the huge military projects in old USSR, and the tendency to neglect the enterprise-level scientific and technical activities. Therefore the re-orientation and re-deployment of the science-technology resources of the former Communist countries is one of the most urgent problems which they confront.[4]

These observations highlight the importance of focusing on the restructuring of the old S&T system. It seems that a blanket approval of marketization, which is pervasive under reformist policies as a talisman to cure problems produced by dysfunctional administrative control, is far from adequate to offer sensible guidance to a smooth transition. This blocks the thinking and hampers the formulation of proper S&T policies under the present reforms. Issues such as (1) a deeper understanding of the various phases of restructuring since the reforms began, and (2) a more exact theoretical interpretation of the abilities and limitations of market mechanisms with respect to the transformation of the S&T system cannot be overlooked in any analysis of intellectual labour.

Other historical observations

While the restructuring of the S&T system is still developing in many places where market reforms are now taking place, other restructuring responses to market forces have been observed previously. Among many others, one useful analysis has been made by D. Mowery and N. Rosenberg, with respect to institutional restructuring in the first half of this century in the U.S. At that time science, or more precisely, the utilization of scientific knowledge, methods, and principles for industrial purposes, was beginning to be widely applied by industries in a market environment. The outcome was that science was integrated into industrial enterprises, in in-house R&D departments. At the same time, independent research enterprises were decreasing in importance, in relative terms, and came to serve as complementary sources of industrial technologies. This analysis is a useful reference-point for our study, in the sense that market rules are just now being introduced in China into a domain in which all industrial enterprises and scientific institutes were previously institutionalized under a quite different system of control. As for the restructuring which the introduction of market rules entails, the following lessons can be learnt from the American experience:

- "The highly uncertain nature of the research enterprise, the imperfect character of knowledge about a given project, and the thin market for specialized research service" undermines "the effectiveness of contracts in the provision of research" [*Mowery and Rosenberg 1989, pp. 82*];
- "Commercially successful innovation requires the combination of skills and information from a wide range of functions within the firm and often exploits firm-specific knowledge emerging from complex production process" [*Mowery and Rosenberg 1989, pp. 91*];
- "to be effective, industrial research requires complementary changes in the structure and organization of firms and markets. Where these changes have not occurred, industrial research has been more modest in scope and less effective." [*ibid, pp. 92*]

1.3 The Scope and Structure of the Paper

This paper aims to make a contribution to the first issue mentioned in the paragraph above, i.e., providing a deeper understanding of the phases of restructuring. In particular, this paper concentrates on spin-offs, which are seen as a significant approach to institutional restructuring. A review of China's S&T reform policy with respect to restructuring R&D institutions has also been conducted and will be presented in a separate paper.

The focus chosen for this paper is justified, first of all, from a pragmatic perspective. Of all the structural responses which have emerged in China's reform programme, spin-off enterprises are the most numerous and successful thus far. Spinning-off is a kind of restructuring in which R&D components are channelled into newly set-up business organizations. The integration of "science" with many other market-oriented functions is achieved and dynamically developed within the newly-created organizational framework. By 1993, about 10,000 spin-off enterprises had been established, employing about 100,000 scientific and technical staff. A number of the spin-off enterprises have become competitive on domestic and international markets. This appears to be a promising approach to the restructuring which is indispensable in concert with the economic reforms, especially because it offers a way of making good use of accumulated capabilities.

This study focuses primarily on two fundamental dimensions: (1) the initiation of spin-off enterprises, and (2) the technological activities which the spin-off enterprises are engaged in. Both are examined in an attempt to understand the basic aspects of the restructuring, i.e. how the existing organizational frameworks can be restructured, how far the spin-off enterprises have come in terms of gaining capabilities to provide users with products and services, and where they are going to.

The twin focuses leave many critical problems uncovered. The one most frequently raised concerns property rights. How, it has been asked, were the assets of an institute, which were being transferred into spin-offs, identified and reinforced? Who decided on the transfer of assets? Is the state still involved in the process of assets transfer? How is the responsibility and liability with respect to transferred assets shared between institutes and spin-offs? and, Who owns the spin-off enterprises?

In fact, the re-allocation of R&D institute assets, associated with the establishment of a new business enterprise, was realized in a "two-step" process. It began with a partial commitment of state-owned institute assets to individual R&D institutes. This was legitimated by the 1985 Decision. Second, institute assets were contracted to spin-off enterprises on the initiative of the individual institutes. The process described here is also generally applicable to the emergence of many other non-state businesses, notably the emergence of rural industry. Rural industry took similar initiatives, with local governmental authorities playing central starting-up roles and the firms being partly owned and run by their managers and staff. This was achieved in the context of administrative decentralization.[5]

This could be seen as a "Chinese way" of evolving out of the old regime. From the early stage of the evolution, and until quite recently, property rights were indeed ambiguous. However, reformist evolution did take place even under this ambiguity, and an examination of how it occurred may provide an introductory understanding of the process. This is the perspective taken by the study. In examining the initiation of spin-off enterprises, the focus is on the actual actors and methods employed, while the officially defined ownership will also be considered. We found that the officially defined ownership structures of spin-offs are usually no more than a sort of record of the past — the record of the original initiating capital with some bias, as we will see below. On the other hand, the ambiguity of property assets has caused problems for the healthy development of spin-offs. It has recently been a focus of attention for those investing in spin-offs and others promoting reform. It is worth remembering that this evolution is on-going, though it is beyond the scope of the present paper.

To gather first-hand material, an intensive field survey was conducted from May to August, 1993, focusing primarily on the two fundamental dimensions mentioned above. This survey is the main source of the findings presented in sections 4 and 5, section 4 deals with the initiation of spin-offs, while section 5 addresses the technological activities undertaken by spin-off enterprises. Sections 1 and 2 provide broader background information about the original emergence of spin-offs, the launch of the Torch Programme — a national programme for the development of new and high technology industries via spinning-off — and the development of Zones for New Technology Industries, which are both delineated geographical areas and supporting institutions for the spin-off enterprises. This information comes from the intensive collection and analysis of both documented and oral information on the subject. Section 3 is an introduction to the approach of the field survey. Section 6 describes the dynamics stimulating the dramatic increase in spin-offs, placing it in the socio-economic context of decentralized market-oriented reform in China.

2. THE DEVELOPMENT OF SPIN-OFF ENTERPRISES IN THE 1980s

'Spin-off' enterprises represent one mechanism for integrating the capabilities (or outputs) of R&D institutes with industrial production. Instead of institutes being incorporated into existing industrial enterprises, or the R&D outputs being 'transferred' to such enterprises through market or other mechanisms, some of the technological assets of institutes (knowledge, skills, product or process specifications, etc.) are spun off to form the nucleus of new ventures. These are combined with other assets (finance, production facilities and competence, market knowledge and marketing expertise, etc.), to start new economic activities based essentially on the original, institute-derived 'technology'.

By the early 1990s, a very large number of such enterprises had emerged from science and engineering R&D institutes. The number of these apparent 'spin-offs' grew very rapidly following the launch of the Torch Programme in 1988, which provided formal policy support for the development of such enterprises. However, the origins of this kind of institutional development can be traced back to the beginning of the 1980s, and the number of spin-offs was already significant by 1988. As in other aspects of change during this period, therefore, the formalities of policy followed the practice, sanctioning and providing further support for institutional innovations that had been at least partially tested and found useful.

2.1 Origins and Early Growth

In 1980, Prof. Cheng Chunxian, a Research Professor at the Institute of Physics, of the Chinese Academy of Sciences (CAS), with the support of the Science and Technology Association of Beijing, created the first technological development entity that was not initiated, financed or owned by the state. It is now a Chinese-American joint-venture: the Beijing Huaxia Guigu (China-Silicon Valley) Information System Corporation Ltd.[6] Other enterprises of this type followed in Beijing, initially in small numbers and with considerable caution in the face of official suspicion and sometimes hostility. At first most were very small ventures, although the boundaries between the ventures themselves and the originating institutions were sometimes blurred. Nevertheless, several rapidly became quite independent businesses. By the mid-1980s the best known of them were the co-called Two Tongs and Two Hais — Si-tong (i.e. Stone), Xin-tong, Ke-hai and Jing-hai. All four began as businesses focusing on micro-electronic devices. By 1985 there were about 100 such ventures, and the main street on which they were concentrated had begun to be called Electronics Street. The 16 largest of these ventures were reported to have a combined turnover of 120 million yuan in 1985 [*Wang Xiaolong (eds.) 1993, pp. 41*].

In the mid-1980s these spatial concentrations of spin-off enterprises were more formally recognised and encouraged. In July 1985, the Shenzhen Science and Industry Park was founded as a cooperative initiative by the CAS and the Shenzhen Municipal Government. The park was set up to create a base area where advanced technology from CAS and other institutes could be combined with foreign investment and technology to open up a new way of developing commercial high-technology products.[7] In May 1988, the State Science and Technology Commission launched the Torch Programme as a mechanism to consolidate and further encourage two linked strands of institutional change: the emergence of 'spin-off' enterprises and the development of areas in which they could be concentrated.

2.2 The Launch of the Torch Programme

The Torch programme was developed in response to concerns for the future and frustrations from the past. New national objectives were being formulated and it was recognized that they would have to be achieved in new international and technological contexts. On the other hand, previous efforts to link R&D capabilities with industrial production were seen to have been unsatisfactory.

The future-centred concerns involved broad and ambitious targets to mobilize domestic scientific and technological strengths to support the development of new and high technology industries and an export-oriented strategy. The export strategy had been announced in 1988, and applied mainly to the coastal provinces of China. Much of the debate about how this export orientation might be achieved emphasized the necessity of "releasing" science and technology manpower from the constraints of existing institutions in order to organize new businesses, i.e., to create "spin-offs". Five main points were frequently stressed.[8]

- China's international market-oriented strategy for industrialization at the end of the twentieth century could not repeat the pattern of fast growth in South Korea and Taiwan in the 1960s and 1970s, which had been characterized by the labour-intensive assembly of components. To drive China's economic take-off, technology-intensive and skill-intensive sectors should be given high priority at the same time as developing labour-intensive industry.
- China had developed strong manpower capabilities in science and technology which should be effectively employed without delay, otherwise other Asian counties would increase their efforts to borrow theses capabilities to upgrade their own industries.
- The most important issue hampering the commercialization of science and technology was the immobility of personnel who were locked into their existing institutions. However, in the changing political and economic climate of the 1980s, it had become increasingly feasible to release scientific and technological talent to create new forms of business enterprise.
- To commercialize technological know-how and expertise, various complements would be indispensable, which were then separate or lacking. However, better access to international and domestic markets under the Open Door policy would make it possible to acquire these complements from the marketplace.
- Creating new, internationally competitive, business entities would introduce international management and institutional norms, so injecting an ongoing momentum to reform and development in China.

Concerns about these broad objectives was combined with frustration over the limitations of previous efforts to link R&D institutes and industrial enterprises during the 1980s. Both the efforts to incorporate R&D institutes into existing enterprises and the use of market-mediated and other mechanisms to strengthen technology transfer links were seen as unsatisfactory. Referring to the weakness of the latter, Mr. Song Jian, Chairman of the State Science and Technology Commission, stressed in his speech at the inaugural National Working Meeting of the Torch Programme ("White Paper" No. 3, p. 415):

> "We acknowledge that we can expect to find better solutions to the problems which were faced by R&D institutes and universities, i.e. the limited ability of large and medium-sized enterprises to absorb [external] technologies and the difficulties arising from excessively small [technology] markets."

The development of the programme also reflected growing recognition of the role being played by the spin-off enterprises that had emerged over recent years. Again this was highlighted by Mr. Song Jian:

> "The business entities which have been initiated by scientific and technical experts, based on their scientific and technological strength and on the integration of [technological] development, production and marketing, are engaged in transforming accumulated S&T achievements into productive power and commodities."

Reflecting theses various concerns, the Torch Programme concentrated on creating new institutions to support the decentralized establishment and development of spin-off enterprises. This marked a significant departure from earlier government plans and programmes which had directly controlled and implemented detailed scientific, technological and related economic activities. An array of policy measures were announced.[9]

- In order to encourage the science and technology institutions to start up spin-off enterprises under a variety of forms of ownership, fiscal and other incentives would be available to approved New Technology Enterprises (NTEs), while patented and other proprietary technology would be allowed to be accounted as equity;
- In order to create a favourable environment for NTEs, Development Zones for New Technology Industries would be established;
- Service Centres for Scientific and Technical Entrepreneurs would be established as "incubators' for spin-offs, especially those initiated by individuals;
- The government would set up "leading funds" for financing the commercialization of technology, and various other financial sources, mainly banks, were encouraged to open and expand credit facilities for commercializing technology.

New Technology Enterprises were to be formally licensed by Zone authorities, but had to meet several criteria [*SSTC 1991a: pp. 563-566*]:

- the technology underpinning the activities of the enterprise should be in specified areas of "new and high" technology defined by the State Science and Technology Commission;[10]
- the enterprises should have appropriate capital and physical resources, market potential, and acceptable organizational and managerial abilities;
- the chief manager should be a scientific or technical professional.

In fact, most of the enterprises which had been spun off from the R&D institutes became formally licensed NTEs. Through the implementation of these measures, the Development Zones for New Technology Industries (hereafter referred to simply as Zones) became the main policy vehicle for promoting and regulating the development of spin-off enterprises.

3. DEVELOPMENT OF THE ZONES FOR NEW TECHNOLOGY INDUSTRIES

The response to the Torch Programme by academics and local governments was enthusiastic. Many municipal governments initiated Zones, applying to the central government for approval of their status as "National Level" Zones. The pace of development generated concerns about the demand for investment resources and the quality of the Zones being created, and the central government warned local governments about excessive haste and placed restrictions on the establishment of new Zones. Nevertheless, as shown in Table 1, the number of Zones expanded rapidly.

TABLE 1
GROWTH OF DEVELOPMENT ZONES FOR NEW TECHNOLOGY INDUSTRIES

Year	Number of NTEs in Zones		Number of Zones
	Total	*In Beijing Zone Alone*	
1983		11#	
1984		40#	
1985		90#	
1986		100#	
1987		148#	
1988		527*	1
1989	1,704	974*	26
1990	1,690	1,343* / 387	36 (27)
1991	2,743	2,442* / 650	39 (27)
1992			
1993	10,000***	3,000**	(52)***

Sources:

(1) the figures marked "#" are cited from Wang Xiaolong (ed.) "Chronicle of Zhongguancun Electronics Street 1980-1988" (Zhong guan cun dianzi yitiaojie dashiji), 1993;
(2) the figures marked "*" are from Beijing Zone 1993, p. 17;
(3) the figure marked "**" is from Interview Notes 11;
(4) the figure marked "***" is cited from People's Daily, overseas edition, 22 Oct. 1993;
(5) the remaining figures are cited from the China Statistical Yearbook on Science and Technology, 1991, pp. 308-309; and 1992, pp. 308, 309.
(6) the figures in brackets "( )" are for Zones approved as "national level" zones.

By 1991 there were a total of 39 Zones incorporating 2,743 NTEs. Of these, 27 had been formally approved by the State Council as "National Level" Zones. Official statistics are not yet available for the period since 1991, but it is evident that both the number of Zones and the number of NTEs has continued to increase rapidly, and one source suggests that there were 52 "National Level" Zones with about 60 ‘Incubation Centres’ and 10,000 NTEs by 1993. In addition, there are about a dozen Zones initiated by local governments, but not approved by the State Council as national zones.

The Zones were geographically widely spread, reflecting the wide geographical distribution of China’s R&D institutes and universities. By 1991, 39 Zones had been established in 22 of the 29 mainland Provinces (including Hainan). Typically, the educational backgrounds of employees in NTEs were much higher than the average. In Beijing Zone, for instance, about 50% of employees had educational qualifications at the level of a university degree or higher [*Beijing Zone 1993, p. 21*]. Although no recent information is available, the role of foreign investment in the development of NTEs seems to have been limited: in 1991, for instance, only 176 of the 2,473 NTEs involved foreign capital.

Not surprisingly, there are considerable differences between the Zones. One attempt to reflect some of this diversity has been made in a study based on a databank of information on the Zones (See Chen Zhaoying et al. 1992, Chapter 3: The Mode of Zone Development). This suggests that most of the National Level Zones can be grouped into three fairly clear-cut categories.

- The first involves Zones located in urban areas with concentrations of R&D institutes and universities. These Zones, based on existing urban infrastructure, usually aim to exploit the potential of the available scientific and technological expertise. The main function of this category of Zones is to promote the development of technology-intensive and skill-intensive enterprises, some of which have been spun off from the R&D institutes and universities. Typical Zones in this category include those in Beijing, Tianjing, Wuhan, Shenyang, and Changchun. Most of the spin-off enterprises examined in this study are clustered in zones of this category.
- The second includes Zones located in existing or planned industrial areas, where the State has invested in big industrial projects, and where there are strong R&D capabilities. A typical example is the Caohejing Zone in Shanghai where there were already (i) firms in technologically advanced industries which had been established during the 1980s or earlier on the basis of imported technologies, and (ii) several universities and institutes of the CAS. In establishing this Zone, the Shanghai municipal government took advantage of the incentives provided by the Torch Programme to further its existing aims of developing technologically advanced industries in the Shanghai area. However, in this Zone as in others of this category, it is not yet clear how establishing a Zone will, on its own, stimulate the development of new ways of linking the R&D capabilities of existing institutes with industrial enterprises.
- A third category of Zone is similar to the well-known research/science park: a relatively small area with a high standard of newly-created infrastructure suitable for foreign and domestic investors in advanced industrial projects. A typical example is the Shenzhen Science and Industrial Park. There seems to be a convergence between Zones of this category and the Special Economic Zones,[11] whose purpose is to attract foreign investment. On the one hand, the technology exploited in the "science park zones" is not particularly high or new, and on the other hand several Special

Economic Zones are moving into newer technology, gradually increasing technology-intensive projects in order to upgrade their industrial structure.

The zones chosen to be surveyed in the study are all in the first category, the category most pertinent to the purpose of our inquiry.

TABLE 2
A BRIEF SURVEY OF NTES IN NATIONAL ZONES FOR NEW TECHNOLOGY DEVELOPMENT (1990 - 1992)

INDICATOR		**1990**	**1991**	**1992**
Zones	units	27	27	52
NTEs	unit	1,652	2,587	5,569
of which				
NTEs with foreign capital involvement	unit	75	167	564
employment	persons	122,889	138,231	340,346
turnover		7,567.1	8,729.5	230,924.9
of which	m. yuan			
turnover from products		56%	51%	65%
tturnover from technological service		16%	20%	11%
turnover from trading		28%	29%	23%
annual exports	m. yuan	688.7	714.6	16,359.1
expenditure for technological development	m. yuan	418.3	781.3	15,238.1

Source: *China Statistical Yearbook on Science and Technology 1993, p. 307.*

Tables 2 and 3, which are based on the latest official statistics, show some features of NTEs. First, a significant part of the business portfolio of NTEs relates to trading and technological services, as can be seen from their income structure. This is particularly true for the Beijing Zone, and for Zones in their earlier years, indicating that most NTEs start by providing retail and user services for computers, and for information related to computer technology. In fact, NTEs are widely regarded in China as a group of non-state enterprises characterised by a higher degree of integration between technology, production and retailing, and run autonomously. The second striking feature is that these integrated ventures have relatively intensive technological inputs, as can be seen from the high ratio between their expenditure for 'technological development' and their turnover. The national average ratio ranges between 5% and 9%, from 1990 to 1992, with the Beijing Zone at 7% in 1992. For all industrial enterprises in China combined, this indicator is less than 1%. A third feature is that the production and services of NTEs are oriented to the domestic market, as can be seen from the small number of NTEs which involve foreign capital, and by the limited value of exports as compared to gross production turnover, at least until 1992. In fact, spinning-off represents a move to respond to, and localize, new technology opportunities, by releasing domestically accumulated strengths. This is in contrast to firms in the Special Economic Zones in the coastal area of China.

TABLE 3
SAMPLE ZONES OF THE STUDY (1992)

Indicator		**Beijing Zone**	**Shenyang Zone**	**Wuhan Zone**	**Hangzhou Zone**
NTEs	units	1,512	631	246	81
of which					
NTEs with foreign capital involvement	units	155	89	46	3
employment	persons	43,567	35,014	14,905	2,405
turnover	m. yuan	58,414	15,166	9,659	2,207
of which					
turnover from products		34%	58%	62%	66%
turnover from technological services		18%	13%	14%	7%
turnover from trading		48%	28%	24%	27%
exports	m. yuan	5,052	892	79	81
annual expenditure for technological development	m. yuan	3,990	898	320	124

Source: *China Statistical Yearbook on Science and Technology 1993, pp. 308-309.*

Notes (for Tables 2 and 3):

1. Turnover from 'technological services' refers to turnover from:
   a. technological transfer;
   b. contractual design, engineering, etc;
   c. technological consultancy services and other technological services;
   d.royalties for intellectual property in various uses outside the company.
   e. contractual R&D projects for outside parties;
   f. sales of products produced in the internal pilot plant.

2. Turnover from trading refers to income earned by selling commodities not produced by the company itself.

The following sections will discuss the characteristics of the R&D institutes, zones and NTEs in more detail.

4. OUTLINE OF THE SURVEY APPROACH

For a preliminary but broad examination of the spin-off enterprises, a field survey was conducted in the summer of 1993.

As was mentioned in the introduction section, the survey focused on: (1) the initiation of spin-off enterprises, and (2) the technological activities which the spin-off enterprises are engaged in. Both are examined in an attempt to understand the basic aspects of the restructuring, i.e. how the existing organizational frameworks can be restructured, how far the spin-off enterprises have come in terms of gaining capabilities to provide users with products and services, and where they are going to.

The survey was designed to examine these questions to three principle kinds of establishments: R&D institutes, Zones, and NTEs. These are assumed to cover all of the main actors supporting or participating in the spin-offs.

R&D Institutes

Seven R&D institutions were chosen for the enquiry:

(a) The Institute of Physics, of the Chinese Academy of Science (Beijing);

(b) The Institute of Chemistry, of the Chinese Academy of Sciences (Beijing);

(c) The Automation Research Institute, of the Ministry of Metallurgical Industry (Beijing);

(d) Wuhan Research Institute for Posts and Telecommunications, of the Ministry of Posts and Telecommunications (Wuhan);

(e) Development Centre for Seawater Desalination and Water Treatment Technology, Number 2 Oceanographic Research Institute, of the State Oceanic Administration (Hangzhou);

(f) Zhejiang Institute of Mechanical and Electrical Engineering Design, Zhejiang Province (Hangzhou);

(g) Zhejiang University (Hangzhou).

These R&D institutions represent the following categories:

(a) Subordinate institutes of the Chinese Academy of Science (a and b above);[12]

(b) Institutes belonging to central industrial ministries (c, d, and e);[13]

(c) industrial technology R&D institutes belonging to local governments (e);[14] and

(d) R&D units in higher education institutions (g).[15]

Zones

Four Zones were selected which were expected to exhibit both the general trends and some unique characteristics. They were:

(a) the Beijing Experimental Zone for Development of New Technology Industries, located in Central North China. Government agencies and other service sectors are clustered in the Beijing region, and the density of Universities and R&D institutes is the highest in the country. This zone was formally approved by the State Council in 1988, as the first Zone of the kind in the country, so it served as a model for other zones in many respects. Its evolution began as a natural process, without any official organizing. The area has been known as "Beijing Electronic Street" since about 1984. Since 1988 it has been the biggest of all the Zones, and it is located in the biggest national market for personal computer and auxiliary products.

(b) Wuhan Eastlake Development Zone for New Technology Industries, and Wuhan Eastlake New-Tech Enterprise Incubator, in Central China. This is located in a major conglomeration of both heavy and light industry, and of R&D institutes and universities in the middle part of China. The area is an important base for the optical telecommunication industry and R&D. The Wuhan Eastlake Enterprise Incubator was the first of the Centres for Scientific and Technical Entrepreneurs. In the summer of 1993, when the field survey was conducted, this was the largest "incubator" in the country.

(c) Hangzhou High-Tech Industry Development Zone, located on the coast in South-east China. The industrial structure in the area has been very "light", with enterprises generally smaller than average. Town and village enterprises have been growing rapidly since the late 1970s. Hangzhou is stronger in higher education: the prestigious Zhejiang University and a number of other universities are located there. The zone is relatively small, and was founded in 1991. It can serve as a typical example of zones of this kind, which comprise the majority of all zones.

(d) Shenyang Nanhu Science and Technology Development Zone, in North-east China. The area has been one of the most important bases for heavy industry since the 1950s. These industries now face serious challenges in the transformation of both their management and technology. There is an important concentration of R&D institutes and universities in the area. This is one of the bigger zones in terms of the number of NTEs and their total turnover.

Note that these four are all in group 1 of the categorization above, of urban Zones in areas with concentrations of R&D institutes and universities, and which are intended to promote the development of technology-intensive and skill-intensive enterprises spun off from these R&D institutes and universities.

In addition, Shenzhen Science and Industrial Park was visited. This park is located in the Shenzhen Special Economic Zone and was jointly initiated by the Chinese Academy of Sciences and Shenzhen Municipal Government. The visit provided useful information about the third category of Zones as defined in section 2 above.

New Technology Enterprises

In each zone, two or three enterprises were visited. The interviews with these enterprises were intended to enrich, verify, or correct aggregated information on NTEs at the zone level, which was provided by the zone managers. There is aggregated data covering some 5,000 NTEs: 3,400 in Beijing, 320 in Wuhan, 160 in Hangzhou, and 1,100 in Shenyang. Firm-level data was obtained for about 10 NTEs, covering their set-up, development, and technological activity.

5. INITIATION OF NEW TECHNOLOGY ENTERPRISES

5.1 Forms of 'Spinning-Off'

The survey enabled us to make some generalizations about three forms which the spinning-off process has taken. They are characterized according to the size, the characteristics of the talent and other assets that were channelled into newly established NTEs from their original R&D institutes, and the relation of the spin-off unit to their parent institute. We recognized these forms from observations in both NTEs and R&D institute establishments, and confirmed their validity from Zone-level aggregate data.

Form 1: Part of an organized institute is channelled into an independent NTE

This is a form of spinning in which a piece of the organized structure (manpower, technological, and, frequently, physical assets) of the original institution is diverted to establish a new independent business entity.[16] The most obvious feature of this form seems to be that the NTE retains some of the organizational structure which it had as a part of the previous organization. This means that they are relatively stronger at the outset, not only in terms of initial capital, physical installations, and real estate ("tangible" assets), but also in terms of internal cooperative relationships, the staff's trust in the leadership, and outside links. All of these were already developed under the organizational framework of the earlier institute. For instance, the Legend Computer Group Corporation (see Case Text 1) has benefited from its perceptive strategy, which was largely realized through the efforts of a rather cohesive and self-assured group of leaders. The General Manager of the Corporation was an engineer of computer technology who had had responsibility for Institute management for a long time before turning to manage the Corporation.

This is the most important form in terms of numbers of NTEs. In Beijing, Wuhan, Shenyang and Hangzhou, 50%, 40%, 30%, and 30% of the NTEs, respectively, were initiated in this form. Thus, at a rough estimate, more than a thousand NTEs have been spun off in this way in all Zones. This form of spinning is also important because many of the very successful NTEs were initiated in this form. The Legend Computer Group Corporation is an example.

CASE TEXT 1: Legend Computer Group Corporation (Legend), Beijing

Legend is an example of spinning form 1. It began in 1984, with about 40 professionals in computer science and technology spun off from the Institute of Computer Technology of the Chinese Academy of Sciences. Legend now ranks among the top NTEs, and is more productive and competitive than most state-owned computer enterprises in terms of turnover, exports, etc. Turnover has reached several hundred million yuan. Legend's ownership is complex: there is a holding company, "Legend Beijing", which is "publicly" owned and licensed as an NTE in the Beijing Zone, and this engages in joint ventures with Hong Kong and other foreign capital.[17]

Technologically, Legend began with selling and after sales service for imported personal computer sets, and soon added their own development work, especially in Chinese character processing systems. They produced a series of ‘Legend CCSs’ (Chinese Character System), which became the ‘core technology’ of Legend. The products of Legend have penetrated into international markets at the "boards" and "cards" level, i.e. sub-systems of PCs, where they have a small share of this segment of the international market. Domestically, Legend has been strong at the level of complete computers. Their range extends from 286 to 486 PCs.[18]

Legend has developed intensive international cooperative links, in various forms. Legend Technology Ltd., Hong Kong, founded in 1989, is a joint venture with a private Hong Kong-based computer company. The technological strength of mainland R&D complements the competence of the Hong Kong company in information and marketing. Broad cooperative links with companies in North America and Europe provide access to technologies for design and manufacturing, and stable supplies of key components, which have enabled Legend to translate their core technology into VLSI circuitry.

Sources:
1. Field interviews;
2. Liu Chuanzhi, ‘Establishing a Computer Industry Competitive on the World Market’, in Science and Technology in *China: Selection from the Bulletin of the Chinese Academy of Sciences,* Vol. 5, pp. 219-224;
3. Lu Tanpin, Speech addressed at the Forum: "Legend Going to the World": "Faithful Cooperation, Going to the World" 1990, mimeo;
4. *Science and Technology Daily* (of China), May 9, 13, 28, and June 2, 6, 8, 10, 11, 1992;
5. *Electronics International* (of China), May 18, 1992;
6. *Electronics Commercial* (of China), May 26, 1992;
7. *Wenhui Daily* (of Hong Kong), April 5, 1992;
8. *Far Eastern Economic Review,* Sept. 23, 1993.

Form 2: S&T manpower move as individuals into independent NTEs

This is a form of starting up NTEs through the mobility of scientists and engineers, moving individually from their previous R&D institutes. A few individual S&T experts were frequently allied in the initiation stage, without any formal organizational involvement from their former institute. Elementary scientific and technological talent is spun off, embodied in manpower. Scientific and technological knowledge, experience in R&D and design, innovative ideas, and management competence are their assets, which serve as the nucleus for the crystallization of a new company organization. Chutian (see Case Text 2) is an enterprise of this kind.

However, assets embodied in personnel are not sufficient to initiate an NTE. Other assets are required, including capital. Especially in the early 1980s, no individual could afford to invest in the initiation of an NTE, though the cost was sometimes not very high. Another requirement was to fall under an officially acceptable category of ownership. The nominal ownership of an NTE matters, and certainly mattered in the 80s. Being "private" meant having more difficulty in getting licensed (as an NTE), and in obtaining bank loans.

Two solutions have been found. One is joining a "Centre for Scientific and Technical Entrepreneurs". Most centres offer institutional support for this form of spinning-off, providing some capital and social-political assets. Such centres usually provide individual S&T persons with physical space, managerial guidance, part of their initial capital, and the right to call their ownership "collective". These facilities are provided, for example, by the Wuhan Centre (the Wuhan Eastlake New-Tech Enterprise Incubator).

CASE TEXT 2: Chutian Optical Electronics Corporation Ltd. (Chutian), Wuhan

Chutian was founded in 1985 by Mr. Sun, now its Chief Manager, who was previously an engineer at the Institute of Optical Technology of Wuhan city. This company was initially incubated in, and a few years later left (graduated from) the Wuhan Eastlake New-Tech Enterprise Incubator. The ownership of Chutian had been "collective with the Incubator authority as initiator and supervisor", and has now been transformed into a Limited Liability Corporation, with the equity shared between the founder, some of the employees, and the Incubator.

Chutian produces lasers: mainly special laser welding machines, but also other laser products such as surgical lasers. Their technological activities are centred on designing. Their designers combine elements of technologies which are not particularly new — laser devices, electric circuitry, mechanical parts, and computer-aided controllers — into new machines with the performance desired by their customers. Design is also the forte of the initiator. A close relationship with his previous research institute and with a few local universities is reported to be very helpful in gaining access to related knowledge. The designs are assembled from components which are usually bought or manufactured to order outside. The company also offers after-sales services such as training and maintenance. These products are quite competitive in the domestic market, and have begun to penetrate the international market.

Sources:
Field Interviews at Wuhan Eastlake Enterprise Incubator, and with Chutian Corporation Ltd. See also Interview Notes 9, pp. 3-4.

The other alternative is to look for the capital (usually very limited) from sources other than the initiator's previous R&D institute. Usually these were local administrative authorities. Of the four famous NTEs in the early days of the Beijing Zone (the 'Two Tongs and Two Hais', mentioned in section 1.1), two, Jinghai and Stone, were started in this way.

Jinghai Computer Room Technology Development Company was founded in 1983 by eight engineers from the Institute of Computer Technology, CAS. They started their business with the support of a subordinate agency of the Haidian District Administration, Beijing. (This agency is responsible for the coordination of local (district) enterprises, and is known as "The United Collectives of the District" (qu lian she) [*Wang Xiaolong (ed.) 1993, p. 11*].

Stone Company, which manufactures Chinese computerized typesetting machines, was founded in 1984 by seven engineers from the Centre for Computerization of the CAS. The initiative was supported by Sijiqing Town, Haidian District, Beijing. The Town Authority provided 20,000 yuan and some physical space for the Company, and the Company was designated as "collective" in ownership, with the Town Administration as its initiator [*Wang Xiaolong (ed.) 1993, p. 15*].

This is a form of starting NTEs which has grown most rapidly in 1992 and 1993. NTEs initiated in this way have accounted for about 20%, 30%, and 30% of the NTEs formed in Beijing, Wuhan and Shenyang Zone, respectively. The data for Hangzhou Zone is very unclear. Thus there are again about a thousand NTEs formed in this way. Their average starting scale is smaller than the previous group, and their performance is mixed: some of them are strikingly excellent, but the number of enterprises of this form among the groups of "malpracticing" NTEs was reported by some Zone as "extraordinarily high".

Form 3: As an organized structure which remains as a department of the initiating R&D institute

In this form of spin-off, a part of the organized structure of the initiating R&D institution is licensed as a business unit by some regulatory authority (usually, the Development Zone for New and High Technology Industries), but remains an integrated part of the R&D institution.

This is a form through which the initiating R&D institutes adjust to the market reform, which has caused very tight institute budgets. The spinning-off usually starts with the aim of creating profitable businesses based on institutional strength to supplement institute income. This paves a way for the commercial exploitation of academic output. Only academically strong R&D institutes are able to take this form while maintaining their academic quality. This form of spinning off is not very common. For instance, in the Beijing Zone about 10 or more NTEs, out of a total of 3,000, were established in this form.[19] Case Text 3 provides one example.

CASE TEXT 3: Physcience Optoelectronics Corporation of Institute of Physics, Chinese Academy of Sciences, Beijing

The Institute of Physics originated in 1928, as the National Institute of Physics, Academy Sinica, and has long remained among the top institutes in terms of its academic quality in some areas of physics. It now has more than 500 researchers working in condensed matter and material physics, optical physics, and atomic and molecular physics. Two National Laboratories, and one Open Laboratory of the CAS, operate within the Institute. The Institute is identified in the reform policy as a "basic research" institute, enjoying "full budget" from the state. The meaning of this funding was clarified in 1986, when a fixed amount was set as the budget. This has since suffered significantly from inflation, and has been insufficient to cover routine operational needs (for general research requirements and staff salaries) since 1992. As for project research, financial support came mainly from state or public funds, which are distributed on a competitive basis depending on excellence.

Within the Institute there is a ‘Department of Development and Applications’, which is also registered in the Beijing Zone as an NTE, the "Physcience Optoelectronics Corporation", in order to enjoy the benefits of that status. This Department is responsible for commercializing research output which appears suitable to be produced in small batches and has a high value added, such as a molecular beam epitaxy system, crystals and related devices. The Department therefore serves as a window to transform some the Institute’s output into products. It also returns profits to the Institute, which are used mainly to increase the average bonuses faster than inflation. This has proved to be very important for the stability of the Institute. To keep the two parts united, the account office of the Department is controlled by the Institute. A system of bonuses rewards individuals who contribute directly to the profits. The bonuses can be very much higher than average. From this, a sort of "symbiosis" has emerged between the two parts of the Institute: on the one hand, the small batch fabrication in the Department needs the expertise and installations of the Institute; on the other hand, the researchers of the Institute require a base for the commercial development of their achievements. In fact, some researcher have moved to the Department for a time, and then back to laboratories; sometimes, the two activities are undertaken simultaneously.

The Institute has also served as a base for form 1 and 2 spinning. One group of experts at the Institute, including a research laboratory, moved out and, with others from another two institutes, became the main power behind San Huan New Material R&D Incorporation, an influential NTE in the Beijing Zone engaged in the commercialization of their research on permanent magnets. This is an example of form 1 spinning. Another group of researchers at the Institute left and, in cooperation with the local government, initiated the Beijing Kehai High-Technology Corporation, another powerful NTE in the Beijing Zone. A similar example is Chen Chunxian, previously a research professor at the Institute, who departed to start a business enterprise as early as 1983. This is seen as a predecessor of the NTEs. These are examples of form 2 spinning.

Sources: 1. Interviews;
2. Institute of Physics (edited and published): Institute of Physics, Chinese Academy of Sciences, 1990 — 1991.
3. Wang Xiaolong (eds.), *Chronicle of Electronics Street 1980-1988* (zhong guan cun dianzi yitiaojie dashiji).

Mixed forms. The boundaries between these three forms are actually ambiguous. In reality many spin-off NTEs just start to experiment, and many of them have not yet been well defined organizationally and managerially. Ambiguity is more likely to be found between forms 1 and 3. Case Text 4, on Open Software, illustrates this to some extent. Features similar to those described in Case Text 4 may also be observed in the Development Centre for Seawater Desalination and Water Treatment Technology, and in many departments of the Zhejiang University, which were interviewed in the field survey (see the list of R&D institutions visited in the Section 3).

CASE TEXT 4: Open Software System Corporation Ltd. of Northeast University, Shenyang

This is an NTE licensed by the Shenyang Zone. It is also the Research and Development Centre of Computer Software (CSC) of Northeast University. The same group of professionals has initiated a joint venture with a Japanese company, called the Shenyang Northeast University Alpine Software Institute Ltd. (NAS). The three titles correspond to three orientations of one entity: the CSC focuses on research and teaching (since 1989), Open Software (since April 1991) undertakes commercial activities as an NTE in the Zone, and the NAS (since July 1991) is a software exporter (to Japan). This experiment is inspired and directed by Prof. Liu Jiren, General Manager of Open Software System, Director of CSC, and Co-Director of NAS, together with his young colleagues with computer expertise (average age, 27) "to manage, in parallel and mutually beneficially, the commercial development of computer software, research, and training."

Open Software produces common (applied) software which is competitive in the domestic market. They have established a joint software venture with the Japanese to gain closer access to Japanese experience in management, quality assurance, and working discipline. The Japanese side also provided capital, and serves as the first overseas user of the products of the venture. The importance of the introduction of Japanese quality assurance may be indicated if one considers that, before the reform, computer training and software production in China was never oriented to commercial applications.* Professor Liu and his qualified team (some 20 to 30 of the 80 in the team have been trained abroad) are actually re-casting some features of the sector in a changed environment.

At the moment it is hard to know whether the disparate targets can be achieved harmoniously within the present organizational form. From the point of view of the university, the Centre is one unseparated part of it, but, in contrast to the Department of Development and Application at the Institute of Physics, this part of the University has been delegated full autonomy in their financial and other business affairs. This may thus be seen as a example standing somewhere between spinning forms 1 and 3. Many Zone managers recognize this as form 1.

* The article in source 5 below makes some observations about the orientation of computer training and software production, from the perspective of foreign investors in software joint-ventures in China.

Sources: 1. Interviews at Open Software;
2. An Introduction of Software Products, 1993, NEU-ALPINE;
3. *Nanhu Development Zone Newspaper* (nanhu Kaifaqu Zhongheng), published by the Association of NTEs, Nanhu S&T Development Zone, July 1, and Aug. 1, 1993;

4. *China Electronics Newspaper*, June 4, 1993, p. 3;
5. *Far Eastern Economic Review*, Sept. 23, 1993.

5.2 The Initiators of NTEs

Another aspect of the description of NTEs relates to the nature of the individual or institution which initiates the enterprise. Three kinds of initiators can be differentiated: organizational, individual, and foreign (or, more precisely, joint initiation with Chinese partners).

5.2.1 Organizational initiators

Organizational initiators were responsible for initiating the majority of NTEs. In 1989 and 1990, they accounted for about 80% of NTEs (Chen Zhaoying *et al.* (eds.) 1992, p. 155). The organizational initiators include R&D institutions, existing enterprises, and local administrations and other agencies.

R&D institutions as initiators

Organizational initiators are primarily R&D institutions, spinning off enterprises in forms which correspond roughly to forms 1 and 3 above. Initiations of this kind account for 50%, 40%, 30%, and 30% of the NTEs in Beijing, Wuhan, Shenyang, and Hangzhou, respectively. The latest data available, for 1989 and 1990, indicates that NTEs initiated by R&D institutions accounted for 48% and 52%, respectively, of the total in all Zones in those years [*Chen Zhaoying et al. (eds.) 1992, pp. 154-155*].

An attempt has been made to further differentiate the contributions made by various R&D institutions in the initiation of NTEs, using the classification of R&D institutions given in section 3, i.e., (1) institutes of the CAS, (2) R&D institutes belonging to central ministries, (3) R&D institutes belonging to local governments, and (4) R&D units of institutes of higher education. The published data for 1990 indicates that initiators from these four categories were responsible for approximately 12%, 12%, 17%, and 11%, respectively, of all NTEs. If we compare these figures with the numbers of institutions in each category, in notes 12-15 above, the institutes of the CAS and higher education seem to be more vigorous than other categories of R&D institutes. In addition, information provided by the Beijing Zone showed that, in the central ministry category, R&D institutes in the electronic, chemicals, aeronautical, and posts and telecommunications industries are more active in initiating NTEs (Interview Notes 11, p. 2).

The entrepreneurship of R&D institutions in initiating NTEs manifested itself in two main areas:

- assigning technological assets to newly spun-off enterprises. The technological assets were transmitted either by transferring an organized sub-structure (spinning forms 1 or 3), or by releasing experienced S&T experts (form 2);
- providing a large part of the initial investment of NTEs, in the forms of monetary capital, real estate and equipment, and, frequently, their prestige and credit-worthiness, which assisted them in getting licences and bank loans (Gu Shulin, 1988). A survey conducted in 1989, sampling 178 NTEs in the Beijing Zone, indicated that 86.5% of their initial capital was invested by the initiating organizations (Zhao Wenyan *et al.*, 1989).

Existing enterprises as initiators

According to the published data for 1990, about 22% of NTEs were initiated by existing enterprises. From the field survey, initiators of this kind account for 5%, 15%, 25%, and approximately 33% of the NTEs in Beijing, Wuhan, Shenyang, and Hangzhou respectively. They are either enterprises which had existed in the area prior to the establishment of a Zone and were suitable to be licensed as an NTE, or newly-established subsidiaries or reorganized versions of existing enterprises. The first kind was not common within the four Zones we visited. Only the managers of Wuhan Zone, where there were 2 or 3 such enterprises, recognized this type. The numbers of enterprises of the second kind seem to be influenced by the density of large existing enterprises nearby and the Zone policy of the local government. In the case of Shenyang Zone, the density of large enterprises was high, and the policy of the local government was to encourage existing enterprises to create their "corners" in the Zone area to reinvigorate state-owned industrial enterprises (Interview Notes 12, p. 3). However enterprise initiators of this kind are not particularly relevant to the focus of this study — the restructuring of previous R&D institutions.

Local administrations and other agencies as initiators

Again, according to aggregate data at the national level for 1990, 'local' agencies' initiation accounts for slightly less than 5% of NTEs [*Chen Zhaoying (eds.) 1992: 155*]. In the survey, only the manager of Beijing Zone was consciously aware of this type of initiator. As shown in the cases of Stone and Jinghai corporations in section 4.1, the local agencies served as suppliers of initial capital (usually partly) and of 'socio-political' assets — an acceptable form of ownership (mostly 'collective', sometimes, 'public'). This type of initiation is usually combined with the participation of individuals with scientific and technological expertise. The manager of the Beijing Zone also discerned a tendency for some trading companies and financing agencies to increasingly become involved in the initiation of NTEs. They seem to serve more as the supplier of capital, which is also a necessary factor. In the Beijing Zone, this type of initiation accounts for about 10% of the NTEs (Interview Notes 11, p. 3).

Most importantly, the entrepreneurship of local governments contributed to the widespread establishment of Zones and Centres. Generally, Zones and Centres serve as regulatory and supporting instruments, protecting newly emerged non-state enterprises. Preferential policies such as tax exemption or reduction are devised to provide incentives. In particular, Centres and Zones serve as an interface between new business undertakings and the existing socio-economic framework, in which some of the facilities which NTEs require are absent or unsatisfactory, as China undergoes a painful transition from the old socio-economic framework.

CASE TEXT 5: The Establishment and Roles of the Wuhan Eastlake New-Tech Enterprise Incubator

The Wuhan Incubator, the first of its kind in China, was founded on June 7, 1987, before the launch of Torch Programme. Oral reports indicate that the local (Wuhan city) Science and Technology Commission (STC) first raised the idea as early as 1985. Two events helped in its implementation. One was support from the State Science and Technology Commission (SSTC). This support was unequivocal by the end of 1986 and gave the Wuhan government confidence. Another was a study of the feasibility of 'incubators', which was jointly sponsored by the Science and Technology Foundation, the United Nations, and the SSTC, starting in

1987. The study produced a series of feasibility reports, and probably had a vital influence on the dissemination of the incubator concept in China.

What the Wuhan initiators perceived was a dissatisfaction with the performance of the ‘technology market’ concept. According to one author, "at that time (1985-1986), though the technology market had developed to a certain scale, the disconnection of scientific research from production was still very serious" (source 3, below). During the same period, individual scientists and engineers started to leave their R&D institutes and universities, initiating their own businesses. The incubator idea was thus intended to help to nurture enterprises initiated by individual scholar-businessmen, transforming their technological knowledge and skills into production.

There were about 120 enterprises in the incubator by the summer of 1993, of which more than half had been founded since 1992. They were selected by the Incubator from about 600 applicants. Since the establishment of the incubator, 3 enterprises have been closed because of bad marketing prospects, or managerial malpractice, 5 enterprises have grown up and moved out of the incubator. About half of the employees working in the incubator came from R&D institutes, universities and colleges, and the rest came from enterprises or had been unemployed. The products and services developed in the incubator were based mainly on personal professional experience and knowledge gained in previous employment, in the form of technological know-how and skills. Avoiding intellectual property conflicts with related universities and institutes has been one of main concerns of the incubator managers.

The roles of the Incubator were introduced as follows:

(1) Help with initiation: Apart from administrative support during the initiation procedure, the incubator authority plays an important role as ‘initiator and supervising unit (zhuban danwei)’ for most of the incubated enterprises. This is recorded in the official license. The incubator authority thereby accepts, explicitly or implicitly, certain liabilities:
   - i) as guarantor for bank loans, contractual obligations, etc. made by the enterprise;
   - ii) as the ‘supplier’ of their public nature, by serving as nominal initiator and supervisor; and
   - iii) as public bodies, they could protect the seniority and privileges (such as housing and insurance) accumulated by the scientific and technical staff working in incubated enterprises.

(2) Providing physical space and public facilities.

(3) Financing: the incubator offers help for the incubated businesses in gaining access to several sources of finance:
   - i) loans from local banks, with the incubator as guarantor;
   - ii) loan *quota* under the Torch Programme, which the Incubator can help the enterprise to obtain;
   - iii) venture capital. A risk investment company has just been created by the Bureau of Finance of the Wuhan Municipal Government, implying that more funds will be available, but no details were provided by the incubator authority.

But it is reported that a significant part of the funds was still collected from personal friends and relatives of individual initiators.

Sources:
1. Interview Notes 9. pp 1-4;
2. Dong Guilan and Peng Ying, *Bridging Knowledge, Technology and Market — Enterprise Incubators*, Guangxi Normal University Press, 1992, pp 153—164;
3. Yan Zulin, *New Technology Development Zones and Science & Technology Enterprise Incubators,* Science Publishing House, 1991, pp. 128-129, 134.

Case Text 6 offers a further illustration of how a zone administration can assist with the interface between NTEs and financial sources. It is interesting to note that the Zone administration served something of a dual function in this respect: they function as expanded components of the existing planning system when the remaining part of that system works, and they also have a function in providing technical and market advice to banks which lack the necessary ability because they have for so long operated as instruments of central planning. Banks are intended to be run more as investing agencies now, in place of directed government intervention.

CASE TEXT 6: The Interface Functions of Zone Administration, illustrated by the Hangzhou Zone

The Zone administration links three actors together: enterprises, the economic planning system, and sources of finance (the banks). One aspect of the interface role is to help firms find finance. In some cases this may be via the central planning process, as illustrated by the case of the Semiconductor Research Institute of Zhejiang University. The Institute planned to scale up their high-purity silicon crystal production, and the Zone administration helped them prepare the project for presentation to the State Planning Commission, which resulted in the project being incorporated in the Plan, which in turn provided the authorization for securing a bank loan. The Zone manager explained that: "The Government has the funds, but it does not have the knowledge about projects like this. We can provide them with that information."

In other cases, the link to finance operates more directly, via the Zone which can itself provide authorization for securing bank loans for projects, up to a certain ceiling. This 'approval' would probably be redundant in the absence of a central planning bureaucracy: the process is necessary because the banks are not permitted to make loans without such authorization. In this connection, the Zone administration may be seen, partly, as a new expansion of the planning bureaucracy.

The Zone also provides technical and market advice to the banks about the projects submitted by enterprises. This is very similar to the technical appraisal work carried out by investment banks in the context of free capital markets. The main difference here is that, in the Chinese system, this takes place almost entirely outside the banks, which have only a very narrow financial and accounting function in the planned system.

Source: Interview Notes 1, pp. 2-3.

5.2.2 Individual initiators

Individual initiators are mainly people who have a certain degree of scientific and technological expertise. The policies for Zones and NTEs stipulated that the manager of an NTE should have such qualifications. There were no statistics available on the numbers of such initiations, but a figure was estimated for each zone, by deduction from the following categorizations, which Zones Administrations employ in their management:

(1) NTEs described as 'collective, and without [organizational] initiator and supervising unit'. These will generally have an individual initiator, or be initiated by small groups. Data indicate that this class accounted for 6%, 7.5%, and 10%, of the total existing NTEs in all zones for 1989, 1990, and 1991, respectively.[20] The direction of change in the figures would indicate that this form is increasingly important for NTEs being established at present.

(2) NTEs whose ownership was "collective, and with local agencies as initiator and supervising unit". Local agencies include Centre administrations, as illustrated in case texts 2 and 5, Zone administrations, district and town administrations etc. NTEs which were initiated jointly by individual S&T experts and local agencies are generally seen as collectively initiated, rather than individually. The Beijing Zone, for instance, reports that this kind of enterprise accounted for about 10% of the total, and classified it as a form of collective ownership.

(3) NTEs with private ownership. There are no figures showing how many NTEs are officially licensed as being privately owned, but the numbers seem to be very low.

Based on these parameters, and estimations and statements made by Zone managers,[21] it is estimated that individual initiators accounted for 30% of the NTEs in Wuhan and Shenyang zones, 20% in Beijing zone, and for Hangzhou zone somewhere between 5%

and 30%. If these four zones are typical, we can estimate that individual initiations account for between 20% and 30% of all NTEs.

5.2.3 Foreign initiators

Foreign (mostly joint) initiations account for between 5% and 15% of NTEs, with the proportion varying from region to region. The Beijing Zone had the highest proportion (15%). Scattered information suggests that foreign initiators were not been very active in initiating joint ventures in the Zones until one or two years ago. It was the Chinese side which was usually more vigorous in seeking ventures with foreign counterparts. The purpose for domestic NTEs seems mainly to be to gain access to the complements of hardware technologies and to management skills (Interview Notes 11, p. 10). However, in a few cases in which NTEs have an internationally-oriented strategy based on strong special assets, access to international market networks (of both users and suppliers) appeared to be important purpose, as was seen in the cases of Legend (Case text 1, and *Science and Technology Daily*, June 6, 1992) and Open Software Systems of Northeast University, which were described above (Case text 4, and Interview Notes 12, p. 11).

Recent evidence reveals that some of the biggest transnationals in computer and information technology are becoming more active in looking for a place in China's Zones. For example, DEC is setting up joint ventures with New-Tech of Beijing University and others (*People's Daily,* overseas edition, Nov. 25, 1993), Motorola is creating a Science and Technology Centre in Beijing Zone (*People's Daily,* overseas edition, Nov. 20, 1993), and AST of America is developing a Chinese writing input computer, jointly with an NTE — Xin Tiandi in Beijing Zone (*People's Daily,* overseas edition, Dec. 9, 1993). It is very likely that foreign involvements in Zones and NTEs expanded rapidly during 1992-1993, when massive international capital flowed in, but there is as yet no official data to confirm this.

6. THE TECHNOLOGICAL ACTIVITIES OF NTEs

6.1 A Broad Picture of Technological Activities

We will now turn to some observations related to the technological activities of NTEs. To begin with, it was necessary to devise a categorization of these activities. The SSTC stipulates the 10 technological areas which the Zones are to encourage (see note 10 above), but Zone managers said they used simpler, and in some respects different, categorizations, varying from Zone to Zone. After making an inventory of these categorization systems, it was decided to adopt a simple categorization as the first step of our analysis. This is the system originally introduced by the managers of Wuhan Centre, with only two clear-cut groups:

- group 1: computers & information technologies/ integrated microelectronic & mechanical technologies;
- group 2: biological & medical products/ new materials/ fine chemicals.

This categorization relies on a fact that, technologically, the products of these two groups differ physically. The products of group 1 are machines or sets of machines, systems and subsystems, parts and components. The products of group 2 are materials of homogeneous composition, produced in more or less comparable processes.

Group 1 reflects the strong tendency for micro-electronic and mechanical technologies to merge. The NTEs which are involved in computer and information technologies aim mainly at assimilating and adapting technologies, rather than pushing the frontier of the field. This reinforces the tendency for them to blend technologies which, according to the SSTC categorization, belong in different fields. This may explain why the managers of Zones could not distinguish activities within this group in more detail.

The distribution of the technological activities of NTEs between these two groups was identified, relying on zone-level aggregate data from the managers of the four Zones. Tabel 4 below summarizes the estimated distribution and some Zone managers' comments.

It can be seen that, in all four Zones, about 60%-70% of the technological activities fall in group 1. Although the data on which the estimates were based is not entirely comparable, there is no indication that this could cause a serious error in this broad estimate. On the other hand, the differing breakdowns of technological activity used in each zone point to regional diversity in the categorization used. A more detailed zone-by-zone analysis of technological activities in each zone was undertaken, which yields more insight into the character of each zone, and also a more differentiated breakdown of the activities in group 1.

TABLE 4
DISTRIBUTION OF TECHNOLOGICAL ACTIVITIES OF NTEs

Zone	Distribution		Statements and References
	Group 1	*Group 2*	
Beijing	70% plus	20% minus	(1) About 50% of NTEs are engaged in electronics and information technologies, and these account for about 50% of annual sales; (51.98%)* (2) Integrated optical, electronic and mechanical technologies account for more than 20%; (22.84%)* (3) New materials, about 8%; (7.18)* (4) Biological and medical products, about 8%; (9.69%)* *Sources:* Figures marked "*" are from *Special Issue of the Fifth Anniversary 1988-1993*, Beijing City, Experimental Zone for the Development of New Technology Industries. The remaining figures are from Interview Notes (11, pp. 3-5)
Wuhan	60%	20-30%	(1) Micro-electronics & computers and integrated electro-mechanical technologies account for about 50% of the number of NTEs and 30% of the profits; (2) Biological & medical products/ fine materials, about 20-30%; (3) Telecommunications, about 10% in terms of the number of NTEs, but 20% in terms of profits. The difference is because a few large enterprises (WRIPT, and Chang-Fei Company, a joint venture with Philips producing optical fibre) are included. *Source:* Interview Notes 9, p. 8.
Shenyang	60% plus	30% plus	(1) Integrated electro-mechanical technologies account for 35-40% in terms of gross sales; (2) Micro-electronics and information technologies, including computer software, about 25%; (3) Biological products, including refined Chinese medical products, about 25%; (4) New materials, about 10%. *Source:* Interview Notes 12, pp. 4-6.
Hangzhou	80%	20%	(1) Electronics and information technologies, 58% of NTEs; (2) Integrated optical-electronic-mechanical technologies, 23%; (3) Materials, 10%; (4) Biological and medical, 4%; (5) New Energy and conservation technologies, 4%; *Source:* Interview Notes 1, p. 4.

6.2 Technological Activities in Detail

Once again, the inventory was carried out using mainly Zone-level aggregate information, supplemented by interviews at some NTEs and visits to related industrial ministries.

6.2.1 Typical products and services

Relying on the knowledge of the Zone managers responsible for monitoring the NTEs, a profile of typical producers and the technological activities associated with ‘competitive products’ was compiled for each Zone.[22] This search produced the following categories of products:

(1) Computers;

(2) Computer parts and peripherals;

(3) Character and graphic processing technology and apparatus;

(4) Automatic operation and production systems;

(5) Industrial control machines;

(6) Telecommunication equipment;

(7) Integrated micro-electronic devices and machines.

Note the category "micro-electronics and information", widely used by Zones, has been dis-aggregated into six smaller categories (1-6), and the word ‘micro-electronics’ has been dropped because there was in fact no significant activity or product which could be classed as ‘real’ micro-electronics in the Zones, although imported micro-electronic components are used in integrated applications.

6.2.2 Technological activities in Beijing Zone

The ‘typical’ products of the Beijing zone were those of categories 1,2,3,5 and 6 above. In all of these categories, the advantages of Beijing in sophisticated Chinese Character processing technologies are crucial. This is the key element in the development of some competitive products. Chinese Character processing is crucial to the commercial use of computer and information technology, other than for scientific research. Beijing’s strength in the field seems to have a close relation to its position at the centre of the market for computer and information technologies in China. This advantage is increased by the presence of a few giant NTEs, such as Legend (See Case Text 1), producing computer parts and micro-computers, New-Tech of Beijing University, producing computer compiling and printing systems, and Stone, producing Chinese typesetting systems etc. Case Text 7, below, provides more details of the typical products and technological specificities in the Beijing Zone.

CASE TEXT 7: Computer and Information Technologies in Beijing Zone

About 50% of the NTEs (3,400 in total), and 50% of annual sales are in the field of Computer and Information Technologies. They produce a range of products (microcomputers, minicomputers, computer terminals, diskettes, work stations, character processing systems, industrial control systems, image collecting & processing systems, etc.) which are not generally produced in other zones.

Important product categories were selected, and the selection was confirmed by the Zone Manager. This provided a ground for further discussions with the Zone manager on questions such as "What NTEs are typically engaged in a certain category?", "What are the characters of technological activities in a certain category and by the ‘typical’ NTEs?", "Where did these NTEs come from?" and "How did they gain the critical technological capability?". Behind these questions, a more fundamental one is: "Why is the Beijing Zone so distinctive?" These discussions produced the summary in the table below, based mainly on interviews with the Director of the Enterprise Development and Management Department, Beijing Zone, with additional reference to documentation. Appendix 1 provides a more detailed breakdown of the zone’s competitive products, compiled from data provided in the zone’s *Catalogue of Competitive Products* (see source 1, below).

category of product	**typical products**	**typical NTE(s)**
computers	micro-computers, mini (and super-mini) computers, work stations;	*Legend* — lianxiang for micro-computers; *Taiji* for mini-computers and work stations;
special function boards and cards		
Character and graphic processing apparatus	office automation, TV and teaching image, scientific graphic, and publishing systems;	*New-Tech of Beijing Univ.* for compiling and publishing systems; *Stone* — sitong for typesetting equipment;
industrial control machines	STD 5000 series	*Kangto* — kangtuo;
telecommunication equipment		

1. Computers

The sophistication of the Chinese Character processing technologies available in the zone, and the ability to integrate it in various computer applications, is the main strength of this Zone. Initially, the Chinese Character processing technologies were embodied in cards or boards which were added to imported machines. Gradually a small number of NTEs gained capabilities to develop specific IC chips, which can be used as components in final products.

Their second area of strength is in the design of complicated machines. It was explained that the Chinese have long been good at the adaptation of various designs. This advantage, however, is limited by the lack of advanced equipment. In the present phase, these capabilities in adoption and adaptation are usually employed in developing computers characterized by simplified structure, reduced costs, and moderate performance for the needs of domestic users.

The competitiveness of the NTEs in the zone is rapidly improving, as compared with the existing domestic computer factories. Legend, spun off from the Institute of Computer Technology of the Chinese Academy of Sciences, is widely regarded as one of the most successful micro-computer enterprises. Its sales of micro-computers on the domestic market in 1992 surpassed those of ‘Great Wall’ and other companies, making it number one in the market. In the international market, Legend is one of China’s most rapidly growing companies. Computer components developed by Legend (as distinct from complete micro-computers, which Legend supplies mainly to the domestic market so far) are penetrating into a number of countries. The international competitiveness of Legend computer parts stems from the sophisticated Legend Chinese Character processing systems, which have been combined into some functional units, such as graphic displays, printers, and RAM expansion, which have been adopted by many computer producers throughout the world. According to Legend’s sales records, in 1992 roughly one tenth of all micro-computers (386 and up) produced in the world were equipped with Legend functional boards.

In mini-computers and work stations, Taiji Computer Corporation and China Computer System Engineering Corporation are dominant in the domestic market. The former is also the No. 15 Institute of the Ministry of the Electronics Industry, and the latter is the No. 6 Institute of the same Ministry. Taiji uses DEC technology to produce VAX systems, while Computer System Engineering has introduced technologies and equipment from Sun Micro. The state provided the investment to import these technologies.

2. Special Functional Boards and Cards

These products are almost unknown on the world market, but important items in the Chinese market. These boards and cards have two main functions. One is for Chinese Character processing, so that computer technologies generated in English can be popularly used for various purposes (not only for scientific calculations, as had long been the case) in the local language environment. Another is networking cards for connecting different types and series of computers.

Most of the card and board developers around the country have not yet been able to produce their designs in the form of IC chips (they are still embodied on printed circuits). But a few, including Legend, and New-Tech of Beijing University, are now able to do so. This brings them big competitive advantages. This is one indicator of the dominant position of the NTEs in the Beijing Zone.

A great variety of networking cards were developed because China has been furnished with almost each type of computer made in the world during the past ten years. As time goes on, networking becomes increasingly demanding. Tight finances force Chinese users to keep their old machines in operation when they obtain new equipment. The Hong Kong brokers who sold most of these computers do not provide support to connect new products to the old ones. The formation of the biggest computer market of China in the Beijing Zone, around 1985, provided stimulus and opportunities for NTEs in the area to accumulate knowledge about imported machines. Many NTEs started by selling and maintaining imported computers. This experience also makes them closely linking to users' demands.

3. Character and Graphic Processing Apparatus

The basic technologies (both hardware and software) are imported, with the local NTEs contributing (1) Add-on Chinese character systems, continually up-dated to keep pace with new products on the international market and (2) specially-designed applied software appropriate for local use. Demand is increasing, with users including government offices, shopping centres, banks, video and broadcasting agencies, industrial firms, and scientific information networks. The market is starting to expand to neighbouring Asian countries in which Chinese is officially or popularly used in communications.

Stone is one of the typical competitive producers in this field. It was founded in 1984 by a group of engineers who had left the Chinese Academy of Sciences (mainly from the Centre for Computation), with the help of Si-ji-qing town of the Beijing Haidian District. Its main products are 4S Typesetting Systems, which have 80% of the domestic market and have almost completely replaced manual Chinese typesetting. Another typical NTE, New-Tech of Beijing University, was founded in 1986 by Beijing University. Their computer compiling and printing systems have revolutionized Chinese publication technology.

4. Industrial Control Machines

The main technological activity in this field is following-up what has been developed overseas. Some standard industrial control machines, such as the STD series, have entered large-scale production, replacing imported models. Kangto, an NTE spun off from the No. 502 Institute of the Ministry of Aerospace and Aeronautical Industry, is the leading producer of this item in China.

5. Communication Equipment

This covers cable and wireless networks, equipment, and advice. The programme control exchange systems developed in the zone are characterized by small production runs (less than 1,000). All were basically the result of the assimilation of imported technologies. Their technological advantages are in the use of Chinese Character and language processing and other adaptations for the local environment, such as an 'auto-switchover' device to replace operators who have to work at the many small exchanges from morning till night.

6. Summary of Comparative Advantages:

The survey produced some overall findings about the comparative advantages of NTEs in comparison to 'old' domestic enterprises, and to foreign companies. These may well be valuable as they are distilled from the managerial experience of over 1,000 NTEs in the Zone. From the perspective of the Zone management, the advantages of NTEs (in technological management) as compared to Chinese enterprises of the old mould were that they were more alert to information about technological changes in other countries and more responsive in adopting and adapting foreign technologies, as well as being more active in their marketing.

The potential comparative advantages of Chinese NTEs *vis-a-vis* foreign firms are in Chinese Character processing technologies. The complexity of the structure of Chinese Characters challenges technological capabilities in collecting, transmitting, and transforming graphic information. This could yield some advantages in graphic information processing technologies for Chinese enterprises. In addition, the specificity of Chinese pronunciation may also challenge capabilities in spoken language recognition and user interface technologies. In fact, some 'competitive products' developed in the Zone already provide evidence of achievements in this field.

Sources:
1. Enterprise Development and Management Department of the Beijing Experimental Zone for the Development of New Technology Industries (ed.): *Catalogue of Competitive Products*, March 1993;
2. Enterprise Development and Management Department of the Beijing Experimental Zone for the Development of New Technology Industries (ed.): *Catalogue of New Technology & Related Products (Engineering), 1992.*
3. Beijing Experimental Zone for the Development of New Technology Industries (ed.): *Beijing City Experimental Zone for the Development of New Technology Industries, Special Issue of the Fifth Anniversary: 1988-1993*;
4. Wang Xiaolong (eds.): *Chronicle of Events of Zhong-Guan-Cun Electronic Street* (zhong guan cun dian zi yi tiao jie da shi ji) 1980-1988, April 1993;
5. Interviews, and Interview Notes 11, pp. 6-15.

6.2.3 Wuhan incubator and zone

In Wuhan Incubator and Wuhan Zone the technological activities associated with group 1 products are considerably different from those in Beijing. NTEs in the Wuhan Zone and Incubator are more concentrated on *applications* of computer and information technologies in (1) practical operation and production processes, and (2) newly-designed devices and machines. The latter corresponds to the category of 'integrated microelectronic & mechanical technologies', which were among the typical products of the Beijing zone but were not discussed in detail because there were no specific characteristics to distinguish them from the production of the same products in other zones. Automatic operation and production systems is a category which did not appear at all in the list of 'typical products' of the Beijing Zone.

The technological activities involved in applying computer technologies in these two fields have different emphases, with applications in operation and production systems concentrating on the development of small automatic systems. In essence this entails modelling the user system, developing it, installing it and providing training. The emphasis in producing newly-developed devices is on developing small machine systems. The central activities are design and assembly and marketing. Chutian Optical Electronics Corporation Ltd., introduced in Case Text 2, is one example of this kind of NTE.

Businesses in both fields, especially those developing automated systems, are usually combined with selling and after-sales service of computers. In the Beijing Zone, many of the producers of computers and character and graphic processors, such as Legend and Beijing Xinghe Electronic Co., are also engaged in developing automated systems for particular users, but these companies have become more specialized in a particular sort of hardware, and the development of small user-specific systems is only a secondary business.

CASE TEXT 8: The Development of Automatic Operation and Production Systems in Wuhan Incubator and Wuhan Zone

Part 1: In the Wuhan Incubator

No structured information was available with respect to technological activity associated with group 1 products, since the managers of the Incubator do not use this classification. Tentative generalizations were produced from interviews in which the incubator management was asked about the typical technological activities of the enterprises in the Incubator, their principal clients, the clients' requirements and how the enterprises meet these, and the forms in which the enterprises deliver their outputs. They were also asked for specific cases which supported their more general answers. The tentative generalizations were later returned to the interviewees for their comments.

Most of the enterprises seem to be engaged in the development of small automatic operation and production systems. The users came from a range of sectors including medicines, ceramics, textiles, tobacco, food processing, oil production, energy generation, and experimental operation in scientific laboratories. The NTE's technological activities centred on the development of system software, (i.e. modelling given processes, and computerizing them). This usually incorporated off-the-shelf hardware, such as sensors and industrial control devices. The producers usually provide their services on the basis of a 'project contract', under which they develop a system for a client up to the point of installing the system. The technologies employed seem to be unsophisticated, both in terms of the hardware employed and the complexity of the systems being developed.

Another type of technological activity in the incubator is designing and manufacturing specialized devices, instruments, machine tools, etc. Products included sensors, numerical indicators used in NC machinery, laser welders and instruments for telecommunication and the electricity net. This type of technological activity also seems to be unsophisticated in terms of technology and complexity. The two types of activity are often intertwined with each other. An enterprise whose main business was the development of small automatic systems might also produce some related device, and *vice versa*.

Part 2: The Wuhan Zone

The NTEs in the zone engage in the same two kinds of activities seen in the Wuhan Incubator. The head of the Enterprise Management Department of the Zone said that the NTEs engaged in developing computerized systems were mainly working with the automation of industrial operations, through contract engineering projects with particular users. These projects usually involve the use of a simple computer, a choice of sensors, and the design of an interface between the automation system which they developed and the production processes to be controlled.

What differs from the Wuhan Incubator is that there is another explicitly recognized field of activity in the Wuhan Zone — telecommunications. Some 10% of the NTEs work in this field, producing about 20% of the profits. A few big units, such as the Wuhan Research Institute for Posts and Telecommunications, and the Chang-Fei Company (a joint-venture with Philips, producing optical fibre) contributed to the higher percentage in terms of profits.

Source: Interview Notes 9, pp. 5, 8-9.

6.2.4 Shenyang Zone

Observations in the Shenyang Zone started with an inventory of scattered information about competitive products and their producers. Interviews helped to answer the questions arising from the initial search. The same two kinds of applications of computer and information technologies — in automated systems for particular users and in newly developed devices — were found. Once again, businesses engaged in developing automatic operation and production systems combined this closely with selling computers and providing after-sales service. The users of the automated systems were largely in non-manufacturing sectors, since large manufacturing enterprises internalize this function. The NTEs specializing in this field tend to be smaller, which, since they combined this function with computer retailing, made it difficult to identify activity in this field from the data on competitive products. The development of integrated micro-electronic and mechanical technologies is a large part of NTEs' activity in the Shenyang Zone. Spin-offs from R&D institutions seem to be dominant among the producers of 'competitive products', even though many the NTEs in the zone were spin-offs from big enterprises. This might partly reflect the distribution of creative technological capability.

Comparing our observations in the Shenyang zone with those in Beijing underlines one unique feature of the Beijing zone: the importance of its position at the centre of the domestic computer market. NTEs in the Shenyang zone, in comparison, are much more influenced by the demands of concrete and local applications. It may well be that a degree of specialization in the zones has been reinforced by the inter-zone network which is developing.

CASE TEXT 9: Technological Activity of NTEs in Shenyang Zone

In Shenyang Zone, the NTEs devoted to 'integrated micro-electronic and mechanical technologies' account for 35%-40% in terms of gross sales, while those engaged in 'computer and information technologies' account for another 25%. This is the reverse of the relative proportions in Wuhan, Beijing and Hangzhou. One reason is obvious: Shenyang is one of the most important bases of the machinery industry in China. R&D institutes and universities in Shenyang also concentrate on electronics and mechanical engineering.

It was difficult to form a picture of the features of technological activities from the descriptions provided by the interviewees. Once again it was necessary to gather some very scattered documentation on 'competitive products'. Conversations with Zone managers supplemented this search through the written materials.

1. Integrated Electronic-Mechanical Technologies

The list of 'competitive products' embraces various power supply devices and transformers, machine tools and parts (saws, numerical controllers for machine tools), some production lines (for example, those used in meat packaging), and some robots. The sophistication of technological activities seems to vary greatly. Some products are obviously more advanced, such as the robotics produced by an NTE spun off from the most powerful institute in the field. Some are more conventional. Although the information available is very limited and the sample is very small (about 10 of the 35 'competitive products' listed), they seem generally to be designed for specific, small-volume uses, and to incorporate new elements of technology. They sell mainly on domestic markets.

The producers of almost all of the 'competitive products' of this type are NTEs initiated by independent R&D institutes or universities, except for one whose origin was unclear. It is surprising that the NTEs initiated by big enterprises are not active in this field, given the hard push by local government. There are about 200-300 NTEs initiated by existing enterprises, in response to a Municipal programme known as 'one enterprise, one corner (in the Zone)'. This means that enterprises are encouraged to establish a branch in a zone, as a step to renewing the enterprises. The interviewees and other information indicated that the 'corner'

NTEs usually acquired their new product designs through technology transfer from spun NTEs, or directly from R&D institutes and universities, usually under the guidance of local government.

Again, the old questions arise: "Can the transfer of core producing technology be effective without continuous communication?" , "How will the new institution of Zones contribute to solving the difficulties which arose under the old regime?"

2. Computer and Information Technologies

Six of the 'competitive products' are recognizably of this type. Two of these are computer software, produced by Open Software System Corporation Ltd. of Northeast University. The third is industrial control systems, produced by Automation Engineering Development Company, also initiated by Northeast University. The fourth is programme control exchange equipment, produced by a firm whose origin was unclear, and the last two are bar-code scanning equipment, produced by Xianda Bar Code Scanner Technology Corporation Ltd., a Corporation initiated by Shenyang Engineering University. In sum, the technological advantage in this area still seems to be in the hands of NTEs from previous R&D institutions.

It appears that most of the large enterprises in Shenyang themselves develop automatic systems to upgrade their production processes, relying on their own computer and software expertise. Frequently they import technology while relying on their own capabilities. Presumably, the technological transformations carried out by enterprises themselves are more conventional, while those through technological importation are more 'packaged'. Sometimes they drew on external R&D when the job was too sophisticated. For example, an advanced numerical control technology was developed cooperatively by an institute of the CAS (the Shenyang Institute of Computer Technology) and a large machine tools manufacturer (the No. 3 Machine Tools Factory). This resulted in one of the 'competitive products' in the Zone, which the local government supported by providing a bank loan.

But what are the NTEs in the Zone doing in this respect? the answer is that they are developing application systems for users, mainly in government agencies, banks, hotels, and restaurants, usually combined with computer retailing, maintenance, and training. The banks had initially to rely on outside salesmen or technicians. A few years ago they began to internalize this function in a computer division, and some banks are now actively initiating NTEs by externalizing their computer divisions. According to the interviews we conducted, more than 10 NTEs which were newly certified by the Zone in the summer of 1993 were of this type.

The Director of the Planning Department of the Ministry of the Machinery Industry confirmed that the transformation of production and operation processes using computer-aided technologies in the big manufacturing sectors proceeds mainly through 'planning' structures, while in non-manufacturing sectors, notably the service sectors, it proceeds mainly through the market. Therefore, NTEs in the Shenyang Zone focus mainly on the service sector, although the area contains a concentration of big state manufacturing factories. The NTEs in Wuhan, where there are more light industrial factories, and more small enterprises, are focused more on applications in light industry. In Beijing, where there are less heavy industries, and many government agencies, banks, publishing houses, news and broadcasting agencies, hotels, etc, the NTEs producing automated systems also focus on the service sectors.

The Computer Market in Shenyang

It was noticeable that some 'giant' Beijing NTEs, such as Legend and Stone, have branches in Shenyang Zone, and have in fact become 'trans-regional' corporations. Both Legend and Stone are listed among the largest 50 NTEs in the Shenyang Zone. Another observation was that domestic products are being sold in many computer shops in the area of Shenyang Zone, alongside imported computers and peripherals. Some of the domestic products are specifically adapted to the Chinese market, such as local language boards and cards, but there are also computers and industrial control machines which are substituting for imported products. There is obviously a developing market for computer and information products: the best domestic producers, no matter where they are based, were all advertising their products in Shenyang. Observation also suggests that a nationwide market framework for computer and information technologies is developing which is backed up by the network of Zones. Within this market there is an inter-dependence between computer retailing and more user-oriented developments.

This seems to be in contrast with conventional commodity markets in China. Many observers have noted that geographic segmentation is getting worse as economic decision-making power is delegated downwards (see: Wu Jinglian and Liu Jirei: *On a Competitive Market Institution*, Finance and Economy Publishing House of China, 1991, especially Chapter 7, and Susan L. Shirk: *The Political Logic of Economic Reform in China*, University of California Press, 1993). It would be useful to explore why the domestic market for computer and information technology is developing more healthily.

Sources:
1. Interviews in Shenyang and Beijing; Interview Notes 12, pp. 4-8;
2. *Nanhu Development Zone Newspaper* (Nanhu kaifaqu zongheng), published by the Association of New and High Technology Enterprises, Shenyang Nanhu S&T Development Zone, May 6, June 5, July 1, August 1, 1993;
3. Wang Chengxiang: Speech at Working Meeting of Shenyang Manhu Science and Technology Development Zone, mimeo.

6.2.5 Summary of typical products and services

To summarize, table 5 brings together the main features of each of the classes of 'typical products' defined in section 5.2.1. and illustrated in Case Texts 7, 8 and 9. The focus is on a comparison between NTEs and their domestic and foreign counterparts, for the purpose of illustrating, at least partially, the position of NTEs.

TABLE 5
FEATURES OF TECHNOLOGICAL ACTIVITY IN GROUP 1 IN TERMS OF TYPICAL PRODUCTS

Typical products	Features of Technological Activity
Computers	1. Foreign machines are still dominant (interview, Ministry of Electronics Industry); 2. Domestic production is based on imported technologies (See Case Text 7); 3. Simplified design and advantages in character processing have given NTEs and other domestic producers a small niche in the domestic market (See Case Text 7).
Computer parts and peripherals	1. Centred on functional boards and cards; special adaption for Chinese market; stimulated by the peculiarity of Chinese language and users (See Case Text 7); 2. NTEs have a dominant position in the development of this kind of product, especially NTEs in Beijing (interview, Ministry of Electronics Industry); 3. International competitiveness is developing in character and graphic processing and display boards and cards (See Case Text 7).
Character and graphic processing apparatus1.	1. Some competitive products have been developed, based on advantages in character processing technologies (See Case Text 7); 2. Very significant achievements in compiling, publishing, and typesetting of Chinese texts (See Case Text 7); 3. The NTEs of Beijing Zone are becoming dominant in the Chinese market (See Case Text 9);

TABLE 5
FEATURES OF TECHNOLOGICAL ACTIVITY IN GROUP 1 IN TERMS OF TYPICAL PRODUCTS (cont.)

Typical products	Features of Technological Activity
Automatic operation and production systems	1. Smaller and non-manufacturing users are supplied by NTEs; these users are mainly in the service and light industrial sectors (interview, Ministry of Machinery Industry, and see Case Text 9); 2. User-specific design and engineering services could not be covered by the planning approach (interview, Ministry of Electronics Industry, and see Case Text 8); 3. Local specificity of operation and management environment cannot easily be dealt with by foreign suppliers (interview, Beijing Zone).
Industrial control devices	1. NTEs seem to contribute to the assimilation and dissemination of imported technologies for smaller and simpler product series (See Case Text 7); 2. Larger industrial control systems are still under planning approach regulations governing the importation and assimilation of foreign technologies (interview, Ministry of Machinery Industry);
Telecommunication equipment	1. The NTEs seem to contribute to assimilation of smaller systems not under planning regulations (See Case Text 7);
Microelectronic & mechanical integrated devices and machines	1. Covers a variety of combinations of electronics, optics, and mechanical technologies (See Case Text 2); 2. NTEs, such as those producing instrumentation, have contributed to specialised small-scale applications which planning could not cover, but which under the market approach may be commercialized (interview with the manager of the Instrumentation Department, the Ministry of Machinery Industry); 3. The potential for the commercialization of scientific instruments is illustrated by Case Text 3.

6.3 Characters of Technological Activities and Some Influencing Factors

This subsection will elaborate on some notable aspects of the technological activities of NTEs in the computer-related group. These should not be seen as conclusions, but rather as hypotheses for further study.

6.3.1 Small System Development

In terms of complexity of technology employed, the technological activities of the majority of NTEs seem to be characterized by *small system development*. They have achieved some degree of sophistication in dealing with systems in a range of related technologies, though there is wide variation between NTEs. Capabilities in the innovative development of small systems are the soil in which NTEs germinate and grow in the face of fierce competition from both foreign suppliers and big state enterprises. The technological capabilities of NTEs in this field are manifest in particular in three types of system technology development:

- *Localization i.e. "chinesization" of computer language*, that is, adapting English-language computer and information technology for Chinese use. Products include functional boards and cards for adding a Chinese Character processing function to computers. Those produced by Legend are competitive in the international market. More frequently, these strengths are combined with other technological efforts for various application purposes, so that these skills are embodied in various products and services such as Chinese compiling and publishing systems. Software development also focuses largely on language adaptations, such as the Hope Corporation's architectural design software (interview at the Hope Corporation).[23] Domestically-produced computers and industrial control machines all incorporate Chinese processing functions.
- *The development of small automatic operation systems*, that is, of user specific system software, incorporating off-the-shelf hardware. This kind of small system development aids in assimilating newly emerging technologies into existing operations in various sectors. It is characterized by modelling (of existing production and operation processes), designing the desired automatic control system, and incorporating the results in engineering services (on-the-spot installation, training, and maintenance). Some local environmental characteristics, such as in language and in managerial procedure, have to be accommodated. A large part of the computer-related NTEs are engaged in this type of activity, with varying degrees of sophistication. Some of them are specialized system developers (as described by the managers of the Wuhan Zone), and others combine this with selling computers.
- *The design and production of various separate devices and machines*. The outputs in this case are *hardware devices and machines*, which are distributed through the market place. Chutian's laser welders (Case Text 2) are one example. In Table 5, the 'typical products' under the headings of 'telecommunication equipment' and 'micro-electronic & mechanical integrated devices and machines' are mostly of this kind. Efforts focus on good design, incorporating novel combinations of some special idea with more conventional elements of technology. Thus far, it is smaller and more specialized products, such as machine tools, medical equipment, instrumentation, electric and telecommunication equipment, which are being developed by NTEs. Bigger, and more conventional varieties are still produced by enterprises of the older type.

This mastery of small system development on the part of many NTEs means that they have a steep learning curve, and quickly achieve moderate, but definitely *innovative*, ability.[24] Contractual assembly work, which has been the first stage in acquiring technologies in the computer and information sectors in many developing countries, is almost never encountered among NTEs in the Zones (but does exist in 'Special Economic Zones'). The NTEs seem to have their own learning sequence, starting with selling and after-sales service. This learning process is discussed in more detail in section 5.3.3 below.

6.3.2 User capability building

The main thrust of the creative activities of the NTEs, as indicated by their clients and objectives, appears to be primarily directed at the widespread applications of computer and information technologies, rather than at the manufacture of microelectronics and computers. This is manifest in different ways for each of the three types of activity above.

The 'localization' function focuses on the linguistic modification of computers and a variety of information technology products in order to bridge the language gap and remove a crucial restriction to the employment of computer and information technologies in a Chinese-speaking environment. The 'development of automatic operating systems' is directed at upgrading various existing operations. User-specific modelling and engineering must necessarily be developed in tandem with the provision of hardware. Service sectors are the first clients for this kind of business, followed by light industry. Most of the clients are small and medium-sized firms. The 'design and production of devices and machines' focuses on incorporating the new computer and information technology into a variety of mechanical products.

The planning approach seems not to be able to deal with specificities related to the applications. An interviewee at the Ministry of the Electronics Industry stated that "applications of computer technology were never well planned by the planning institution. The planned economy is in essence in favour of quantitative outputs of mass-produced hardware. The investment nomenclature in the planned economic regime was dominated by categories such as 'plant for mainframe machine manufacturing', 'plant for peripheral equipment manufacturing' etc.. There was little room for terms such as 'application development' and 'technological services'."

The great significance of user capability building may also be highlighted by a statement from a manager from the Ministry of the Electronics Industry who said, "It is owing to the NTEs, which have accelerated the development of computer applications, that computer technology has started to become a useful instrument for various sectors, rather than only for scientific calculations as it was until the end of 1970s" (Interview, Ministry of the Electronics Industry).

6.3.3 The learning process

A very preliminary attempt to understand the process of learning by NTEs reveals some remarkable characteristics which are closely related to their orientation to building user capabilities.

First, very interestingly, the learning is initially triggered by *selling and after sales service* of computers. In fact there are fascinating stories about the initial emergence of both the NTEs and the Personal Computer market in China. The NTEs and the market were actually born as twins. In 1984-1985, when about 100,000 personal computers were imported into China,[25] scholar-businessmen were called on to offer their skills in the procurement, merchandising, user training, networking, and maintenance of computers. The distribution of these new technology-intensive products was an entirely new challenge which the existing framework for commodity distribution could not meet. A multiple-link-chain developed, starting with manufacturers abroad, through Hong Kong middlemen, to coastal cities or firms which had been granted autonomy in the use of hard currency, and ending in the street known as Zhong Guan Cun, in Northwest Beijing (interviews from around 1985). There the necessary conditions came together: the street is in the backyard of the capital city, where a huge demand for computer technologies had arisen, and where many of the top-ranking research institutes and universities were clustered, offering the potential to sustain such a market. This street, 'Electronic Street', was formally approved by the State Council as the Beijing Experimental Zone for New Technology Industries in 1988, so becoming the archetype of today's Zones.

Second, the learning is very *user and market oriented*. Selling provided NTEs with information on overseas producers and domestic users, along with opportunities to accumulate capital. Triggered by the enormous demands which they perceived while selling, many of them almost immediately incorporated in-house development into their commercial activities. This process may be illustrated by the changing composition of their income. In 1984, 75% of the overall turnover of the NTEs in the Beijing Zone stemmed from 'trading', and 4% and 21%, respectively, came from 'products', and 'technical services' [*Yu Weidong 1988, p. 129*]. In 1991 these proportions were 33%, 37%, and 29% respectively [*China Statistical Yearbook on Science and Technology 1992, p. 309*].[26] Thus selling, which was at first the dominant activity, is now roughly equalled by production and technological service activities. Similar indications can be derived from examining the expenditure of NTEs. Although this firm-level data is not very consistent it does indicate that the increase in production and services has been rapid, and that NTEs' R&D is closely governed by the demands of the market [*China Statistical Yearbook on Science and Technology 1992: pp. 308-309*], (Interview Notes 7 and 10, and other interviews).

All of the technological activities needed in localization, custom-built systems, and devices, are strongly linked to the specificities of the users' requirements and environment. The change in the way in which R&D activities are organized must have been radical for these scholar-businessmen. It would be very interesting to explore how they were able to make this transition so rapidly. Some evidence suggests that they were consciously aware of, and stressed, the need to re-orientate their technological activities (compared with their previous work in R&D institutes), and that was achieved by intensive study of the technological skills which the market demanded, such as product and engineering design. It would also be interesting to study how their previous experience in R&D was (or was not) transferred to learning the skills needed for market profitability.

Third, a *learning sequence* could be recognized, reflected in continuous upgrading of the sophistication and complexity of the technologies mastered by NTEs. Starting with selling and after-sales services, the internal development of NTEs undergoes, first, a stage characterized by simplified designs and embodied on printed-circuit boards, as in the case of Chinese Character adaptations. This is followed by a stage in which the 'core technology' is developed, designed to international standards, and embodied in custom-made circuits. Legend and New-Tech of Beijing University, for instance, have entered this stage.

6.3.4 Impact of the 'personal computer revolution'

Some effects of the 'personal computer revolution' could be observed. On the demand side, the service sectors have been the most important users, parallel to the worldwide rise in demand for computers in the management and operations of banks, airports, hotels, publications, broadcasting, advertising, and government offices. The 'open door' policy made in essential that these basic services in the social infrastructure should conform to international standards.

On the supply side, the availability of microprocessors and other core components has been crucial in the process which Ernst and O'Conner call the 'commodification' of computer hardware, i.e. the standardisation of basic design features of the computer system, and transforming them into mass-produced and general-purpose black boxes [*Dieter Ernst and David O'Connor*, *1992: pp. 72-75*]. This lowers entry barriers to the point at which organizations and individuals with no exceptional wealth could afford to initiate enterprises.27 The widely-adopted NTE strategy of developing a 'core technology' and obtaining its 'complements' from outside the firm could in part be a reflection of the fact that the basic components and parts had become easily available in the market place [*Yu Weidong 1988, p. 127*].

7. DECENTRALIZATION AND THE EMERGENCE OF NTEs

This section offers, tentatively, a broader perspective on the emergence of NTEs. As is well known, the advent of a non-state sector and its swift expansion has been the engine behind China's rapid growth and the spread of reform experiments in the country. This arose from a historical background in which there decentralization has been characteristic of the political-economic structure. This decentralisation developed further under the centrally planned economy after the 1950s, resulting in a 'Chinese version' of the planned regimes. Qian and Xu (1993) use the term 'multi-layer' form, or 'M-form' in describing the Chinese model, to differentiate it from those in Eastern European countries and the former Soviet Union, which Qian and Xu call 'U-form', or unitary form, centrally planned economies.[28]

The market reform deepened and transformed the "M-form" structure in China to such an extent that the bottom level bureaucrats, in particular, become entrepreneurs. They are driven by having real responsibility, and have incentives to attain financial self-sufficiency by improving local development. The continuous expansion of the non-state sector, of which the largest component is rural industry (in towns and villages), has taken place within such a framework. Drawing particularly on the work of Qian and Xu mentioned above, an explanation will be sought for the dynamism in the development of NTEs, in comparison with rural industry. The discussion here is still constrained by the limitation mentioned at the beginning of the paper, to the entry and early expansion of the NTEs.

NTEs as a distinctive part of the non-state sector

NTEs constitute a distinctive part of the non-state sector. Their significance has been rather neglected by many observers of China's reform, however. The NTEs are distinguished by their access to the best-educated manpower with the greatest experience in R&D. They serve to support activities in the rest of the economy, helping to upgrade existing production, and to supplement the large-scale manufacturing sectors. While the barriers to entry to large-scale manufacturing prevent most NTEs penetrating this field thus far, there is a real possibility that some important economic sectors may be created on the basis of non-state investment. The growth of rural industry, in contrast, has duplicated and expanded activities which already existed, in competition with state sectors.

The depth of decentralized autonomy

The high degree of decentralised autonomy has permitted the emergence of a non-state sector initiated at the lowest levels. The wide dispersion, both geographically and hierarchically, of research institutes and universities has been a critical factor. The mushrooming of spin-offs required almost simultaneous decentralization along two lines

— within regional administration and within the S&T administrative system (the development of rural industry, in contrast, required only the decentralization of the regional administration). An alliance between R&D and city administration has thus formed in many places in the process of developing Zones and NTEs. Within the regional administrative hierarchy, the 'city' level and the 'district' level were critical in the initiation of Zones and Centres.[29] In the S&T administration, the bottom level, i.e. the R&D institutes, the universities, and the departments of universities were critical.

Rationale for permitting entry

The rationale for permitting the entry of non-state initiated NTEs to the pool of industrial enterprises is very different from that behind the encouragement of rural non-state industry. In the case of the NTEs, it is based mainly on the newness of their businesses, which warranted an exemption from the normal rules of play. The creation and expansion of businesses for new technology applications does not erode the existing production and distribution networks, on the contrary, the domestic production of computers, for instance, has obviously benefited from the rapid increase in demand, which would not have occurred without the NTEs. Moreover, these services could really not be managed under the planned approach. The rationale for the expansion of non-state initiative in the case of rural industry related to remoteness from the centre, given the multiplicity of the M-form hierarchy. This remoteness buffered the new entry from the dominant rules governing the establishment of new enterprises. However heated disputes about NTEs continued up to 1990-1991. The industrial Ministry responsible was at best unhelpful for a few years, gradually turning to toleration and now to support.

Incentives

The greater incentives offered to NTEs by the decentralized structure in the context of the expansion of market institutions, because of the delegation of both authority and responsibility, encouraged the entrepreneurship of both local governments and R&D academics. Local governments had a strong incentive to achieve better performance in local development. Academics had a strong incentive to exploit their special assets under the new rules, under which technological assets were no longer a free commodity. Rivalry between cities and between academics to achieve better reform performance reinforced the incentives. A similar competition between territorial units occurred in the case of rural industry. This helped to expose and resolve uncertainties, and accelerated learning from each other. To the managers of NTEs, the 'high powered incentives' of the market make more sense. Compared with the managers of rural industry, the managers of NTEs had a more credible autonomy, partly because of the newness of these undertakings. Besides, the spheres in which NTEs are involved have been more directly influenced by international contacts, so that the zones have competed "to establish internationally compatible norms" in zone management. This has encouraged them to refrain from administrative intervention in NTEs' operations.

Financing commercialization of technology in NTES

The deeply decentralized structure provided a framework for financing the initiation and expansion of NTEs. Three kinds of actors are involved: R&D institutions, banks, and Zones. There is a division of labour among these actors: the R&D institutions provide mainly venture capital for the initiation of NTEs, the banks provide funds for expansion, and the Zones (from local governments) mainly provide investment in infrastructure [*Zhao Wenyan et al., 1989*].[30] To a lesser extent, Centres also work on providing venture capital to NTEs initiated by individual scientific and technical experts, at least during the early stage of their development (Interview Notes 9: pp. 2-3).

The ability of these actors to finance NTEs comes from the central government's credible commitment to reformist decentralization, which has delegated financial autonomy to the lower levels of each line of administration. The differentiated functions of these actors stem from their special positions. For instance, the immediate knowledge which the R&D institutions had of the underpinning technology, and the intimate understanding which the managers of the initiated NTE had of their own businesses made them better suited than others to manage the risks and rewards of their investments. This is why they act as the main risk-capital investor, although there is a government financing agency known as the Venture Investment Corporation.

Although there is the nationwide Torch Programme whose declared purpose is to provide 'leading funds' for the commercialization of technology, financing is decisively dominated by the local branches of banks.[31] The function of the banks is closely related to decentralization within the banking system, under which "each regional branch of the specialized banks was required to link their credit to deposits collected within the region" (Qian and Xu, 1993, section 4.3). The result is that the involvement of the banks is strongly influenced by the policies of the local branch. In fact, in each of the booming Zones one may find very active branch banks which sustain its prosperity.[32] It is noteworthy that the Zone administrations usually provide technical and market advice to the banks about the projects, a role very similar to the technical appraisal work carried out by investment banks in free markets.[33]

The hardening of 'budget constraints'

The commitment to decentralization was linked with the hardening of 'budget constraints'. The investors who had been delegated more responsibility monitored the efficiency of their investments closely. NTEs which incurred losses or engaged in malpractice were re-structured. The restructuring process was mainly administrative, within the jurisdiction of the initiators concerned, due to the lack of commercial law and court systems.

The performance of individually-initiated NTEs may throw some light on the importance of this supervision. More of this group made losses, and an even higher proportion appeared among the NTEs which were under investigation for malpractice, though the proportion of them which were successful was at the average level. One of the reasons for the relatively poor performance was that such enterprises were usually not subject to monitoring by investors and creditors [*Beijing Zone 1992, pp. 23-24, and Lin Chenhui, in Science and Technology Review No. 9, 1992, pp. 12-14*]. On the other hand, the high cost and low efficiency of monitoring in this way has been a driving force behind the efforts to establish market institutions. Indeed the entrepreneurs in R&D institutions and local governments were among the most dynamic actors in this respect. The principle of 'corporation organization' to normalize the internal management of NTEs and their relations to investors was also forcefully suggested.[34]

CONCLUDING REMARKS

1. The study thus far has established that spin-off restructuring of R&D institutions is pervasive. It has shown that the entrepreneurship of R&D institutions is central for the large-scale establishment of New Technology Enterprises. Technological assets accumulated in R&D institutions have been channelled into NTEs on a significant scale, and there is widespread organizational experimentation. In the NTEs, the technological assets derived from the R&D institutions become a source of competitive advantage for commercial business organizations.

   A few forms of spinning and channelling have been identified from the research:

   (1) spinning-off a part of the organized structure of an R&D institution;
   (2) the movement of individual scientific and technical personnel; and
   (3) the creation of an internal department of the R&D institute, responsible for the commercialization of the outcomes of academic research.

   Some mixed forms were also encountered. The importance of this categorization is that different forms have different characteristics in terms of the transferral of R&D assets to commercial applications and the impact on the initiating R&D institute. The latter effect has only been lightly touched on in the study thus far. It is apparent that different forms of spinning suit different types of R&D institution, but the study thus far has not examined this in detail. Further research on these aspects would be useful.

2. The analyses show that, in a time of transition, the existing organizations can play an important part in the success of the restructuring if there are proper policy incentives and other conditions. R&D institutions and local governments have a critical role in providing financial, infrastructure, and institutional support for the spin-off enterprises which constitute the basic framework for the implementation of the Torch Programme. Deficiencies in the institutional infrastructure needed for the new enterprises, such as guarantees for the rights of individual initiators, are being replaced with *ad hoc* structures, at least for now. The context of reformist decentralization is setting in motion some social dynamics which foster the continuous emergence and expansion of spin-off enterprises.

3. Perhaps the most striking findings of the study concern the character of the technological activities being performed by the New Technology Enterprises. The great majority of the NTEs are engaged in computer and information technology and computer-based product development and operation engineering. The technological efforts in this field concentrate on capability-building for the users of computer and information technologies (rather than on manufacturing). Three types of capability-building emerge from the empirical evidence:

   (1) adaptation (localization) of English-language computer and information technologies;

(2) the development of user-specific automatic operation and production systems and the associated engineering; and
(3) the development of single devices and machines for special purposes.

The latter two are characterised by the incorporation of computer-based information technology, though at a preliminary level at present, in special applications.

4. To return to the historical development of Chinese R&D with which this paper began, our observations in China show that this *is* the time when science, released from the framework of the administrative machinery, is entering into industry as part of the process of market-oriented economic reform. The evidence of the study shows that the requisite restructuring is pointing in the direction of integrating science (R&D activities) with various commercial functions. The NTEs are one generally successful structure for this purpose.

The findings of the study point to a general hypothesis: user capability-building in computer and information technologies is a promising direction, assuming that the integration of R&D functions with production and engineering is accepted as imperative. It could be that the continuous rapid growth in NTEs in China is a sign of an approaching wave of widespread computer application in other developing and formerly centrally-planned economies. From the perspective of both supply and demand, this is plausible. It has probably been hindered thus far by poor interfacing, which divorces local users from the new technological opportunities, as Ernst and O'Connor say:

> What is increasingly clear is that to be an efficient user of new information technologies, a country must possess a degree of familiarity with the design and development of the hardware components and software which determine the basic functionality of various information-based systems or subsystems. It must also be knowledgeable about the interface between the new information technologies and other (e.g. mechanical) technologies to be able to combine them effectively. [*Ernst and O'Connor: 1989, p. 39*]

As for how the needed interface is to be established, Ernst and O'Connor focus on overseas or domestic producers of computer technologies. However our study indicates that the interface has started to function in China, but from within domestic R&D institutions.

China's experiences indicates that organizational innovation, i.e. the creation of autonomous NTEs, is central to the process. This establishes a new institutional ground for new functions. The reason seems to be that the various special requirements of new technologies and working methods are far beyond the ability of any administrative system to plan in detail. The birth of NTEs has created effective centres in making use of resources.

Some technological assets were already there, but were previously isolated and locked into institutions. These institutions do have some strengths, such as the necessary knowledge, which can be re-orientated in the process of market reform. The R&D institutions, if they have been developed, are probably the only suitable domestic resource in many developing countries in which the industrial structures are very conventional and lack the experience required to effect technological diffusion. In addition, the special local features of the diffusion process, such as language, management systems and operational environment, all require more or less user-specific designs and services, at least at the earlier stage of the diffusion. Foreign suppliers would hardly be expected to meet these demands well.

ENDNOTES

1. In terms of total manpower for R&D, for instance, the figure for the U.S. (in 1989) is 943,000, for the U.K. 276,000 (in 1988), and 899,000 for Japan (in 1990). Note that this data is only illustrative, since there is some incompatibility between the statistics for different countries. For the U.S. the definition is "research scientists and engineers", for both the U.K. and Japan, it is "total R&D personnel" in all fields of science and with all levels of educational background [*OECD: Basic Science and Technology Statistics, 1993 Edition, pp. 319, 306, and 191*].
2. The details of the market orientation of the Decision have been discussed in many works. See, among others, Richard Conroy 1992: *Technological Change in China*, OECD 1993, pp. 91-96. The author states that "The overall trends of the S&T reform, driven by the need to optimise the output of S&T investment in production, has since their onset implied that technology is a commodity with an exchange value...." [*ibid pp. 91]*. The market orientation of the reform design stirred up vigorous debates in China about the value of technology, for which see Erik Baark: The Value of Technology: A Survey of the Chinese Theoretical Debate and its Policy Implications, *Research Policy* 17 [*1988*] pp. 269-282. The author stated that policy-makers at the highest level accepted the idea that the price of technological commodities should be regulated by ‘free’ market forces.
3. For example, in the Commonwealth of Independent States (CIS), "demands for R&D by industrial and agricultural enterprises dropped considerably," and "national and public financing to R&D was curtailed." [*Science and Public Policy, Vol. 19, No. 2, April 1992, pp. 111-118*]. In Hungary, "the direct links between institutes and enterprises tended to favour lower quality R&D", "In a quite not short period [even in the longer term], there would not be a strong market demand for out-mural R&D by industrial enterprises as users" [*Science and Public Policy, Vol. 19, No. 2, April 1992, pp. 89-97*]. In the case of the former German Democratic Republic it is reported that, between December 1989 and July 1990, the number of employees in industrial R&D dropped by 23%, because the institutes were not successful in the market. Another estimate put the reduction in industrial R&D manpower as high as 50% in the same period [*Bentley 1992, pp. 155*].
4. Christopher Freeman, in Bentley, 1992, pp. xiii-xvi.
5. For the emergence of rural industrial firms, and the property rights which are applicable, see Dwight Perkins: Completing China’s Move to the Market, *Journal of Economic Perspectives*, Vol. 8, No. 2, pp. 23-46.
6. See: Chen Zhaoying *et al.* (eds.): *Report on the Development Zones for High and New Technology Industries in China*, Science and Technology Publishing House of China, 1992, p. 2.
7. See: Zhang Yiyi: "Exploring China’s Development of High-Tech Zones Through the Practice of Shenzhen Science and Industry Park", *Selection from the Bulletin of the Chinese Academy of Sciences*, 1988, p. 336.
8. These features of the debate have been reviewed in Wang Ke, Gu Shulin and others: Research Report No. 9003, National Centre for Science and Technology for Development, 1990, mimeo. This report was summarized in the *People’s Daily*, overseas edition, June 19, 1990. Similar perspectives may be found, for instance, in Suttmeier [*1991*].
9. For details see "*White Paper*" No. 3, pp. 245-250.
10. Ten areas of technology were defined: (1) micro-electronics and computer technology and products; (2) information technology and products; (3) new material technology and products; (4) new energy, energy conservation technology and products; (5) bio-technology and products; (6) space and ocean technologies and products; (7) laser technology and products; (8) products for the application of nuclear technology; (9) products with integrated mechanical and electronic technology; and (10) other new and high technology.
11. The establishment of Special Economic Zones began in 1979, as part of the Open Door policy. The first four Zones of the kind were in Shenzhen, Zhuhai, Shangtou, and Shamen. Since 1984, the area open to foreign investment has expanded many times to include more coastal port cities, where the special locations for ventures involving foreign capital are known as "Economic and Technology Development Zones" [*Contemporary China 1985, pp. 385-393*]. Since the beginning of the 1990s, the open area has been expanding to inland cities. In short, the "Special Economic Zones", including the sub-group of "Economic and Technology Development Zones" are intended for foreign investment, in contrast to the Zones discussed in this paper, for which the policy goals are quite different.
12. The Chinese Academy of Sciences has about 120 subordinate institutes, most of which are engaged in natural science and engineering R&D. These institutes are the top rank of the research institutions in the country [*China Science and Technology Statistical Yearbook 1991, p. 28*].

13. There are about somewhat less than 800 institutes at the central ministry level, most of which are engaged in industrial technology R&D [*China Science and Technology Statistical Yearbook 1991, p. 5*].
14. At the local government level, there are about 4,000 R&D institutes, only about half of which are engaged in industrial R&D (the other half are engaged in agricultural and public service R&D) [*China Science and Technology Statistical Yearbook 1991, p. 7*.] Another source states that there are about 2,700 R&D institutes (i.e., categories a, b and c) engaged in "engineering science and technology" ("*White Paper*" Vol. 4, p. 215, table 1.1.4).
15. There are about 300 universities and colleges which are categorized as engaged in "natural science and engineering" [*China Statistical Yearbook on Science and Technology 1992, pp. 210-211*].
16. The spinning processes were usually ambiguous with respect to both organizational boundaries and ownership, as will be seen in the case descriptions which follow. The decisions to initiate spin-offs of this form and form 3 below were usually made by the institutes involved, based on the delegated autonomy in management of R&D institutes since 1985. After spinoff, operational decisions are generally made by the chief managers. Contracts for the transfer of institute assets to spin-offs were frequently not well defined and documented. This ambiguity did not cause any difficulty at first, but appeared to become a problem some time after start-up. One problem is how to return profits to the initiating institutes when the spin-offs have developed successfully. Problems of another kind relate to who should bear liability when the spin-offs fail. These problems, however, seem to have facilitated efforts to clarify and regulate the relationship between initiating organizations and initiated NTEs.
17. Here "public" ownership is a term used in the management of NTEs by Zone administrations in China. It refers to NTEs whose initiating capital came from "public" owned institutes, in contrast to "collective" and "private" initiating capital. The capital invested may originally be allocated from the state budget, or may have been earned by the institute itself during the years of reform. The "public" NTEs do not have any significant similarity to state-owned enterprises in their relationship with the state.
18. By mid-1994, Legend was producing 586 PCs for the domestic market.
19. There are no official statistics relevant to the form. The information comes from interviews. Usually the managers of Zones could not or do not differentiate form 3 from form 1. Thus the number of NTEs of this type may well be under-estimated by these managers.
20. This is calculated from overall data for all Zones, using the statistics for the group of NTEs designated as having "collective ownership without initiator and supervising unit" [*Science and Technology Industries of China, No. 10, 1992, p. 13*].
21. In Shenyang the manager estimated that about 50 out of the total of 1,100 NTEs were ‘private’, and slightly less than 60% of the 488 ‘collectives’ have no direct involvement from their originating institute. (Interview Notes 12, pp. 2-3). In Wuhan the manager estimated that individual initiations accounted for slightly less than 30% of the total, and that most of the group ‘collective, without [institutional] initiator and supervising unit’ were in fact individually initiated (Interview Notes 9, p. 7). In Hangzhou about 8 of the 161 enterprises were ‘private’ (about 5%), and another 45 NTEs (about 28%) are ‘collectively owned’, but it was not possible to get further information on the character of this latter group (Interview Notes 1, p. 4). In Beijing the manager confirmed that this form of initiation is rapidly increasing in importance (Interview Notes 11, p. 3).
22. ‘Competitive products’ is a term used by Zone managements to refer to products with good market prospects. Many Zones identify their "competitive products".
23. Hope Corporation was founded by a group of postgraduates from the Institute of Automation of the CAS. It produces computer software and some telecommunication and information equipment.
24. A typical description of the learning sequence has three steps: first, acquiring foreign technology; second, the effective diffusion of imported technology within an industry and across industries; third, local efforts to assimilate, adapt and improve imported technology and eventually to develop one’s own technology. See Kim, Linsu, and Carl J. Dahlman, ’Technological Policy for Industrialization: An Integrative Framework and Korea’s Experience’, *Research Policy*, 21 [*1992*] pp. 473-452.
25. For reports on the massive import of PCs in 1984-1985, see, for example, *China Business Review*, March-April 1988, pp. 30-33.
26. ‘Technological services’ are defined in Chinese statistics to include mainly technology transfer, engineering and testing services, contractual R&D and technological consultancy.
27. There is no systematic data on the initial monetary investment of NTEs. However, one survey made in 1988 reported that the total start-up capital of 13 NTEs with three-years histories had been 16 m. yuan, i.e. about 1 m. each [*Yu Weidong 1988, p. 103*], equivalent to a few hundred thousand US dollars at the official exchange rate of the time. A 1990 estimate for about 400 business entities sponsored by the CAS and its subordinate institutes indicated a similar level of investment, i.e. between half a million yuan and one million yuan. But the initial investment in intellectual assets is very high, since the intensive involvement of scholar-businessmen should also be accounted for.

28. The distinction between M-form and U-form centrally planned economies, used by Qian and Xu, is based on terms used by O.E. Williamson [*1985*] to describe firm structures under the capitalist system. The distinction is used to highlight differences between U-form central planning, characterized by control by the top-level administration of the coordination of the economy, and therefore by the primacy of the principle of functional specification, and the M-form planned economy hierarchy, found in China prior to the reform, in which the primary principle in the organization of economic administration is territorial, supplemented by the functional specification principle. Under such principles of organization, self-contained regional levels play an important role in the coordination of the economy. The distinction is used to highlight and explain many other features of China and China's reform [*Qian and Xu 1993*].

29. The territorial levels of administrative hierarchy are classified in two ways: for the 'rural' districts, the levels are central, provincial, prefectures, county, town, and village. For cities, they are: central, provincial, municipal, district, and neighbourhood. In this paragraph, 'city' means urban areas.

30. A study of 178 NTEs in the Beijing Zone showed that 86.5% of their initial capital was invested by their organizational initiators. Expansion was primarily financed with bank credits and re-invested profits. The study also revealed that the local branches of many specialized banks (and banking agencies) contributed to financing the expansion of NTEs in the Beijing Zone. The biggest contributors at that time were the Industry and Commerce Bank of China, the Agriculture Bank of China, and the Foundation for the Promotion of Economic Development through Science and Technology, which was jointly sponsored by the former State Economy Commission and the Chinese Academy of Sciences.

31. In fact, the leading funds from the central government constituted only a very small part of the overall investment in Torch Programme Projects, ranging from about 0.5% to 3% between 1988 and 1991 [*China Statistical Yearbook on Science and Technology 1992*, *p. 308*]. The leading funds in fact acted more as an policy guideline than as a financing source. The predominant role of the banks was in fact intended under the Torch Programme.

32. For Beijing Zone, see Zhao Wenyan *et al.* 1989. For Wuhan Zone, *People's Daily*, overseas version, May 3, 1993. For Shanghai, *People's Daily*, overseas version, Nov. 1, 1993, and for Shenyang, *People's Daily*, overseas version, Aug. 5, 1993.

33. The main difference is that, in the Chinese system, this function is almost entirely external to the banks, which have only very narrow financial and accounting functions under the planned system (Interview Notes 1). The ability of the Zone administrations to provide investment analyses derives from their alliance with academics. The Zones and Centres have recruited many experienced academics.

34. See Hu Qihen (Vice-President, Chinese Academy of Sciences): Report to the 1989 Working Meeting of the Chinese Academy of Sciences, 5 Nov., 1989, mimeo., and Wu Jinglian, in *Science and Technology Review*, No. 5, 1991, pp. 12-15.

APPENDIX
COMPETITIVE PRODUCTS OF THE BEIJING ZONE

The following table is compiled from data provided in the zone's *Catalogue of Competitive Products* (see source 1, below). It is useful as a sketch of the landscape, but is far from exhaustive since the information source was edited informally by the contributors. Important omissions include Kangto's STD 5000 series of industrial control machines.

TYPICAL COMPETITIVE PRODUCTS AND THEIR PRODUCERS IN COMPUTER AND INFORMATION TECHNOLOGIES IN BEIJING ZONE

Product	Producer (NTE)	Initiating and/or supervising institution	Notes
CAD work station; MAG Series Graphic Controller Board;	Beijing CA Automation Technology Company (founded March 1985)*	Institute of Automation, CAS	
RISC System (Work station; Super minicomputer; Multi-processor systems; Mainframe-class Servers;	Beijing Taiji Computer Corporation (Oct. 1987)*	No. 15 Research Institute, Ministry of Electronics Industry (MEI)*,**	
TJ 2242 Super Minicomputer	Beijing Taiji Computer Corporation	No. 15 Research Institute, MEI	Compatible with DEC VAX 4000 Model 200
IEAS Microcomputer	Beijing Kedian Microcomputer Technical Development Department (Sept. 1985)*	Institute of Electronics, CAS	Kedian started with selling and maintaining scientific istruments imported from Hong Kong*
TJ 2433 MP Super Minicomputer	Beijing Taiji Computer Corporation	No. 15 Research Institute, MEI	
WM 480 Computer System (Word Processing; Message Manager; Spelling Check)	Beijing Wang Ma Computer Corporation	n.a.	Wang Ma's president is Prof. Wang Yong Ming, inventor of the 'Five-Stroke Structure' of Chinese Characters, which has been patented in the U.S. (1986), U.K. (1987) and China. This technology is used by over 90% of domestic users, including all newspapers.

Product	Producer (NTE)	Initiating and/or supervising institution	Notes
ICRS-Microcomputer Image Collecting & Processing System	Beijing Sanlian R&D Corporation (founded in 1988)	Jointly sponsored by the Chinese Academy of Geological Exploration, the Remote Sensing Centre for Geology, and the Beijing Geological Instrument Factory, all subordinated to the Ministry of Geology and Mineral Resources	
4S Super Science Computer Typesetting System; and 4S Typesetting Output System	Beijing Stone Group Co. (May 1984)	Initiated by a group of engineers from the Centre for Computation of the CAS, and Si-ji-qing Town, Haidian District, Beijing*	Their main products, the MS Character Processing Computers (based on 4S Systems) have 80% of the domestic market
Xinghe SRC 386/33 Microcomputer	Beijing Xinghe Electronic Co. (June 1987)	A branch of Guangdong Xinghe Electronics & Audio Corporation of Electronics Acoustics	
Dolphin Terminal	Beijing Hua Hai Computer Equipment Co	A subsidiary of Beijing Hua Hai New Technology Development Co., initiated by the Department of Engineering Physics, Tsinghua University and the General Corporation of New Technology Development of Haidian District, Beijing (Jan. 1985)*	The products are cooperatively produced by Beijing Electronic Display equipment Factory
OFS Optical Disk File Management System	Beijing Golden Optical Disk Co.	Founded by General Corporation of Electronic Industry of China, State Education Commission and Tsinghua University	
Pecan OS System; Pecan Laser Printer; and Founder Electronic Publishing System	Pecan Information Technology Inc. (1988)	Jointly founded by Beijing University, Canon Inc. of Japan and Rosel Inc. of Japan	
Legend 486, 386, and 286 Microcomputers; Legend Chinese Character Information Processing System	Legend Group (Nov. 1984)*	Institute of Computer Technology of the CAS	
DL Microcomputer; 5.25" and 3.5" Floppy Diskette	Beijing Long Yuan Electronics Technology Co. Ltd. (1989)	Jointly initiated by Dalong Technology Corp., a subsidiary of China International Trust & Investment Corp. (CITIC), the China National Instrument Import & Export Corp. (CNIIEC), and G. Yean Electronics Technology Co. Ltd (Hong Kong)	

Product	Producer (NTE)	Initiating and/or supervising institution	Notes
DY Multi-effects Caption System	Beijing Dayang Image Technology Corporation	n.a.	
Caption Generators	Toute Electronics Technology Company	n.a.	
AGC Series Graphic and Image Controllers	Beijing Sunstep Electronics Technology Co. Ltd.	Joint venture with an American company	This is the only NTE specialized in computer graphic and image controlling systems
ANNO Raster to Vector Conversion System (Graphic Input System)	Beijing Tsinghua 3i Computer System Corp. (Sept. 1988)	Tsinghua University	
FY-PC 286/386 Industrial Microcomputer System	Beijing Industrial Control Computer Factory		
"New-Century' TV-Image System	Beijing New-Auto electronic Technology Co.	n.a.	
CVS Series of Computer Video Image Creation Systems	Beijing Shihui Science & Technology Company	Beijing Normal University	
TS 8000 Series STD Bus Industrial Control Machine	Beijing Tian Shi Industry Control Technology Corp.	n.a.	
Huasun 4075 work station	China Computer System Engineering Corp	No. 6 Research Institute, MEI	This is the largest producer of work stations in China, also a major retailer of Sun Micro-System Inc.
2.13 Integrated Office System	Beijing Xiaojun Computer Co.	n.a.	
Founder Electronic Publishing System	Founder Group Corporation (New-Tech Corporation) of Beijing University	Beijing (Peking) University	

Data marked with "*" is cited from source 2. Data marked with "**" is from interviews. Other data is from source 1.

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