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A Review of Reform Policy for the S&T System in China:

From Paid Transactions for Technology to Organizational Restructuring

By Shulin Gu

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1. INTRODUCTION

1.1 The Subject of the Paper — The Need to Address Reform Policy

This paper is intended to open discussions about science and technology policy, as part of market reform exercises, with a particular focus on China. Because of the great complexity and diversity of the R&D system in any modern country, this study is limited to policy issues relating to industrial technology R&D. It is not the intention to consider academic (theoretical) R&D, or R&D in fields such as agriculture, health care, environmental protection, calamity prevention etc., except to the extent that cross-over is unavoidable. When we have to deal with policies whose purpose is more general, the analysis will concentrate on those elements which are closely related to the transformation of R&D institutions for industrial technology.

The terms 'market reform' and 'market-oriented reform' are employed in this paper as synonyms, and in their most basic sense. They refer to the introduction of the basic rule of the market that transactions are determined in the market place through negotiations between the buyer and seller. This is genuinely crucial to the transition of China's industrial technology R&D institutions, which were organized and developed in a substantially different regime.

The central concern of the study is that market reforms require the restructuring of industrial technology R&D institutions. This is in contrast to the generally accepted view, which is usually restricted to the pure use of market power. This obsession has led to simplistic policy formulations that amount to no more than relying upon the expansion of a 'free' market. This has already considerably weakened the effectiveness of policies for the R&D system.

The industrial technology R&D institutions inherited by countries currently undergoing market-oriented reforms are basically characterized by the separation of the industrial R&D and innovation system from its production users. As several authors have indicated, these systems, in centrally planned economies, were characterized by (1) the centrally-planned governance of investments related to industrial technology and (2) extensive externalization (outside firms) of elements relating to industrial technological changes such as research, development, design, standardization, etc. [*Hanson and Pavitt, 1987, pp. 25-30*]. This kind of institution developed mainly in the 1930s and 1940s, with the inception and consolidation of the first centrally-planned economy in the former Soviet Union, and was later adopted by about a dozen centrally planned countries, including China, after World War II. A number of countries in Latin America, Asia, and later Africa, began to build up their own industrial R&D capabilities from the 1950s, following rather similar patterns. Their R&D capabilities were established in centralized institutions, and financed and operated by governments. The roles and effectiveness of these centralized industrial research and service institutes have been continuously debated.[1]

Numerous attempts are reported to have been made by the Soviet Union and other Eastern European countries from the 1960s to the late 1980s, most of which were focused on intensifying links between the separate organizations and functions necessary for technological change. These efforts can be illustrated by the hard push for the establishment of ‘science-production associations’ in the former Soviet Union. Generally three types of measures were used by the Soviet Bloc countries until the late 1980s, all aiming at improving the efficiency of the centrally-planned regime: (1) to merge the originally separate research institutes either with groups of enterprises or with large individual enterprises; (2) to institute full-cycle planning for research work, with each major project having planning targets to cover the development of technology and its application in production, specifying both users and expected effects; and (3) to increase incentives to both researchers and users of industrial technology, by means of favourable pricing, bonuses etc. This packet of measures has been called by some authors ‘efforts under a planned regime’.[2]

The policy issues addressed here became sharper when the former centrally-planned economies began to take drastic steps toward market reform. Since around 1990, economic plans have been radically abandoned in these countries, and the funds granted from government budgets to both enterprises and R&D institutes have been dramatically reduced. R&D institutes are forced to sell themselves on the market. "Inability in selling themselves" (on the part of specialized and former government-financed R&D institutions) was then widely seen as the most pressing difficulty, and this became the focus of attention in science and technology policy communities in these countries and worldwide.[3]

Assuming that there is a problem of "inability in selling R&D", the next question which is commonly asked is, "Are the limited market functions sufficient to support market reform for the R&D system?"[4] Authors who have posed this question begin with the reality that R&D institutes have proved to be bad sellers, which they argue is due to low demand from users and the inadequacy of legal protection for intellectual property. They conclude that government appropriations are urgently needed to prevent the existing R&D organizations being dispersed and lost.

It must be admitted that the market institutions are definitely poor, and that the users of industrial R&D are weak, at a time when the reformist efforts are just starting to transform them. In practice, the question raised by the debate is: Should the reform process step back to the old regime? Can the transformation of the S&T system, which has proved to have limited abilities in selling itself and dealing with the market, proceed on the basis of a market orientation? An OECD report has put the question in slightly different terms, and suggests an answer: "The problem ... was whether measures were designed to keep capacity or the present structures. The latter ... were judged ... to be unsuitable for S&T development. Government should fine-tune approaches designed to preserve capacity and to change present institutional arrangements." [*OECD, 1992b, p. 168*]

Apart from the practical question of the ability of the S&T to work through the market, there are theoretical questions about the suitability of the marketplace for mediating between the suppliers and users of technology and knowledge. Many presently preferred policies emphasize the soundness of market intermediation, assuming the perfection of the technology market itself. There are reasons to question this assumption.

In industrially-developed market economies, industrial firms are the institutional basis for industrial technology [*Freeman, 1982*, especially section 5, and *Kline and Rosenberg, 1986*]. A large part of industrial R&D and designing is internalized within firm organizations. The uncertainty of technological innovation, and the tacitness of technological knowledge, have favoured institutional rather than pure market mechanisms. It is argued that the commercial success of industrial technology depends on continually seeking to match uncertain technological opportunities to changing market possibilities, and the match can be realized more easily within firms, with better information feedback between the various activities. This internalization has developed spontaneously in market economies, underlining the imperfections of the market mechanism in dealing with technology transactions. Williamson has discussed these imperfections more extensively in the context of markets and hierarchy [*Williamson, 1985*, especially Chapter 2].

Market reform requires institutional restructuring, because the old institutions were developed to fit within the old economic regime. If the necessity of restructuring was ignored (i.e., if R&D institutions were expected to produce the same products as in the past, within the same structures, but to sell them in a technology market), policy-making would be unlikely to respond to the widespread phenomenon of the integration of production and research functions within organizations. For instance, in Hungary, during the last two decades "all types of research institutes adjusted themselves to the opportunities offered by business and restructured their activities accordingly ... The R&D institutes themselves started manufacturing new equipment instruments." "In the 1970s production had become a common activity of R&D institutions ... the market regulators [i.e., rules] made them interested in ‘in-house’ production." "Thus, frequently, the mass production goods of the research institutes were also sold,..." [*Balazs, 1993*].[5] In East Germany, approximately 100 ‘research companies’ had been established from elements of former combines by November 1990 [*Bentley, 1992, p. 156*]. Such realities have often been seen, in the light of "neoclassic" theory, as evidence of extraordinary chaos.

This study, therefore, addresses industrial technology R&D reform policy, with the focus on the "extraordinary" institutional restructuring.

1.2 The Approach of the Study — Empirical Observation of the Historical Evolution of Reform Policy in China

No systematic framework has yet been developed for analyzing reform policies. Recently the OECD has organized studies on science, technology and innovation policies in some formerly centrally-planned economies, addressing transitional issues. These studies seem to be at an early stage, of seeking to describe and define problems through empirical examination.[6]

An analogous approach is taken in this study which, by surveying the formulation and implementation of, and responses to, policies, is intended to provide ingredients for the conceptualization of the subject, relying upon empirical examination. China is a promising subject country because the reform has been going on there for fifteen years with little interruption, and may be supposed to illustrate the ‘natural’ evolutionary process in the medium term. Our study differs from the OECD projects in two respects: it is elaborated in a longer historical context, with greater attention to the causes and consequences of important policy-making since the market-oriented reform began, and is more narrowly focused on R&D institutions for industrial technology, a segment of the national science and technology (S&T) system which was more urgently faced with the need for restructuring.

The historical examination of reform policy asks these questions: (1) what demands were made on R&D institutions by the changing economic environment and international relationships, and how were the requirements perceived by policy-makers? (2) how were the related policies formulated and what policy measures were devised for implementation? and (3) how did the R&D institutions respond to the policies, and how were the reform policies amended in response? These questions imply an examination of the most important events in the development of S&T policy, in relation to the most important changes in economic regime, at the expense of overlooking many other facets which may also have been influential, but to less extent.

It will be evident that the possibility of establishing an historical perspective brings considerable benefits. It is evident that there is an evolutionary sequence in efforts to adjust the S&T system in step with the economic reforms. In China, market-oriented reform was begun in the late 1970s, starting with the agricultural sector. This was followed by reforms for industrial sectors, launched in the first half of the 1980s. Following on from this process, market-oriented reform for the S&T system has been in place since 1985, when the Decision on S&T Management System Reform was promulgated. Many observers have stopped there, but a close examination will show that institutional restructuring has been developing ever since, in parallel with the expansion of market dynamics.

The restructuring of R&D institutions thus far has produced a few recognizable forms: (1) merging R&D institutions into existing enterprises; (2) spinning-off new technology enterprises from R&D institutions; and (3) transforming whole individual R&D institutes into manufacturing or engineering corporations with intensive in-house R&D and design. Policies for facilitating these kinds of restructuring were created in a clear time sequence, from merging R&D into enterprises in 1987, to spinning-off in 1988, to the transformation of individual R&D institutes since the 1990s. The different mechanisms underpinning these transformations will be tentatively probed, along with the review of policy initiatives, in order to illustrate what kind of "fine-tuning" reform policies were developed, in interaction with particular kinds of restructuring, at each stage of the process.

This paper is organized in seven sections. The remaining parts of the introductory section will quickly sketch changes in the economic environment since the end of the 1970s (section 1.3), and outline the institutional heritage of the system for industrial R&D in China (section 1.4), so as to provide a broad background for the following sections. Section 2 introduces the main policy initiatives from the end of the 1970s to 1985, as a basis for comparison with those taken after 1985. This period saw an overall rehabilitation and enhancement of the planning apparatus and of state-run R&D institutions, to meet ambitious economic targets, at a time when market-oriented economic reform had just started. Section 3 analyzes policy measures stipulated by the Decision on S&T System Reform in 1985. This launched the systematic introduction of a technology market into the operation of R&D system. Section 3 also outlines some responses by R&D institutes to the technology market. The following sections deal with policies for various kinds of restructuring of industrial technology R&D institutes. Sections 4 addresses restructuring by merging R&D institutes into existing enterprises; Section 5 is on the process of spinning-off enterprises; and Section 6 deals with the transformation of entire individual

R&D institutes. Finally, the concluding section summarizes findings and suggestions for further study.

Information for the study is drawn from policy documents, S&T statistics, and journalists' reports, incorporating intensive interviews conducted in the summer of 1993 and over the previous ten years when the author worked on S&T reform policies with some important policy agencies in China.

1.3 Changes in the Economic Environment Since the end of the 1970s

The centrally-planned economic regime in China was introduced in the 1950s, along with massive imports of industrial technology from Soviet Bloc countries. The institutionalization of the R&D system in China was also accomplished in the 1950s, along lines which were broadly coherent with the economic regime. This system existed for twenty years, in an environment in which there was very little international participation and very little motivation for institutional reforms, so that only marginal evolution occurred in that time.[7] Nevertheless, there were many efforts to reduce the degree of mis-matching in the system and to adapt it to Chinese conditions. These efforts were at times intensive, such as during the radical 'Chinese style' revolutions of 1958-1960 ('Great Leap-Forward'), and 1966-1976 (the 'Cultural Revolution').[8] However, the reality was that after each radical revolution, the basic rules of the established institutions remained unaltered, retaining Chinese characteristics which were different from other versions of the planned economy.

The present reform in China was initiated at the end of the 1970s. In 1978, the top leaders of China decided to revise the objectives of economic development to give more attention to: (1) the efficiency of economic growth, at the same time as accelerating the speed of economic development; and (2) improvement in the people's standard of living. To realize these objectives, it was declared that political principle should no longer to guide economic affairs [*CCCPC, 1981*]. Two accompanying changes in the strategy of economic development were crucial. First, the overwhelming priority of heavy industrial development was replaced with a more balanced pattern, with consumer goods and service sectors getting a greater share of resources. This stimulated the decentralization and diversity of the economy, and accelerated the development of local and non-state owned industry. Second, an open-door policy to the international community was announced, a dramatic departure from the 1960s and the first half of the 1970s. China has since taken corresponding steps to remove rigid planning controls and has increasingly introduced market elements.[9]

The market-oriented economic reforms have had vital effects on the existing S&T system, largely recasting the relationships of the system to the firms using its output. The *first effect* followed from the rural economic reforms. By the end of 1981, the previous 'commune system' had broken down, more than 90% of farmers had begun to work under a 'household responsibility system' whereby land was entrusted to peasant families. They received more freedom to use the land and to sell their output in a free market, after having met a grain quota for the state. Moreover, rural residents were allowed to run various non-cropping businesses such as fish farms, animal husbandry, transportation, construction, and industry. The rapid growth of rural industry, in particular, created huge demands for industrial technological expertise which were entirely beyond the capacity of the old institutions. By 1989 there were nearly one million township and village enterprises, employing more than fifty million workers [*China Statistical Yearbook 1990*, English version, pp. 390, 387].

Second, the extent of the state plan steadily shrank, and state-owned enterprises were granted more autonomy and thus took more responsibility. This occurred the success of the agricultural reform. In 1984 the "Decision on Reform of Economic Management System" was implemented. This granted state-owned enterprises autonomy in their product portfolios, marketing, purchasing, staffing, and pricing, but not in capital investment and enterprise equity [*CCCPC, 1984*]. A new tax system allowed enterprises to retain their profits after taxation, for the first time since the 1950s. This re-defined the relation between firms and the state significantly, although enterprises were still subject to many constraints [*Contemporary China, 1985,* pp. 342-343]. Around 1987, a 'management contract system' for medium and large industrial enterprises, and a 'leasing system', mainly for smaller (state-owned) enterprises, were widely implemented, with the aim of clarifying and consolidating firms' autonomous responsibility on a contractual basis.[10] The operation of state-owned enterprises was therefore increasingly moved out of administrative governance.[11] As a result, the domestic users of industrial R&D became, to a significant extent, able to make decisions on their own as to what should be bought, from whom, and what activities should be undertaken 'in-house'. This was a fundamental alteration in the supplier-user relationship for industrial technology.

Third, due to the open-door policy, China's international economic links were substantially intensified, in terms of the inflow of investment, technology and capital goods, from the late 1970s on.[12] Importation became the most important source of industrial technology, so that domestic suppliers faced fierce competition. To give an approximate idea, one survey indicates that at present about two thirds of the technology employed in production in the machinery industry is directly acquired from overseas suppliers (interviews with the Ministry of the Machine Industry, Sept. and Oct. 1994).

1.4 The Institutional Heritage of Industrial R&D Institutions

It is proper to summarise some of the institutional inheritance of the R&D system, which has had a profound influence on the restructuring in the subsequent period of market reform.

The system was at first basically transplanted from the Soviet Union, along with a vast inflow of industrial technology in the 1950s. This system was then consolidated by, and within, the centrally-planned regime in China, whose administrative machinery had complete authority in economic decision-making, including decision-making for the R&D system. The R&D system became an important component of the regime as a whole, and continued to operate under planning control until 1985.

As has been widely recognized, the separation (or externalization) of the R&D units from the production units is one of the most prominent organizational features of this kind of system. In comparison with countries with similar per capita GNPs, but under market economic regimes, this system was generally over-extensive in terms of quantitative indicators such as numbers of institutions, manpower, expenditure etc.. In China, there were more than 4,500 'independent' R&D institutes affiliated to the governing machinery at levels higher than 'county'[13] in 1985, of which more than 2,000 were engaged in industrial technology (see Table 7 in the appendix). In this system, other functions necessary to technological changes were also segmentally organized within the administrative framework, the most notable being the design institutes.[14] In addition to these generally recognized features, other institutional characteristics which appear not to have been adequately discussed thus far will be briefly mentioned below.

Integral position in the administrative framework

Having long been subordinate establishments, these institutions were 'locked-in' to the administrative framework. Industrial R&D institutes were locked in to the specialized departments of industrial ministries or bureaus. Other functional institutions were locked in to other departments or 'bureaus'. Design institutes, for instance, were locked in to 'capital construction' departments. It is characteristic of China, where the planned economy has a "stronger local authority" (Tidrick and Chen Jiyuan 1987, pp. 180-186), that the R&D system was widely extended, and separately locked in to different levels of administration (central and regional).[15] This locking-in had a strong influence on the behaviour of industrial R&D institutes in the process of reform, both positively and negatively.

Very physical orientation

Since they served industrial production units which were weak in in-house R&D, any output presented as generalized knowledge, theory, or analysis was unlikely to be understood and employed by the firms using it. The only way was to make a physical prototype and perhaps even install it directly on site. This pulled R&D institutes very much 'downstream'.[16] It is safe to estimate that the majority of the work performed in industrial 'R&D' institutes was not R&D.[17] The situation is also found, to some extent, in other formerly centrally planned economies.[18] As the market reform proceeded, this characteristic favoured the transformation of some industrial R&D institutes into profitable businesses. Market-profitable manufacturing was easily started in pilot plants or trial production workshops which already existed inside these institutes.

The weakness of enterprises

Because they were assumed to be pure 'production' units, the industrial enterprises were weak in R&D and design, and also in marketing and information collection. Besides, the enterprises had no means of financial accumulation. One should conceptualize the enterprises under a centrally planned economy as entirely different from the enterprises in market economies. The R&D institutes in the two different kinds of economic regimes are also entirely different from each other.

2. THE PRE-‘DECISION’[19] PERIOD — REFORMATION OF PLANNING PRACTICE (1978 — 1985)

Though the revision of economic development priorities and the reform of the agricultural and industrial sectors had begun in the late 1970s, as outlined in the section above, science and technology policy in China was still run on rather traditional lines. Between the late 1970s and the mid-1980s, two initiatives were taken by the Chinese authorities in accordance with the revised economic strategy. One initiative was the rehabilitation and improvement of R&D institutional establishments which had existed prior to the ‘Cultural Revolution’ [*1966-1976*]. This initiative was realized between 1978 and 1980. Another initiative was the elaboration of a planning system for S&T activities, which was begun in the first half of 1980s, in parallel with the formulation and implementation of the 6th National Five-Year Economic Plan. This section discusses these two major initiatives to provide a glimpse of the characteristics and formal practices of traditional S&T policy institutions, under the planned regime.

The traditional practice may be illustrated by two features common to both of the initiatives in this period: first, the efforts are focused on the supplier side, and on the array of externalized R&D establishments, and second, the government has twin roles: it formulates development strategy, and takes action to implement it. Thus in "conventional" planned economies, science and technology policy amounts to no more than establishing priorities, plus their administrative implementation.

In accordance with the situation in China at that time, the first initiative (i.e., the rehabilitation and improvement of R&D institutional establishments) was adopted as a remedy for the damage wrought in the ‘Cultural Revolution’. This was done in the belief that the original established institutional base could have performed well without the disruption of the Revolution, and that the re-building of the system would be critical to the success of the newly-defined economic development plan. The second initiative (the elaboration of the planning procedures for S&T resources) followed the first one, to bring the re-built R&D system into line with the revised economic objectives, which placed a higher priority on the efficiency of growth and the people’s standard of living. In particular, the second initiative was triggered by the difficulties being encountered in the fulfilment of the economic objectives around 1980.

2.1 Rehabilitation and Improvement of R&D Institutions

The 1978-1985 National S&T Programme

Efforts to rehabilitate R&D institutions were led by a national S&T programme — the ‘1978-1985 National Science and Technology Programme’, which was announced in 1978 [*Fang Yi, 1978,* in "White Paper" Vol. 1, 109]. Eight S&T areas were chosen as national priorities. They were (1) agriculture; (2) energy resources; (3) materials; (4) computing; (5) lasers; (6) space science and technology; (7) high-energy physics; and (8) genetic engineering. It is obvious that this programme focused on attaining a leading status in science and technology (see "White Paper", Vol. 1, pp. 262-266).

It is remarkable that the justification for the S&T policy made in this period was surprisingly analogous to the justification for the initial creation of the S&T system twenty years earlier.[20] It was perceived that the emerging revolution in science and technology would have a far-reaching impact, would lead to an enormous improvement in productivity, and that science and technology should therefore be seen as an important factor in determining economic production. In particular scientists and engineers, who had been popularly denounced and dismissed from R&D in the ‘Cultural Revolution’, were declared to be part of the working (and therefore, leading) classes [*Deng Xiaoping, 1978*]. In institutional terms, efforts focused on the rehabilitation of pre-‘Cultural Revolution’ patterns at the macro level, and on the improvement of R&D institutes’ management at the micro level. After the experiences of the ‘Cultural Revolution’, which tended to punish the supplier side of S&T because of dissatisfaction with its separation from economic production, China now turned to promoting the rejuvenation of the original R&D system, until the mid-1980s, when the broader economic institutions had been significantly altered. Several measures which were taken to rehabilitate and improve the R&D institutions will be described below.

Rehabilitation and expansion of independent R&D institutions

The drive to establish and complete a "national scientific research system", which was part of the National S&T Programme, [*Fang Yi, 1978*], led to the almost complete rehabilitation of the R&D institutions, and other institutional establishments such as design institutions, which had been established before 1966, and which had been closed or down-graded to affiliation with lower levels of the administration. Moreover, a large number of new independent institutes were created, especially in the fields "where there was weakness previously, where regional development could not be adequately supported, and where there is rapid progress which is of great importance" [*Fang Yi, 1978*]. No official data is available for the expansion of R&D institutions for that period, but one indicator, the "expenditure for scientific research from the government budget" is, indirectly, significant: this figure reached a peak between 1978 and 1980, and has been falling since. The expenditures were 1.5%, 1.6%, and 1.5% of GNP for 1978, 1979, and 1980, respectively. Since then, this indicator has steadily decreased, to about 1.0% in 1988 and 0.71% in 1992 [*State Statistical Bureau, 1990*, pp. 202-203, and *China Statistical Yearbook 1993,* p. 23].

Improvement of R&D institute management

At the micro level, policy efforts in this period focused on the improvement of the management of individual R&D institutes. Much was learned from the lessons of the past, when political criteria had been substituted for professional standards. This was seen as an important reason for the lower performance of the system. The following measures were set in motion [*Fang Yi, 1978*; "White Paper" No. 1, p. 14]:

- substitute experts for political cadres as directors of institutes;

- set up academic committees at individual R&D institutes, as the authoritative bodies in academically-related appraisal and review;
- re-establish the excellence principle, which had been suspended for twenty years, as the basis for the assignment and promotion of S&T professionals.

Creation of in-house R&D and design departments in enterprises

Enterprises were also encouraged to create their own R&D departments. Though no statistics are available, in-house R&D and design departments were certainly widely established within big industrial enterprises in these years, and this continued, in more enterprises, throughout the 1980s and up to the present. The usual process was the enlargement and re-assignment of units which had previously functioned as testing, measuring, designing, or maintenance offices in the host enterprise (Interviews, particularly with the Ministry of the Machinery Industry).

2.2 Elaboration of Planning Practice

The second policy initiative in this period was the elaboration of planning practices. This began in the first half of the 1980s, with the aim of aligning industrial technology R&D with the Five Year Economic Plan. For the first time in the history of planning in China, R&D projects were closely combined with the economic programme. One important reason for it was the frustration of the ambitious industrialization plan which had been set out around 1978, which projected large-scale procurement of foreign machines but proved to be unattainable because of a shortage of hard currency. The resulting critical review of the S&T policy turned to address the effectiveness of the allocation of domestic S&T resources [*SSTC, 1981*].[21]

The redirection of S&T resources was carried out by means of a planning apparatus which will be discussed in the paragraphs below. This was a significant initial step towards setting more realistic targets for technological development, although the efforts in this period were not very successful. This was motivated by a great concern to improve economic performance, which was widely accepted from the end of the 1970s. Before then, the lower standard of industrialization required no more than the duplication of technologies imported in the 1950s. The duplication process, behind a ‘closed door’, placed little pressure on industrial R&D to meet the requirements of technological upgrading. This period of qualitative stagnation was ending.

Planning for the re-allocation of R&D resources to industrial technology

The planning for the re-allocation of R&D resources was based, once again, on direct priority-setting and investment by the state. The intention was to achieve improvements "in the development of product and process techniques, and in the assimilation and dissemination of S&T achievements" [*Zhao Ziyang, 1982*]. Eight areas were chosen for the "Key S&T Projects of the Sixth Five Year Plan" ("White Paper": No. 1, pp. 114-130) based on economic and technological criteria, as follows:

(1) agriculture;
(2) the consumer goods industry;
(3) energy resource development and energy conservation;
(4) the raw material industries and geological exploration;

(5) mechanical and electrical equipment;
(6) transportation;
(7) new technologies; and
(8) social development.

It can be seen that, of these eight areas, at least five, i.e. (2), (3), (4), (5), and (6), relate to industrial product and process technologies. The re-allocation of R&D resources was mandatory, relying on the power of state control.

The management of planned projects

The management of the planned S&T projects utilized the existing administrative framework. Some major characteristics are listed below:

- Officers from industrial ministries served as the coordinators of the projects, supported by experts from the R&D community;
- The technological work of the projects had to cover a wide range from basic research to small batch production, because the project targets were for the development of production technology, rather than for 'generic' technology.[22]
- Participants of a particular project had to be drawn from different units, given the high degree of institutional segmentation which had developed. The project coordination had to correlate the tasks of the various participants.
- The principal participants were industrial technology R&D institutes, not the academic institutes of the Chinese Academy of Sciences, nor enterprises (Interviews).
- Industrial firms played secondary and complementary roles (Interviews).[23]

Limitations of the elaborated planning approach

As was said above, the re-allocation of R&D resources was mandatory, relying on the planning institutions. This seems to have had serious drawbacks as regards the economic performance targets. The following limitations have been derived from perceptions expressed in articles or by ministry managers.

- The capacity of the administrative authorities was limited: administrative power was unable to deal with the innumerable different needs of various industrial users (Interviews, Ministry of the Machinery Industry, and Ministry of the Electronics Industry);
- There was a loss of efficiency due to the arm's length collaboration among participants. This was caused by the 'outside' coordination of a large number of participants [*Ou Wen, 1991*].
- Deficiencies in the dissemination of the resulting technologies were significant: the planning approach was found useful in acquiring some important industrial technologies, and in putting them into first use, but it proved far from efficient in achieving the widespread adoption of new technologies (Interviews with the Ministry of the Machinery Industry).[24]

3. DECISION ON S&T MANAGEMENT SYSTEM REFORM (1985) AND THE CREATION OF A 'TECHNOLOGICAL MARKET'

From 1985 on, China's science and technology policy came to concentrate on the reform of the system itself. The turning-point was the promulgation of the 'Decision on Reform of the Science and Technology Management System' ('The Decision'), which was put into action in that year. Note that this followed reform in the agricultural sector, which began at the end of the 1970s, and the reform of industrial sectors, which had been decided on just one year previously (in 1984), as mentioned in section 1.3 above. The central concern of the Decision is with the problem of the lack of "horizontal and regular connection between S&T and production", which was in fact increasingly incompatible with the operations of the agricultural and industrial sectors. In his speech at the 1985 National Working Conference of Science and Technology, former Premier Mr. Zhao Ziyang spoke on the advantages and disadvantages of the existing system. This analysis may be seen as a reflection of disappointment with the old methods, based on long experience, including the intensive experiments with the S&T system since the late 1970s. He said:

> The current science and technology institution in our country has evolved over the years under special historical situations. The advantages embodied in this system manifested themselves in concerted efforts to tackle major scientific and technological projects, with great success. However, there is growing evidence to show that the system can no longer accommodate the situation in the four modernization programme, which depends heavily on scientific and technological progress. One of the glaring drawbacks of this system is the disconnection of science and technology from production, a problem which is a source of great concern for all of us....
>
> By their very nature, there is an organic linkage between scientific research and production. For this linkage a horizontal, regular, many-levelled and many-sided channel should be provided. The management system as practised until now has actually clogged this direct linkage, so that research institutes were only responsible to the leading departments above, in a vertical relationship, with no channel for interaction with the society as a whole or for providing consultancy services to production units. This is the root cause of the inability of our scientific research to meet our production needs over the years.... This state of affairs can hardly be altered if we confine ourselves to the beaten track. The way out lies in a reform [*Zhao Ziyang, 1985*].

This speech expressed a very strong inclination to appeal to the power of the market to solve these problems. This obviously revealed the agreed consensus of those guiding the market reform which was then going on in most economic sectors.

> Experience in the past thirty years shows that, as long as commodity transactions exist in an economy, we cannot achieve the desired results in any economic-related undertakings if we ignore the commodity-currency relationship, ignore the law of value and the role of economic levers. Often our efforts have got nowhere, have gone contrary to our wishes, or at the most were partially rewarded. You cannot force farmers to provide urban residents with food, cotton, and meat by administrative means. You have to do business with them in accordance with the law of value. The farmers would not hear of it if you expected them to produce for the sake of equalitarian idealism...The same is true with scientific research. If you want scientific research to serve production needs, you must acknowledge the value created by mental labour and allow most

> technology achievements to become tradable. If you want research institutes to serve the whole society, you must break down hurdles of all descriptions to open up a technological market. If you want the scientific personnel of the research institutions to voluntarily and regularly go to enterprises to identify research items, you must alter the funding system in which research institutions depend entirely on appropriations from the state. To bind research institutions and production units in a common cause, you must adopt a variety of economic means linking them with ties of interests [*Zhao Ziyang, 1985*].

Section 3.1 below analyzes the main measures of the Decision, which focus on a 'technology market' approach, Section 3.2 addresses other policy measures of the Decision intended to support the central 'technology market' approach. Sections 3.3 and 3.4 provide a preliminarily summary of some consequences of the technology market approach.

3.1 Central Policy Measures — The 'Technology Market' Approach

The chief policy thrust under the Decision was to introduce the market mechanism into the operation of the R&D system. Two strands of practical measures were put in place concurrently:

- diminishing government grants to put pressure on R&D institutes so that R&D institute would have to turn to real demands;
- creating a technology market as the intermediate institution for transactions between R&D institutes and their industrial users.

Diminishing government grants (Decision: sections I and II)

A general survey was carried out in 1986.[25] On this basis, a categorisation was made. The industrial technology R&D institutes were identified and their grants began to be progressively reduced.[26] The process was to be completed within five years (from 1986 to 1990). The policy also offered incentives: both institutes and individuals were to be permitted to retain a proportion of their earnings. The incentives were open to all types of institute, not just the industrial technology institutes ("White Paper": No. 1, pp. 314-315).

As a result, by 1991 the 2,000 plus R&D institutes engaged in industrial technology had had their 'operation fee' entirely or partly cut, a total reduction of slightly less than one billion Chinese yuan per year, or about one tenth of the overall government S&T budget in 1985.[27]

Creating a 'technology market' (Decision: section III)

The term 'technology market' implies several things: First, it represents a new concept which legitimizes paid transactions for technology. This new concept was critical to the reform since the ideological tradition provided no ground for market transactions in technology. The 'public good' nature of scientific and technological knowledge had long been the basis on which the whole of the old system was constructed and run.

Second, it represents a set of regulations and supporting agencies. The Law of Technological Contracts was promulgated in 1987, to govern this special type of economic contract [*SSTC, 1991a, pp. 146-152*].[28] The agencies to support technology transactions were established, derived mainly from administrative bodies related to science and technology. After a few years' confusion, they were defined as "non-profit regulatory agencies, in charge of the registration of technological contracts" ("White Paper" No. 4, pp. 45-47). Now a broad network of these agencies has been formed.

Third, the term ‘technology market’ refers to a range of technology-related transactions. These are categorized in the Law of Technology Contracts [*SSTC, 1991a: pp. 372-378*] as:

- contractual development of technology;
- technology transfer;
- technological consultation; and
- technological services (such as designing, engineering, testing, and services for computer applications).

3.2 Other Policy Measures to Support the Technology Market Approach

Other policy measures of the Decision to support the market approach provided for: (1) the government and public financing of R&D, (2) the autonomy of R&D institutes, and (3) the mobility of S&T personnel.

Policy for the government and public financing of R&D (Decision: section II)

The distribution of the remaining government and public S&T funds was placed on a competitive basis. First, the National Natural Sciences Foundation was established in 1986, in charge of distributing central government funds for basic research and ‘fundamental’ applied research though peer review, based on the excellence of the applicants.[29] Second, a competitive bidding procedure was adopted in 1986 for government investments in the ‘Key Science and Technology Projects’ of the five-year plan. Thus a quasi-market for government funds was created.

The introduction of competition for funding for basic research and state S&T projects helped to improve the efficiency of the remaining public investment. This might be seen as an expansion of the market approach, and the same procedure was adopted for newly created governmental funds later on. The ‘leading funds’ of the Torch Programme, which aims to accelerate the commercialization of technology, is one example (see section 4 below). The excellence-based competition also seems to have protected some more able institutes and individuals from inevitable disruption in the transitional period.

Policy for the autonomy of R&D institutes (Decision: section VII)

The policy for the autonomy of R&D institutes released R&D institutes from vertical controls, so that they could interact with the technology market which had been created. The directors of R&D institutes were given delegated authority in the following areas ("White Paper": No. 1, pp. 318-319):

- to decide on contractual R&D and contractual services with their users;
- to register various joint-ventures with enterprises, design units, and institutes of higher education;
- to decide on matters of institute personnel and internal organization;
- to dispose of their income from contracts; and

- to enter into international cooperation, and to retain foreign currency obtained, in accordance with state regulations.

Policy for the mobility of S&T personnel (Decision: section IX) and the emergence of a quasi-market for S&T personnel

The policy to encourage the mobility of S&T personnel contained two principle elements:

- the replacement of life-long recruitment with term appointments to defined posts;
- permission for scientific and technological personnel to take second jobs, so long as they perform well in their primary assignments.

The real mobility of S&T personnel was still very limited, at about 2% per year in the second half of the 1980s [*CSTD, 1988, p. 65*]. However a 'quasi-market' for well-educated workers has emerged as an alternative, with several opportunities for permanent or temporary mobility:

- taking second jobs;[30]
- applying for temporary or permanent leave under terms such as 'leave without pay, but with staff status reserved' (tingxin liuzhi), 'resignation' and 'early retirement';
- the re-entry of retired S&T personnel.

An institutional framework to support the quasi-market is developing, consisting of a significant number of 'personnel exchange and recruitment centres'. Most of the centres have, once again, emerged out of administrative agencies related to science and technology. The mobility of the talent needed for various transformations of the R&D institutions, including the development of New Technology Enterprises (see section 5 below), is supported by these centres [*CSTD, 1988, pp. 62-68*]. This ensures the required mobility of S&T personnel, although a fully-developed labour market does not yet exist, by offering the following services:

- protecting the professional title and welfare insurance which S&T persons enjoyed as public employees; and
- providing S&T personnel recruitment services outside the planned personnel distribution system.[31]

3.3 Responses to the Technology Market Solution

Inefficiency of the technology market

It is useful to review the responses of R&D institutes to the technology market, bearing in mind that it was the intention of the Decision that the technology market would intensify the links between scientific research and its productive uses, as a remedy for the chronic horizontal dis-connection of the system. Having been granted quite full autonomy, and being under pressure to survive financially, R&D institutes hastened to play the market. There is considerable evidence that, in the first years after the Decision, approximately from 1985 to 1987-1988, technology transactions took the form of either (1) once-and-for-all exchange, or (2) the formation of long-term contractual alliances, which were primarily intended to secure an economic return.[32] Most industrial R&D institutes did not find that the technology market, as they had experienced it in these transactions, met their expectations. A few examples, presented in case texts 1, 2, and 3, may illustrate this. Some efforts toward structural transformations were in fact driven by these early experiences, with the outputs in the transactions shifting from 'software' know-how to 'hardware' outputs or integrated engineering services. These structural transformations will be discussed in sections 4, 5, and 6 below.

CASE TEXT 1: The General Institute of Coal Mines Science and Technology

This institute belongs to the State General Corporation of Coal Mines, formerly the Ministry of the Coal Industry, with 17 branch institutes and centres scattered around the country, in charge of production technologies for coal mining. They detailed three phases of response to the reform.

The first phase was from 1985 to 1986, when 'technological consultancy', 'technology transfer', 'technological services', and 'technological training' dominated in their efforts. They were basically 'selling technologies' (form 1 transactions, as above). At that time the payment from each contract was very low, and the yearly income was uncertain. As government funding diminished, they felt that it would not be possible to rely only on providing 'software'; therefore they must also produce 'hardware'.

The second phase was from 1987 to 1988, when partnerships with firms were established based on technology transfer (presumably form 2 transactions, as above) or monetary investment. Some investments were made blindly in businesses such as beverages, food processing and kinds of manufacturing which were irrelevant to the institute's strengths. Most of these failed either because they were acting outside their field of competency, or because the institute's contractual rights could not be protected effectively. The institute gained very little even when the enterprise side benefited considerably.

The third phase began in about 1988. Since then various businesses have been established, with the main purpose of preserving the institute's core technological abilities and the installations developed and accumulated in the past.

Source: SSTC, 1991c, pp. 55-58.

CASE TEXT 2: The Automation Research Institute of the Ministry of the Metallurgical Industry (ARTMI)

This is a leading institute belonging to the Ministry of the Metallurgical Industry. It is in charge of the development of metallurgical automation technologies, with more than 800 engineers and technicians. Beginning in 1985, the Institute attempted to respond to the 'technological market' by delegating responsibility and profitability to a number of smaller teams, so as to intensify the incentive for researchers to contract their services to outside users. This would be reasonable if the stronger incentives led these teams to produce technologies, which could be contracted more actively and carefully. However a strategic shift had to be made in 1987 to re-build the hierarchy of the institute as a whole because:

(1) these teams' technologies were usually "un-packaged", "not in the form of a complete set", and "not good in reliability";

(2) these technologies were usually under-valued by buyers; and

(3) there was fierce competition from foreign suppliers, who provided their technologies in well packaged sets, of high quality and accompanied by satisfactory engineering services. This further reduced the competitiveness of the Institute in the marketplace.

Sources:
1. Interview Notes 6;
2. SSTC, 1991c, pp. 62-65;
3. *Information on Science and Technology of China* (zhongguo keji xinxi), 1992, No. 6: pp. 5-11).

CASE TEXT 3: The Research and Design Institute of Chemical Engineering of F. city

This is an Institute at the municipal level. The fine chemicals they developed were mostly substitutes for imported ones, used as additives or intermediate inputs in various processes. Their scientific experiments used to be carried out at the scale of laboratory research. This led to some problems in technology transactions, which pointed to the necessity of expanding their activities to pilot-plant and trial production.

The first problem with laboratory-scale research was that some technological problems such the recovery of catalysts do not show up or cannot be solved at the laboratory stage. The technological uncertainties in large-scale production use are liable to be higher, which damaged the institute's credibility with buyers.

Second, market tastes cannot be tested, in even a preliminarily way, without a pilot plant because the volume of laboratory samples is too small to do trial marketing. Market risks are therefore likely to be higher, and this is even more serious where competing imported chemicals are already available. There is no niche for a substitute without trial marketing to win the first buyers.

Third, estimates of techno-economic norms cannot be based only on laboratory work. The lack of information about the commercial potential sometimes halted promising transactions.

Fourth, the limited capability of the user firms created difficulties. Many users, mostly smaller firms, "did not have even a limited understanding of technological problems. They do not understand that further testing and modification are indispensable for the establishment of a chemical process. If something could not be settled in one or two trials, they became disappointed".

Source: Science and Research Management, 1992, No. 1, pp. 45-47.

Factors influencing the failings of the technology market

Three causative factors can be discerned from these cases, all of which are attributable to the difficulties encountered in selling laboratory software or segmented pieces of a system technology. Note that while some of the factors below have been widely discussed by researchers both in China and abroad, some are still seriously neglected, particularly the weakness or deficiency of the market in dealing with uncertainties. Indeed, this is an issue deserving more study.

Uncertainties of technological innovation. Any new elements of technology, such as the new chemicals, new machine designs, and new automation controller units referred to in the cases above, entail a degree of uncertainty as regards their technical feasibility and market potential. The market mechanism itself is in essence not well adapted to dealing with the uncertainties which are intrinsic to technological innovation, because an accurate calculation by buyer and seller of their gain or loss is essential to efficient market transactions.

The cases also show that the more complex the user's system, the more difficult it will be to demonstrate the commercial value of novel system components (case 2). Besides, the more robust the existing technology, the more demanding buyers will be in considering substitutes (case 3). The existence of capable foreign suppliers reinforces this: it may have undercut the market potential of domestically developed technology.

Inexperience of users. Having long been passive recipients of new equipment, the industrial buyers of technology lacked experience in evaluating technological know-how. They also had limited abilities to assimilate technological knowledge or un-packaged technologies, as all the cases show. This is because the transfer of technology itself is a technology-intensive process [*Mowery, 1983*], and the firms had had no chance to learn how to acquire technology at a time when they had just been thrust into the technology market.

Underdevelopment of market institutions. Breaches of contractual obligations by the parties, and the inability of the market mechanism to rectify the breaches, as case 1 shows, indicate the underdevelopment of the market institutions. The problem of the weakness of market institutions has already been perceived and discussed by other authors, as was pointed out in section 1.1.

3.4 The Growth of the Technology Market

Nevertheless, the technology market has been growing since its establishment. Some characteristics of the market are analyzed in this section, in drawing on data which is obviously too incomplete to justify a more precise discussion.

The rapid growth of the technological market is illustrated by its *turnover*. It is reported that the overall value of signed contracts increased from 2.3 billion yuan in 1985 to 8.1 billion by 1989 ("White Paper" Vol. 4, p. 42). These figures should be treated with caution because analysis shows that (1) some transactions were not for technology but for non-technological commodities [*SSTC, 1989a, pp. 86*], and (2) that some of the transactions were for R&D projects proposed and funded under state and local plans ("White Paper" Vol. 3, p. 39).

The rapid growth of the technological market is also illustrated by *the development of market institutions*. It is reported that the number of agencies in charge of the management of the technology market had increased to 21,132 units by 1991, up from 9,649 in 1987 (*China Statistical Yearbook on Science and Technology 1992,* pp. 342). The number of scientists and engineers formally employed by these agencies had risen to 124,000 in 1991 (ibid, p. 342). This means the market network has expanded to cover many medium-sized cities, which the Chinese call "counties". As was mentioned above, these agencies have emerged mainly from administrative bodies related to science and technology ("White Paper" Vol. 2, p. 43; SSTC, 1989a, p. 71; and *SSTC, 1988, p. 83*).

The limited official data which is available on the *contract structure* in the early years, from 1987 to 1989, is shown in table 1 below. The data indicates that technological consultations and technological services, combined, were the most traded item in these years. They accounted for three quarters of the contracts, and more than half of the value of all contracts. This picture remained fairly constant over the three year period. Contracts for the 'development of technology' accounted for about 12% of all contracts in these years, and in value terms for 27% in 1987, increasing to 37% in 1989. It is reported that some state-financed S&T projects relating to the development of technology entered the technology market, as has been mentioned ("White Paper" Vol. 3, p. 39). Contracts for 'technology transfer' accounted for about 11% of contracts signed, and 13% in terms of the value of the contracts, in 1987, and this proportion is reported to have been quite stable in between 1987 and 1989 ("White Paper" Vol. 4, p. 43).

TABLE 1
TRANSACTIONS IN THE TECHNOLOGY MARKET (1987-1989)*

	Technological Consultation & Technological Services	Contractual Development Of Technology	Technology Transfer
contract quantity	three quarters	about 12%	about 11%
contract value	50%+	about 30%	about 13%

* Data on transactions in the technology market is incomplete for the early years. For prudence's sake, the table presents aggregate figures, which have been summarized from, and checked with, those scattered in the sources below.
Sources:
1, "White Paper" Vol. 3, p. 39;
2, "White Paper" Vol. 4, p. 43.

Some trends during the recent several years are illustrated in table 2 below, which is for 1993. The 'contractual development of technology' increased significantly, accounting for 28% of contracts, and 48% of the value of contracts. The increase can hardly be explained merely by the partial inclusion of state S&T projects, given that overall expenditure under the state plan in the period was not growing. Technological consultation and technological services, combined, still dominated in terms of numbers of contracts, but less than in the earlier period. Technology transfer also declined, but less markedly. These trends may be considered to be rather solid, since other scattered data for various years points toward a similar shift.

TABLE 2
TRANSACTIONS ON THE TECHNOLOGY MARKET (1993)*

	Technological Consultation & Technological Services	Contractual Development Of Technology	Technology Transfer
contract quantity	63%	28%	9%
contract value	41%	48%	11%

* To enable comparison, the data in table 2 has been presented in the same format as table 1.
Sources: SSTC 1994, *Databook of Statistics on Science and Technology 1993* (keji tongji shuju ji), p. 160.

Many features deserve further exploration. One concerns the quality of the technology market. Is it not homogeneous? Can it be said to be more 'friendly' to some kinds of transaction? The answer to the latter questions seems to be affirmative, as indicated by the aggregate of 'technological consultation' and 'technological services'. This corresponds to observations with respect to contractual R&D undertaken by research enterprises in the U.S. in the first half of the century [*Mowery, 1983; and Mowery and*

Rosenberg, 1989]. The reason for the popularity of transactions in 'technological consultation' and 'technological services' might be that they are more easily defined, and less involved in the core part of the 'in-house' activities of the buyers.

As regards the quality of the technology market, the significant increase in the 'contractual development of technology', in particular, requires some interpretation. Such an increase seemingly contradicts the assumption in the paragraph above, supposing that such contracts involve more 'core' activities of the buyers.

A subsequent study, which concentrated on the machine industry, has found that for that industry at least, the 'contractual development of technology' covered mainly machines or production systems developed for a particular buyer's purpose. The machines or production systems usually incorporated testing or controlling units and user application software. This was, roughly speaking, because the existing machinery enterprises were not able to meet demands of this kind, while foreign suppliers were not able to fulfil the user's specific requirements. This situation may also be illustrated a little in cases 5 and 6 below. In these cases, the 'contractual development of technology' is not 'real R&D': it is more like the 'contractual provision of custom-made products' (or custom-made machinery, in the case of the machine industry). Papers discussing the results of this study of the machine industry in more detail are forthcoming.

The dynamics of the market also deserve further exploration. The technology market has been expanding rapidly so that all kinds of contracts were in fact increasing in absolute terms. There seems to have been some causal relation between the greater effectiveness of technology transactions and the widespread efforts of R&D institutes to integrate R&D with commercially-profitable activities, which the following sections will address.

4. MERGING R&D INSTITUTES INTO EXISTING ENTERPRISES (1987)

4.1 The Justification for Merging — A Policy Response to the Inefficiency of Technology Market

Early in 1987, one and half years after the implementation of the 'Decision', reform policy took a bold step by urging industrial R&D institutes to enter into enterprises. Signed by the State Council, the document, "Stipulations of the State Council for Furthering the Reform of the S&T Management System", presented the rationale for this move:

> [though the reform has achieved preliminary success over the past year and more ...] one should be conscious that the disconnection between S&T and production has not yet been fundamentally improved. The pattern of the organizational structure of the S&T system is basically untouched, the system remains closed (to the outside); the important R&D institutes are still affiliated to administrative organs rather than being bound up with the national economy; there are more qualified scientists and technicians than required in big research institutes belonging to central ministries and institutes of higher education, while there is a serious lack of S&T manpower in light industry, commercial enterprises and rural areas; the policy measures intended to intensify the links between research institutes and enterprises have been inefficient, so that a considerable number of research institutes are undertaking a kind of 'self-accomplishment' [of the commercialization of their technological strengths] without devoting much effort to making outside connections,... [*State Council, 1987a*]

Here the disappointment with the responses of R&D institutes to the technology market solution is explicit. R&D institutes were mainly moving to capitalize on their technological know-how by themselves, and inside their own institutes, rather than transmitting it to productive units. The independent R&D institutes had in fact become more closed rather than more open to the outside. They were reserving their technological strengths for commercial exploitation. Reform policy thus turned to focus on organizational mergers, by first breaking the organizational borders and then combining the two types of organizations in a single unit, with enterprises as the basis of the combination. As the document stressed, "the majority of research institutes engaged in technology development, especially in the development of product technology, should enter into enterprises, or into groups of enterprises, or should closely cooperate with enterprises,..." [*State Council 1987a*, point 2 in part one].

4.2 Policy Measures for Merging

Policy measures encouraging R&D institutes to enter into existing enterprises fell into two categories. The first category encouraged them by means of protecting the preferential position they enjoyed as independent institutes. Under these measures [*State Council, 1987b*]:

- R&D institutes, after being combined into enterprises, would still retain relative independence from the host enterprise in financial matters and professional activities, providing they accomplished the tasks required by the host enterprise;
- R&D institutes, after entering into enterprises, would continue to enjoy tax exemption for income from sales of both technology and pilot plant products;
- R&D institutes, once absorbed into enterprises, would continue to get 'operational funds' and 'capital construction investments' from the Government, based on their appropriations in the last year before they entered the enterprise.

In addition, more incentives were established to encourage merging [*State Council, 1987b*]:

- the wages and bonus standards of the host enterprise could be adopted, if these were higher than those of the institute;
- host enterprises were requested to increase investments in the R&D units they obtained;
- host enterprises were recommended to rely mainly on the R&D unit they had acquired to deal with affairs relating to technology imports, etc.

But the results were not up to expectations. Only a very few industrial R&D institutes, out of a total of 2,000, responded. In the Ministry of the Machinery Industry, for instance, only two of the 64 ministry-level R&D institutes were merged with enterprises during the whole of the 1980s. Frustration with the lack of success in encouraging mergers was admitted officially. The central focus of the S&T reform policy was further modified one and a half years later, in mid-1988, with a shift to facilitating the establishment of 'new technology enterprises', which were largely spin-offs from R&D institutions. This will be the subject of section 5 below.

4.3 Explanation of the lack of success, for two industrial sectors

Three factors which were thought to be to blame for the lack of success in encouraging mergers became evident from the explanations made by some responsible managers from the Ministries of the Machinery and Electronics Industry.

The inability of enterprises

All the legacies inherited from the past, as summarized in the section 1.4, particularly the enterprises' lack of financial reserves, contributed to the frustration of enterprise-based mergers. A responsible officer from the Ministry of the Machinery Industry (Interview Notes 7, pp. 6) estimated that sustaining an R&D institute would entail an annual expenditure of several million yuan. To shoulder such a financial burden, the host enterprise would need an annual turnover to the order of a billion yuan. Not a single enterprise in the instrumentation sector in 1987 had reached the point at which they could afford to accept one of the 13 ministry-level R&D institutes engaged in instrumentation technology. This resembles problems encountered in other attempts to re-structure enterprises in China, where the average size of enterprises is relatively small.[33]

Compared with the machinery industry, enterprises in the electronics industry were even weaker. They had to renew their key installations, relying heavily on large-scale technology imports throughout the 1980s, because of the rapidity of technological change in electronics.[34] As a result, the production technology of the industry became more heavily dependent on foreign suppliers, leaving domestic R&D no place as a supplier to the sector. Managers in the electronics industry seemed not to see merging as having any significant potential in the near future, while the Ministry of the Machinery Industry is now actively promoting mergers (Interview Notes: pp. 7-8).

Lack of Congruity of R&D Institutes with Enterprises

The knowledge and physical equipment of R&D institutes was seriously outdated. They lacked experience in working with rapid change, and organizational rigidity impeded steps to keep up with change. During the 1980s, the domestic R&D institutes were basically barred from importing technology, and their value as suppliers of industrial technology was considerably reduced. In fact, not only the electronics industry, but also, to a less extent, the machinery industry saw the physical installations of R&D institutions lagging behind those of leading enterprises during the 1980s. In a sense, the massive importation of industrial technology has destroyed the compatibility which had developed prior to the reform (Interview Notes 7: 3-4). Enterprises in general did not tend to welcome merging.

In addition, R&D institutes have an ‘institute culture’ which is different from production enterprises. They enjoyed more privileges than production units. Painful failures experienced when trying ‘to combine with production’ in the past in fact inhibited their response (interviews in a number of R&D institutes, 1994). Besides, the work programmes of many R&D institutes were much more extensive than could be maintained if they merged with any single enterprise. All these were ‘institutional barriers’ arising from their previous institutional separation from enterprises.

The attitude of industrial ministries

The industrial administration has ample power to accelerate or delay the merging process. The market seemed not to be strong enough to guide organizational merging. In 1987, the Ministry of the Machinery Industry discreetly set up five criteria to guide possible mergers.[35] This resulted immediately in one case of merging. During the 1980s, two institutes, of the total of 64 (at the ministry level), entered into two big enterprises. One of these mergers had been achieved prior to the 1987 national policy push, on the initiative of the Ministry: the Automobile Research Institute of the Ministry merged into the No. 1 Automobile Factory in Shenyang city. Some apparently feasible mergers were suspended at that time, to be completed a few years later.[36] Efforts to promote merging revived in the early 1990s. Another six or so mergers have been realized recently, and it was estimated that a dozen of the 64 institutes would be transformed in this way (Interview Notes 7: p. 5). It was explained that some of the reasons for the lack of success in merging during the mid-1980s are now changing. There was no indication of a possible revival of merging in the electronics industry, however.

4.4 Transformation after Merging into an Enterprise — The Case of the Automobile Research Institute of the Ministry of the Machinery Industry

The first merger which was completed, when the Automobile Research Institute of the Ministry of the Machine Industry became part of the No. 1 Automobile Factory, illustrates some profound transformations which resulted from such a merger. Being an integral part of an enterprise ensured that the previously independent R&D institute would work to support the core technological efforts of the host enterprise. The embodiment of this focus in the institute structure was accompanied by significant structural remodelling.

CASE TEXT 4: The Restructuring of a Research Institute After Merging-in — The Case of the Automobile Research Institute

The Automobile Research Institute was combined into the No. 1 Automobile Factory in 1980. This was decided and effected under the direct supervision of the Ministry of the Machine Industry. Ten years later, the Institute has been thoroughly transformed as an integral part of the host enterprise.

Change in staff occupation structure
In 1980, the Institute staff totalled 1,280, with 476 engineers and technicians, 220 administrators, and 584 workers. In 1991, there were 2,245 staff, of whom 1,318 were engineers and technicians, 42 administrators, and 885 workers. Thus the staff almost doubled, largely due to the huge increase in technological professionals, while the administrative staff was cut drastically.

Change in financial structure
The main source of finance after the merger came from the Factory. In 1991, the Factory contributed about six sevenths of the total Institute income, and the Institute earnings from outside contracts accounted for less than one tenth. In the period 1980-1991, the annual expenditure of the Institute multiplied ten times, with the increased inflow almost entirely coming from the Factory; funds from the state were reduced to a few percent. The change in the financing structure indicates that the Institute has shifted to serving mainly the needs of the host factory.

Change in the priority of investment and technological activity
The investment priority was explicitly shifted to testing. More than 40% of the increased income was used for constructing and equipping testing facilities such as a road test site. This is a reflection of the fact that there had been virtually no such installations and activities within the factory. In addition, product development and designing has become more important. Eight new models of automobile, a large number of modifications based on these models, and a few new series of automobile engines were developed, some of which have been put into production. Before 1980, only very marginal modifications to imported designs had been made since the Factory was erected in the 1950s. Becoming part of the factory has ensured that the previously independent R&D institute works to support the core technological efforts of the host factory. Indeed testing, product development and designing are really at the heart for an automobile manufacturing factory. It must be noted that this profound transformation took 10 years to complete.

Sources: 1. SSTC, 1991c, pp. 323-327;
2. SSTC, 1989b: pp. 59-67

5. SPIN-OFF ENTERPRISES AND THE TORCH PROGRAMME (1988)[37]

5.1 The Rationale for Reform Policy to Support Spin-off Enterprises

In mid-1988, a new initiative under the reform policy, known as the 'Torch Programme', was launched. This was one and half years after the 1987 national policy to promote merging. The launch of the Touch Programme was partly a policy response to frustration with the merging initiative.

Instead of institutes being incorporated into existing industrial enterprises, the Torch Programme supported the integration of R&D institute assets, including experts, technological know-how, and some physical equity, with commercial production and service activities within newly-created business organizations. These enterprises, which were spun-off from the R&D institutes, were known in the Programme as New Technology Enterprises (NTEs).

In fact, spin-off enterprises had emerged long before the Programme began. The first was reported to have been established in 1980. More appeared in several large cities from around 1984-1985. By 1985, there were about 100 such enterprises clustered in northwestern Beijing, where many of the best R&D institutes and universities in the country were found. Most of the new businesses were engaged in computer technology, starting with sales and user services of imported personal computers (PCs). Some had become quite successful in developing their core technology, and in the combination of Chinese Character Processing with computer technology for various applications. Active local governments and academics had facilitated the accelerating growth. The first Science and Industry Park was co-sponsored by the Chinese Academy of Sciences and the Shenzhen Municipal Government in 1985. Thus the archetypes of NTEs and the Development Zones for New Technology Industries, both of which were endorsed by the Programme as institutions to promote restructuring, had already emerged.

It is safe to say that the emergence of spin-off enterprises was authorized by the 1985 Decision, although it had not exactly envisioned the advent of NTEs. The 1985 Decision had largely released R&D institutes and S&T personnel from rigid control, thus empowering them to begin ventures in response to various opportunities. This was happening at a time when the 'computer revolution' had reached the point of having a huge potential for incorporating computers in various operations, while the rapid expansion of the economy produced a high demand for computer utilization. Selling computers, and developing user-specific applications of computer and information technology, required an intellectual service sector. The old planning framework had not been designed to provide services of this kind, which need on-going institutional innovation.

The Torch Programme was founded to foster spinning-off as a new reform thrust for the better use of technological strengths in economic development, as Mr. Song Jian, Chairman of the State Science and Technology Commission, stressed in his speech at the National Working Meeting of the Torch Programme ("White Paper" No. 3, p. 415):

> We acknowledge that we can expect to find better solution 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 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.

5.2 Policy Measures for Spinning-offs

Two strands of reform policy

We have examined reform policies for R&D institutions in a chronological sequence, with the 1985 Decision representing a decisive turn towards market solutions. It has been shown that market reform entails a whole set of policies which differ from those of the past, particularly in using indirect rather than direct interventions. It will be useful, before proceeding with the analysis of the Torch Programme, to introduce a rudimentary conceptualization, based on observation, which divided the policies put in place to foster the transition of the R&D system into two strands:

- the establishment of regulations and incentives; and
- the creation of a regulatory agency framework.

Various initiatives under the market reform required regulations and incentives. We have seen that regulations and incentives were set up by the Decision to promote the ‘marketization’ of industrial R&D. These included the delegation of autonomy to R&D institutes, laws for technological contracts, and stipulations for rewarding institutes and individuals with earnings from contractual technological activities, etc.. We have also seen the second strand of policy that the Decision announced, the creation of "technology market agencies", which amounted to a regulatory infrastructure for marketization. Moreover, the Decision provided an impulse for the emergence of a quasi-market for S&T personnel, in the context of the lack of a normally developed labour market.

The creation of a regulatory agency framework is the most interesting of these two strands of policy. The organizational foundation which are required if regulations are to be put into practice had to be established. Regulations can be drafted in months, but the regulatory framework took years to develop (naturally the development of new economic organizations such as New Technology Enterprises was also needed, and was also a long-term process). Organizational evolution is a very complex process, entailing various modifications of social cells. We have seen that the technology market agencies and the personnel exchange and recruitment centres, which supported the quasi-market that encouraged the mobility of S&T talent, were derived from existing administrative agencies related to science and technology. We will discuss the policy measures devised under the Torch Programme, distinguishing between these two strands.

(1) Policies for Regulations and Incentives for New Technology Enterprises[38]

First, the Commission named several criteria which were to guide the **licensing of NTEs** [*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;[39]
- 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.

Second, *incentives* were established for licensed NTEs, mainly in the form of preferential taxation (SSTC, 1991b, pp. 233-238);

Third, *preferential stipulations* were promulgated for licensed NTEs in export and import licensing, finance and investment, pricing, and employment (ibid.). The taxation incentives and other preferential stipulations resembled those for foreign investments, since NTEs are technology-intensive and there was no regulatory practice dealing with domestic non-state initiatives.[40]

Fourth, *intellectual property* began to be included in incentives ("White Paper" Vol. 3, p. 247). Not only patented and other proprietary technology, but also the special technological skills of individual initiators could in some cases be counted as equity (interviews in 1988-1989 and in 1993). However this policy has not yet been systematically realized, because of the lack of the institutional framework for property transactions.

(2) Policies for the regulatory and other supporting infrastructure

First, *Development Zones for New Technology Industries* (Zones) were encouraged ("White Paper" Vol. 3, p. 249), in order to create a favourable regulatory environment for NTEs. The Zones regulate NTEs in matters such as licensing, taxation, international trading, financing and investment, employment, intellectual property, etc.. Some Zones have invested in physical infrastructure such as roads, buildings, communications etc. to attract more domestic and foreign investors, as is the case in many 'science parks' and 'technopolises' around the world [*Castells and Hall, 1994*].

Second, *Service Centres for Scientific and Technical Entrepreneurs (Centres)* were established as 'incubators' for spin-offs, especially those initiated by individual S&T persons ("White Paper" Vol. 3, pp. 248).

In practice, both the Centres and Zones were established at the initiative of city governments. They are also administered, from their inception, by local authorities. This had become possible in China because of the decentralized delegation of economic power under the market-oriented economic reform programme. The policy of the central government functioned (1) to put the government's authority behind the campaign for the commercialization of technology; and (2) to guide the experimentation and disseminate the lessons on how to achieve better performance which were learned during the campaign.

Third, a variety of *sources of finance* were opened up or encouraged, such as governmental 'leading funds', bank loans, foreign capital etc. ("White Paper" Vol. 3, pp. 247), in order to broaden the resources invested in the commercialization of technology.

A new kind of bank loan, known as "loans for the development of science and technology", intended for the commercialization of S&T achievements, was announced. The National Construction Bank and its city and provincial branches, for instance, decided to issue loans of this kind. The Bank and the State Science and Technology Commission [SSTC 1991b, pp. 458-459] stipulated that:

- the loans are available to R&D institutes, collectively-owned enterprises, and state-owned enterprises. This implies that commercial loans were officially available to R&D institutes and most NTEs.
- the loan could been used for the development of new product and process technologies; for pilot plants and the trial production of new technology; for the assimilation of imported technology; and for small-scale capital investment for the commercialization of technology.
- the State Science and Technology Commission and its local branches were in charge of appraising loans, although the bank retained the right to make the final decision. Thus there was a system of ‘outside’ professional appraisal to support the new banking service. This was necessary, given that banks had little experience in appraising loans because they had been used to doing no more than accounting, under the planned regime.[41]

A network for financing NTEs developed under the umbrella of decentralization, with three investors involved: R&D institutions, banks, and Zones. A division of labour was forged among these investors: the R&D institutions provided mainly ‘venture’ capital for the initiation of NTEs, the banks provided funds for the expansion of NTEs when they had passed their first stage of development, and the Zones provided mainly investment in infrastructure (Zhao Wenyan *et al.*, 1989).[42] To a lesser extent, the Centres also worked on providing venture capital to NTEs initiated by individual scientific and technical experts (Interview Notes 9: pp. 2-3).

The differentiated functions of these investors were based on their special positions. The R&D institutes, for instance, depending on their immediate knowledge of the underlying technology, and close involvement in the initiation of the NTEs, were better suited to manage the risks and rewards of their investments. They acted as the main risk-capital investors in the 1980s, although there was also a government financing agency known as the Venture Investment Corporation.

While national ‘leading funds’ for the commercialization of technology were established by the Torch Programme, the projects set up under the Programme were predominantly funded by the local branches of banks.[43] Bank operations had also been altered by the decentralization of 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 involvement of the banks was strongly influenced by the policies of local governments. Each of the booming Zones had very active branch banks which sustained its prosperity.[44]

As a result of these policies, spin-off enterprises expanded rapidly and continuously. In 1992, there were 52 Zones scattered throughout the country and approved as national level zones. In that year, 5,569 NTEs were registered in these Zones, producing products and services worth 231 billion yuan, and spending 15.2 billion yuan on their company R&D, according the latest official data (China Statistical Yearbook on Science and Technology 1993, p. 307). In comparison, the S&T funds from the state budget in that year were 17.6 billion yuan (ibid. p. 24). In the same year, the total expenditure for ‘research and development’ of the country amounted to 16.9 billion (ibid. p. 23).

5.3 The Initiators of NTEs

Our survey revealed that organizational initiators were the biggest contributors to the establishment of NTEs. R&D institutions initiated about half of the NTEs. Institute assets — talent, monetary capital, and credit-worthiness — were channelled into NTEs. The R&D institutions can be broken down to four sub-classes: (1) institutes of the Chinese Academy of Sciences (CAS); (2) R&D institutes belonging to central ministries; (3) R&D institutes belonging to local governments; and (4) R&D institutes of higher education. Of these, the institutes of the CAS and of higher education were more vigorous than the others in founding NTEs.

In addition to those who were involved in organizational initiation, S&T individuals also founded about one quarter NTEs, acting outside of their previous institutes. When working independently, individual S&T initiators usually turned for help in obtaining financial capital, credit-worthiness etc. to various organizations, including Zones, Centres, other local government bodies, enterprises, and so on. In other words, many non-R&D organizations also contributed to support the initiation of NTEs.

5.4 The Role of NTEs

The great majority of the NTEs were engaged in computer and information related-technology. A small proportion were engaged in other fields such as new materials, fine chemicals, medicines, biotechnology products. The technological activities of the NTEs in the computer and information-related technology concentrated on what we have called user capability-building for applications of these technologies. Three types of capability-building emerged from the empirical evidence:

(1) adaptation of English-language-based computer and information technologies to the Chinese environment;
(2) development of user-specific automatic operation systems; and
(3) design and assembly of special purpose single devices and machines.

The latter two usually embraced the incorporation of computer or information technologies in various devices or user systems. All the three demanded a moderate degree of complexity in the systems, and in a few cases the NTEs have a quite competitive mastery of sophisticated technology. The capabilities which NTEs have acquired is impressive, given their short history.

The success of NTEs has been widely accepted in China. The fact that the majority of NTEs are engaged in computer and information technology strongly suggests that a surge of computer applications may be expected in other developing and formerly centrally-planned economies. In these countries, computer applications have apparently been hindered thus far, probably by poor interfacing, which divorces local users from the new technological opportunities. A combination of accumulated R&D experience with local user-specific engineering has proved to open the way to accelerate the applications in countries where the revolutionary expansion of the computer and information industry has not been indigenously cultivated. Spin-off restructuring bridges the gap by creating innovative and autonomous NTEs, and should also be applicable to the exploitation of other new technologies which are emerging.

6. THE TRANSFORMATION OF ENTIRE R&D INSTITUTES (SINCE THE 1990s)

As a continuation of the market reform programme, there have been widespread transformations of existing industrial technology R&D institutes since the mid-1980s. These transformations involve internal restructuring to adapt to external changes, to the extent that the nature of the existing organizations is altered. In comparison, restructuring by means of spinning-off NTEs transfers only some ingredients of institutes into new establishments, while the parent institutes continues with little interruption.

General Trends of Transformations

The general results of the transformations are shown by aggregate statistics which clearly indicate a trend to much higher market profitability for the institutes.

Table 3 below shows that the main source of income for industrial technology R&D institutes as a whole has shifted, and now comes from 'horizontal', i.e., market earnings, which accounted for 70% of total income by 1993. Government funds contributed a remarkably small share of their overall income, 15% in 1993, a large part of which was for S&T projects sponsored by state and sectoral plans, and state investment in laboratory installations. As for the structure of the 'horizontal' earnings, table 4 shows that 'other production and activities' accounted for the largest part, 43%. This income is obviously derived from conventional products and services. 'Technology development' and 'trail production' followed as the second and third sources. Together they contributed 37% of the horizontal earnings. These two activities probably relate to new products and services, and involve searching for commercially promising technologies.

TABLE 3
INCOME STRUCTURE OF INDUSTRIAL TECHNOLOGY R&D INSTITUTES* (1993)

Overall Income	**Structure of the Income (Billion Yuan)**			
	Government Funds	*'Horizontal' Earnings*	*Bank Loans*	*Other Sources*
15.07 (billion yuan)	2.33	10.59	1.50	0.66
100%	15%	70%	10%	4%

*The 'industrial technology R&D institutes' are the institutes which belong to central industrial ministries, plus those that belong to local industrial bureaus at municipal and provincial levels. This group totalled 1,804 institutes in 1993.
Source: SSTC 1994, Databook of Statistics on Science and Technology 1993, pp. 13, 52.

Table 5 presents the income structure for the 'remainder' group of independent R&D institutes, for comparison. It shows that government funds are much more important for this group, accounting for 43% of their total income, compared with 15% for the industrial technology group. The market component, that is their 'horizontal earnings', of 47%, is evidently less important than for the industrial technology group, yet the 'remainder' group has also been significantly marketized.

TABLE 4
THE STRUCTURE OF 'HORIZONTAL EARNINGS' OF INDUSTRIAL TECHNOLOGY R&D INSTITUTES (1993)

Overall 'Horizontal Earnings'	Structure of the 'Horizontal Earnings' (Billion Yuan)				
	Technology Development	*Technology Transfer*	*Technological Consultation & Technological Services*	*Trial Production*	*Other Production and Sales*
10.59 (billion yuan)	2.00	0.57	1.32	1.97	4.75
100%	19%	5%	12%	18%	43%

Source: ibid. pp. 13, 70.

TABLE 5
INCOME STRUCTURE OF THE REMAINING R&D INSTITUTES* (1993)

Overall Income	**Structure of the Income (Billion Yuan)**			
	Government Funds	*'Horizontal' Earnings*	*Bank Loans*	*Other Sources*
11.10 (billion yuan)	4.75	5.20	0.43	0.71
100%	43%	47%	4%	6%

* The "remaining R&D Institutes" refers to the all independent R&D institutes, excluding the industrial technology R&D institutes defined in table 3. This group totalled to 3,701 institutes in 1993.
Source: ibid. pp. 13, 52.

In accordance with the general trend shown in these figures, some consensus seem to have been reached recently in the community of policy researchers and institute directors in China, that the major direction of reform for R&D institutes engaged in industrial technology is to develop technology-intensive production.[45]

However we cannot simply conclude that the transformation of existing industrial technology R&D institutes involved only a general shift towards the market. Before turning to alternative kinds of transformations, we will provide some observations of the general trend at institute level.

Transformation into a Market-Profitable Corporation

The general trends of the transformations point to the development of a number of manufacturing or engineering corporations with relatively intensive in-house R&D, as illustrated in case text 5. This institute is a well-known example, which we visited personally. Many similar cases have been emerging recently (SSTC, 1991b; and interview notes 5 and 8).

CASE TEXT 5: Automation Research Institute of the Ministry of the Metallurgical Industry (ARTMI) (continuing case text 2)

In 1987, the Institute made a strategic shift toward re-building the hierarchy of the Institute as a whole, in response to the failure of their delegation of decision-making power to small research teams contracting separately on the technology market.

The new strategy, which was intended to upgrade the Institute to enable it to provide automation systems competitively, required a thorough re-organization of the Institute. Six larger departments were set up for (1) automation systems, (2) motor drives, (3) metallurgical instrumentation, (4) power generation components, (5) a.c. servo devices, and (6) an engineering design department. Most of these departments embrace R&D, design, manufacturing, and marketing, i.e., each department is organized as a profit-making unit with integrated functions. Design, which is thought of as the "gateway through which R&D enters into the economy" has been integrated at both the department level and the Institute level. At the institute level, the engineering design department was established to provide design services for automation systems. Quality control has also been enhanced. It has been incorporated into the routine operations of departmental workshops, using the ISO 9000 as basic quality standard.

Decision-making powers were re-centralized, away from the small teams to a two-level structure. The central power is at the Institute level, while the departments have flexibility to make business decisions within their specialized field in accordance with the overall targets of the Institute. The central power at the Institute level acts in several ways:

(1) The Institute is in charge of decisions regarding contracts for big projects involving more than one department.
(2) The accounts office of each department is a branch of the Institute accounting office, working under the control of the Institute;
(3) Investment decisions are exclusively the domain of the Institute.

Foreign involvement is sought to complement the institute’s capabilities in the design and manufacture of some devices which the new institute strategy requires. Four joint ventures have been set up: one with a German company for a.c. and d.c. drives; one with an American company for PLC and CNC devices etc.; one with a company from Hong Kong for instruments; and one with a French company for a.c. servo devices and CNC. The greater mobility of manpower in general, resulting from the reform of the S&T system, made it easier for the Institute to strengthen their engineering capabilities through the aggressive recruitment of key design personnel.

Capabilities in complex metallurgical automation systems were built up by contacting international suppliers of the domestic market. The institute worked (1) as a sub-contractor for a large system initially contracted by foreign suppliers, or (2) as a co-contractor with foreign contractors. They were attractive to their foreign partners because of (1) the Institute’s technological strengths in particular technology areas, such as drives, (2) their cheaper technologically-skilled labour, and (3) their closeness to, and awareness of, the user’s environment, leading to advantages in adapting imported systems for the operational site. These advantages make the Institute an indispensable local partner for the transnationals. As a result of their learning, the Institute has become quite competitive in the domestic market for smaller and less sophisticated metallurgical automation.

The transformation can be illustrated in financial terms. In 1993 ‘market sources’ (contracted projects and product sales) were estimated to constitute more than 90% of gross income, and more than 80% of net income. This is a reversal of the situation in 1987, when ‘state sources’ constituted two thirds of net income. The change was mainly due to the expansion of the 'market sources': contractual engineering projects increased twenty-fold over that period.

'Spin-off' enterprises have been created from the Institute, but with entirely different roles. 26 spin-offs have channelled about 300 staff members, mainly from the procurement and logistical department of the Institute, into retail shops and restaurants. There is no question of spinning-off R&D capability; rather, there is a partial externalization of some general and social services which were previously over-internalized within various 'units' of the R&D institute.

Sources: 1. Interview Notes 6;
2. *Information on Science and Technology of China* (zhongguo keji xinxi): No. 6, 1992, p.5;
3. SSTC, 1991c: pp. 62-65;
4. Yu Chanyou: On the Creation of Groups for Development of New and High Industries, in *Information on Science and Technology of China* (zhongguo keji xinxi), No. 6, 1992, p.8;
5. Introduction to the major projects accomplished by the Institute, provided by the Automation Research Institute of the Ministry of the Metallurgical Industry.

The case demonstrates that the formulation of institute strategy is critical. Market reform in general does not provide adequate guidance for individual institutes on how to interact properly with the market, and how to exploit their institutional strengths. The directors of the Automation Research Institute in case 5 said emphatically that reformulating their own strategy to shift away from internal delegation of powers to research teams was the most difficult step during the reform (SSTC, 1991c, pp. 91-95; and Interview Notes 6).

A profound internal restructure proved to be indispensable to put the institute strategy into effect. Usually pilot plants and trial production workshops, which already existed within many institutes, were re-organised as the basis for commercially exploiting the institute's assets. Departmental structures were adjusted. Decision-making power was re-divided. Abilities in design, manufacturing, quality control, marketing etc., were usually weak, and were complemented in various ways which were more accessible because of the market reform. The profundity of the restructuring, illustrated to some extent in case 5, explains why the transformation of R&D institutes took some time, before the institutes themselves were convinced this was the right path, and it was widely accepted by the S&T community.

Policy Response to the Restructuring of Industrial Technology R&D Institutes

Clarification of Alternative Kinds of Restructuring. Up to the beginning of the 1990s, the reform policy attempted to answer the questions of what the future of restructuring of industrial technology R&D institutes would be, and how it would be achieved. A document on the acceleration of S&T system reform, drawn up jointly by the State Science and Technology Commission and the State Economic Reform Commission, clarified some alternative paths for transformation which were encouraged. This document was circulated in late 1992. The many experiments and experience which had been built up by then are evidently reflected in the five possible transformations which were suggested for industrial technology R&D institutes:[46]

- merging with existing enterprises, mainly for institutes engaged in the development of product technology;
- continuing with the establishment of NTEs, and expanding the Zones;

- transforming entire R&D institutes into new and high technology enterprises;
- transforming R&D institutes into (1) productivity centres, providing technological services to small and medium enterprises in management, training, and information, or (2) into consultancy centres;
- retaining a small number of state-supported institutes engaged in providing technological infrastructure for the whole society. Their total costs must be low enough to be sustained in the long term by the state.

National Engineering Centre Programme. The Programme aims to re-organize and invest in 'National Engineering Centres', most of which are located within existing industrial R&D institutes. The Automation Research Institute of the Metallurgical Industry, for instance, has been authorized to establish the 'National Engineering Technology Centre for Metallurgical Automation' [*in 1991*].[47] It is reported that by the second half of the 1990s there will be nearly one hundred national engineering centres in operation, with investment funds coming partly from the State Planning Commission and the State Science and Technology Commission, and partly from the host institute.[48] Some ambiguity can be seen in the targets of the policy initiative, and its effects on the transformation process will require further study.

The delegation of autonomy in doing business with foreign companies. It was announced in 1993 that one hundred R&D institutes were to have autonomy in doing business with foreign companies.[49] The majority of the one hundred are industrial technology R&D institutes. The remainder are from the Chinese Academy of Sciences (7 institutes) and institutes of higher education (7 units). This is a privileged position equivalent to the best-performing state owned firms, which have also just started to enjoy the privilege. This seems to be intended to encourage the transformation of R&D institutes which are becoming engineering or manufacturing corporations.

It is too early to evaluate the effectiveness of these policies. Moreover, the present policies are still far from sufficiently coherent to guide the complicated transformations, although progress has been made. Some institutes will unavoidably be dispersed, in the sense that they will cease to function as a unit undertaking any R&D or technology-related work. This could be considered as a cost of the transformation (Interview Notes 7: 6).

7. CONCLUDING REMARKS

Some findings emerged from the survey above.

1. The reform of industrial technology R&D institutions is in dispensable to adapt them to the new economic regime

This is strongly suggested by the parallels between R&D policies and the various stages of the economic reforms, as shown in table 6. In China, the new strategy for economic development was fixed in 1978, with the declaration that political doctrine must not be allowed to interfere in economic affairs, and the opening of the door to the outside, with the aim of giving more attention to the efficiency of economic growth and the people's standard of living. This led to economic reform of agriculture, which was put in place around 1980, and inspired the industrial economic reform which was in full stride by about 1984. There had been wide-spread attempts to adjust industrial technology R&D to the revised economic strategy, but on the previous institutional basis, prior to 1985. Since then, R&D institutions which were operating by central planning have had to be remodelled, as their users have been substantially released to act within the market.

Under the centrally planned institutions, as shown in Section 2, policy measures were restricted to the supplier side. Nevertheless they were effective on both the macro level, with measures for the re-allocation of investment, and on the micro level, with measures such as the adjustment and improvement of institute establishments. All measures were characterized by direct intervention under the state plan. The general pattern of 'externalized' R&D institutions was sustainable under the pervading administrative power.

Once they had moved out of the planned regime, plurality or diversity, a key characteristic under market regimes, started to be much more evident in policy measures and institutional restructuring. Once delegated decision-making authority, R&D institutes and industrial enterprises acquired increasing importance in response to the policy and economic environment. Interaction between policy makers and affected parties evidently had a greater influence on the evolution of the reform policy and reform practice.

2. The Technology market approach proved to be ineffective in adapting the old R&D system to market-oriented economic reform. restructuring is the essence of the transition of industrial technology R&D institutions

The technology market was originally devised, in the reform policy of 1985, as the main bridge linking suppliers and users of industrial technology. It has been shown to be ineffective on its own in meeting this target. The uncertainty of technology transactions limits the efficiency of the market, and this problem is intrinsic to the process of technology innovation. In particular, the fierce competition resulting from the opening to foreign suppliers of technology, and the increasing complexity of the systems employed in various industrial operations, seem to heighten the uncertainty. It can also be seen that the inexperience of buyers, and the under-development of market institutions, were additional obstacles to concluding technology transactions. Releasing R&D institutes from rigid controls, though not sufficient in itself, did enable R&D institutes to act with the technology market, and it opened the way for various kinds of organizational restructuring involving functional redefinitions in the environment created by the general market reforms. The technology market turned out to be complementary to various transaction agents linking firms and the restructured R&D units.

TABLE 6
THE MOST IMPORTANT ECONOMIC EVENTS AND POLICY FOR R&D SYSTEM REFORM

YEAR	IMPORTANT ECONOMIC EVENTS	IMPORTANT POLICY FOR R&D SYSTEM	YEAR
Before 1978	** The established of planned economy (the 1950s) ** 'Great Leap-Forward' (1958-1960) ** 'Cultural Revolution' (1966-1976)	** the institutionalization of the R&D system (the 1950s)	Before 1978
1978	** 'Open Door' Policy (1978)	** rehabilitation and expansion of R&D system (1978-1980)	1978
1979			1979
1980	** rural economic reform (around 1980)		1980
1981		** elaboration of R&D planning practice (1981-1985)	1981
1982			1982
1983			1983
1984	** urban economic reform (1984)		1984
1985		** market reform Decision for R&D system (1985)	1985
1986			1986
1987			1987
1988		** merging R&D institutes into enterprises (1987)	1988
1989			1989
1990			1990
1991	** reform for taxation and banking system; and for state-owned firms (1993)	** Torch programme (spin-offs) (1988)	1991
1992			1992
1993		** transformation of R&D institutes (in the 1990s)	1993

A tentative analysis indicates some characteristics of the technology market. First, 'technological consultation' and 'technological services' were the main subjects of market transactions in the first ten years of recorded activity in China. These transactions were probably less deeply involved in the core activities of the buyers. Second, 'technology transfer' transactions were very rare in the market. Third, the 'contractual development of technology' displayed a significant increase, in terms of both contract numbers and contract value. This seems to point to some peculiar aspects of the market in linking R&D units and firms which are in the course of restructuring. Focusing on this hopeful sign might produce good results. Another study which is now under way, concentrating on the machine industry, reveals that some R&D institutes in the industry are restructuring themselves as suppliers of customized producer goods, while the technology market helps to link them with their clients. These transactions are recorded as the 'contractual development of technology'. However it is measured, the technology market has been expanding, in absolute terms, since it was created, in step with the deepening of the market reforms.

3. *The principle directions of restructuring, and some factors influencing the restructuring*

The common direction of restructuring in the overwhelming majority of cases thus far has been to integrate more activities within the same organizational territory. The integrations were intended to capitalize on institutes' technological assets under the market rules. Transaction costs, which were even higher because of the inexperience of the actors, underdeveloped market institutions, and increasing complexity of technology, have pushed the restructuring toward more hierarchical forms of integration. The plurality of the restructuring process is illustrated by the fact that a few restructuring schemes have been widely experimented with, with varying degrees of success.

- *Merging R&D institutes into existing enterprises*. This was initially prompted by the reform policy in 1987, as a response to dissatisfaction with the technology market solution. Successful cases of merging were rare, but all those achieved under the supervision of the responsible ministries in the two sectors survived. Many aspects of *institutional incompatibility*, mostly inherited from the past, were the *main factor obstructing* the organizational fusion. Technology imports tended to widen the gap between the institutes and the enterprises, in terms of technological norms and physical installation, but at the same time the increasing wealth of enterprises in a rapidly growing economy tended to make merging more affordable.[50] Once the organizational barriers were surmounted, R&D assets tended to be well combined into the core technological activities of the host enterprise. Careful guidance of potentially feasible mergers was seen to be indispensable to overcome the institutional barriers, which seems to be beyond the capacity of the market. In this connection, the responsible ministry can have a positive function where there is a lack of well-developed regulatory agencies for merging.

- *'Spinning-off' new technology enterprises*. This kind of restructuring began to take place as a spontaneous response to the market reform, on the initiative of autonomous R&D institutes and S&T personnel. It is characterized by channelling ingredients of the technological assets accumulated in R&D institutes into newly established enterprises. The integration of the assets with other factors necessary for commercial success is thus realized within new organizational setups. The policy measures in response to this spontaneous development, in the initiatives of the Torch Programme of 1988, sanctioned and accelerated the process. This kind of restructuring has expanded very significantly in China. It would be reasonable to devote more attention to it in formulating policy, since it has proved to be the most popular method of restructuring thus far, in both China and other counties.[51]

Factors influencing the boom of the 'spin-off' approach: *first, both the academic community and the local governments have been active.* R&D institutes and S&T personnel were the main initiators of New Technology Enterprises in various forms, while the local governments supported the initiation of both NTEs and Zones. This was achieved in the context of the decentralization of decision-making authority in China's reform. *The second factor concerns the impact of the personal computer revolution,* which has reached the stage at which widespread applications have become feasible. Skill-intensive and knowledge-intensive work is urgently needed to localize the global technology trajectory in the various sectors of national economies. In China, spin-off enterprises concentrated on this area, and the importance of this factor seems far from unique to China.

- *Transforming entire R&D institutes into manufacturing or engineering corporations with relatively intensive 'in-house' R&D.* This kind of restructuring also began as a spontaneous response to market reform. The integration of institute assets with other factors necessary for market profitability was achieved within the territory of particular individual institutes, usually accompanied by profound internal restructuring. The profoundness and severity of the internal restructuring required to remodel the institute, perhaps including shifting the focus of its specialisation, explain why successful transformations of this kind came to be known and accepted only very recently, much later than 'spin-off' restructuring. Thus far, institutes restructured in this way have almost exclusively been moving towards becoming market profitable manufacturing or engineering corporations.

Two factors modified the general direction which may be identified from this review of China's reforms. *First, very tough financial pressure* was imposed on institutes throughout this period. This was deliberately designed to goad the institutes into the market. In other words, the policy environment in China's case was quite unique, although a trend to reduce government funds for R&D institutes is currently very common in many other countries. *Second*, the strong *orientation to physical output*, which was characteristic of institutes in China, underpinned the direction of the transformation. This characteristic is shared by many former centrally-planned economies to some extent, but there are some in which the analogy can be applied only with caution, such as India, where government-financed industrial technology R&D institutes have been relatively more academically oriented. Moreover, *as far as the success of transformation in a certain institute goes, proper institute strategy seemed to be the most important factor*. The transformation of institutes is basically a matter of institute management, given that a high degree of autonomy has been granted to them.

The outline of directions and influencing factors above should be seen as an effort to illustrate, rather than exhaustively describe, the restructuring possibilities. Nevertheless this typology of restructuring is quite solid as regards the types of transformation which have been tried on a large scale under China's reforms. It should be noted that the Chinese practice has not yet been able to show how to successfully manage the transformation of a part of existing R&D capabilities into unprofitable functions (in market terms), such as the provision of technological services for small and medium-sized enterprises in fields such as training, management, and information;[52] and into R&D for more advanced and fundamental industrial technology. These issues are being addressed by reform policy in China right now.

The analysis of restructuring outlined above has been carried out only at an aggregate national level. Sectoral research is desirable and is likely to produce insights as to the dynamics of restructuring in the context of the relationship between R&D institutes, enterprises, foreign suppliers, and governmental policies. The characteristics of the underlying technologies of particular sectors warrant close examination in such research, since these usually have a large impact on the pattern of restructuring.

4.The main subject of reform policy — to address the lack of institutions.

Plurality or diversity has become the main characteristic of S&T policy in China, since the reform began to recast the political-economic regime, as has been pointed out above. Two strands of policy measure were provided for China's S&T system reform: one setting up new regulations and incentives, and another for the creation of regulatory and other supporting frameworks. Both point to the establishment of new institutions necessary if players were to operate under the new rules. Policy for the creation of regulatory and supporting frameworks, i.e., creating the organizational basis for putting regulations into effect, is particularly necessary in a transitional period, when these frameworks are especially inadequate.

Different reform targets were embodied in different sets of supporting institutions. To introduce the technology market, policies under the 1985 Decision concentrated on laws, regulations, and agencies for technology-related transactions. An extensive and impressive framework of 'technology market agencies', and 'personnel exchange and recruitment centres' to support a quasi-market for S&T skilled labour resulted. To endorse and accelerate 'spin-off' restructuring, the policies under the 1988 Torch Programme concentrated on regulations, incentives, and agencies for technology-intensive, non-state small and medium-sized enterprises. The development of Zones, Centres, and financial institutions as vigorous organizational networks supporting NTEs was thereby encouraged.

One significant highlight of this review is the cumulative nature of institution-building. Each successive effort resulted in some components of institutional construction which was useful in the next stage of the reform. The framework of centres for personnel exchange and recruitment, for instance, which was created earlier, largely supported the mobility of S&T persons required for the establishment of New Technology Enterprises. Both the technology market and the Development Zones for New Technology Industries helped the transformation of individual R&D institutes. Throughout this cumulative process, market institutions were expanded, elaborated, reinforced, and adjusted, so paving the way toward the successful transition which was the goal of the reform.

ENDNOTES

1. For instance, the secretariat of UNIDO, in their 1979 evaluation of industrial research and service institutes in developing countries inquired: "Is an (independent, government-financed) Industrial Research and Service Institute (IRSI), ...a reasonable option for developing countries which have not reached a relatively advanced stage of industrialization?" (or equally, for those that have achieved some degree of industrialization?) "What can government and industries do to make more effective use of existing IRSIs?" and "What priority role or function should an IRSI perform?" [*UNIDO, 1979, p. 34*].
2. For the Soviet Union, see Amman and Cooper, 1982, Chapter 10; for the German Democratic Republic, see Bentley, 1992, Chapter 2; for an earlier comparative analysis of these countries, see Poznanski, 1985.
3. 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." [*Piskunov and B. Saitykov, 1992*]. In Hungary, "the direct links between institutes and enterprises tended to favour lower quality R&D", "In a quite not short period, there would not be a strong market demand for out-mural R&D by industrial enterprises as users" [*Balazs, 1992, pp. 89-97*]; (3) 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 these institutions were not able to sell themselves. Another estimate was that the reduction in industrial R&D manpower was as high as 50%, in the same period [*Bentley, 1992, p. 155*].
4. See the papers cited in footnote 3 and, more recently, Balazs, 1993.

5. Hungary had gone further than other former Eastern centrally planned economies in introducing elements of market rules before the end of the 1980s. From the perspective of ownership and control mechanisms for industrial enterprises, see for instance, Sadao Nagaoka, *Reform of Ownership and Control Mechanisms in Hungary and China,* Industry and Energy Department Working Paper, Industry Series Paper No. 7, World Bank, April 1989.
6. See: OECD, 1992a; 1992b; 1994a; 1994b. Interestingly, intensive discussions between outside experts and domestic decision-makers are an important aspect of the approaches used in these studies.
7. Precise analyses regarding the situation of the planned economy in China and of R&D institutions under it have been made by a number of authors. See, for example, OECD: *Science and Technology in the People's Republic of China*, 1977, OECD, especially Chapter 2 (The planning System, by Audrey Donnithorne), Chapter 3 (Scientific Institutions, by Richard P. Suttmeier), Chapter 4 (The institutionalization of Science, by Richard P. Suttmeier and Genevieve Dean), Chapter 8 (Industrial Structure and Technology, by Hans Heymann), and Chapter 9 (Research and Technological innovation in Industry, by Genevieve Dean).
8. See, for instance, Suttmeier, 1974. In chapters 4 and 5 of the book, Suttmeier analyzes the Chinese mobilization of the labour force for accelerating technological innovation in the period 1958-1960, and in the 'Cultural Revolution'. Genevieve Dean [*1973, pp. 187-199*] provides another interesting discussion, focusing on design reform in the period 1964-1966.
9. Many works have described the process of market reform in China. Probably the best of the journalists' reviews is that published in *The Economist,* which outlines the key steps and factors of Chinese reform, see: China, the Titan Stirs, November 28th 1992.
10. The central feature of the planned economy was that enterprises were to be a part of an administrative framework. This implies that enterprises operated under command instruction (largely through quantitative indicators) from the administrative authority, based on ownership by the state. China's reform, in the mid-1980s, started with delegating decision-making authority for routine operations to enterprise managers, at the same time retaining ownership by the state. Since about 1993, the ownership issue has been seriously addressed, along with tax and banking reforms. The approach chosen is to re-organize firms as corporations, with investors becoming shareholders. See: "Decision on Some Issues for the Establishment of Socialist Market Economy" (made by the Central Committee of Chinese Communist Party), in the *People's Daily*, overseas edition, Nov. 17, 1993. Many reviews have reflected on the reform measures. See, among many others, 'China, Birth of a New Economy', in *Business Week*, January 31, 1994.
11. In 1985, the number of products to be distributed directly by the state was reduced from 123 to about 60 [*Contemporary China, 1985, p. 188*]. This was further decreased to 36 in 1993 (*People's Daily,* overseas edition, Aug. 10, 1993). As for the real extent to which state control acts to influence the operation of enterprises, surveys indicated that 87% of raw materials were distributed by the state in 1984, which was reduced to 49% in 1987, and 30% in 1988; 71% of outputs were distributed by the state in 1984, falling to 30% in 1987 and 27% in 1988. Sources: for the 1984 data, Zhang Shaojie: 1987, p. 195; for the 1987 and 1988 data, CSTD, 1988, p. 73. Note that these figures refer only to state-owned enterprises. Non-state enterprises have never been seriously controlled by the state plan. The rapid expansion of non-state enterprises has changed the balance of enterprise ownership to the extent that, by about 1990, the non-state sector was approximately equal in size to the state-owned sector in terms of industrial output. The majority of the non-state sector is rural industry, resulting from the rural reform just mentioned.
12. Up to mid-1993, 13,000 enterprises had foreign investors, with real foreign investment amounting to more than $US 40 billion. The economic importance of these enterprises has been increasing, to the point that they accounted for 25% of total exports in the first half of 1993. With respect to technology imports, in the period between 1979 and 1992 about 5,000 agreements were signed, embracing various forms of technology importation, mostly in turn-key projects or incorporated with key equipment procurement, for a total cost of $US 34 billion [*People's Daily, overseas edition, Sept. 29, 1993*]. As for the degree to which China's economy is integrated with international markets, data indicates that in 1992, China's exports amounted to $ 85 billion, and its imports to $ 81 billion [*People's Daily, overseas edition, March 20, 1993*], so that merchandise trade as a ratio of gross national product (GNP), measured at the official exchange rate, had increased from 12.8% in 1980 to 38% in 1992 [*Financial Times, Nov. 18, 1993*]. This ratio was about 6% in the 1960s and early 1970s.
13. 'County' is a local administrative unit with an average population of about 500,000. There are slightly more than 2,000 counties in China. At the county level there are roughly 3,000 more 'science and technology' related establishments. They are mostly charged with the dissemination of information, especially for agricultural technology.
14. The official science and technology statistics do not cover the design institutes, so it is difficult to obtain well-defined data. Many sources suggest that there were several thousand units with about 300,000 staff

in 1980. The design institutions later expanded in step with the high levels of capital investment during most of the 1980s (See: for example, Lu Yanlin, 'On the Licensing of Design Institutions', *Management of Architecture and Design*, No. 3, 1992, pp. 6-11). Note that the several thousand units mentioned can be divided into two classes: those specialised in 'plant design', which are usually 'independent' from enterprises, and those engaged in product and process design, which have gradually integrated with manufacturing firms or R&D institutes, although some of them have, at the same time, been guided by senior levels of the government administration. The restructuring of design institutes is not included in this study.

15. 'Locking-in' meant not only that their professional technological work was governed by the administrative power, but also that they had managerial and technological supporting duties, to assist the administrative body. These managerial and supporting duties included: compilation of product and technology standards, formulation of sectoral and sub-sectoral development projects, and testing and examination of product quality for firms in the sector. In addition, they were required to help to organize technological exchanges and other working meetings for industrial ministries. These tasks accounted for about a quarter or more of the overall activities of R&D institutes at the ministry level (Interview Notes 7: p. 4), and of those at the local levels too (Interviews in 1993 and 1994).

16. Some outside observers noted the fact that "R&D institutes in the field of engineering seem to do no R, only D — i.e. their scientific activities appear to be aimed not at research to discover new knowledge or novel solutions within their specialities, but at developing practical applications of existing knowledge." See: OECD, 1977, pp. 148-149.

17. Only aggregate data is available. The first national general survey was conducted in 1986 and aimed to acquire data on the situation at the end of 1985. This showed that, for the R&D institutes affiliated to central ministries and commissions (622 units), more than 50% of their activities in terms of expenditure were not R&D; and for the institutes affiliated to local administrations above the 'county' level (3,946 units), about 80% of their activities were not R&D. These non-R&D activities may be categorized as 'engineering and design', 'dissemination and consultant services', and 'production activities' (defined by the State Science and Technology Commission of China), with the composition varying for the different groups ("White Paper": No. 1, p. 238).

    Another study indicated that, of the 4,690 independent R&D institutes in 1985, only slightly more than 600 had more than 50% of their activities in areas which, according to the definition in the Frascati Manual, fall within R&D. Nearly 3,000 of these institutes had almost no activity which could be classified as R&D [*Xu Zenji et al., 1987*].

18. For example, in the former German Democratic Republic (GDR), the proportion of research establishments' activities falling outside Frascatti's definition of R&D was reported to be between 20% and 50%, depending on the sampling and the time of surveys [*Bentley, 1992, pp. 64, 142*].

19. "Decision" here is the "Decision on Reform of Science and Technology Management System", in force since 1985, which was orientated mainly toward market solutions, see section 3 below.

20. The great impact of the science and technology revolution was the main rationale for the first initiative for the establishment of R&D institutions in 1956. The late Premier Zhou Enlai, in the most important policy statement of that time, said: "Science is a decisive factor in the development of defence, economy, and culture." To support this statement, he drew at length on various advances in technologies, including those in mechanics, automation, aircraft, materials, electronics, and atomic energy, and concluded by repeating his Soviet counterpart Bulganin's statement (to the Soviet party's plenum in 1955) that "These recent achievements bring mankind to the brink of a new revolution of science, technology, and industry; its impact will be more far-reaching than the industrial revolution which took place due to the emergence of the steam engine and electricity." [*Zhou Enlai, 1956: pp. 181-182*]

21. This is reflected in an important document drafted by the State Science and Technology Commission, entitled the "Report on Guidelines for the Development of Science and Technology of Our Country". The report criticized the neglect of industrial production technology under the current R&D investment strategy. It argued that more attention should be given to the assimilation and dissemination of imported technologies, as well as to applications of domestic R&D outputs. It also argued that coordination between domestic R&D and technological importation should be improved [*SSTC, 1981*].

22. In 1988, 4,732 contracts were signed for the implementation of key S&T projects. Contracts for "applied research", "experimental development", and "design and trial manufacturing" accounted for 34%, 27%, and 29%, respectively, of these. The rest (about 10%) of the contracts were for "basic research", "dissemination", and "small batch production". Source: State Statistical Bureau 1990, p. 315.

23. The industrial enterprises' roles were (1) as the users of the resulting equipment or processing technologies; (2) as the operators of manufacturing trials for the developed product technology; and (3) in a few cases, as designers or co-designers of products under development.

24. The first use of some technologies was also planned, in this system: the outcomes from a particular S&T project would be included as inputs to particular "capital construction projects" or "technological renovation projects" listed in the economic plan.

25. As a result, China has compiled internationally comparable science and technology statistics since 1986, using the definitions provided in the Frascati Manual.

26. Four types of institute were distinguished for the implementation of the grant cuts: (1) technology development type, — institutes engaged primarily in technology development; (2) basic research type — institutes primarily doing basic research or doing applied research which could not have any practical value in the short term; (3) public welfare and infrastructure type — institutes engaged in R&D related to the public welfare such as medicine and health, labour protection, family planning, calamity prevention and control or environmental sciences, along with institutes engaged in technology infrastructure activities such as standard-setting, taking measurements, testing, and providing information, and institutes engaged in agricultural science and technology; and (4) the multi-activity R&D institutes, with major activities in more than one of the three areas: basic research, applied research, and experimental development. The government grant was cut only for type 1 institutes, along with lesser cuts for type 4 institutes according to the proportion of their activities which focused on 'experimental development'. About 2,000 institutes suffered government grant cuts (Interim Stipulations for the Management of Science and Technology Grants, State Council, Jan. 23, 1986, in "White Paper" Vol. 1, pp. 314-315).

27. In 1991, the first year after the completion of the cuts, the structure of income for the group of industrial technology R&D institutes became: (a) that from government (including contractual research on government-financed projects) accounted to 22%; (b) that earned by the institutes themselves, 61%, (c) that from bank loans, 12%, and (d) others, 4%. Thus the "market" source dominated for the group. To compare, for the group of agricultural R&D, the sources accounted to for 55%, 33%, 5%, and 6%, respectively. For the institutes of the Chinese Academy of Science, the figures were 68%, 21%, 1%, and 10%. And for the R&D institutes engaged in meteorology, seismology, survey and mapping, measurement, and environment protection, they were 72%, 27%, 2%, and less than 1%, respectively (calculated from the data in SSTC, 1992, pp. 70, 74, 77). Following in the Section 6 more analysis relying on the 1993 data, will be provided.

28. Earlier, in 1981, the Law of Economic Contracts had been issued and put into effect. Under this law "contracts for science and technology-related transactions" were one category of economic contracts. In 1984 the Law of Patents came into force.

29. The predecessor of the Foundation was the Natural Science Foundation, initiated and operated by the Chinese Academy of Sciences from 1982 on. The operational procedure of this Foundation drew heavily on the practice of the National Science Foundation of the U.S. A number of smaller foundations with specialized objectives in particular fields have emerged since 1985. These act as complementary sources of finance for basic and fundamental applied research in special fields, or for particular purposes [*Bulletin of the National Natural Science Foundation of China, No. 1, 1987, pp. 20-34*]. The government appropriation for the National Foundation has steadily increased, from 100 million yuan in 1986 to 170 million in 1991 [*China Statistical Yearbook on Science and Technology 1992*, p. 306].

30. It is reported that more than half of the best-selling products from the Shanghai suburban area (largely the surrounding rural areas) were produced under the guidance of "Sunday engineers" (second job takers) from Shanghai city [*CSTD, 1988, p. 21*].

31. The performance of the "quasi-market" for talent may be reflected in the fact that, in 1991, there were about 150,000 staff working in New Technology Enterprises around China, of which about half were "S&T professionals" [*China Statistical Yearbook on Science and Technology 1992, p. 309*].

32. Williamson calls the latter 'transactions with bilateral governance'. In the Chinese literature many different terms are used for this form of transaction, such as joint business or coordinative management (lianying), combined undertaking (lianhe ti), and horizontal cooperation (hengxiang hezuo). These have sometimes been translated as "joint-ventures" or "combinations", which is not very accurate.

33. In many centrally-planned economies the average size of enterprises was much larger (which causes other problems). The enterprise structure in China developed with smaller units [*State Council, 1990:* Part 1 Chapter 4, and Part 8 Chapter 4]. This very much hampered improvements in productivity, especially in those sectors which are sensitive to economies of scale. More serious was the problem of specialization among enterprises (State Council, 1990: Part 10 Chapter 2). According to the officers from the Ministry of the Machinery Industry, an over-vertical integration, i.e. a "specialization" in terms of final products, rather than in terms of underpinning technology ("vertically dis-integrated specialization"), was developed by the planned economy in China. This was in part due to the principle of maximizing output (rather than value-added), and partly to the segmented resource allocation system. Both the small size and poor specialization limited the wealth of enterprises, suggesting that making them more innovative and competitive in a market environment will not simply be a matter of adding an R&D

element to them, or of delegating autonomy and imposing incentives on them (Interview Notes 7: pp. 3-4; and other interviews).

34. The pattern of technology imports for the electronics industry has been widely reported. For instance, for consumer electronics (such as black and white and colour TVs, video-corders, and cassette recorders) see: *Contemporary China 1987*, pp. 188-189; for computers, see: *Contemporary China 1987*, p. 175; for electronic instruments, see: *Contemporary China 1987*, pp. 213-214; for transistor and electronic components, see: *Contemporary China 1987*, p. 257. The development of this sector had long been focused on military purposes. The shift to civilian production since the late 1970s also resulted in a need to import production technologies.

35. The five criteria were: (1) 70% of the institute R&D activity should be needed by, or have been committed to, the enterprise or group of enterprises with which a merger is contemplated; (2) the enterprise or group of enterprises must be wealthy enough to sustain the institute; (3) the two sides must be compatible with each other in their business portfolios; (4) the two sides should be geographically adjacent; and (5) the two sides should be willing to merge (Interview Notes 7:3).

36. It is reported that the merging of a big tractor technology institute into a big tractor factory had been suspended. During the first round of negotiations, all the criteria defined were fulfilled, but the ministry officers and the institute managers were unwilling to merge. About 1991 the situation changed since (1) government funds were definitely diminishing, and (2) the market for contractual research was very limited and mostly from small firms, which was not attractive to the 'key' institute; (3) it had proved impossible for the institute to produce final products for tractors, since the investment required was too great and it was not possible to turn to producing tractor instrumentation, because of competition in a crowded market; (4) the factory had invested heavily in their own R&D and testing, implying that the institute would definitely lose its value as an influential power in tractor technology. Source: Research Centre for System Analysis, Research Institute of Mechanical Science and Technology (RIMST): *A Study on the Direction and Paths of R&D Institutes in Moving towards Self-Reliance* (in Chinese) mimeo, Dec. 1992.

37. For details see Shulin Gu: Spin-off Enterprises in China: Channelling the Components of R&D Institutes into Innovative Businesses, UNU/INTECH Working Paper, forthcoming.

38. For details of the policies see "White Paper" No. 3, pp. 245-250. Mr. Song Jian's speech at the National Working Meeting of the Torch Programme explains the policies further (see "White Paper" Vol. 3, pp. 415-419).

39. 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.

40. The NTEs enjoyed a tax exemption for the first three years, and then paid enterprise income tax of just 15%; whereas state-owned enterprises at that time paid 55%. Since Jan. 1 1994, the tax rate for enterprise income has been lowered to 33%. *People's Daily*, overseas edition, Dec 18, 1993.

41. For an example of the involvement of a Zone in loan appraisal, see Case Text 6 in the UNU/INTECH working paper "Spin-off Enterprises in China", referred to in footnote 37 above.

42. 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.

43. 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). On the other hand, bank loans accounted for 10% [*1988*], 13% [*1989*], 50% [*1990*], and 70% [*1991*] of the investment in 'Torch Programme Projects', indicating a dramatic increase between 1989 and 1990 (*ibid*). The leading funds in fact acted more as a policy guideline than a source of finance. The predominant role of the banks was in fact intended under the Torch Programme.

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

45. One commentator has said:

"By 1991, the cuts in government grants for R&D institutes of the 'technological development type' had been completed. The main question now became how to further reform this type of institute."

"Many institutes of this type are currently inclined to develop profitable production with intensive R&D as their main option (keji changye) when they plan their development in the eighth five year plan period [*1991 - 1995*]. Examples can be seen in Jiangsu Province, and in the construction materials sector,..."

"Most R&D institutes of the 'technological development type' have their own testing workshop, pilot plant or trail production bases. Experience in the past few years has shown that institutes that fully exploited the potentials of these plants and facilities have attained higher levels of income, more adequate to sustain their normal operations. Moreover, in these cases, all the research, development, production, and re-training of staff were better managed in the long term ...." See: Li Fan, 'Developing technology-intensive production is the direction of reform for R&D institutes engaged in the development of technology', in *Forum on Science and Technology in China*, 1992, No. 3: pp. 41-43.

46. See: *Chinese Science News*, Dec. 6, 1992.
47. *Science and Technology Daily*: April 28, 1993.
48. *Science and Technology Daily*: Dec. 12, 1992; April 30, 1993.
49. *Science and Technology News*: March 23, 1993.
50. For the possible reduction of barriers to merging in the machinery industry, see Zhu Sendi, *The Re-structure of the R&D System of Machinery Industry and Its Impact on the Development of Economy in China*, paper presented at the UNU/INTECH workshop "The Restructuring of Industrial R&D Institutions in China", June 29 - 1 July 1994.
51. In addition to the facts cited in Section 1.1 above, more evidence may be found in the OECD report on Science, Technology and Innovation Policies in the Federation of Russia. It is said there that there were 7,000 small enterprises "involved in science and science services", and that "some innovative 'subsidiaries' are forming a 'business sphere' near scientific centres" in Russia. This is obviously restructuring of the spin-off type. See OECD 1994b, pp. 99-101.
52. The transfer of industrial R&D from government affiliated to non-profit organizations for the provision of technological services to small enterprises is also strongly suggested by an OECD report on the transformation of industrial R&D. See OECD, 1992a.

APPENDIX
STATISTICAL DATA ON CHINA'S R&D SYSTEM

APPENDIX TABLE 1
GOVERNMENT APPROPRIATIONS FOR SCIENCE AND TECHNOLOGY FROM THE STATE BUDGET (1953-1991)

Year	Appropriations, in Million Yuan	Percentage of		
		Government Budget %	National Income %	GNP %
1953	56	0.3	0.1	
1954	122	0.5	0.2	
1955	213	0.7	0.3	
1956	523	1.7	0.6	
1957	523	1.7	0.6	
1958	1124	2.7	1.0	
1959	1915	3.5	1.6	
1960	3381	5.2	2.8	
1961	1949	5.5	2.0	
1962	1373	4.5	1.5	
1963	1861	5.5	1.9	
1964	2427	6.1	2.1	
1965	2717	5.8	2.0	
1966	2506	4.6	1.6	
1967	1535	3.5	1.0	
1968	1480	4.1	1.0	
1969	2415	4.6	1.5	
1970	2996	4.6	1.6	
1971	3768	5.1	1.8	
1972	3610	4.7	1.7	
1973	3459	4.3	1.5	
1974	3465	4.4	1.5	
1975	4031	4.9	1.6	
1976	3925	4.9	1.6	

APPENDIX TABLE 1 (Continued)

Year	Appropriations, in Million Yuan	Percentage of		
		Government Budget %	National Income %	GNP %
1977	4148	4.9	1.6	
1978	5289	4.8	1.8	1.5
1979	6229	4.9	1.9	1.5
1980	6459	5.3	1.8	1.5
1981	6158	5.5	1.6	1.3
1982	6529	5.7	1.5	1.3
1983	7903	6.1	1.7	1.4
1984	9472	6.1	1.7	1.4
1985	10259	5.6	1.5	1.2
1986	11810	4.8	1.5	1.3
1987	11574	4.6	1.2	1.0
1988	11800	4.4	1.0	0.8
1989	12787	4.2	1.0	0.8
1990	13912	4.0	1.0	0.8
1991	16069	4.2	1.0	0.8
1992	17563	4.0	0.9	0.7

Source: China Statistical Yearbook on Science and Technology 1991, pp. 24, 31; and *China Statistical Yearbook on Science and Technology 1993*, pp. 24, 31.

Notes:
1. The appropriations in this table do not include funds used for R&D purposes by enterprises and institutions of higher education;
2. Before 1977, there were no available statistics on GDP in China.
3. The science and technology appropriations from the government budget were used for wages, R&D expenses, and prototype testing.

APPENDIX TABLE 2
NATIONAL EXPENDITURE FOR R&D

Year	Expenditure for R&D (millions)	Ratio of R&D Expenditure to GNP
1990	12543	0.71
1991	14230	0.72
1992	16900	0.70

Source: China Statistical Yearbook on Science and Technology 1993, p. 23.

APPENDIX TABLE 3
THE DISTRIBUTION OF STATE-OWNED NATURAL SCIENCE AND TECHNOLOGY RESEARCH AND DEVELOPMENT INSTITUTES, BY SECTORS

Year	A*	B*	C*	D*	Total
1980		722*	3495	n.a.	4217#
1981		757*	3597	n.a.	4354#
1982		811*	3647	n.a.	4458#
1983		857*	3593	n.a.	4450#
1984		909*	3796	n.a.	4705#
1985	122	622	3946	3267	7957
1986	122	922	4227	3360	8631
1987	123	910	4189	2361	7583
1988	123	877	3933	2498	7431
1989	123	887	4001	n.a.	5011#
1990	123	904	4057	n.a.	5084#
1991	123	912	4092	n.a.	5127#
1992	123	915	4078	n.a.	5116#

A* = Chinese Academy of Sciences
B* = Institutes Affiliated to Central Government
C* = Institutes Affiliated to Local Government at Higher than County Level
D* = Institutes Affiliated to County Government

Source: 1. State Statistical Bureau, Division of Science and Technology Statistics(ed.): Statistics on Science and Technology of China 1949—1989, Statistical Publishing House of China, 1990, p. 207.
2. *China Statistical Yearbook on Science and Technology* 1991, pp. 67, 68, 69; and *China Statistical Yearbook on Science and Technology 1993*, pp. 65, 67-69.

Notes: 1. The figures marked "*" are the sum of the institutes of the Chinese Academy of Sciences and institutes affiliated to ministries and commissions of the central government.
2. The figures marked "#" do not include institutes which are affiliated to county governments.

APPENDIX TABLE 4
R&D INSTITUTES OF THE CHINESE ACADEMY OF SCIENCES

Year	Number of Institutes Affiliated	Scientists and Engineers (1000)	Annual Expenditure in million yuan

1985	122	32.2	833
1986	122	34.5	850
1987	123	37.0	886
1988	123	38.9	1034
1989	123	n.a.	n.a.
1990	123	41.0	1319
1991	123	41.5	1398
1992	123	41.5	1828

(*Source*: see table 7)

APPENDIX TABLE 5
R&D INSTITUTES AFFILIATED TO MINISTRIES AND COMMISSIONS OF THE CENTRAL GOVERNMENT

Year	Number of Institutes Affiliated	Scientists and Engineers (1000)	Annual Expenditure in million yuan
1985	622	93.0	2525
1986	922	175.1	6033
1987	910	197.1	6176
1988	877	206.2	7299
1989	887	n.a.	n.a.
1990	904	229.3	9682
1991	912	261.0	12049
1992	915	264.7	14194

(*Source*: see table 7)

APPENDIX TABLE 6
R&D INSTITUTES AFFILIATED TO LOCAL GOVERNMENTS (EXCLUDING THE INSTITUTES AFFILIATED AT THE COUNTY LEVEL)

Year	Number of Institutes Affiliated	Scientists and Engineers (1000)	Annual Expenditure in million yuan

1985	3946	105.8	3375
1986	4227	114.7	3875
1987	4189	127.6	3620
1988	3933	138.4	4490
1989	4001	n.a.	n.a.
1990	4057	154.0	5697
1991	4092	153.7	6989
1992	4078	154.2	9068

(*Source*: see table 7)

APPENDIX TABLE 7
DISTRIBUTION OF GOVERNMENT-OWNED R&D INSTITUTES BY FIELDS (IN 1988)
(EXCLUDING THE INSTITUTES AFFILIATED AT THE COUNTY LEVEL)

Field	Number of Institutes	Scientists and Engineers (1000)	Government Appropriations in million yuan	Expenditure in current yuan (million)
Natural Science	344	50.2	1087.8	1385.9
Engineering Science and Technology	2704	265.9	4493.1	9352.1
Medical Science	389	23.7	453.9	757.5
Agricultural Science	1496	43.6	949.3	1327.2
Total	4933	383.5	6984.1	12822.8

Sources:
1. "White Paper" Vol. 1 p. 232, Table 1-1;
2. "White Paper" Vol. 2 p. 269, Table 2-6;
3. "White Paper" Vol. 3 p. 344, Table 2-1;
4. "White Paper" Vol. 4 p. 212, Table 1.1.1, p. 215, Table 1.1.4.;
5. China Statistical Yearbook on Science and Technology 1991, pp. 75-77, 125-126;
6. China Statistical Yearbook on Science and Technology 1992, pp. 75-77, 125-126;
7. China Statistical Yearbook on Science and Technology 1993, pp. 75-77, 124, 126, 128;
8. State Statistical Bureau, Division of Science and Technology Statistics (ed.): *Statistics on Science and Technology of China 1949-1989*, Statistical Publishing House of China, 1990, p. 215, Tables 2-10.

APPENDIX TABLE 8
R&D IN INSTITUTIONS OF HIGHER EDUCATION

Year	Number of R&D Laboratories Affiliated	Scientists/Engineers Engaging in R&D (1000) (in full time equivalents)	Annual Expenditure for R&D (million)
1986	1490	83.9	597
1987	1514	94.2	736
1988	1715	106.9	874
1989	1739	112.1	991
1990	1666	116.4	1194
1991	1676	117.1	1353
1992	1819	122.3	2080

Source:
1. *China Statistical Yearbook on Science and Technology 1991*, p. 209;
2. China Statistical Yearbook on Science and Technology 1992, p. 209;
3. China Statistical Yearbook on Science and Technology 1993, p. 209.

APPENDIX TABLE 9
INTERNAL R&D OF LARGE AND MEDIUM-SIZED ENTERPRISES

Year	Number of Enterprises having Internal R&D Departments/ Total number of Enterprises	Scientists/Engineers engaged in R&D (1000)	Annual Expenditure for internal D&D and other technological development in million yuan
1987	4,633 / 9,681	198	8,798
1988	5,119/ 10,738	269	11,604
1989	6,424 / 12,222	307	12,377
1990	7,289 / 13,475	314	13,306
1991	7,899 / 14,935	334	16,599
1992	8,576 / 16,991	373	20,881

Sources:
1. *China Statistical Yearbook on Science and Technology* 1992, p. 149;
2. *China Statistical Yearbook on Science and Technology 1993*, p. 149.

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