TECHNOLOGY POLICY AND TECHNOLOGICAL INNOVATION IN THE PEOPLE'S REPUBLIC OF CHINA

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DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF ASTON IN BIRMINGHAM

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SUMMARY

- THE UNIVERSITY OF ASTON IN BIRMINGHAM
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The objective of this research is to unveil the dynamics of technological innovation in planned economies in transition. It is proposed in the thesis that all innovation systems in the world, in fact, consist of certain configurations of market and hierarchy. These systems have always been shifting from one existing market-hierarchy mix to a new one, which is expected to be more conducive to technological innovation and economic development. Current reforms in many planned economies in transition reflect this theoretical proposition. A research framework is constructed to include three main dimensions for the study of a specific innovation system, i.e. Arrangements, Achievements and Actors. China, which has undergone reforms since 1978, is chosen as the empirical basis of the research. The research examined technology policy and technological innovation in China between 1978 to 1988.

The thesis starts from Arrangements - R&D System in China and Its Reform. The thesis illustrates reforms in the R&D system in relation to government technology policy. There exist coherent government efforts to promote innovations through various plans, and the planning process incorporates both market and command elements. The institutional structure of Chinese R&D system remains still vertically departmentalised, but horizontal links are created through the market.

Secondly, Achievements - Performance of Chinese R&D System is assessed through patterns of technological innovation. Data from National Awards for S&T Progress (1978-1988) are included in a substantial database, which is used to generate patterns of technological innovation and patterns of innovating organisations. These patterns were presented and interpreted in relation to geographical differences, sectoral differences, typological differences, forms of co-operation and the impacts of S&T policy and reform.

The third dimension is study on Actors - Innovation in Applied R&D institutes. Through semi-structured interviews and questionnaire survey, internal structure and research management are analysed in the light of ongoing reforms. The reform of R&D funding system greatly affected the way applied R&D institutes operate. Both organisational and individual incentives for innovating are increasingly associated with economic or material benefits. The research suggests there is a need to put reforms in the R&D system into a wider societal and political context. Some general attributes of applied R&D institutes are also discussed in the thesis.

KEY WORDS:
1) TECHNOLOGY POLICY
2) INNOVATION
3) CHINA - PEOPLE'S REPUBLIC

I DEDICATE THIS THESIS TO MY

BELOVED PARENTS

AND

THEMIS

WITH MUCH LOVE AND APPRECIATION

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LIST OF ABBREVIATIONS

AHS - Anhui Province
BJS - Beijing Municipal City
CAS - Chinese Academy of Sciences
CAST - Chinese Association of Science and Technology
CPC - Communist Party of China
CPE - Centrally Planned Economy
FJS - Fujian Province
FYP - Five-Year Plan
GDS - Guangdong Province
GSS - Gansu Province
GXQ - Guangxi Zhuang Nationality Autonomous Region
GZS - Guizhou Province
HEB - Hebei Province
HEN - Henan Province
HLJ - Heilongjiang Province
HUB - Hubei Province
HUN - Hunan Province
JLS - Jilin Province
JSS - Jiangsu Province
JXS - Jiangxi Province
LNS - Liaoning Province
MITI - Ministry of International Trade & Industry, Japan
NMG - Neimonggu (Inner Mongolia) Autonomous Region
NRCSTD - National Research Centre for Science and Technology Development
NXQ - Ningxia Hui Nationality Autonomous Region
PLA - People's Liberation Army
PRC - People's Republic of China
QHS - Qinghai Province
R&D - Research and Development
RMB - Renmingbi (Chinese Yuan)
S&T - Science and Technology
SCS - Sichuan Province
SDS - Shandong Province
SEC - State Economic Commission
SEDC - State Education Commission
SGX - Shanxi Province
SHS - Shanghai Municipal City
SPC - State Planning Commission
SSTC - State Science and Technology Commission
SSTCND - State Science and Technology Commission for National Defence
SXS - Shaanxi Province
SYB - Statistical Yearbook of China, 1988
TJS - Tianjin Municipal City
XJQ - Xinjiang Uygur Autonomous Region
XZQ - Xizang (Tibet) Autonomous Region
YNS - Yunnan Province
ZJS - Zhejiang Province

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CHAPTER 1 INNOVATION THEORIES AND RESEARCH OPPORTUNITIES

It has been generally accepted that technological innovations are an important factor of economic growth of a country. Technological development is treated as part of the social and economic development process in many countries. The complexity and diversity of innovation systems in different socio-economic systems, and their common goal to achieve economic development through technological innovation, underline the importance of innovation studies. This research starts from the basic question - What is technological innovation.

1.1 Definition of Technological Innovation

The definition of technological innovation involves diverse perspectives as a result of wide variety of disciplines involved. A useful distinction may be drawn between 'invention' and 'innovation'. Invention is often regarded as the discovery of a new tool or technique and as an initial event; but innovation as the implementation of the new tool or technique discovered and as the final event.

According to Saren, "it is now generally agreed what is meant by the term 'innovation' and the sort of activities it involves. Innovation is the process by which an invention is first transformed into a new commercial product, process or service. It can be distinguished from both invention - the

discovery of a new technique, and imitation." (Saren, 1984, pp11-12)

There are two simplified traditional models of the process of innovation.(see Figure 1.1) Both regard innovation process as a linear sequence. The first model depicts that an innovation starts from basic scientific discovery, and evolves into applied technology, then reaches production and marketing. It is basically a science or technology-push model. The second model contributes an innovation to the result of market needs, which inspire the consequent R&D work and later production and market launch. This model is based on the market-pull concept.

(a) SCIENCE DISCOVERIES, TECHNOLOGY PRODUCES, FIRM MARKETS

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/-------\   /-----------\   /-------------\   /---------\
| Basic |   | Applied   |   |             |   |         |
|       |-->|Science And|-->|Manufacturing|-->|Marketing|-->
|Science|   |Engineering|   |             |   |         |
\-------/   \-----------/   \-------------/   \---------/
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(b) NEED PULLS, TECHNOLOGY MAKES, FIRM MARKETS

Figure 1.1 Simplified Models of Innovation Process
(Source: Rothwell, 1985, p49)

It has become evident that both the pure technology-push and demand-pull models are inadequate to explain the increasingly complex innovation process. Freeman argued, "whilst there are instances in which one or the other may appear to predominate, the evidence of the innovations

considered here points to the conclusion that any satisfactory theory must simultaneously take into account both elements... The vast majority of innovations lie somewhere in between these two extremes, and involve some imaginative combination of new technical possibilities and market possibilities." (Freeman, 1986, p31)

Rothwell also argued, "in the first case, it is obvious that more R&D has not necessarily resulted in more innovation. In the second case, overemphasis on market needs can result in a regime of technological incrementalism and lack of radical innovation. Moreover, the relative importance of technology-push and need-pull might vary considerably during different phases of the industry cycle." (Rothwell, 1985, p50) In order to overcome the limitations of the linear model, Rothwell proposed an interactive model.

Figure 1.2 Interactive Model of Innovation Process
(Source: Rothwell, 1985, p50)

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1.2 Innovation, Market Economies and Planned Economies - An Research Framework

If we follow the line of Jamison's argument, the traditional boundary of studies on innovation process has to be expanded. If we admitted that all technological innovations are socio-economic events, we may in fact admit that specific socio-economic and institutional context determines innovation activities per se. One obvious example is that innovation activities appear to be so different in a planned economy when compared with a market economy.

1.2.1 General Propositions

One of the fundamental difference, with regard to technological innovation, between a planned economy and a market economy, is that technology is treated as public good in a planned economy, while in a market economy as private property. Traditional theoretical debates suggest that a 'pure' market economy, due to private ownership of technical information, is unable to establish an efficient flow of information, thus inhabits innovative activities. At the same time, an 'ideal' planned economy would be able to overcome the information sharing problem quite easily through a centralised planning mechanism. But in reality all governments of market economy have introduced additional measures to improve as well as protect information flow. Innovative activities in capitalist systems are therefore not as theoretically

predicted. On the other hand, due to inefficient user-producer interactions in most planned economies, the theoretical advantages of centralised planning have been severely undermined. Innovative activities in socialist systems are generally inferior to what socialist theories claimed to be.

It is important to make clear that a capitalist system could no longer be understood as a simple set of markets and a socialist system as a hierarchy of central planning. Historical experiences by various so-called socialist and capitalist countries, have demonstrated that neither a pure market or a planning mechanism would be optimal for innovation activities. The present view is that both capitalist and socialist systems have included various combinations of market and planning mechanism. Given the extensive use of markets in modern socialist countries and the frequent presence of planning in modern capitalist countries nowadays, this view is far more convincing and realistic. (Freeman, 1988)

1.2.2 Innovation and Market Economies

As far as market economies are concerned, particularly since the Second World War, government intervention or support in R&D has become an important part of the capitalist innovation system, although the degrees of involvement may vary from country to country. In Japan, for example, the Ministry of International Trade and Industry (MITI) has orchestrated R&D efforts in many key industries, getting companies together to

think through which directions should be followed and what strategies should be adopted. Even in the market believer United States, although there is no MITI equivalent, the federal government has been actively involved in R&D, particularly in military technologies through the Department of Defence or other government agencies. (Rothwell & Zegveld, 1984; Nelson, 1988) Needless to say, universities and national research laboratories and specific technical programs are predominately supported by public spending.

Many governments have employed both explicit and implicit methods to promote technological innovation. Souder and Chakrabarti believed that government "influences" are more important and effective than regulations. They define government influences as any promotive or stimulative actions. (Souder & Chakrabarti, 1978, p24) The combination of these measures can be called government innovation policy. According to Rothwell, government innovation policy is essentially a combination of S&T policy and industrial policy. These policy tools are categorised under three main headings:

> "1. Supply - provision of financial and technical assistance, including the establishment of a scientific and technological infrastructure;
>
> 2. Demand - central and local government purchases and contracts, notably for innovative products, processes, and services;
>
> 3. Environmental - taxation policy, patent policy, and regulations." (Rothwell, 1982, p3)

Lee, based on South Korean experiences, argued that

government innovation policy contains a number of policy instruments to promote S&T development explicitly and implicitly. These aspects are:

"Policy instruments to build up an S&T infrastructure
- S&T planning (explicit)
- Financing of S&T activities (explicit)
- Manpower training (explicit)

Policy instruments to regulate technology imports
- Registries of technology transfer (explicit)
- Import controls (implicit)
- Foreign investment controls (implicit)
- Joint ventures (implicit)

Policy instruments to define the pattern of demand for technology
- Industrial programming (implicit)
- Industrial financing (implicit)
- Price controls (implicit)
- Fiscal measures (implicit)
- Incentives (explicit)

Policy instruments to promote the performance of S&T activities in enterprises
- Special credit lines (explicit)
- Fiscal incentives (explicit)

Policy instruments to support the performance of S&T activities
- Consulting & engineering design organisations (explicit)
- Technical norms and standards (explicit)
- Technical information systems (explicit)"

(Lee, 1988, p36)

1.2.3 Innovation and Planned Economies

If we look at the situation of planned economies, none of the existing ones can be regarded as strictly planned. There has always been certain degrees of reliance on the market, only through which centralised planning can be exercised. The reason is that there are many uncertainties and imperfect information about economic and technological activities. Any

planning could not possibly include everything. In a widely acknowledged book devoted to innovation in Soviet industry, Berliner used the Soviet case to illustrate the difference between a "perfect command economy" and a practical one. He wrote, "the Soviet economy is not as centralised as this model of a perfect 'command' economy. The state not only cannot but does not wish to make all decisions for every enterprise. Therefore it must formulate certain decision-making rules for enterprise managers. These rules have a substantial influence on the development of the economy and its effectiveness. They also exert a strong influence on the rate of innovation." (Berliner, 1978, p401)

So, what we had seen in these so-called "planned economies", should be more appropriately described as "planned market" or "organised market", although the market here is a distorted one according to its original meaning. Furthermore, if market reforms in the Soviet Union, China and East European countries are taken into consideration, it can be found that more and more market elements have been added to these former planned economies. Therefore, it seems that the distinction between a planned economy and a market economy becomes less clear-cut or critical in practice. But for the purpose of academic debate, the difference will probably remain for some time, and will be referred to from time to time.

1.2.4 The Research Framework

Pelican typified planning mechanism as hierarchies, and argued that "the technical innovativeness of capitalism is definitely not to be judged from the technical innovativeness provided by pure markets... different regimes should be judged according to how conducive they are to the formation and the development of suitable structures, which in any modern economy will most likely contain both markets and hierarchies." (Pelican, 1988, p373) He emphasised that "markets as well as hierarchies can be of very different qualities, and that some regimes may be conducive to the formation of markets and hierarchies of better qualities than other regimes." (Pelican, 1988, p373)

Pelican's argument provides a possible answer to an old question, i.e. the relative superiority of technological advance in capitalist countries could be interpreted as the result that these regimes have managed a relatively advantageous balance of markets and planning. In the same light, the present reforms in various socialist countries suggest that they are now searching for a new balance to replace the old system. With regard to innovation system, Nelson summarised three main characteristics of the capitalist innovation system, which are believed to have facilitated the innovation success. "One is the privatization of much of new technology, which harnesses profit incentives and market forces to its creation. A second striking feature is the existence of

multiple, independent, generally rivalrous sources of new technology. A third, and related, characteristic is heavy reliance on ex post market forces to select on the innovations offered by different firms, and on the firms themselves." (Nelson, 1988, pp312-313) These three factors are also those elements which reforms in China and other former planned economies are trying to introduce into their systems.

If the difference between capitalist and socialist innovation systems can be interpreted by the concept of balance between markets and hierarchies, a new starting point for innovation studies can be established. Studies could be carried out in a generic way. No matter what kind of balance an economy actually locates itself, three general parameters are identified by the author. These parameters are:

1. Actors - Companies, government agencies, research establishments or individuals etc., who are involved in the innovation system/process.

2. Arrangements - How actors are related together through a combination of markets and planning mechanisms.

3. Achievements - Performance of actors involved. This could be measured individually or collectively through patents, awards or other indicators.

Each country, due to its own unique political, economic and social condition, has different innovation actors and system arrangements. For example, company-based R&D is the main source of innovation in U.K., but in China research institutes become the dominant R&D force. There may also be different standards in judging the success of technological innovation.

Different indicators may be used. For instance, success of technological innovation has traditionally been measured by its financial returns. It appears that such a measurement, although it is one of the most easily quantifiable parameters, is far from satisfactory on many occasions. Cooper and Kleinschmidt identified three independent and strong dimensions to measure the performance of innovation. These include financial performance, opportunity potentials and market impacts. (Cooper & Kleinschmidt, 1987, p216) Social impacts of technological innovation are also important considerations. For example, governments have to consider the employment implications upon the introduction of certain new technologies.

This three-parameter framework provides a very useful tool when a complex innovation system is encountered. It will be used in the later analysis of a specific innovation system in the thesis. But before specific discussions are carried out, the existing knowledge on innovation in planned economies need to be reviewed.

1.3 Existing Knowledge on Innovation in Planned Economies

Discussions on innovation in market economies have been abundant. Respective emphases were placed on firms and markets, (Acs & Ausretsch, 1987) entrepreneurs or product champions, (Schumpeter, 1975; Madique, 1982) innovation strategies, (Utterback & Abernathy, 1975; Madique & Patch, 1982) technology cycles (Freeman, 1984) and organisational structures

(Utterback, 1982) and so on. There are also large-scale quantitative research efforts, e.g. the SAPPHO project at Sussex University and the Technology Monitor at Aston University. A list could be almost endless and it is not the aim of the present thesis to review all of them.

However, a survey of literature on innovation in planned economies shows there are considerably less discussions. As a result of political rivalry, isolation between the East and the West, made access to information on technological innovation very difficult or even impossible. Western scholars had to rely mainly on secondary materials. This situation greatly affected the extent and depth of research on technological innovation in planned economies.

Despite the overall difficulty, two Polish-origin scholars managed to give some insights. Based on two Polish empirical studies and other empirical studies, Gomulka summarised what he regarded as the distinctive characteristics of innovative activities in centrally planned economies.

> "One such characteristic is that innovating firms are motivated primarily by the need to overcome supply difficulties... The enterprise's innovation strategy would thus appear to be primarily defensive rather than offensive, with the resource-constrained rather than demand-oriented nature of the economy emerging as a key underlying factor."
>
> "The second characteristic is that not product but process innovations appear to dominate."
>
> "The third systematic characteristic is that financial incentive for undertaking an innovation is weak, and although industrial R&D personnel have

considerable freedom in their work, the decision-making freedom and the resources available to enterprises for implementing inventions are severely limited."

"The fourth characteristic is that enterprises in CPEs tend to trade off choice and quality for quantity."

"The fifth characteristic is that in CPEs the time-lag between domestic inventing and innovating is high and that the subsequent spread of inventions tends to be slow." (Gomulka, 1986, pp46-48)

Another Polish academic Poznanski, when studying the environment for technological change in centrally planned economies, echoed many of Gomulka's conclusions. His conclusions are:

(1) Centrally planned economies are less efficient in pursuing technological change.

(2) The system also appears to induce a bias for process innovations rather than product innovations

(3) Centrally planned economies have another system-related problem - slow diffusion of technological innovations.

(4) Industries in centrally planned economies are slow to shift away from obsolete technology. (Poznanski, 1985, pp32-34)

On the economic incentives to innovate, Amamn and Cooper argued that "a fundamental distinction must be drawn between the innovative behaviour of industrial firms in centrally planned economies and those in market economies. In the case of the latter, consumer demand, competition and the pressures exerted by component suppliers are powerful levers of technical change... The typical Soviet firm, on the other hand, has no strong direct relationship with its customers, and the scale of operation is such that it either manufactures its own

components (a tendency accentuated by supply uncertainties) or purchases them from non-specialist enterprises having no incentive to innovate on behalf of the industry." (Amamn & Cooper, 1982, pp11-12)

They added that, "profit and profitability are by no means irrelevant considerations, but the climate of 'neophily' and the desire for prestige (both national and personal) are equally crucial elements. The successful Soviet entrepreneur, depending upon the ambitiousness of his ideas and the scale of resources required to implement them, can receive honourable mentions in the national press, valuable state prizes or even become the acknowledged leader of a new school of thought commanding a powerful 'empire' of R and D facilities." (Amamn & Cooper, 1982, pp27-28)

On the basis of the study on automated manufacturing equipments in the Soviet Union, Baranson concluded, "past efforts of the Soviet Union to introduce technological innovation, in spite of a continuing series of economic and institutional reforms, have been inhibited by (i) an incentive system that inadequately rewards (and, in fact, inhibits) innovational efforts at the enterprise level, (ii) price mechanisms that fail to reflect the added value (and implicit risk) associated with innovation and (iii) organisational structures and rules on decision taking that do not allow production units sufficient autonomy to make innovational decisions." (Baranson, 1987, p86)

The last problem was also acknowledged by Poznanski. He believed that the manner of allocative or centralised decision making in planned economies impeded the pace and direction of technological innovation. "The way allocative decisions are made under central planning strongly affects the motivation of state-owned enterprises and research establishments to engage in technological change. The allocative mechanism puts these agents in a situation where productive factors have zero prices, a situation that inspires little interest in cost-reducing innovations or in innovations aimed at quality improvements. The lack of interest in quality improvements is reinforced by the weak influence of buyers, particularly consumers, on allocative decisions. The allocative system also isolates national agents from the influence of the world economy, delaying their reactions to global changes in relative scarcity and in tastes." (Poznanski, 1985, p52)

In the economic reforms in many planned economies, the importance of S&T development and its practical forms - technological innovation has been recognised for the following reasons: "(1) the increasing complexity of the social and economic order, (2) the increasing need for technical expertise (including managerial competence), and (3) the salvation seen in technology as a means to overcome lagging starts and admittedly ineffective administrative practices in the process of economic and social growth." (Welsh, 1978, p22)

According to Welsh, the recognition of the role of technological innovation is part of "an inexorable movement in socialist systems toward pragmatism and a problem-solving posture toward contentious issues of an economic and social nature. Orthodoxy - though not necessarily ideology - has declined dramatically in importance. Similarly, ideology is increasingly playing a rationalising, as opposed to a prescriptive, function in decision making." (Welsh, 1978, p23)

However, if technological innovation is expected to achieve full results, Hungarian, Polish and Soviet experiences suggest that economic reform must be comprehensive, consistent, and contain self-stabilising elements and/or enjoy popular support. Poznanski called for broader reform to redesign the allocative system, because "reforms limited to changes in the organisation and administrative procedures for research and enterprises - accompanied by minor improvements in such things as prices, bonus systems, technological targets, and procedures for technology imports - have absorbed much of the energy spent on systemic changes over the last decade." (Poznanski, 1985, p52)

In many centrally planned economies, the critical dilemma is that "any significant increases in productivity may mean fundamental changes in the political system. Increased productivity is linked to the introduction of new or improved products, industrial equipment and management systems (that is, innovation). In turn, innovation is linked to social

incentives at the enterprise level, which are then linked to organisational structures and policies governing basic decisions on the allocation and pricing of production factors and end-products.... All efforts to adapt or reform the system, with a view to increased productivity, run into the constraints of altering the basic tenets of the system, namely (i) the limited range of differences in income, (ii) central control over production targets, allocation of resources and price mechanisms and (iii) highly restricted autonomy in enterprise decisions." (Baranson, 1987, pp86-87)

Therefore, market reforms in centrally planned economies until 1988, have largely been incomplete and on a piecemeal basis. Peter argued that "socialist market conceptions are usually obscure because they can hardly solve the problem of double co-ordination mechanism in the same economy.... the State expects socialist entrepreneurs to behave as capitalists behave, but without capitalism. It is quite plausible that the essence of market consists of three elements: (1) mobile signal-system (of prices, wages, interests, profits, etc.); (2) mobile adjustment system of capital, labour, land, and information; and (3) universality: few separated 'partial' markets hardly can work effectively without new and newer 'manual' interventions. Just as reform-concepts do not satisfy, as a rule, the triple requirements of reform-efficiency, market-concepts within these reform ideas exclude the consistent satisfaction of these three conditions." (Peter, 1987-88, p79)

In addition, it is extremely important to note that the quality of the political leadership in promoting and guiding reform in centrally planned economy may prove to be decisive. Leung argued, "a strong, resolute and responsive leadership is a key variable, indeed the pre-condition for successful reform in Soviet-type systems has long been recognised, albeit not sufficiently emphasised, in Western literature. To prevail over the formidable barriers posed by ideological constraints, the footdragging by the party-state machineries and the absence of a natural constituency supporting reform a strong and skilful leadership is called for in order to push reform through and to adapt policies to maximise support for the movement. This demands extraordinary feats in balancing the interests of various social categories and in granting timely concessions and compromises without sacrificing the strategic goals of economic reform. The reform leaders must show great ingenuity in building a broad coalition among highly divergent social groups and in winning over or outsmarting die-hards opposing change." (Leung, 1985, p230)

1.4 Research Opportunities and Methods

Literature survey on studies on innovation in planned economies suggests that current understanding of innovative activities in these economies is far from satisfactory and lack of comprehensiveness. There are various potential research opportunities in the area.

1.4.1 Research Opportunities

It can be identified in the literatures that research on innovation in planned economies were largely conducted on the basis of secondary materials. Existing understanding of innovation processes and innovating organisations in planned economies remains partial and incomplete. The existing literature suggests a strong bias towards studies on the external climate for technological innovation, including political influence, industrial structure and social environment. But, the internal dynamics of an organisation, which have equal important impacts on technological innovation, is less weighed. If a balanced, not partial understanding of technological innovation is to be achieved, studies on both the internal dynamics and the external climate and their relationships are essential.

Previous research has also been strongly influenced by established academic perceptions, particularly on the roles of research organisations and production organisations in the process of innovation. While acknowledging that research and production are largely separated by administrative barriers as the most important distinction associated with planned economy, many researchers still adopted the conventional methods of analysing innovation in the market economy, by placing industrial enterprises at the centre of their analysis. They often found that the innovation rate was very low, and R&D was

poorly funded etc. However, this approach presumes that production enterprises are the core of innovation activities. The validity of such a presumption obviously requires further questioning. As a result of the design of R&D system in planned economies research institutes tend to concentrate much superior research resources and personnel. They should play a more important role in technological innovation. Further empirical research is required to clarify their role in the innovation process.

Due to the problems of access to quality data, many studies stayed at the descriptive level, and tended to focus on single industries or regions. Case study method was commonly used. There were very few attempts to quantitatively examine innovation performance, especially when cross-sectorally or cross-regionally. This forms a major deficiency of the past studies on innovation in planned economies.

1.4.2 China - The Research Subjects and Research Methods

If the three-parameter framework proposed earlier is brought in at this stage, it can be found that what needed is a comprehensive study by using the "actors, arrangements and achievements" framework in the analysis of a specific innovation system of planned economy. The results of a comprehensive analysis would greatly enhance our knowledge on innovation activities in planned economies. To avoid the danger to be over-stretched by the diversity of research object, the

research has to confine its focus in a particular innovation system in order to achieve the best result.

China, one of the most important and representative planned economies in the world, offers excellent opportunity for research. More importantly, China has undergone a far-reaching economic reform since 1978. Major institutional changes have occurred in both economic and innovation systems. Market elements were introduced into the R&D system. National technological plans were drafted. This could be seen as an attempt to reach an appropriate balance of markets and planning in the arena of technological innovation. Compared with Soviet Union and other East European countries, China is perhaps the only one who had managed to maintain a relatively high degree of state control, and at the same time bring in market competition into the economy. In addition, China is basically still a developing country. But, because of its sheer size and resources, it has been able to achieve technical lead in selected areas. The case of China would be of great importance, as far as innovation studies are concerned.

In the following chapters, arrangements, i.e. China's R&D system and its reform, are first illustrated. This includes planning process, institutional structure and change, and national technical plans etc.. Secondly, achievements, i.e. performance of Chinese R&D system, will be at the centre of discussion. This is primarily achieved through a database approach, analysing national patterns of technological

innovation. Finally, efforts will be spent on actors, i.e. innovating organisations. Here the focus will placed on applied R&D institutes - China's main R&D contingent, using information collected through interviews and questionnaire survey to give some insights into innovation process in China, with wider reflection onto planned economies in general.

1.4.2.1 Arrangements - R&D System in China and Its Reform

Without a thorough understanding of Chinese R&D system, it is impossible to analyse innovation process and innovation performance. It seems a natural starting point is to set up a clear picture of China's innovation system. Like other R&D systems in the world, the Chinese system can be regarded as a combination of market and planning mechanism. Especially, in the current economic reforms, significant amounts of market elements have been introduced into the old planning system. This breaks the old balance and results in considerable institutional changes. On the other hand, the Chinese R&D system is also a product of its own political, social, economic and cultural conditions. As a result, the present Chinese R&D system has to be placed in the light of these different strands of influence. In the following chapter, reforms mainly the introduction of market, institutional structure, and plans and planning process are the three key clusters of discussion.

1.4.2.2 Achievements - Performance of Chinese R&D System

It has been noted that previous research failed to offer a quantitative study of innovation performance. Difficulties may result from, on the one hand, lack of adequate data, and on the other hand, sheer amount of data processing, even when data became available.

While the second problem can be solved with the application of computers, the first problem needs more careful considerations, such as, reliability of data, representativeness of the data and coverage of the data etc. As far as this research is concerned, after careful preliminary study, data of the National Awards for Scientific and Technological Progress (1978-1988) were chosen, and database approach was used to assess innovation performance by analysing national innovation patterns. This also laid a foundation for the analysis of innovating organisations, i.e. the actors. The main reasons of choosing data from the scheme are their relatively high objectivity, wide coverage and systematic availability. This is explained in detail in later chapters.

As far as pattern analysis is concerned, it is intended to answer the following questions:

a) In terms of innovation, what are the differences between geographical regions, industrial sectors and innovation types? And what are the impacts of government S&T policy?

b) What roles have been played by organisations of different nature, such as research institutes, production enterprises and universities, in technological innovation? And what are the relationships between these organisations?

Due to the involvement of large amount of data, a special database was constructed during the research, to store, classify and analyse the data. Detailed descriptions of the database and pattern analysis can be found in later chapters.

1.4.2.3 Actors - Innovation in Applied R&D Institutes

As shown in the literature survey, few previous research actually went down to the organisation level. The present research intends to make contributions in this aspect through empirical study.

Results from the study on innovation performance through patterns of technological innovation lay the essential basis for this part of the research. In the pattern analysis, it is identified that research institutes are the main sources of innovation. (see chapter 4 & 5) The bulk of innovation activities take place there. As a result, they are the focus of studies on innovating actors and innovation process. There are a number of objectives to be achieved.

a) Enhance understanding of the organisation and control of innovation activities at the organisational level.

Identify organisational factors of influence in technological innovation.

b) Analyse the impacts of economic reforms and the market mechanism on research organisations, and how they respond to the change.

c) Assess the incentives for innovating at both the organisational level and the individual level.

Two methods of empirical research were used to achieve those objectives. The first one was a questionnaire survey of a sample of R&D institutes in China. Two industrial sectors i.e. mechanical engineering and chemical industry were selected to compare research institutes in different sectors. The choice of the two sectors was for two reasons: Firstly, the author's own expertise, and secondly, industrial sectors which were not subject to detailed research before. Due to the author's own engineering background, manufacturing industries were favourite choices. But there has been a detailed study of China electronic industry by D F Simon & D Rehn. As a result, mechanical engineering and chemical industry were chosen. 46 R&D institutes in mechanical engineering and 44 in chemical industry were surveyed. All of them were selected from the database of award-winning innovations constructed in the research. Details of the database and questionnaire are outlined in later chapters. The distribution and collection of questionnaires were administered with the assistance of officials within the SSTC.

The second method of empirical research was semi-structured interviews with 38 researchers from various R&D institutes. Because it was not possible to conduct emprical research in China in the summer of 1989 due to unsettled political situation, the sample of the interviewees was identified through personal contacts in UK. All of the interviewees were studying or doing research at UK universities. During the interviews, the interviewees asked to keep their names anonymous. In order to carry out the research, this was agreed. But broad indications of the interviewees are: they are mostly from award-winning R&D institutes in various provinces; their technical ranks vary from assistant engineer to chief engineer. The duration of each interview was about 45 minutes to 1 hour. All interviews were recorded. Information drawn from the interviews was used in many parts of the thesis but only those of better quality were transcribed. Details of the interviews can be found in Appendix A.

CHAPTER 2 R&D SYSTEM IN CHINA AND ITS REFORM

First of all, it is worth noting that different terminologies are used by different researchers, but in fact, refer to the same system. The R&D system in China is sometimes be termed as the scientific and technical planning system, or as the S&T system , or the innovation system. They may arguably carry different meanings, but in this research they share interchangeable meanings.

Before moving on to details of R&D system in China and the changes brought about by the economic reforms. It would be useful to look back to see what the existing knowledge on innovations in China are. This could supply us some background and help us to understand a truly complicated system.

2.1 Existing Knowledge on Technological Innovation in China

As a result of frequent political interference throughout the entire history of Communist China, the development of S&T was an uneasy one. The early dependence on and the later withdrawal of Soviet technical assistance in 1950s and 60s forced the formation of a largely self-reliance policy for S&T. There were very limited contacts between China and the outside world. This situation made access to information on technological development in China difficult and sometimes impossible. Consequently, most of the studies until recently have had to depend heavily on incomplete and secondary

information. (Dean, 1979) For similar reasons, studies on S&T development were by large qualitatively descriptive and less quantitatively analytical. (Sigurdson, 1980)

Since late 1970s, with the announcement of the "open door" policy and the Four Modernisation programme, the development of S&T has been given national priority in the modernisation drive and seen as the foundation for rapid economic development. As a result, studies on S&T policy, technological innovation and their relationships with economic development became of great interest to both Western and Chinese researchers as well as policy makers.

2.1.1 Innovation and Politics

Technological innovation and S&T development can never be treated separately from political movements in China. There have always been conflicts between two fractions, i.e. the radicalist and the pragmatist over the view how S&T and innovation should be developed. (Tang, 1984, p29)

On the one side, the Maoist or "radicalist" wing represented the revolutionary fraction. They "have tended to give highest priority to the need for continuing ideological and social change. Their aim is to achieve nothing less than a fundamental spiritual transformation of values, designed to inculcate China's population in a new revolutionary morality and ethics. Their hope is to create a population of activists

wholly dedicated to revolutionary change and willing to subordinate personal and parochial interests to the collective good."(Barnett, 1977, p205)

As a result of political indoctrination, technological development was also regarded as political task, to be achieved by political motivation. This belief formed the basis of Mao's belief in "mass science and technology". He emphasized mass participation, egalitarianism, self-reliance, and indigenous scientific and technological development. "Campaigns involving political mobilization and ideological exhortation rather than scientific study and laboratory experiments were supposed to achieve desired technological breakthroughs." (Simon & Goldman, 1989, p8)

The other fraction can be called Non-Maoist, or "pragmatist" "Non-Maoists have tended to be less visionary, and more empirical in trying to solve problems, usually focusing their attention on concrete immediate problems. They are generally more willing than the Maoists to compromise when encountering obstacles and more predisposed to adjust ideals to intractable social realities. Chinese Non-Maoists have tended to favour rapid but relatively orderly, incremental economic development and social change."(Barnett, 1977, p205)

The post-Mao policies of economic reform are clearly characterised by the pragmatist approach. Compared with the revolutionary fraction, the pragmatists tended to be more

attracted to economic development, rather than putting political class struggle at the highest priority. While the Maoists were trying to achieve social development through continuing promotion of ideological consciousness, then moving on to promoting economic growth; the Non-Maoists were experimenting to achieve social development through steady economic growth, then reaching coherent promotion of ideological consciousness.

The difference between revolutionists and pragmatists also lay in whether S&T carries "class character". The pragmatists believed that "science and technology had no class character. China could borrow both from wherever it was available, but the Chinese social system would decide how and for what purpose science and technology could be used."(Deshingkar, 1985, p29) However, revolutionalists emphasised that technical innovations can only raise from production practice, through stages of perceptual knowledge, rational knowledge and then conceptualisation. Another difference lies in the use of market concept in S&T development. In the post-Mao period, S&T is treated as an exchangeable commodity, that is to be sold and purchased through market.

2.1.2 Innovation, Culture and Society

Aspects of Chinese culture were also relevant to the R&D process. As Lockett pointed out: "(1) Respect for age and hierarchy; (2) Group consciousness, especially of the family

but also other groups; (3) 'Face', the recognition of one's social standing by others; (4) Importance of relationships, personal connections and an ongoing relationship (Guan Xi) rather than relying on law in business deals."(Lockett, 1987[a], p25) Moreover, a new dimension of regional culture revealed the plural nature behind the unified Chinese culture in general. A critical point is that many regions in China had experienced a different history in the past development. Some were occupied under foreign colonists; some were more agriculturally self-contained. Therefore, regional cultures were formed under their own special historical conditions. Those cultural factors played their roles in the process of technological innovation and development.

The social organisation of people into tight control of work units proves to hinder technological innovation. Suttmeier argued, "the role of the work unit, or "danwei", in its appropriation of technical knowledge and control over the movement of personnel, is one of the most serious obstacles to the modernisation of S&T. From the viewpoint of central authorities, it is also an obstacle to policy implementations. Yet, the power of the work unit lies in the fact that it supplies housing, medical care, and retirement benefit which are not readily available to the individual through other means. Efforts to erode the power of the work unit by the establishment of national social-security schemes, for instance, could have important consequences for state-society relations." (Suttmeier, 1989, pp383-384)

2.1.3 Innovation and Policy

Since 1949, China has experienced fundamental social, economic and technological changes. Rawski examined these changes and suggested that past Chinese technology policies played a determining role in technological development. The deliberate policy of giving priority to heavy industries succeeded in the sense that it provided China with a fairly independent industrial basis, although at the expense of uneven development in other industrial branches. This massive expansion of large-scale heavy industries during 1950s under Soviet assistance had significant effects on the later stages of technological development. Having examined the pre-civil war industrial development in the Republican China, Rawski reached a conclusion that "the contribution of pre-war development to industry's subsequent achievements underlines the long-term nature of the industrialisation process [in China]".(Rawski, 1980, p219) The combination of these two factors heavily influenced the direction and pace of technological development.

Geraedts studied policy making process in China and classified it into three different levels: (A) The first type, the highest level, is called "formal or intended policy". (B) The second type, next level downwards, is called "rhetorical policy", or interpretive policy, which is actually an interpretation of the formal policy. (C) The third type, and the lowest level, is that of "actual or implemented policies". (Geraedts, 1983, p125) Inertia or influence of past policy

often existed for a quite long time. Thus, any interpretation of policy changes based merely on official information can hardly present the actual practice, and often lead to misunderstanding. At the same time, changes in leadership at the top level in many cases caused significant reversals in policy directions. (Geraedts, 1983, p124) It is not surprising to find that the policy changes in China are swift and difficult to follow.

Suttmeier discussed recent Chinese S&T policy and the environment in which it operates. In his opinion, current policy changes encouraged needs for greater S&T manpower and called for closer co-operation with Western countries on S&T development. He expressed the view that the Chinese S&T development programme "can be thought of as having four main components: (1) industrial reform, including important improvements in the treatment and official status accorded technical intellectuals; (2) a national research plan expressing research priorities; (3) educational reform and plans for manpower development; and (4) initiatives designed to establish active scientific and technological relations with other nations, particularly the advanced capitalist countries". (Suttmeier, 1981, p22)

2.1.4 Innovation and R&D Structure

In the existing literature, R&D structure is probably the subject most written about. China's present scientific and

technological structure was adopted from the Soviet Union in the early 1950s, and remained without fundamental change. This system is strongly vertically-chained, by levels of administrative organs.

Simon commented on this centrally controlled system. Clearly, "the centrally orchestrated, plan-oriented, Soviet model of science and technology development was inappropriate for PRC needs... In addition, the vertical structure of the research system, promoted compartmentalisation rather than co-operation, communication and co-ordination. While a highly centralised task-oriented mode of organisation was conducive to accomplishing such major projects as the development of atomic weapons, it was not appropriate for stimulating the type of innovative behaviour that leads to new and better quality products or more efficient production processes".(Simon, 1985, pp65-66)

There are generally four levels in Chinese R&D system, according to Fischer. "At the highest level the State Science and Technology Commission (SSTC), in co-operation with other commissions, such as the State Economic Commission (SEC) [no longer existing] and the State Planning Commission (SPC), establishes and supports national science and technology plans... The next level involves the ministries which are responsible for the various industrial sectors within the economy... The third aggregate level within the Chinese system involves the industrial and regional decentralization of

ministerial activities. This occurs at the provincial level... The fourth level in the industrial hierarchy is that of the enterprises themselves".(Fischer, 1983[a], p65)

Apart from the above discussion of a top-down planning system, Fischer also argued elsewhere that the Chinese S&T system is, in essence, a bottom-up planning system. Except for those projects of national priority, the S&T plans were actually initiated by factories' chief engineers, and then reported to the higher administrative level. The whole planning system seems to be merely a fund allocation, negotiation and file compilation process.(Fischer, 1983[b]) This situation reduced the advantages of central planning and encouraged those of sectoralism and regionalism.

This vertically connected structure is under re-organisation in China. On the one hand, the lower levels are given greater autonomy; on the other hand, lateral links between horizontal units are encouraged, especially the co-operation between research and production organisations. The emergence of "commercialisation of research" and "joint research-production entity " confirms this trend.

In a vertically-chained system, as a result of lack of horizontal communication, the most achievable resources are either from superior level of administration or from sub-ordinates. Because of competition over scarce resources, each organisation is trying to build up its own jurisdiction as

independently as possible. With the establishment of such self-contained units, central control is sometimes sheltered away from access to the lower level, or sometimes only has limited impact. This creates a situation where on the one side, the central government tries to control everything as a whole; on the other side, local organisations try to defend their own self-sufficiency. Nevertheless, these two elements are interlocked in an extremely complicated manner. Lieberthal and Oksenberg argued, therefore, "two popular concepts of the Chinese system that it is highly centralised (Beijing-in-command) or a cellular system with considerable local autonomy are both inaccurate... Negotiations, bargains and exchanges, in short, are essential ingredients of the Chinese system". (Lieberthal & Oksenberg, 1986, pp27-28)

2.1.5 Innovation and Decentralisation

The Chinese authority had hoped that decentralisation would bring a number of benefits. Greater operating autonomy of industrial enterprises and research institutes, firstly, would eliminate a considerable amount of administration in a vertical system. Secondly, promotion of horizontal links between research institutes and industrial enterprises would create an environment of market competition. Thirdly, through economic leverages and market mechanisms, these organisations' dependence upon the State would be reduced significantly. Also, by introducing direct contacts between the research and production sectors, technological innovation would become more

one of "demand-pull" than "technology-push". However, a simple decentralisation could not solve all the problems. Besides, decentralisation itself also creates new problems, such as repetitive research, barriers for information sharing and risk-averse decisions etc. As a result, an appropriate balance between centralised co-ordination and market self-adjustment has to be articulated by policy-makers in the subsequent decentralisation process.

With regard to centralisation and decentralisation in China, Leung wrote that "both elements are probably present in varied, uneasy combination at all times. Constant shifts can and do occur differentially, and in one direction or another. These reflect the dialectical nature of the local prefects in these systems. Most importantly, since regions in these systems do not actually enjoy entrenched rights or areas of jurisdiction that are constitutionally guaranteed, there is no recognised permanent division of power in these systems. Whatever power the centre allows to be devolved to the local levels, it remains the ultimate right to intervene and take back whenever it feels necessary. Decentralisation in these systems is therefore not decentralisation in the Western sense, which implies a strict demarcation of spheres of jurisdiction for different levels of government, but rather measures of de-concentrating power contingent on the centre's current policies and preferences. Finally, the degree of 'indeterminancy' is further compounded by centralisation or decentralisation in another."(Leung, 1984, pp157-158)

From this point of view, the current Chinese decentralisation can only be seen as an economic purpose-oriented policy, rather than a politically structured or constitutionally guaranteed one. Leung's point of view represented sincere doubts on the credibility and continuity of China's decentralisation policy. The experience since 1988 partly proved his doubt in this regard.

2.1.6 Innovation and the Market

However, such measured decentralisation may be a deliberate attempt by Chinese policy makers. It is argued by Goldman & Simon that "China's reforms are following this 'two-pronged' strategy for bringing about fundamental improvements in science and technology system. China has introduced 'market forces' as tools for stimulating scientific advance and technological modernisation. And, at the same time, it continues to rely on centrally directed control over research in key areas to promote rapid progress in important economic and military sectors." (Simon & Goldman, 1989, p16) China's current S&T development policy combines elements of both market competition and state control. This type of mixed strategy, as suggested by the experiences of South Korea and Taiwan, may not necessarily bring about rapid technological advance and technical competitiveness. But it may help China to retain freedom of choice and make incremental changes in the appropriate direction.

Nevertheless, the Chinese have been trying to use market mechanism to encourage more technological innovations. As argued by Conroy, "because of the effective absence, until recently, of the market, commercial competition, private (institutional) ownership of knowledge, and profit as important criteria of innovation decision making ... The main generator of new S&T knowledge in China is a formal research sector ... The main agent for transforming this knowledge into products/technology is the production sector ... The state controls the development and orientation of research and development (R&D) through the planning of research topics and allocation of resources. It also largely controls the demand for new technology through decision making on what new products and processes are to be manufactured". (Conroy, 1984[a], pp2-3)

Fischer argued that "Even where market forces are introduced, in a country as big as China, where demand has traditionally exceeded supply and where, under central planning, there was little or no incentive for managers to manage anything other than factory operations, it should not be taken for granted that market forces will induce the desired result. In fact, statistical analysis to differentiate between those enterprises that perceive market influences as being important and those that do not suggest that it is the level of formal education of the manager of the enterprise that is the most important variable in explaining the perceived importance of market influences in the enterprise's planning. Introducing

market forces into an economy, therefore, will be far less effective in stimulating innovation and industrial change if the managers in that economy are not predisposed, through education and incentives, to recognize the opportunities inherent in such market influences and respond to the new operating environment." (Fischer, 1989, p133)

Both direct and indirect means have been employed. The use of direct intervention possesses a straightforward effect, and enables the policy maker more effective control over the expected outcomes. But direct interventions will not bring fundamental changes to a centrally planned economy in order to achieve marketisation. Indirect approaches, or interpreted as operating through market mechanism, can fundamentally change the overall operating environment, and bring much more significant impacts than mere limited direct interventions. What of vital importance is the creation of an appropriate macroeconomic environment through the establishment of indirect inducements for innovation through market-type mechanisms. This is probably regarded as the single most effective policy intervention that can be undertaken to encourage and support industrial innovation in the Chinese context.

A study on Soviet innovations carried out by Amamn and his colleagues at the Birmingham University claimed that process innovations are favoured under centrally planned economy. (Amamn & Cooper,1982) Two Polish academics, Gomulka and Poznanski, also reached similar conclusions from their

respective research on Polish innovations. (Gomulka,1986 pp46-48; Poznanski, 1985 pp32-34) As far as China is concerned, Fischer pointed out, there is a "continued preference for process innovation rather than product innovation. Part of this is probably attributable to the lower need for product innovation in markets where demand exceeds supply. A second reason may be the strong engineering and manufacturing background of Chinese industrial managers, who are more used to pursuing cost reductions than new product development. Third, since process innovations qualify for preferential treatment in capital availability and political approval, given the current emphasis on 'technological transformation', it is not surprising that it is relatively more attractive to the manager than the more risky product innovation. A fourth possible reason is the difficulty caused by product failures in a geographically large market with inadequate channels of repair and resupply. Such conditions make both innovator and consumer wary of new, untested, technologies." (Fischer, 1989, p129)

2.1.7 Some General Points on Innovation in China

Having examined different aspects of Chinese R&D system, Suttmeier made several general propositions with regard to technological innovation in China.

Firstly, "China has the institutional capacity to mobilize the talents and the material resources required to achieve high-priority national security objectives. Yet, the general inability to bring R&D results into commercial application is symptomatic of a Chinese political economy ill-suited to technological innovation."

Secondly, "The fragmentation we see in these (infrastructure) technologies suggests an underlying institutional or political fragmentation, revealing a disjunction between the pretensions of a strong centralised state and the institutional requisites for technologies needed to make such pretensions credible."

Thirdly, sometimes "higher authorities or central coordinating bodies had severe difficulties coping with entrenched ministerial power."

Fourthly, "the existence of a 'technological nationalism' in which 'choice-of-technology' decisions are expanded beyond the bounds of strict economic, or even more general instrumental, rationality to include considerations that seem to have both political and psychological overtones... The tension is between the perception of the technical superiority of the foreign technology and the belief that China should be able to provide all or most of these systems itself."

Finally, political instability causes "the existence of widespread anxieties and insecurities, social mistrust, and normlessness... These characteristics would, of course, also work against the successful operation of the technologically and organisationally complex enterprises." (Suttmeier, 1980, pp377-379)

In a later separate study, Suttmeier identified four key issues in relation to the attempts to promote technological innovation in China.

1) "The Issue of Centralisation" - "China's political system has yet to find the 'right formula' for the relationship between centralisation and decentralisation of its political and administrative institutions. The reforms of the 1980s in the economy, in S&T, and in the political system more generally, while portrayed as decentralizing, also have the objective of increasing effective central power."

2) "The 'National-Security State'" - "Given the central political role of the military in the past, and the fact that so much of the nation's investment and R&D had been committed to the military... A central issue facing the post-Mao leadership has been the extent to which the national-security state should be disestablished."

3) "The New Elite" - Economic reform has brought about the emergence of a more educated and technocratically inclined elite. "There seems to be a bifurcation in the leadership between those who have backgrounds in economic work and those

with engineering backgrounds. We would expect the former to approach the evaluation of policy options with criteria of economic efficiency and cost-effectiveness; for the latter - with more of a technocratic orientation - orderliness, control, and technical efficiency would be the relevant criteria."

4) "State-Society Relations" - "We would expect to see changes in the formal/legal proscriptions on the powers of the state... The interest in law seems more directed to the creation of the proper infrastructure for economic development, and to the prevention for future arbitrary exercises of power by wilful individuals. ... The new interest in law could, however, indirectly lead to some eventual limitations on the state... As economic growth proceeds and the economy becomes more complex, it will become increasingly difficult for the state to control it without expanding its own control apparatus."(Suttmeier, 1989, pp 379-383)

2.2 Science and Technology Policy and Reforms

China has experienced many policy changes since 1978. A number of important Government and Party conferences were convened to set the direction for both economic and scientific development. The leadership in China considered that S&T activities could not be separated from politics and economics. In fact, changes in general political direction laid the basis on which reforms of the S&T system were carried out. One fundamental guideline since the Third Session of the 11th Congress of the Communist Party of China (CPC) in December 1978 has been to link S&T work to economic and societal development.

The post-1978 period can be further divided into two phases. The first phase (1978-1984), when the primary efforts were: (a) to draw up a national plan for S&T development, (b) to establish an award system for S&T achievements, and (c) to rationalise the S&T organisational structure. The second phase (1985-1988) was marked by the issue of "The Decision of the

Central Committee of the CPC on the Reform of S&T management system" in March 1985. Overall reforms of the S&T system were introduced in this period, including (a) the R&D funding system, (b) new S&T legislation, (c) the stimulation of commercialised technology transfer through a "technology market", (d) changes in the S&T personnel administration system and (e) policies to encourage rational technology importation.

Great caution was observed in the formation and execution of reform policy. Policy makers seem to believe that rush decision may result in uncontrollable outcomes. Due to the experience of the Cultural Revolution, Chinese society has a tendency to seek short-term benefits, the predominance of self or group-interest consciousness and low responsiveness to ideological or administrative propaganda. This is reflected in a strong desire in the policy making process to balance needs and likely reactions from different interests with the aim to achieve stability, which in turn will strengthen the power structure in the reform process. Balance and negotiation, are the most prominent characteristics in Chinese policy making in the post-1978 period, to reassure different political and social groups.

2.2.1 Ideological and Political Rethinking

In recent years, scientists and technologists have been granted the right to play more important roles in national and regional policy making processes. The establishment of various

policy research organisations under different levels of government characterised the recent policy and its technocratic implementation.

However, this policy to incorporate more technocrats into the decision making process has one obvious dilemma. As Simon argued, "the Party seeks control to achieve these ends [effective use of intellectuals]; scientific and technical personnel seek autonomy. In the PRC, as in the Soviet Union, the effort to incorporate the scientific and technical community into the policy-making apparatus will, in all likelihood, alter the character of the party-S&T relationship and give new definition to the nature of political authority. Yet the extent and pace of change will continue to be a source of tension for some years to come." (Simon, 1985, pp75-76) He believed that "the ongoing attempt to incorporate more scientific and technical personnel into leadership ranks at all levels could also have important implications for the evolving nature of the PRC political and social systems." (Simon, 1985, p76) In his opinion, the ongoing attempt in China "is not simply to co-opt this group [S&T personnel], but rather, in some respects, to have them 'co-opt' the party." (Simon, 1985, pp76-77)

The post-1978 Chinese theory about the role of S&T for economic development has been redefined with strong pragmatic characteristics. S&T are regarded as productive forces. There is no longer a difference between socialist S&T and capitalist

S&T. Further, scientists and technologists are recognised as working people. These ideological changes resolved a long existing dilemma to obtain the full co-operation of the S&T community. Chinese newspapers claimed it as a development of Marxist-Leninist theory according to Chinese practice. It was seen as the first pragmatic attempt to bring new elements into Chinese guiding ideology. Meanwhile, China has adopted other theoretical innovations including the acceptance of market mechanisms and even a new theory of the primary stage of socialism, delivered in a report by Zhao Ziyang, the Party's General Secretary then, at CPC's 13th Congress in November 1987.

2.2.2 Reform of R&D Management System

It has been gradually realised that the most severe bottlenecks which constrained technological innovation and its integration with economy are managerial inadequacy and organisational structure deficiency. Ideological recognition of S&T only solved part of the problem. As a consequence, a National Working Conference on S&T was held in March 1985, which marked the beginning of reform in the S&T management system. Top leaders like Deng Xiaoping and Zhao Ziyang addressed the meeting. The "Decision of the Central Committee of the Communist Party of China on the Reform in S&T Management System" was issued several days after the conference. The Decision was based on several years' small-scale pilot experience. Most aspects expected to be changed in the reform

were included in the Decision.

As a directive, the Decision emphasised three major areas. (1) Reform of the operating system, which entailed reforming the funding system, establishing of a technology market and overcoming defects in the administrative control over S&T activities. (2) Reform of the organisational structure, which implied enhancing the integration of organisations under different jurisdictions and strengthening enterprises' capabilities to absorb and develop new technology. (3) Reform of the personnel system, which aimed to achieve optimum use of talented people by means of rational job mobility. (White Paper No.1, 1986, Appendix)

2.2.2.1 Reform of the Operating System

As far as the funding system is concerned, state expenditure on S&T will be increased steadily, but it will be allocated in a different way. Instead of all research institutes receiving operating funds in the same way, they are categorised into three broad groups, i.e. developmental research, basic or applied research, and public services.

On the operating expenses for funding research in various types of research institutes in order to make research institutes more financially independent, the State Council stipulates the following guidelines:

"1. Units engaged primarily in technology development which is expected to have practical value within a short term shall receive reduced government funding for operating expenses for scientific research year after year during the Seventh Five-Year Plan period until a time when such funding is basically or completely suspended.

2. With units that are primarily doing basic research or applied research which is not expected to achieve practical value in a near future, their research funding shall become gradually dependent on applying for science funds, with the State giving only a limited amount of operating expenses so as to ensure regular expenses and expenses for public facilities.

3. Research institutes engaged in such public services as medicine and health, labour protection, family planning, calamity prevention and control, environment sciences, and other units engaged in technical basic work or information, standards, measurements and observations, and agricultural research units shall continue to receive state funding for operating expenses under the system whereby they are totally responsible for their surpluses and deficits." (White Paper No.2, 1987, p15)

In addition to these funding guidelines, the State Council also encourages units engaged in various kinds of research to obtain funds from a variety of channels in the light of their specific circumstances. "With respect to the funds conserved through cut-backs on the operating expenses for research institutes, two thirds shall be retained by the competent departments under the State Council for technological work in particular industries or trades and for major national research projects, while one third shall be retained by the State Science and Technology Commission for use as funds with deducted interest for S&T credit loans and loans for the whole country. (White Paper No.2, 1987, p16)

The technology market is an important institutional change introduced in the S&T reform. The term carries a conglomerate

of practical meanings in relation to market-based technology trade, which includes exhibition fairs, technical services and research contracts etc. "In essence, the technology market refers to the sum of the relations between exchange of intellectual commodities." (White Paper No.1, 1986, p237).

Technology markets are claimed by the Chinese press to have played an active role in the current reform in Chinese press. There are a number of rationales behind such an institutional change. First, technology markets serve as an effective means to transfer research results into production applications. In so doing, research institutions obtain the funds required for further research, while production units improved their technology or product design. Second, they brought the market mechanism into S&T activities, which in turn should encourage rapid development in S&T research and rapid application of new technologies. Third, they removed rigid administrative barriers so that organisations in different administrative sectors could easily communicate.

Since the First National S&T Fair held in Beijing in 1985, various technology fairs have been organised all over the country. Over 1,100 exchange centres were set up, which diffused S&T information throughout the country. In 1987, over 130,000 technical contracts were made, amounting to a total of 335 million Yuan [Chinese currency unit, roughly £1 = 7.3 Yuan at the time], which is a 60% increase over 1986. Statistics reveal the technology market pattern in 1987: (1) Research

institutes and enterprises are the major suppliers in the markets. Research institutes take 38% of the market share. But technology supplied by enterprises are mature and of quicker application, and therefore welcome. (2) The majority of the technology transfers are towards industries. (3) Enterprises are the major buyers, taking 42% of the total, in which 53% are bought by state-run big and medium enterprises. (People's Daily, 23/2/88, p1)

According to the official White Paper No.2 on S&T, technology market "not only plays an important role in promoting our scientific, technological and economic developments, but also gives rise to the change of social ideas." It is thought that the technology market has helped people to acquire or realise the "sense of value", the "sense of orientation towards the economy", the "sense of market" and the "sense of operation [running business]". (White Paper, No.2, 1987, pp66-67) However, there are still factors hindering the development of technology markets. Firstly, the irrational price system has caused complaints from all parties. Secondly, legal responsibilities concerned parties in the contract are not clearly confined by law, but by administrative regulations, which are very liable to change. Thirdly, administrative interventions in many cases remain the most decisive method.

2.2.2.2 Reform of the Organisational Structure

The reform of the organisational structure encouraged

close integration between research and production organisations from different sectors and localities. Four major types of co-operation are particularly promoted: (1) Between research sector and production units; (2) Between developed regions and less developed regions; (3) Between the military sector and the civilian sector; and in a broader sense (4) Between advanced countries and China. These co-operations are in fact technology transfers, from technologically more developed areas/sectors to technologically less developed ones.

One important component of the Decision of CPC is that greater decision-making power is granted to research institutes. A system under which directors of institutes assume overall responsibility was introduced, while party branches in such organisations were recommended as only responsible for political or ideological work. This policy was further confirmed at the CPC's 13th Congress in November 1987, by the slogan: "Separating party leadership from governmental administration and economic activities". However, because the Party has assumed governmental functions since the very beginning of Communist China, the implementation of this policy requires drastic changes in ideology, administration, the political system and people's perception. This requires painstaking efforts. Changes in China since 1989 indicate that this is going to be a long process. At the moment, only partial separation and delegation of power appear to be feasible.

2.2.2.3 Reform of the Personnel System

In the area of personnel system reform, a number of changes have been witnessed. Deng Xiaoping's statement on the social role of scientists in 1978, changed political attitude towards S&T personnel. Thereafter, a series of policy adjustments placed them in a more legitimate position. In July 1984, a system of "job appointment" was piloted in a number of research institutes. This meant that research institutes could choose competent persons for specific jobs. Meanwhile, scientists and technologists could select jobs which suit their interests and ability. The job assignment system was also reformed, which began to allow scientists and engineers in misplaced jobs to transfer to more suitable ones instead of rigid job allocation. This also gave the flexibility for people working in an institution with surplus manpower, to be able to transfer to other places where S&T expertise are in short supply.

By 1985, 1,203 personnel exchange centres had been set up nation-wide; (White Paper No.1, 1986, p108) 285,000 successful transfers were completed from January 1983 to December 1986. (People's Daily, 18/12/87, p1) It was reported in the People's Daily that from January 1984 to June 1987, research institutes had a personnel outflow of 61,000, universities an inflow of 4,400; big and medium size enterprises an outflow of 74,900. (People's Daily, 23/12/87, p1)

Another important change in personnel administration is that S&T personnel are permitted to undertake secondary jobs, provided they have already fulfilled job allocations in the institutes they are attached to. This is regarded as a feasible measure to fully utilise the scare S&T manpower in China and to bring S&T research closer to economic needs.

2.2.3 S&T Policy in the Economic Reform

In general, the development policy for S&T in China since 1978 has adopted a pragmatic approach. The old all-out politicised approach for technological development was abandoned. Priorities have shifted from heavy industries to a number of key new technical fields and to overall balanced development of economy as a whole. The development pace has been adjusted according to the existing technological conditions. In general, a much more cautious and realistic guideline was followed in drafting China's S&T policy for technological innovation in the 1980s. An eminent Chinese economist, Liu Guo Guang presented his views which are shared fairly widely.

> "In terms of choice of technology, our long-range goal is to apply the most advanced science and technology to all sectors. But in view of existing conditions, it is impossible to attain such a goal by the end of this century. Therefore, we should first popularise advanced technologies that suit our needs, create a multi-level technological structure, hold to the strategy of combining automation and mechanisation with semi-mechanisation and hand labour, while steadily increasing the proportion of advanced technology." (Liu, 1984, p53)

He argued more specifically, that the most sophisticated

technologies should be used as much as possible in key sectors and for turning out key products; intermediate technologies should be applied in less important sectors and for turning out ordinary products; other sectors should keep to their existing production technologies. The technical level within the same sector and among enterprises will also differ. (Liu, 1984, pp53-54)

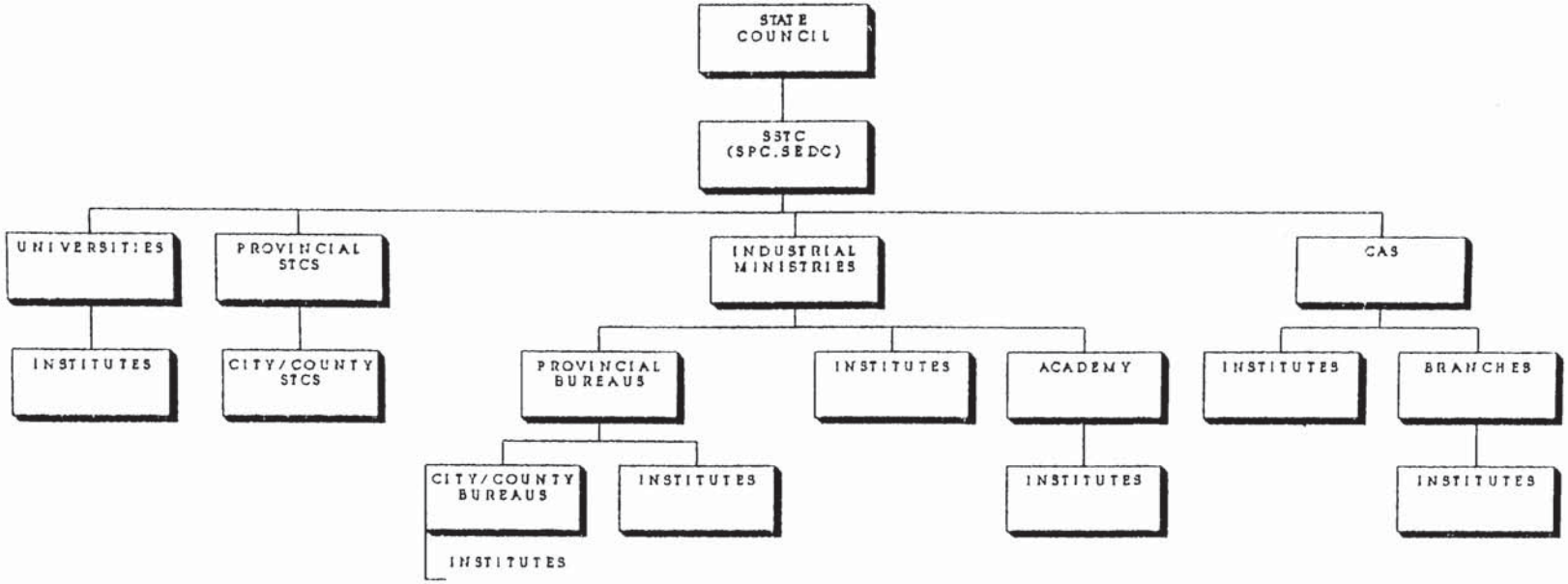
On technology imports and technology transfer, Liu suggests "The import and dissemination of science and technology and their application to production must be integrated into a closely linked and co-ordinated network. In importing advanced technologies various departments and regions must carry out technological transfer among themselves so as to raise the technical level of backward regions and departments. This will enable us to solve the contradiction between our development objectives on the one hand, and insufficient funds and backward technology on the other, and to make use of our limited manpower, materials and money in urgently needed and cost effective projects." (Liu. 1984, pp53-54)

2.3 Institutional Structure of R&D System

2.3.1 R&D System in General

The institutional context of R&D in centrally planned economies is the most fully explored one in previous studies on innovation in centrally planned economies. Strong vertical

FIG. 2.1 R&D SYSTEM IN CHINA



The R&D system in China can be described in another fashion. R&D capacities are organised into five different sectors, namely, the Chinese Academy of Sciences (CAS), the industrial ministries, the higher education sector, the defence research sector and the local research sector. Figure 2.1 illustrates the general design of Chinese R&D system.

Both classifications are based on the administrative structure of the Chinese R&D system, and are useful to help us understand how the Chinese R&D system is working. However, they have problems in many aspects, even though they are popularly used.

First of all, the Chinese R&D system follows the Soviet R&D model, which is closely related to the "science/technology push" mode in the linear model of technological innovation. The logic behind the original design was that universities provided S&T manpower to research institutes; CAS generated basic scientific ideas; industrial research institutes supplied applied technologies; production enterprises manufactured products. The whole Chinese R&D/industrial system was planned in a <u>self-contained</u> fashion. All industrial ministries are equipped with their own universities, research institutes and production enterprises. Provinces replicate the State structure at a reduced scale.

Secondly, research institutes, universities and industrial enterprises are structurally separated from each other. In the

cases of the Chinese Academy of Sciences and the institutions of higher education under the State Education Commission, they are completely external to industrial ministries. Even within the industrial ministries, it is a common practice that research, production and training are supervised by different functional departments. Industrial enterprises are normally administered by the department of a certain product family; research institutes are administered by the department of S&T; universities are supervised by the department of education.

Thirdly, it is, in fact, very difficult to identify organisationally a complete independent defence R&D sector in existence in China. Defence-related R&D undertakings are co-ordinated by the State S&T Commission for National Defence, but are largely performed by research organisations in industrial ministries and the Chinese Academy of Sciences. The Commission has very few research institutes and conducts little R&D entirely by itself. Since, industrial ministries perform both civilian and defence research and production, two types of control exist within industrial ministries and create corresponding organisational difficulties.

Fourthly, there are confusions in the definition of the higher education sector. Since every ministry has its own universities, the State Education Commission has, in fact, only controlled the administration, personnel and finance of a small portion of Chinese universities. It seems that the definition of the higher education sector should be extended to include

these "ministerial" universities, if an analysis to this sector is going to bear substance rather than merely superficial meaning.

Finally, many local research institutes are subordinate to industrial bureaux at the provincial or municipal level. Since these industrial bureaux are local representatives of their respective industrial ministries, local research institutes are still controlled by central ministries, although local governments may assert significant influences and their research preferences are more directed towards local needs.

Here, a preliminary conclusion on Chinese R&D system can be reached. The Chinese R&D system is, in essence, a centralised system, and is largely following the classical "science/ technology push" model. Universities, research organisations and production enterprises are structurally separated and administered.

There are three pervasive rationales behind the design of Chinese R&D system. Firstly, the classical concept of "science push" influenced all Soviet-type systems. Secondly, the guiding principle of socialist economic theory argues that centralised planning provides more efficient and effective use of resources and scientific/technical research results. Thirdly, there was enormous reconstruction work and a poor industrial, technical and economic basis when the Communists took over power after a long period of wars. In order to re-build national R&D

capacity, China had to use its limited resources in a selected and centrally controlled way.

Even the Chinese system is organised largely in a self-contained manner at different levels, and departmentalisation is widely regarded as one of the most severe drawbacks, within each self-contained sub-system, where levels of administration have been reduced, co-operation between different units in some cases could be unexpectedly high.

As far as industrial enterprises in centrally planned economies are concerned, their primary role is to produce, not to innovate. Technological innovations, according to the socialist division of labour, are duties of research organisations. Therefore, industrial enterprises are structurally excluded from the group of R&D performers. Instead, they become the key player in supporting and facilitating technological innovations by turning research results into commercial products.

Government intervention plays a much more active role in technological innovation in centrally planned economies than in market economies. Government departments often directly get involved in the innovation process, particularly in large technological undertakings.

Considering the original design and current situation, the China's R&D system can be better presented by only three main

categories, namely, the Chinese Academy of Sciences, the higher education sector and the industrial research sector.

2.3.2 Chinese Academy of Sciences (CAS)

The Chinese Academy of Sciences is the most prestigious research organisation in China since its founding. Over the past forty years, its role in the Chinese R&D system varied a great deal at different times. At the very beginning, it was not only the centre for scientific research, but also the centre for S&T policy making. The latter role has now been taken over by the State S&T Commission. Its research areas have also diversified from pure basic scientific research to a mixture of scientific, applied and developmental research. In recent years, CAS has directly involved in the commercialisation of technology, provision of technical service etc.

The CAS has 123 research institutes and nearly 67,000 employees, and more than half of its employees are engaged in R&D. (SYB, 1988) Total research expenditure in 1987 amounted to 88.6 million RMB Yuan. "Around 15% is devoted to basic research, a little under 50% to applied research and about 35% to developmental research". (Saich, 1989, p66) Its academic council consists of more than 400 China's most distinguished scientists and technologists from all fields within and outside the CAS.

The structure of the CAS imitated the structure of the Soviet Academy of Sciences. It has six academic divisions as well as regional branches. The basic units are research institutes. The divisions are set according to aggregate academic fields, e.g. geological sciences and biological sciences. Branches are, in fact, groups of research institutes according to their geographical closeness, such as Shanghai and Wuhan branches. The power of these branches has varied over time. At the present, research institutes directly supervised by the Academy become more and more independent. (Saich, 1989, pp66-71; Sigurdson, 1980, pp61-70) On the other hand, research institutes, in recent years, have been given more autonomy over administration, finance and personnel. A director responsibility system has been introduced at the institute level. The internal structure is shown by Figure 2.2.

```
                    PRESIDENT
                        |
                    PRESIDIUM
                        |
              SCIENTIFIC COUNCIL
        /--------------------------------\
    DIVISIONS                          BRANCHES
        |                                  |
RESEARCH INSTITUTES              RESEARCH INSTITUTES
```

Figure 2.2 Structure of the Chinese Academy of Sciences

As China's leading research organisation, CAS is expected to fulfil a number of roles in China's technological progress. First of all, it should devote a sizeable resources to basic research, which will lead China's S&T development in the long run. Secondly, it should use its technical expertise to promote

China's economic development. Since 1983 the research emphasis has shifted from basic scientific research to applied and developmental research. The task of the Academy was then described as "to strengthen applied research as much as possible, to participate enthusiastically, but selectively, in development work, and to continue to put priority on basic research". (Guo, 1987, p1) The Academy is expected to contribute to the solution of technical problems in the national priority projects, to participate in the high technology programme, and to accelerate the support of technological upgrading of industrial enterprises and the assimilation of imported technology.

Various approaches have been introduced to achieve the expected goals. New institutional changes were made, such as linkages with industrial enterprises, high technology ventures, and national open laboratories. A Natural Science Foundation was set up to finance basic scientific research.

2.3.3 Higher Education Sector

All together, there were 1063 institutions of higher education in 1987, a sharp increase over 598 in 1978. (SYB, 1988, p873) However, there are only 512 concentrating on science and technology. Among them, the State Education Commission directly supervises less than 100, and most of which are comprehensive universities. The majority of technological universities are under the jurisdiction of industrial

ministries. For example, the Ministry of Mechanical and Electronic Industries has over 70 universities within its system.

In the higher education sector, there are two types of universities. Those which receive funding from the State Education Commission are structurally separated from industrial enterprises. If they are going to develop any kind of R&D links with industry, they have to overcome strong departmental barriers. Problems faced by universities under industrial ministries are slightly less serious. They were designed to provide specialised scientists and engineers to specific industries. Their course designs are specifically set for one industry or even for product lines. Consequently, if they develop industrial R&D links, they normally operate in the familiar technical field. Unless they are diversifying into other ministries' jurisdictions, they will face less problems from departmentalisation. In addition, the connections through "in-breeding" graduates of in-house universities in the industry may also favour the industrial universities.

However, it is rather difficult to accurately assess R&D activities in the higher education sector. Conroy tried to give a general picture by using the available statistical data. In 1986, there were 1490 R&D organisations in the higher education sector, and 164,355 people were involved in R&D work, giving a full-time equivalence of 97,185. The total allocation for R&D in higher education sector in 1986 was 726 million RMB Yuan.

(Conroy, 1989, pp38-70) Although the information is far from giving a satisfactory explanation, it does suggest that institutions of higher education have been actively involved in R&D activities and developed various links with industrial enterprises and made prospective progress.

2.3.4 Industrial R&D Sector :

According to Chinese statistical sources, research institutes under this heading are classified, firstly into two groups, i.e. subordinate to government departments at the county level and subordinate to government department above the county level. Then the latter is further divided into three subgroups: subordinate to local government departments, subordinate to ministries, subordinate to the Chinese Academy of Sciences. (White Paper No.1, 1986, pp313-329)

Research institutes at the county level are mainly concerned technologies of low novelty or merely the diffusion of an established technology. The official White Paper reveals that the majority of technological innovations took place in the research organisations above the county level, particularly those directly attached to the provincial governments and the industrial ministries. (White Paper No.1, 1986, pp323-329)

Apart from CAS institutes discussed in section 2.3.2, the 1987 figures show that there were 4189 research units attached to the local government above the county level with 439,285

employees, and 932 units directly attached to various ministries with 515,599 employees. Roughly half of their employees are R&D personnel. (SYB, 1988, pp917-919) These figures also indicate that research institutes directly led by the industrial ministries are much bigger in size than those attached to the local governments. Some research institutes have several thousands of employees.

There are different forms of institutional R&D structure within Chinese industrial ministries. Two broad types can be defined. The first one is the conventional model, which is primarily associated with civilian industries. The control over R&D extends from the department of S&T of the ministry to its ministerial-level research organisations or its provincial bureaux, then passed onto provincial research organisations or next lower level bureaux, etc. This is the traditional way of planning, largely adopted by civilian industries. The Ministry of Textile Industry and the Ministry of Light Industries are typical examples.

The second type of R&D structure can be defined as the strategic model, which is more related to defence industries. The typical way of organising is that one or several national research academies are set up directly under the ministry. These academies consist of a considerable number of research institutes located all around the country. R&D work within the ministry is co-ordinated through the academies. Usually, those ministries do not have any local bureaux to represent them. R&D

and production are directly controlled and planned by the ministry centrally. Ministries representing this type are the Ministry of Aeronautic and Aerospace Industries and the former Ministry of Ship Building (now China Corporation of Ship Building). Figure 2.3 summarises the two types of R&D structure.

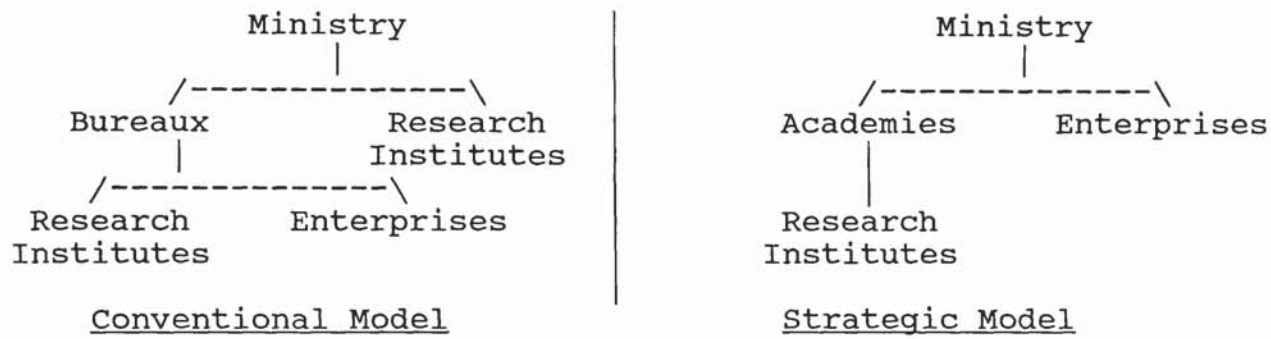


Figure 2.3 Structure of R&D in Industrial Ministries

Through years of evolution, merges and breakups of ministries, some ministries possess characteristics of both conventional and strategic models for R&D. The Ministry of Mechanical and Electronic Industries is a good illustration in this regard. This super ministry is the result of merging three big industrial ministries, - Machine Building, Electronic Industry and Ordnance Industry. As a result, R&D in this ministry runs on two tracks: defence-related projects are co-ordinated in a strategic manner, while civilian R&D projects are administrated through conventional channels.

There are two basic structural elements to be considered

in the analysis of the Chinese R&D system, i.e. hierarchical levels and sectoral compartmentalisation. When the two elements evolve and interact, and people representing different hierarchical and sectoral interests negotiate via political means, rational planning becomes rather difficult or impossible to achieve. Many evidences in the past suggested that the planning process in China is highly politicised and often irrational. However, in the reform process, with the reinstatement of professionalism, there is a tendency that planning has adopted techno-economic criteria.

2.4 Planning Research and Development

2.4.1 Plans for S&T Development

In the period from 1978 to 1988, a number of national S&T plans were drafted. The first and most noted one is the "Outline National Plan for the Development of S&T 1978-1985", which was unveiled at the National Science Conference in March 1978. The plan was the first comprehensive plan drawn after the Cultural Revolution. Ambitious targets were set for both basic applied research. 108 priority projects were selected in 8 key areas, namely, agricultural science, energy, material science, computer, laser, space technology, high energy physics and genetic engineering. Basically, the plan tried to approach or reach the world advanced level in a number of fields, and to train a competent research contingent and develop a number of experiment bases within a rather short time scale. In relation

to China's economic and technological capacity at the time, such a plan seemed rather ambitious and unrealistic. Soon, it was made redundant and replaced by a revised modest short-term plan, which was incorporated in the Sixth Five-year Plan.

Later, although long-term plan for the period 1986-2000 was claimed to be in preparation, it seemed it had little impacts on what was really carried out in S&T arena. Instead, mid-term plans incorporated in the National Five-year Economic Plans seem to have more practical influences. Table 2.1 gives priority technical areas in various plans from 1978 to 1990.

There are four S&T plans at the national level. One is concerned with technical issues in economic development; one is specifically for the rural sector; the other two are focused on long-term and short-term high technology development respectively.

2.4.1.1 Programme for National Key S&T Projects

The first one is the Programme for National Key Projects in Science and Technology, which is normally associated with the Five-year Economic Plan. Its basic contents are to tackle some technical issues in relation to economic and social development. It started from the Sixth Five-year Economic Plan. Table 2.1 illustrates some basic points.

Eight Year Plan 1978-85	Outline Report 1981	6th FYP 1981-85	7th FYP 1986-90
Agriculture	Agriculture	Agriculture	Agriculture
Energy	Light Indu.	Light Indu.	Energy
Raw Materials	Energy & Energy Saving	Energy & Energy Sav'g	Communication & Transport
Computer Sci.	Communication & Transport	Raw Material	Raw Materials
Lasers	Machine Bldg.	Machinery & Electronics	High Tech.*
Space	Raw Materials	Transport & Communicat'n	
High Energy Physics	New Tech.	New Tech.**	
Genetic Eng.		Other Tech.***	
8 areas, 108 key projects	7 areas, over 10 items	8 areas, 38 key projects	5 areas, 76 key projects

* This includes biotechnology, space technology, information technology, laser technology, automation, energy and new materials.

** This includes optical fibre communication, lasers, superconductivity and biotechnology.

*** This includes contraception, cures for various diseases and environmental protection and pollution treatment.

Source: Saich, 1986, p15 and the author's compilation.

Table 2.1 Priority Areas in S&T Development Plans (1978-90)

However, changes were made in the Eighth Five-year Economic Plan (1991-1995). Instead of a single programme at the national level, there are three levels in the programme, i.e.

national, sectoral and regional. It is expected that the national key projects programme would cover those cross-region or cross-industry technical problems. The sectoral programme would focus on those key technical issues in the sector, while regional programme would make effort to solve key technical problems with regard to local economic development. Since these plans are actually incorporated in economic plans, the State Planning Commission played the decisive role in the planning process in conjunction with the State S&T Commission. (People's Daily, 8/4/89, p1)

2.4.1.2 The Spark Programme

The second important plan for S&T development is mainly concerned with the development in rural areas - The Spark Programme. This plan is to encourage the use and diffusion of appropriate agricultural technology, to utilise local rural natural and labour resources effectively and bring quick commercialisation results.

Since 1978, agriculture has always been given top priority in S&T development plans. To ensure modern agricultural technologies are widely and efficiently adopted and diffused, the State S&T Commission initiated the Spark Program in 1985, which had been an important part in both S&T development plan and national economic plan. At the national level, the objectives of the Spark Program were as follows: (1) The development of equipment especially designed for village and

township enterprises; (2) The establishment of pilot plants in rural areas; (3) The training of young employees and local cadres; (4) Regional development of poor areas; (5) The set-up of production bases for export and sideline food. (White Paper No.1, 1986, p220)

The Spark Program is reported to have achieved good economic effects in the past years. In 1987 2,800 projects were completed and the total output of the rural areas in China was 904.1 billion Yuan, a 12.7% increase over 1986, in which agricultural production accounts for 49.2%, while rural industrial production 50.8%. (People's Daily, 25/2/88)

2.4.1.3 The High Technology Programmes

There are two national plans at the high technology end. The long-term one is named "86-3 Plan", the Chinese equivalent to Europe's EUREKA Programme. The main objective is to lead or follow the world level scientific research in a small number of selected high-technology fields. The research in these selected areas will lay a foundation for China's technological development in the 21st century. An "Outline Plan for High Technology Development in China" was issued by the State Council and the plan went into practice in February 1987. It identified seven areas for priority development, namely biotechnology, space technology, information technology, laser technology, automation, new energy and new materials. In the five areas supervised by the SSTC, (except space technology and

energy), 886 projects have been arranged. Total investment from 1987-1989 reached Y4,000 million. (People's Daily, 19/4/90, p1)

In August 1988, a new high technology programme was introduced - the "Torch Programme". It is actually the combination of high technology part of the Five-year Economic Plan and the stage plans of "86-3 Plan". It aims at a quick application of high-tech research results into commercial production. Projects included in the "Torch Programme" are selected annually. More that 50 projects were selected from 500 applications in 1988, with a total investment of Y1,600 million. (People's Daily, 6/3/89, p4) In 1989, a further 234 projects were chosen from more that 1500 applications. Except direct state sponsorship, finances are encouraged from local governments, enterprises and overseas companies. A package of tax relief on high-tech products was also drafted. (People's Daily, 6/8/89, p4). These projects were focused on new materials, biotechnology and integration of electro-mechanical technology.

In addition to plans mentioned above, China also introduced other programmes to promote technological upgrading in production enterprises, to acquire and assimilate imported technologies and to encourage basic research projects of national priority. (White Paper No.1, 1986)

2.4.2 The R&D Planning Process

The planning process is strongly associated with the institutional structure. It has been argued that technological innovations tend to occur in the form of technology push in the centrally planned economies. The State, through the planning of research topics and allocation of resources, decides the direction and pace of R&D. It also controls the demand for new technologies through administrative means, on what products to be produced and processes to be used in industrial enterprises. As a result, the State planning and control are pervasive throughout the entire innovation process, even when market mechanism was introduced in recent years. However, it is interesting to notice that there are different ways of R&D planning process in the Chinese system. Some are fairly centralised in a top-down fashion; some, on the other hand, are quite flexible, allowing reasonable negotiation between different parties.

2.4.2.1 The "Top-down" Model

Firstly, the R&D planning may be regarded as a top-down process, which is the dominant and common perception about centrally planned economies. This type of planning is most commonly seen at the national level, and frequently at the ministerial and regional levels. However, it is normally applied to high priority projects of national or regional economic significance or long-term importance. The origins of

such projects are the planning bodies at different levels.

At the national level, the State S&T Commission, in conjunction with other State Commissions, holds extensive meetings with technical experts in various fields. Sometimes, a planning team is formed temporarily with experts drawn from all kinds of S&T agencies, such as universities, CAS, ministries etc. After careful consultations and discussions, a preliminary plan is drafted. This plan will be carefully examined and balanced by the State Planning Commission to incorporate it into the national economic plan. At this stage, necessary modifications are made and budgets are calculated It is also at this stage, that the plan for defence-related R&D drawn by the State S&T Commission for National Defence, and the plan for technical transformation in industrial enterprises prepared by the State Economic Commission (now incorporated into the State Planning Commission), are integrated into a comprehensive national plan.

The planning process just outlined is a complicated one. Many parties are involved and different interests are represented. This leads the planning process to be of a highly political nature, rather than a simple rational selection process. (Lieberthal & Oksenberg, 1987) In some circumstances, the State S&T Commission seems to be not powerful enough to co-ordinate. Examples are the Shanxi open coal mine, the Three-Gorges dam project, and large scale IC production lines. To resolve departmental conflicts in the planning process, super-

commissional leading groups on S&T were created directly under the State Council and chaired by more powerful figures. These groups often consist of representatives from all state commissions and ministries concerned. Such high-level compositions aim to ensure these groups to provide authoritative, efficient and co-ordinated R&D planning in relation to overall economic planning, and the training and allocation of S&T personnel.

These super-commissional leading groups, such as the State Council Leading Group on S&T, the Leading Group for the Development of Electronic Industry, and the Leading Group for Major Technical Equipments etc., were set up only as a temporary measure to solve planning problems. Recently, many of these super-commissional groups have been abolished and their personnel transferred to the State S&T Commission. The State S&T Commission seems, over the past a few years, to have improved its position as the national centre for S&T planning.

Once a plan is finalised, funds are normally provided accordingly. Then the State S&T Commission is responsible for the allocation of research projects and research budgets. However, the Commission does not handle this task face to face with the research organisations. Both research projects and funds are distributed through the existing R&D system, i.e. industrial ministries, CAS etc. (Also see Conroy, 1984[b] for additional discussions.)

2.4.2.2 The "Bottom-up" Model

The second planning model is described by W A Fischer as a "bottom-up" process. (Fischer, 1983[a], p76) The national plans for S&T only cover a selection of major projects. Many other projects in the ministerial and regional plans are originated in different ways. They may be actually formulated by the research units themselves and approved by the higher planning authorities. This type of planning is best reflected at the ministerial level.

A senior research engineer from the Ministry of Chemical Industry interviewed in the research outlined the planning process in the Ministry. Here is a summary. Two important planning meetings are held annually by the Department of S&T of the Ministry. The first one is the meeting of representatives from major production units and local bureaux within the ministry. At the meeting, technical problems encountered in the production, problems concerned with production capacity, new products etc. are raised to the S&T department.

After preliminary screening of these problems by the personnel in the Department of S&T, sometimes in consultation with outside experts, the second meeting is held. This time the participants are personnel in charge of research or directors of research institutes in the Ministry. The list of problems put forward by the first meeting is the focus of discussion. In addition, each institute also brings its own proposed research

projects for the Ministry to approve. These projects are not necessarily all production related; some might be basic research in nature. At the meeting, these research projects are discussed, assessed and roughly allocated. A preliminary plan is achieved at the end of the meeting.

However, this plan needs budget evaluation to ensure they are within the capability of the Ministry's R&D budget. If some projects are too big for the Ministry to handle, they are handed over to the State S&T Commission for consideration to be included in the national plan. Projects within the Ministry's budget capability are allocated to research organisations after approval. Since nearly all of these projects are generated from below through consultations, the allocation can be regarded as a formality. Planning at the regional level is quite similar to what described, where the regional S&T commissions take the overall responsibility. (Interview M, Appendix A)

2.4.2.3 The "Centralised" Model

In addition to the two popular models of planning outlined above, a different approach is adopted in defence-related ministries. In the Ministry of Aeronautic and Aerospace Industries, a special research institute was set up to forecast and plan R&D activities of the Ministry. The task for this special research institute is to monitor the international trends in aeronautic and aerospace technology, examine existing technological level and capacity of Chinese aero-industries,

incorporate military and defence needs, and then devise an R&D plan for the Chinese aerospace and aeronautic industries. The institute is located in one of the ministry's research academies. Because of its expertise in the given industrial sector, plans prepared by the institute are rather specific, including what model of fighter is to be developed, what technical performance is to be expected, together with budgetary requirement and completion time. Although there are flexibilities over timing and budget constraints on big defence R&D undertakings, completion on time and technical performance are the most important criteria. (Interview K, see Appendix) Under these circumstances, every aspect of R&D process is tightly centrally planned.

Although the ongoing S&T reform in China calls for more market competition and less government intervention, the essence of the Chinese R&D system can not be completely changed overnight. Particularly when China faces constraints of limited financial resources and there is an urgent need to develop key industrial sectors, market forces alone may not be sufficient to bring about desired outcomes. As a result, both the top-down and bottom-up planning mechanisms may co-exist with the market mechanism for some time to come. There will be inevitable changes in the planning process. More elements of competition will be gradually introduced.

CHAPTER 3 DATABASE OF AWARD-WINNING INNOVATIONS

Having outlined the Chinese R&D system and its reform in the previous chapter, only one attribute of the research framework - i.e. Arrangements are discussed. In this chapter and the following two, it is intended to assess another attribute - innovation achievements of Chinese R&D system. As suggested earlier, previous research remains limited along the quantitative dimension. This research used data from the National Awards for S&T Progress to provide quantitative analysis of innovation achievements in China. But before moving on to the actual analysis, the award system in China and the database approach used in the research are illustrated.

3.1 Award System in China

The evolution of science and technology award system in China has been a tortuous one. The system was first constructed in the 1950s, and subsequently abandoned in the Cultural Revolution. Then it was re-introduced in the post-cultural revolution period. Relevant changes can be clearly seen by monitoring regulations issued by the government chronologically.

As can be seen from Table 3.1, the evolution of the science and technology award system falls into two separate phases. In the pre-Cultural Revolution period, three basic award schemes were in operation, i.e. Awards for Inventions,

1951	1) Decision on Awarding Production-related Inventions, Technological Improvements and Rational Suggestions 2) Interim Regulations on the Protection of the Rights of Invention and Patents
1954	Interim Provisions for Awarding Production-related Inventions, Technological Improvement, and Rational Suggestions
1955	Interim Regulations of the Chinese Academy of Sciences on Science Cash Awards
1958	[SSTC was established by merging the Science Planning Committee and the State Technology Committee.]<a>
1963	1) Regulations of the People's Republic of China on Awards for Inventions 2) Regulations on Awards for Technological Improvement
1966	[The Cultural Revolution started.]
1969	[SSTC was abolished. But its last press appearance was in 1965.]<b> <c>
1976	[The Cultural Revolution ended.]
1977	[SSTC was resumed.]
1978	1) Regulations on Awards for Inventions 2) Restoration of Regulations on Awards for Technological Improvement
1979	Regulations of the People's Republic of China for Natural Science Awards
1982	Regulations on Awards for Rational Suggestions and Technological Improvement
1984	Regulations on Awards for Scientific and Technological Progress

Source: <a> Suttmeier, 1980, p20.
<b> Suttmeier, & Dean, in OECD, 1977, p81.
<c> Conroy, 1984, p14.

* Other information is abstracted by the author from the White Paper No.1, 1986.

Table 3.1 Evolution of Science and Technology Award System

Awards for Technological Improvements and the Natural Science Awards (CAS). However, only a small number of significant scientific and technological achievements were actually awarded by 1966 before those award schemes were suspended. In total, 34 Natural Science Awards (White Paper No.1, 1986, p119) and 251 Invention Awards were conferred by 1966 (People's Daily, 18/1/88, p8).

In the Cultural Revolution, the use of material incentives was under severe attack. At that time, any use of material incentives was considered as economistic and bourgeois. Official policy encouraged the use of non-material incentives, e.g. ideological concerns, nationalistic ideals and political consciousness. Consequently, when Chinese science and technology system was severely destroyed in the Cultural Revolution, the award schemes also came to a halt.

After the Cultural Revolution, the science and technology award system was reinstalled and implemented along with other science and technology systems. This was marked by the announcement of a number of government regulations on awards.(see Table 3.1) There are three main award schemes in operation, namely Awards for Inventions, Awards for Natural Sciences and Awards for Scientific and Technological progress. As their names imply, each of them aims to encourage innovative activities in a specific area. Although a fourth scheme - Awards for Rational Suggestions and Technological Improvements - may be included, this scheme is mainly concerned with minor

product or process improvements. As far as important innovations are concerned, it is less significant than the other three schemes.

The top political leaders of China paid special attention to science and technology awards and regarded awards as an effective way to promote technological innovations. In October 1982, Zhao Ziyang, Premier at the time, addressed the National Conference on Science and Technology Awards. His speech -- "A Strategic Question on Invigorating the Economy" gave a clear indication that science and technology development is on the top of the political and economic agenda. The establishment of an effective award system for scientific achievements and technological innovations formed an important part of government science and technology policy.

The rationale for establishing an effective award system was made clear by a Vice-Minister of the SSTC, Mr. Guo Shuyan "a) It effectively encourages and motivates scientists and engineers' desire to invent and innovate. It encourages the popularisation of innovating activities and the discovery of innovative talents; b) Through correct evaluation and encouragement of experts, people devoted to innovation and invention are accepted and respected by the society; c) Science and technology awards speed up the commercialisation of technological achievements. It also introduces domestic technologies into the international market".(People's Daily, 8/12/87, p4)

Furthermore, for both research individuals and research organisations, to be an award-winner would attract more finance for future research. It also provides an opportunity to improve social image, academic prestige and social status. There are also political incentives to be an award-winner. It was reported that some award-winning individuals have been enrolled into the Party and promoted to leading positions.(People's Daily, 16/3/89, p4)

Unlike the award system before the cultural revolution, the new system has conferred a large number of awards in a comparatively short period. Statistics show that from 1979 to 1988 a total of 1561 inventions were awarded. 3086 awards for scientific and technological progress were conferred from 1985 to 1988. And 304 natural science awards were given in 1982 and 1988.

3.1.1 Award Schemes at the Present

Three major national awards schemes mentioned above, form the mainstream of the Chinese science and technology award system. These award schemes refer to different sectors or types of scientific and technological activities, as their names imply. Different criteria are used in the selection and examination process.

Awards for Inventions:

"a) Novel,
b) Advanced,
c) Applicable as proven by practice".
(White Paper No.1, 1986, p114)

Awards for Natural Sciences:

"... Any achievement of scientific research made by collective work or individual effort in revealing natural phenomena, characteristics, and law which is of great significance to the advancement of science and technology..."(White Paper No.1, 1986, p120).

Awards for Scientific and Technological Progress:

"A. Scientific and technological achievements (including new products, new technologies, new processes, new material, new design, and new biological strains, etc.) that have been applied to the socialist construction and modernisation drive and are (a) novel in the country, (b) advanced in the profession, (c) capable of generating significant economic returns or social benefit as proven through practice.

B. Having made creative contributions and achieved considerable economic and social benefits through the popularisation, transfer, and application of the existing scientific and technological achievements.

C. Having made creative contributions and achieved considerable socio-economic benefits through the introduction of new technologies into major construction projects, research on and development of key equipment or facilities, and technological transformation of enterprises.

D. Having made creative contributions and achieved remarkable results in the areas of science and technology management, standards and metrology, and scientific and technical information." (White Paper No.1, 1986, p122)

These award schemes also differ in other aspects. Table 3.2 shows the time of introduction and the class structure of three main award schemes.

In addition to these national award schemes, ministries and provinces also run different award schemes. However, most of them are of smaller scale covering narrower spectrum of scientific and technological activities, usually focusing within regional or sectoral boundaries. Notable ones are the

National Youth Awards of Science and Technology, set up by the Chinese Association of Science and Technology in 1988; the Harvest Awards created by the Ministry of Agriculture, Husbandry and Fishery in 1987; the Awards for Scientific and Technological Progress in Medical and Pharmaceutical Professions; and the Awards of Spark Programs set up by the SSTC in 1988.

Scheme Name	Introduction	Classes	Cash Award
Inventions	1979 (annually)	4 classes & special	1) Y 20,000 2) Y 10,000 3) Y 5,000 4) Y 2,000
Natural Sciences	1982 & 1988 (then bi-annually)	4 classes & special	1) Y 20,000 2) Y 10,000 3) Y 5,000 4) Y 2,000
S&T Progress	1985 (annually) (except 1986)	3 classes & special	1) Y 15,000 2) Y 10,000 3) Y 5,000

Source: Compiled by the author. Information also drawn from White Paper No.1, 1986, p114, p120 & p123.

Table 3.2 Main Award Schemes in China

Awards for scientific and technological achievements are also offered by non-governmental organisations. For example, Chen Jiageng Prize, by Chen Jiageng Foundation, offers prizes in the fields of material science, life science, geo-science, technological science, agricultural science and medical science. As complements to the national award schemes, those additional award schemes provide wider opportunities for

innovations, so that more scientific and technological research can be appreciated and made known to the public.

Among the existing award schemes, the National Award for Scientific and Technological Progress is selected as the basis of empirical studying in the research. This is because it has the widest coverage of innovation activities in China, including significant technological innovations in nearly all industries. Hereafter, discussion will be primarily based on this specific scheme.

3.1.2 Administration of the Award System

Due to the influence of existing economic and industrial structure, the administration of the national award system follows a similar centralised manner.

3.1.2.1 Administration of Awards

Under the jurisdiction of the SSTC, a National Office for Science and Technology Awards is responsible for co-ordinating the award activities nationwide. As far as each award scheme is concerned, respective committees are set up under the Awards Office. Along government horizontal and vertical networks, there are three levels of administration.

> "The State Science and Technology Commission's attention is focused on the administration of S&T achievements of national significance.
>
> The provincial governments and ministries and

departments under the State Council are responsible for administering their S&T achievements, their examination, registration, filing, granting awards, exchange and popularisation.

The grassroots level units are responsible for the administration of their own S&T achievements."

(White Paper No.1, 1986, p128)

Provincial governments and industrial ministries play the most important role in the awarding process. For easy administration, each award scheme is run on the basis of existing Chinese ministerial-industrial structure. In the case of Awards for Scientific and Technological Progress, 29 industrial categories are used in the scheme. Accordingly, 29 examination offices were created and affiliated to respective ministries. Table 3.3 gives its structural breakdown. (People's Daily, 15/7/87, p4), (Note: In 1988, China reorganised government structure. Some ministries were dissolved and some took on additional responsibilities. People's Daily 12/4/88)

3.1.2.2 Application for Awards

Applications for awards made by the innovators or inventors have to go through industrial-administrative channels, screened, examined and aggregated level by level, from local industrial bureaux to provincial bureaux, then to the superior ministries. At the ministerial level, applications are dealt with by the examination offices concerned. After that it is the responsibility of respective SSTC award committees to review the applications, make the final examination, and to determine the class of award to be conferred. But a final approval is essential from the SSTC.

Industry	Examination Office
1. Machine Building	Dept. of S&T, State Commission of Machine Building
2. Electronics & Instruments	Dept of S&T, Ministry of Electronic Industry
3. Chemical Eng.	Sect. of Patents & Achievements, Dept of S&T, Ministry of Chem. Ind.
4. Metallurgy	Sect. of P&A, Dept. of S&T, Ministry of Metallurgy
5. Geology & Mining	Sect. of Achievement, Dept. of S&T, Ministry of Geology & Mining
6. Light Industries	Sect. of P&A, Dept of S&T, Ministry of Light Industries
7. Textile Industry	Sect of Achievement, Dept of Sci. & Education, Ministry of Text. Ind.
8. Health Service	Sect. of Achievement, Dept. of S&E, Ministry of Health Service
9. Pharmaceuticals	Dept. of S&E, State Administration of Pharmaceuticals
10. Agriculture etc.	Dept. of S & T, Ministry of Agriculture, Husbandry and Fishery
11. Forestry	Dept. of S&T, Ministry of Forestry
12. Urban Construction	Dept. of S & T, Ministry of Construction
13. Eng. Construction	Dept. of Engineering, State Planning Commission
14. Eng. Design	Dept. of Design, State Planning Commission
15. Building Material	Dept. of Tech. Development, State Administration of Building Material
16. Hydrology & Power	Dept. of S&T, Ministry of Water Resources & Power Industry
17. Transportation	Dept. of S&T, Ministry of Railway
18. Standards	State Administration of Standards
19. Natural Forecast	Dept. of S&E, State Administration of Meteorology
20. Public Security	Dept. of S&T, Ministry of Public Security
21. S&T Information	Dept. of Information, SSTC
22. Metrology	State Administration of Metrology
23. Natural Resources	Dept. of Geo-sciences, Chinese Academy of Sciences
24. Culture & Sports	Office of S&T, Ministry of Culture
25. Soft Science	Dept. of S&T Policy, SSTC
26. Aeronautical Eng.	Office of Achievement, Ministry of Aeronautical Industry
27. Nuclear Tech.	Dept. of S&T, Ministry of Aerospace
28. National Defence	Office of Achievement, State Comm. of S&T for National Defence
29. General Logistics	Sect. of Tech. Equipments, Dept. of
30. Environmental	State Administration of Environment

Table 3.3 Administration of National Awards for S&T Progress

The application for award may go through different channels depending on the nature of the applicant organisation and its position in the R&D hierarchy. Applicant organisations usually report to their direct superior bodies, then level by level upwards. There are generally four routes to apply for national awards: through provincial science and technology commissions, ministries and other ministry-equivalent organisations of ministorial rank, the Chinese Academy of Sciences(CAS) and the State Education Commission.

In the case of last two routes, the process seems quite simple. Applicant organisations file their applications directly to the CAS or the State Education Commission; then applications are passed to examination offices of the technology concerned. If the first two routes are followed, applications have to be made to local industrial bureaux or local science and technology commissions, then submitted to their provincial counterparts. Upon review and examination at the provincial level, innovations of sectoral or national significance are selected and passed to ministries, in the case applicants are direct supervised by the ministries. After review by the ministries applications are then sent to respective examination offices for specific technology. But in the case applicants are provincial organisations, applications are passed directly to respective examination offices after provincial review. However, all applications for national awards are subject to examination and review by SSTC award

committees and the final approval by the SSTC before official announcement. Those applications, which failed to obtain national awards, usually become eligible for ministerial or provincial awards. The application process outlined in the above paragraph is very complicated and confusing. Although the administration costs are not known, the figure can be quite high. The time delay can be lengthy.

The following example tries to explain this complicated process. Suppose an innovation of an electronic nature is made in an R&D institute which is a subordinate of the Ministry of Textile Industry. In this case, the application for award is first submitted to the municipal bureau of Textile Industry. If the innovation involved is regarded as novel, the municipal bureau submits the application to its provincial bureau. After review and examination at the provincial level, the application could be either submitted to the Ministry of Textile Industry to contend a national or ministerial award, or to be awarded provincially. Suppose the application is submitted to the Ministry of Textile Industry and the Ministry reckons the innovation is eligible for a national award, since the technology is electronic, the application is passed onto the examination office responsible for electronic technology, which is attached to the Ministry of Electronic Industry. Then it is up to the examination office to make its recommendation to the SSTC award committee. If the application is approved by the SSTC, an award decision is finally made. Otherwise the innovation may be considered for a ministerial award within the

Ministry of Textile Industry.

Having been examined by experts and approved by the SSTC, the SSTC award committees announce the list of awards to be conferred. Announcements are normally published in the major national newspapers for public contention, e.g. Science and Technology Daily. Natural Science Awards are normally announced in March, allowing two months' time for public contention, then subsequently awarded in July. Awards for S&T Progress and Awards for Inventions are usually announced in July and April respectively, giving three months' time for public contention and finally awarded in December. If anyone has queries about any particular entry of award, he or she could write to the SSTC award committee concerned for re-examination. Normally, there is no official ceremony of awarding. Certificates and cash are distributed to award-winning individuals and organisations through administrative channels.

3.1.3 Statistics of National Awards for S&T Progress

Compared with the other two main award schemes, this award scheme covers the widest range of scientific and technological activities. Within the scheme, the degree of technical novelty is differentiated by classes of award. There are four classes: Special, first, second and third. Coupled with a merit award certificate, cash awards are also given to those who participated in the innovation process. Judgements of specialists in the respective technical professions ensure a

reasonable guarantee that these innovations are leading technical innovations in China. From its establishment in 1984, until 1988 there were three sets of awards. A total of 3086 awards were given in this period.

	Special	1st	2nd	3rd	Total
1985*	23	135	535	1068	1761
1986**					
1987	4	50	237	516	807
1988	2	33	153	330	518
Total	29	218	925	1914	3086

Source: 1) Catalogue of National Awards for Scientific & Technological Progress, SSTC, 1985, 1987 and 1988
2) People's Daily, 16/7/88, p4.
* Awards in 1985 covered the period from 1978-1985.
** The scheme did not operate in that year.

Table 3.4 Statistics of National Awards for S&T Progress

Significant economic returns have been reported from the application of those innovations. According to incomplete statistics, the special and first class awards in 1988 alone had generated 5.5 billion RMB Yuan and 23.7 million US Dollars export income. (People's Daily, 16/7/89, p4)

3.2 Availability of Data and Database Construction

3.2.1 Availability of Data

The previous section indicates that, since the late 1970s China had resumed and further developed an elaborate system of government awards for scientific and technological achievements. Different award schemes were set up, which not

only give a list of important innovations made by Chinese scientific and technical researchers, but also provide an excellent basis for analysing technological innovation in China. The abundance of quantitative information in these award schemes encouraged the use of database method in the research.

Among a number of major award schemes, the National Awards for Scientific and Technological Progress is the most broad and comprehensive in scope, covering some 30 categories ranging across the whole spectrum of the economy. The basic criteria for the awards are similar to those used to identify significant innovations in other countries, i.e. a) the innovation is technically novel; and b) the innovation has delivered significant social or economic benefits. Items for nomination are based on peer opinions and economic success and then selected through various levels of administration.

In addition to its wide coverage, this scheme is primarily concerned with technological innovations, which have already been applied in industries. Thus, it offers an excellent opportunity for accessing patterns of technological innovation in relation to economic performance. Moreover, all entries in the scheme are judged by experts nation-wide as of either international or national technical significance. This greatly enhances the quality of data from the scheme, which attracts frequent concern in innovation studies. Due to these advantages, the Awards for S&T Progress are chosen as the source of empirical data in this research. It is important to

mention that this is the first time a quantitative study on innovation in China is carried out on such a large scale in the West.

Access to empirical data has always been a critical problem in social science research. In many cases, the degree of access determines how valid and representative the research results would be. As far as this research is concerned, a list of National Awards for Scientific and Technological Progress was made available with the assistance of the SSTC. The list includes data of three award-conferring years of the scheme -- 1985, 1987 and 1988. But the actual coverage of time span is from 1978 to 1988. There were originally 3086 innovations awarded in total, but only 2371 were published. The others were deliberately omitted from the list, largely due to their defence connections. After screening of the list, 1393 award-winning innovations were selected to be included in the database of this research. The choice of entries was to cover innovations in all major manufacturing and consumer industries. This is the focus of the research. Main industries included in the database are listed below.

ME - Mechanical Engineering
EI - Electronic Industry
CE - Chemical Industry
MT - Metallurgical Industry
TP - Transportation
TI - Textile Industry
LI - Light Industries (Consumer Industries)
MD - Medical Equipment & Pharmaceutical Industry
HS - Health Service

Note: Abbreviation listed here are used as codes in the database.

Although the overall representativeness and validity of the sample are satisfactory, there are still inevitable limitations. Since all the data are national-level significant innovations, what they represent may not be a complete reflection of innovation activities at lower levels. However, they are the most comprehensive data currently available. They provide a rare opportunity to unveil innovation activities and achievements in China, and a platform to conduct insight analysis.

3.2.2 Database Structure

The database of award-winning innovations is designed in a way that it can be easily maintained, updated and retrieved. On the other hand, it should be able to keep the maximum original information, and also to include other new analytical elements for research purposes. Due to these considerations, the database of award-winning innovations consists of three inter-dependent databases. Figure 3.1 shows the relationships between them.

```
/----------\          /------------\          /---------\
|Innovation|<------->|Intermediate|<------->|Innovator|
|          |          |            |          |         |
| Database |          | Database   |          | Database|
\----------/          \------------/          \---------/
```

Figure 3.1 Relationship between Constituent Databases

3.2.2.1 Structure of Constituent Databases

The Innovation Database is the main database among the three, which contains information about specific innovations. The Innovator Database includes information of award-winning organisations. Whereas, the Intermediate Database, as its name implies, serves as a bridge between the Innovation Database and the Innovator Database. It links a specific innovation to its innovator(s) or vice versa. So search and information retrieval can be initiated either from an innovation or an innovator.

<u>The Innovation Database</u>

Information included in this database is innovation based. 1393 award-winning innovations are included in the database. Information recorded in the form of fields can be put into three groups. The first group of fields record the original information of each innovation supplied with the SSTC list.

INNOVATION	- Name of the innovation.
PRODUCER	- A list of organisations involved in the innovation.
LOCATION	- Where the innovation is primarily carried out.
AWARDNO	- Award registration number.
CLASS	- Class of award.
DATE	- Date of awarding.
INDUSTRY	- SSTC industrial classification.
MINISTRY	- Through which ministry or province the application is made.

The second group of fields are designed for analytical purposes, which includes several classification schemes used in the research. These fields are as follows:

GENERIC - Generic industrial classification.
SUBGENERIC - Sub-generic industrial classification.
TECHNICAL - Technical classification.
NATURE - Type of innovation.
COLLABRATN - Independent or collaborative work.

The last group consists of a number of miscellaneous fields. These fields are used either for putting in additional information or used as common field in database communication, or merely for book-keeping.

INPUTDATE - Date the record is inputted.
RECORDNO - Number of the record. This field is used as the common field between the Innovation Database and the Intermediate Database.
DESCRIPTN - This is a memo field to put extra information.

The Innovator Database

This database holds information of 2064 different innovating organisations. Compared with the innovation database, the two databases do not have equal number of records. This is because some innovations were completed by several organisations jointly, and some organisations were involved in more than one innovations. As far as the database structure is concerned, this database is much simpler.

PRODUCERNO - This field is the common field between the Innovator Database and the Intermediate Database.
PRODUCER - Name of the innovating organisation.
LOCATION - Where the organisation is located.
ORGAN_TYPE - Primary function of the organisation.

The Intermediate Database

This database establishes a link between the Innovation Database and the Innovator Database. It is in this database the role played by a specific innovating organisation in a specific innovation is identified. This database has a very simple structure, with 3009 records in total.

PRODUCERNO - Common field with the innovator database.
RECORDNO - Common field with the innovation database.
CONTRIBUTN - Role played by an organisation in an innovation.

3.2.2.2 Classification Systems in the Databases

The original material in Chinese had its own classification system. Firstly, innovations are classified according to the class of award, the date of award and the award number. Secondly, innovations are grouped according to industrial sectors based on existing ministerial structure. In the database of award-winning innovations, the original classification system is kept for the purpose of reference and comparison. However, it appears inadequate if analysis of innovation patterns is to be performed. More sophisticated classification system is required for analytical purposes. These new classification schemes are outlined below.

Generic Division	Sub-generic Division
1- Agriculture, Husbandry & Forestry	11 - Agricultural Technology 12 - Husbandry Technology 13 - Fishing and Fish Farming 14 - Forest Technology
2- Material Industries	21 - Metallurgical Industry 22 - Chemical Industry 23 - Building Materials 24 - Mining Industry (except fuels) 25 - Other Materials
3- Energy Industries	31 - Fuel Extraction 32 - Power Generating 33 - Power Distribution
4- Construction & Environment Protection	41 - Civil Engineering 42 - Engineering Projects 43 - Environmental Protection
5- Communications	51 - Post and Telecommunication 52 - Aeronautic & Space Technology 53 - Vehicle Engineering 54 - Transportation 55 - Public Media
6- Health Service	61 - Medical Practice 62 - Medical Equipments 63 - Pharmaceutical Industry
7- Services	71 - Information & General Standard 72 - Economic Research 73 - Others 74 - Basic Research
8- Industrial Manufacturing Industries	81 - Mechanical Engineering 82 - Electrical Engineering 83 - Electronic Engineering 84 - Instrument Engineering
9- Consumer Manufacturing Industries	91 - Food Technology 92 - Textile Industry 93 - Domestic Products 94 - Others
0- Defence Industry	00 - Defence-related Technology

Note: Numbers given in the table are used as codes in the database.

Table 3.5 Industrial Classification in the Database

Database Classification	SIC Classification	SSTC Classification
Divisions	Divisions	Divisions
1	0,956	10,11
2	2,48 (except 257)	3,4,5,15 (except 3.5,5.3)
3	1 (except 17)	3.5,5.3,16,27 (except 16.1)
4	5,17	12,13,14,16.1,30
5	7,35,36,3441	1.11,2.3,17,26
6	257,3750,95 (except 956)	8,9
7	97	18,19,20,21,22 23,24,25
8	3 (except 3441,35 36,3720)	1,2 (except 1.11,2.3)
9	4 (except 48)	6,7
0	no counterpart*	no counterpart**

* No such category in the SIC classification.

** Militarily related entries come from all industries. Although divisions 28 & 29 are administrated by defence organisations, innovations published, however, are largely civilian applicable and classified into divisions 1 to 9.

Note: For detailed information on SIC classification, refer to "Standard Industrial classification, central statistical office, HMSO,1979. For detailed information on SSTC classification, see Explanation on National Awards for Scientific and Technological progress, SSTC, 1985.

Table 3.6 Comparison of Industrial Classification Systems

Generic and Sub-generic Industrial Classification

The original industrial classification used by the SSTC has 30 categories, which are largely associated with the existing ministerial structure, rather than technological criteria. Therefore, in the Innovation Database, a new classification system is introduced to overcome this problem. Table 3.5 illustrates the structure of this new classification system.

Compared with the original 30 categories used by the SSTC and the Standard Industrial Classification (SIC) of U.K., divisions 1 to 6 of the new classification system are closely related to the infrastructure of an economy, while divisions 8 and 9 include main manufacturing industries. Division 7 comprises of non-technical items in the award scheme. Division 0 currently holds a small number of defence-related innovations. Since many unpublished award-winning innovations are defence-related, this division could be fairly big if full information becomes available. Table 3.6 shows the comparative relationship between the new system to the original SSTC classification and the SIC classification.

Types of Innovation

In the Innovation Database, in addition to the conventional two types of innovation, namely product and process innovations, one additional category is introduced to

differentiate innovations in the Chinese context, i.e. the project category, which refers to big industrial undertakings, e.g. the construction of a hydraulic dam or a steel complex. Strictly speaking, these items should not be regarded as single innovations. However, they are especially useful when analysing development priorities of China's industrial sectors and their impacts on technological innovation.

PD - Product Innovations
OP - Process Innovations
PJ - Projects (construction of an entirely new industrial undertaking, normally very big in term of capital investment)

Note: Abbreviations listed here are used as codes in the database.

Types of Innovating Organisation

To assess roles played by various types of organisations in technological innovation, four broad categories are used in the Innovator Database.

UN - University (Education Establishment)
RI - Research Institute (Research Organisation)
PO - Production Unit
GO - Government Agency

Note: Abbreviations listed here are used as codes in the database.

Roles in the Innovation Process

Having defined different types of innovating organisations, the role played by an organisation in a specific

innovation needs to be differentiated. In the Intermediate Database, for those innovations achieved jointly by more than one organisations, two basic functions are defined, by which the contributions by different organisations in the innovation process can be measured.

P - Principal Innovator/Involvement
S - Supportive Innovator/Involvement

Note: P and S are used as codes in the Intermediate Database)

The action being a principal innovator is called the principal involvement. Similarly, the action being a supportive innovator is defined as the supportive involvement. These concepts will be used in the analysis in later chapters. For innovations completed by a single innovator, the single innovator is regarded as the principal innovator.

Other Classifications in the Database

In addition to those classification schemes mentioned above, other classification schemes are used in the databases to support analysis. The most important one is the Geographical Codes, which are generated on the basis of provincial regions, 30 in total corresponding to the number of provinces in China. The codes are in the form of three capital letters, abbreviated from provincial names. The full list of those codes can be found in the List of Abbreviations.

3.3 Information Retrieval from the Database

The Database of Award-winning Innovations was constructed by using DBase III plus. The three constituent databases and associated utility files and programmes occupy a total memory of around 2MB. As a result, the operation of the Database requires a 640KB RAM IBM Compatible computer with hard-disk support.

When the database was initially designed, considerations were given to future potential users of the database. The operational and programmable power of Dbase III Plus allows users of the Database of Award-Winning Innovations in China to retrieve information according to their individual needs. Generally there are two main ways of information retrieval.

3.3.1 Interactive Information Retrieval

This method of information retrieval requires knowledge of Dbase III Plus software. By using Dbase III Plus functions, it is able to retrieve information in groups upon certain criteria according to individual requirements. Information obtained can be either displayed on the screen or printed out in a report form.

Since the Innovation Database and the Innovator Database are linked by the Intermediate Database, it is possible to search from either end. Starting from an innovation, it is

possible to find out who did the innovation. Similarly, it is possible to find out how many awards a specific organisation had won. Through the link provided by the Intermediate Database other more complicated search could also be carried out. In fact, it is possible to categorise information on either single conditions or multiple conditions. Such combinations are numerous and users have ultimate freedom of utilising the data.

3.3.2 Programmed Information Retrieval

Programmed information retrieval offers great efficiency of processing large quantity of data, when the objective is clearly defined and enquiries are repetitive. It is particularly useful for users who do not have much knowledge of DBase Plus III software. By means of a programme, a large number of operations can be performed in an efficient way. However, programmed information retrieval offers limited flexibility, since programmes are not designed for specific needs. For similar reasons, only seven programmes, which are used in this research and are likely to be frequently used by future users, are compiled. Their respective functions are listed as follows.

1) Searching by SSTC Industrial Code in the Innovation Database. Outcome is given by class, by year and in total. (Programme: Indcount)

2) Searching by Geographical Code in the Innovation Database. Outcome is given by class, by year and in total. (Programme: Geocount)

3) Searching by Generic Industrial Code in the Innovation Database. Outcome is given by class, by year and in total

in the first set, and by sub-generic industrial codes, by year and in total in the second set. (Programme: Genecoun)

4) Searching by the Type of Innovation Code in the Innovation Database. Outcome is given by year, by class and by generic and sub-generic industrial codes. (Programme: Natcount)

5) Analysing co-operation patterns between organisations of different natures. Searching three databases at the same time. Outcome is given by year, class and participation; by individual completion and inter-organisation co-operation; and by inter-region and intra-region co-operations. (Programme: Co-op)

6) Analysing award-Winning organisations primarily by region, and also by organisation type and by role played in an innovation. Searching the Innovator Database and the Intermediate Database at the same time. (Programme: Pdcount1)

7) Analysing innovating organisations primarily by year and class, and also by organisation type and by role played in an innovation. Three databases are searched at the same time. (Programme: Pdcount2)

Note: Original programmes are included in the Appendix C.

The first four programmes retrieve information from the Innovation Database only, while the last three programmes, however, interact with the Innovation Database, Innovator Database and the Intermediate Database at the same time.

Information retrieved by the programmes unveils important patterns of technological innovations in China. These patterns are used to assess innovation achievements and innovating organisations in the following chapters.

CHAPTER 4 PATTERNS OF TECHNOLOGICAL INNOVATION

Having outlined the award scheme, the available award data and the database approach used in the research, some of the patterns generated from the database are discussed, to provide a quantified assessment of innovation achievements in China. In this chapter, the focus shall be placed on three main groups of innovation patterns, i.e. geographical pattern, sectoral pattern and typological pattern.

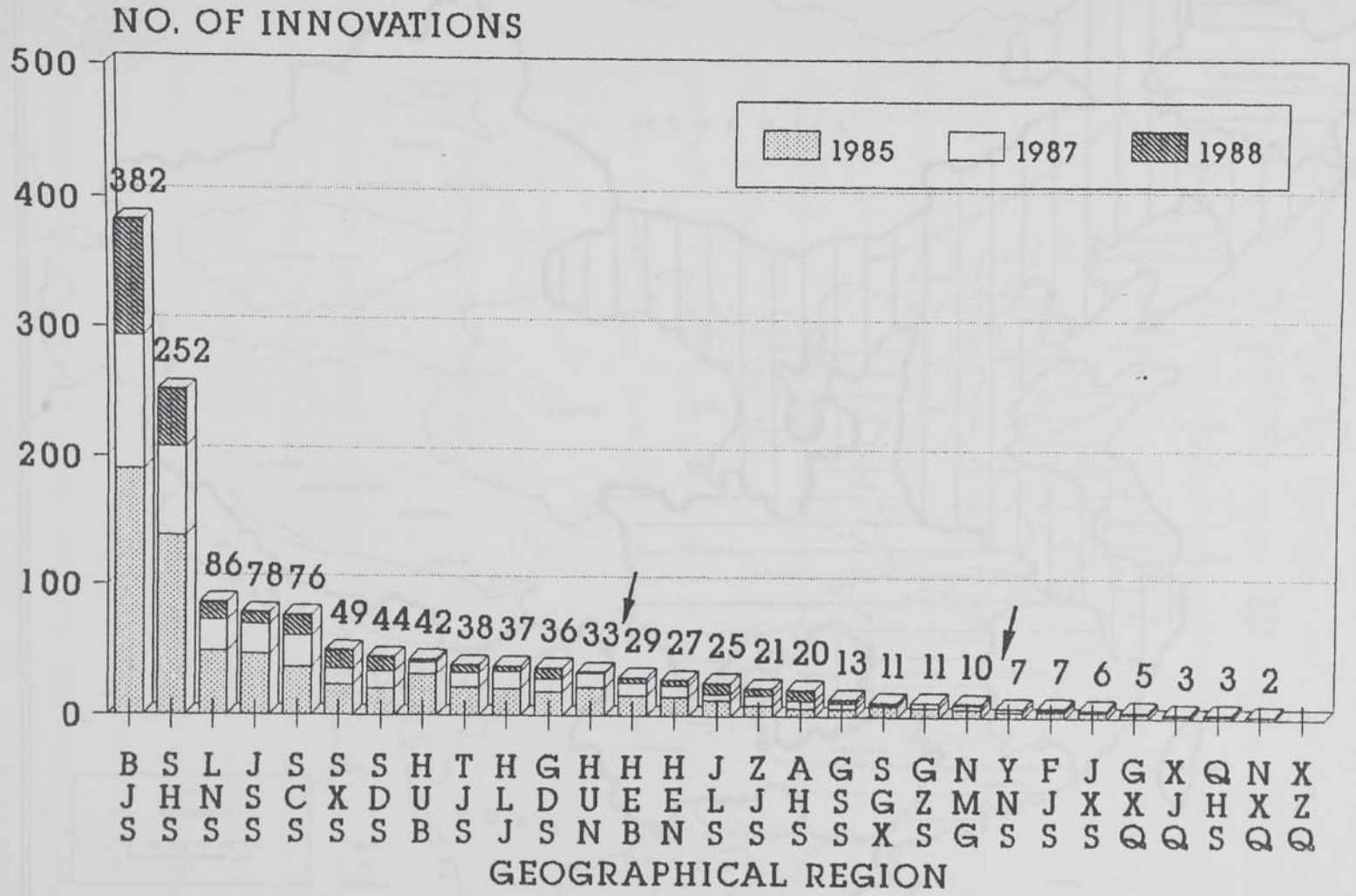
4.1 Pattern of Geographical Difference

Geographically, China is almost the same size as Europe. History and natural environment have brought about gap in economic and technological development among regions. For example, Eastern China is much more economically prosperous than the Western part. Even within the Eastern regions there are considerable differences in the level of development.

4.1.1 Categorisation of Geographical Regions

As can be seen from Figure 4.1, Beijing and Shanghai are the most innovative regions in terms of award-winning, taking an absolute share of 46.8% (28.2% and 18.6% respectively). Pareto analysis is used to differentiate degree of innovativeness of different regions. The three categories, namely <u>highly innovative, medium innovative, and poorly innovative</u> are defined accordingly. The statistical percentage boundaries used

FIG. 4.1 GEOGRAPHICAL PATTERN
(1978 - 1988)



SEE LIST OF ABBREVIATION FOR CODES

Aston University

Illustration removed for copyright restrictions

Figure 4.2 Geographical Pattern of Innovation in China (Map)

in the Pareto analysis are 97% for the highly and medium innovative regions and 85% for the highly innovative regions alone. The boundaries are indicated by two arrows in Figure 4.1 (between HUN and HEB, and between NMG and YNS). As discussions go along, it will become apparent that the classification of the three groups in such a way has great analytical advantages in the analysis of geographical difference in innovation performance.

It is clearly shown in Figure 4.1 that 12 highly innovative provinces claimed 1153 from a sample of 1353 awards (85.2%), while 9 medium innovative regions took further 167 awards (12.4%), leaving 8 poorly innovative regions only 33 awards (2.4%). XiZang(Tibet) had no award at all. If this unbalanced pattern of geographical innovativeness is plotted onto the map of China, some interesting points are revealed. (See Figure 4.2)

4.1.1.1 Highly Innovative Regions

Highly innovative provinces are indicated by horizontally-shaded area on the map. They concentrated in three blocks, the North-East (Heilongjiang and Liaoning), the Coast line (Beijing, Tianjin, Shandong, Jiangsu, Shanghai and Guangdong) and the Central (Shaanxi, Sichuan, Hubei and Hunan). There are a number of important factors, which helped the formation of the pattern: economic conditions, level of pre-communist industrialisation, impact of government policies and influence

of international environment as well as concentration of research institutes and institutions of higher education.

The North-East Provinces

The North-East was a well-established industrial base under the Japanese occupation before and during the Second World War. It was further invested and developed in the 1950s with the Soviet help. A strong agricultural basis, rich natural resources plus a well-developed railway system greatly assisted industrial and technological development in the region. China's biggest iron and steel complex, biggest oil field and refinery, automobile factory and aeronautic company are all in this region. Although some of its research organisations and factories were moved into the hinterland upon the break-up of Sino-Soviet relations in the 1960s, the North-East provinces still kept the majority of its research and industrial capacities. In both economic and technological terms, the North-East is regarded as backbone of China's heavy industries.

The Coastal Provinces

Provinces on the coast contain another contingent of China's research strength. Six regions in this group except Beijing, had reached considerable level of industrialisation in the pre-Communist era, especially Shanghai, Tianjin, Jiangsu and Guangdong. As a result of their geographical locations, so close to the sea, these provinces were easily accessed by

foreign businessmen. Overseas trading allowed industrial development to prosper in these provinces. Education and training levels were also relatively higher than other provinces in the hinterland.

After 1949 when the Communist Party took over power, recovery of national economy was on the top of the Party's agenda. Coastal provinces were much relied on, because their dominant position in the industrial production. For example, at that time, Shanghai produced nearly half of China's GNP. Naturally, those provinces, after 1949, continued to enjoy the state help and a somewhat quasi-monopoly position in the market, in terms of both industrial and consumer goods.

Unlike Shanghai and other coastal provinces associated with pre-Communist development, Beijing as the capital city received high priority under central planning, and gradually developed into the cultural, educational and technological centre of the nation. For example, according to 1987 statistics, Beijing hosts 447 research institutes above the county level, out of a national total of 5568. (SYB, 1988) A large number of them are under the Chinese Academy of Sciences and industrial ministries with higher technical level than national average. Beijing has become China's most important research centre.

The Central Provinces

The last group of highly innovative provinces are different from the first two groups in nature. They do not possess much pre-Communist industrial development, except part of Hubei (Wuhan). Some of them are even economically backwards provinces (Shaanxi and Hunan). However, all of them showed good performance in terms of technological innovation. This could be interpreted as the result of defence-related government innovation policy.

In the 1960s and 70s, under the pressure from unsettled international relations, many research institutes, universities and production units, which are closely related to national defence, were moved under the central directive from the North-East, the East coast and other parts of China into inner provinces, in order to shelter China's main defence-related industry from unexpected external attack. For example, Chenxing Research Institute of Manufacturing Technology, specialised in weapon technology, is one of those institutes moved to Sichuan in 1965. (Interview F, Appendix A) The move was largely due to strategic considerations at the time. But the side effects are technological capacities of these provinces are strengthened, and economic development in these localities are encouraged. So, although a lot of defence-related award-winning innovation were omitted from the published list, it is clear that these defence-related R&D institutes also contributed to the civilian technological progress.

4.1.1.2 Poorly Innovative Regions

Provinces classified as poorly innovative, shown as blank areas in Figure 4.2, share some similar problems. Poor climate or natural conditions makes them very difficult to be agriculturally developed. Unfavourable natural conditions also hinder the development of a good transport network. Education levels are generally lower in these regions. Most provinces in this group had little or virtually no pre-Communist industrial basis. Tremendous efforts have been made to develop economy and promote education in those provinces. Although there has been gradual progress, significant improvements in innovation performance by the group are unlikely to emerge in the short future.

4.1.1.3 Medium Innovative Regions

There is another group of provinces between the two extremes, with medium innovative performance. They are shown by vertically-shaded areas in Figure 4.2. Those provinces have reached reasonable level of economic development and research capacities. Some of them, e.g. Zhejiang and Jilin, have relatively strong industrial basis. But most of them are agricultural provinces of self-sufficiency.

4.1.2 Performance Over the Time Span

Having described geographical pattern of innovation generally, this section is to explore the pattern in relation to time horizon by different group of provinces. Along the time horizon, National Awards for Scientific and Technological Progress were granted three times in the period 1978-1988, First awarding in 1985, second time in 1987 and third time in 1988. Over this period, relative share of awards achieved by three groups of provinces are articulated in the Figure 4.3.

FIG. 4.3 GEOGRAPHICAL PATTERN OVER TIME

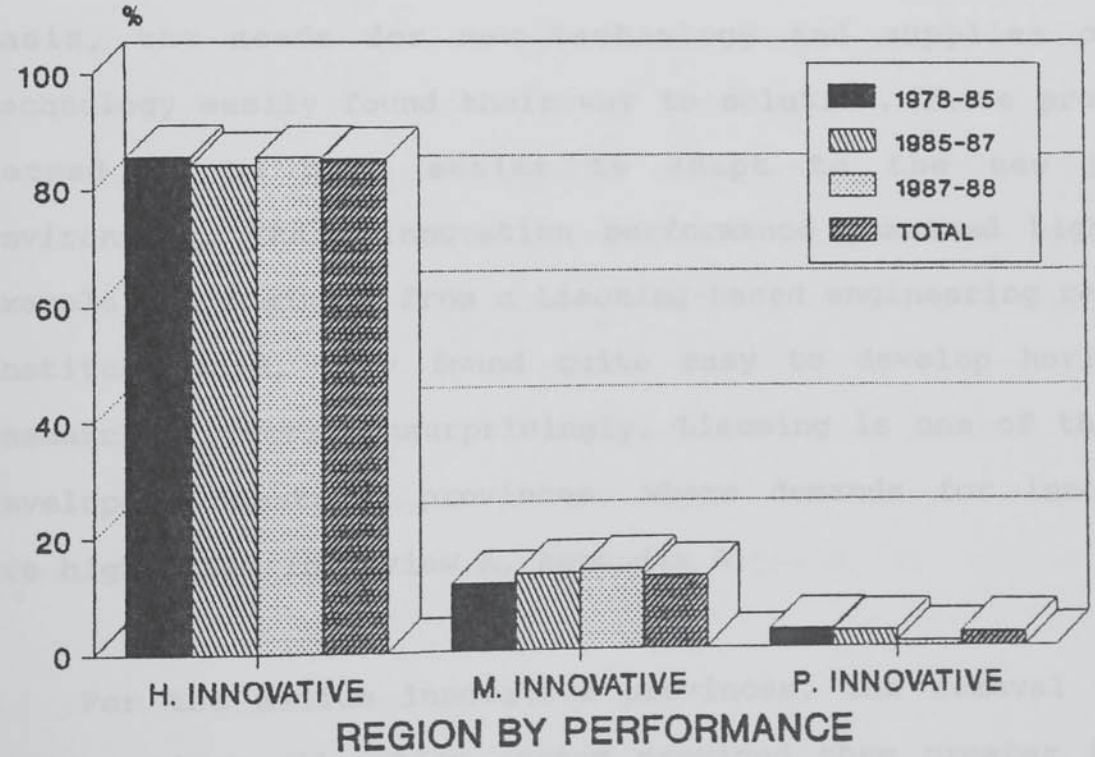


Figure 4.3 suggests that over the period from 1978 to 1988 that the highly innovative provinces kept a stable share. While medium innovative provinces increased their share gradually, poorly innovative regions lost their share gradually. Such change can be interpreted in relation to the impacts brought about by the reform in the R&D system. The most important factor is that State allocation was no longer the only means of setting up research projects. Research projects could be initiated through the market mechanism.

Due to their different innovation capacities, provinces responded differently. Provinces of high innovative capacities tended to respond to central policy change rapidly. Since those provinces have relatively strong economic and industrial basis, the needs for new technology and supplies of new technology easily found their way to solution. These provinces seemed to be much easier to adapt to the new policy environment. Their innovation performance remained high. For example, an engineer from a Liaoning-based engineering research institute said, they found quite easy to develop horizontal research projects. Unsurprisingly, Liaoning is one of the most developed industrial provinces, where demands for innovation are high. (See Interview A, Appendix A)

For the medium innovative provinces, the removal of the rigid project allocation system provided them greater freedom of operation. They had greater autonomy over R&D management and more opportunities to use existing research capacity. Compared

with the highly innovative provinces, the medium innovative provinces used to be allocated smaller shares of state-assigned projects in the past. Now, they found the new policy rather favourable. At least, projects, which in the past might have been assigned to research organisations in highly innovative provinces under the central planning system, now can be competed for by research units from medium innovative provinces.

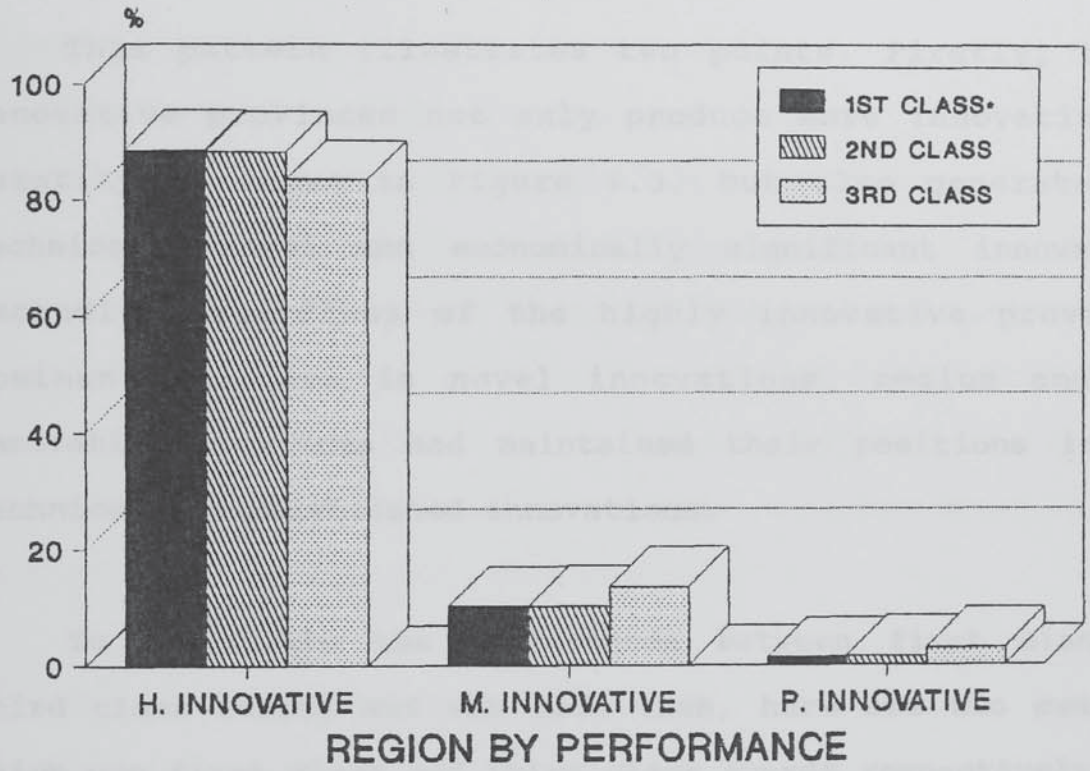
But for those poorly innovative provinces, the change had unfavourable effects. First of all, because of their poor research capacity, they were not able to attract many research projects, or were only able to get technically less complicated contracts. This is shown in Figure 4.3 as poor ability of award winning - only 0.8% in 1988. Even many technical problems arising from these provinces, were contracted out to or undertaken in co-operation with research institutes in more innovative provinces. Here is a simple example. One record in the database shows that a Yunnan provincial research project on "the Prevention of Steam Corrosion and Wear to Stainless-steel Turbine Wheels" was jointly completed by Kunming Machine Tool Factory in the province and Shanghai Research Institute of Materials, an outside expertise in the field.

4.1.3 Performance by Degree of Novelty

It was mentioned in Chapter 3 that there are four classes in the National Awards for S&T Progress. They are the key

indicators to mark the degree of technical novelty and economic benefits of a specific innovation. Technical capabilities of these regions can be measured, by the number of awards won in different classes.

FIG. 4.4 GEOGRAPHICAL PATTERN BY CLASS



* SPECIAL CLASS AWARDS INCLUDED

Figure 4.4 summarises performances of three groups of regions in relation to the class of award from 1978 to 1988. Since special class awards are conferred for exceptional cases, only a few were awarded each year. For the convenience of analysis, they are included with first class awards in later discussion.

Clearly, highly innovative provinces took a consistent dominant lead in higher classes, but relatively less so in the third class. On the contrary, medium and poorly innovative provinces showed significant increases in the third class awards, a nearly one third increase for medium innovative provinces, and a 100% increase for poorly innovative provinces.

This pattern illustrates two points. Firstly, highly innovative provinces not only produce more innovations in quantity as shown in Figure 4.3, but also generate more technically novel and economically significant innovations. Secondly, regardless of the highly innovative provinces' dominant position in novel innovations, medium and poor innovative provinces had maintained their positions in less technically sophisticated innovations.

To illustrate the differences between first class and third class awards and who made them, here are two examples, which won first class and third class awards respectively. "The High-speed and Ultra High-speed Bipolar digital Integrated Circuits" jointly developed by No.871 Factory of Ministry of Electronic Industry, Shanghai Research Institute of Metallurgy, No.24 Research Institute of Ministry of Electronic Industry and Shanghai No.19 Radio Factory, represented the state-of-art technology and won a first class award in 1985. The project attracted research expertise from both Beijing and Shanghai. On the other hand, "The ZZD-06 Circular Electronic Carrier Equipment" developed by Yunnan Telecommunication Equipment

Factory, won a third class award in 1985. The technology did not achieve significant technological breakthrough.

Analysis also suggests that Beijing have won relatively more first class awards than lower class awards. Beijing's share drops from 35.4% of the first class to 30.9% of the second class, and to 26.3% of the third class. Meanwhile, Shanghai took 12.7% of the first class awards, 20.4% of the second class and 18.3% of the third class. The percentages suggest that Beijing and Shanghai are both national innovation centres in absolute terms outnumbering other provinces by wide margins. But in relative terms, Beijing is more oriented towards new advanced technologies and research projects of national significance (first class), while Shanghai is relatively more dedicated towards medium sophisticated technologies (second and third classes).

Over the period 1978-88, Beijing has actually increased its share in winning awards, from 26.6% in 1978-85 to 26.9% in 1985-87 and to 34.9% in 1987-88. Other provinces correspondingly had decreases over the same periods. This seems to confirm that Beijing, as the nation's most prestigious innovation centre of huge technological potentials, performed an increasingly more important role in the reform process.

4.2 Pattern of Sectoral Differences

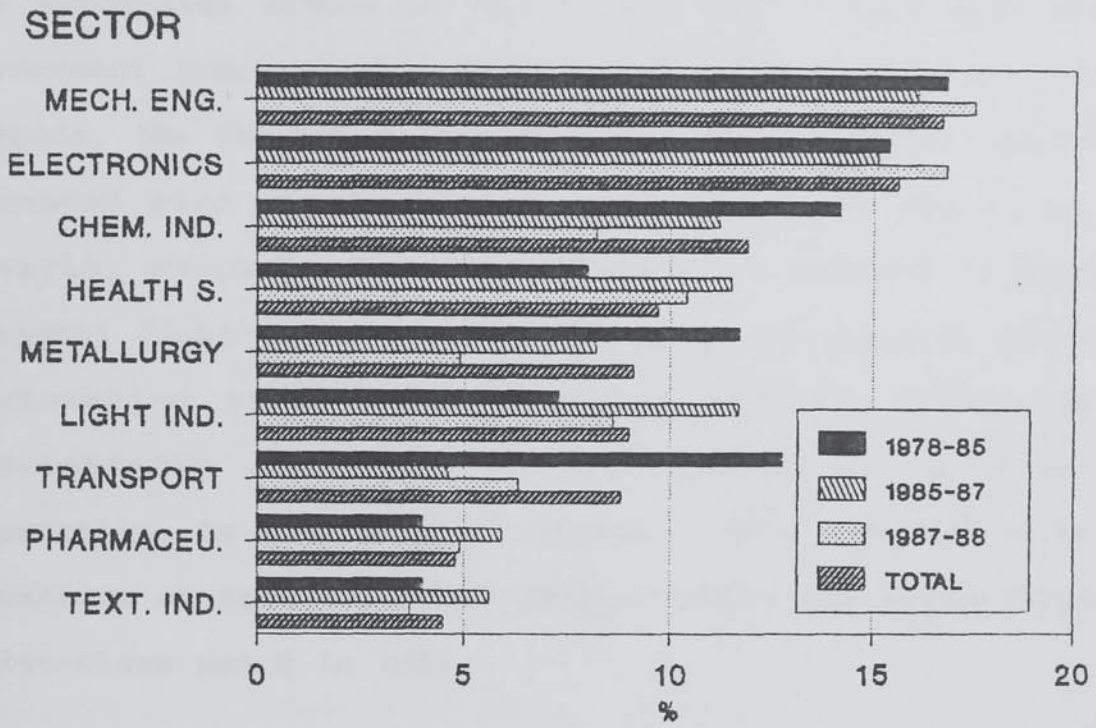
4.2.1 Pattern Based on SSTC Classifications

The initial data were available in the form based on the SSTC classification scheme. It has been argued that the SSTC classification is largely based on administrative structures for the purpose of easy administration of the award scheme. As a result the classification scheme reflects more elements of China's industrial ministerial structure than technological divisions. It is also a hybrid scheme, which mixes the industrial sector and the ministerial structure together. It remains an useful tool to illustrate sectoral innovation patterns.

4.2.1.1 Sectoral Differences Over Time (SSTC)

As shown in Figure 4.5, according to the SSTC classification, three basic industries, namely, mechanical, electronic and chemical industries are on the top of the list. This fits rather well with sectoral capacities of Chinese industries. But it is interesting to notice that the chemical industry, and metallurgical industry did less well over the period 1978-88, despite of government's claim of high priority of development given to these industries. Their rankings in relation to other industries have decreased generally over the period.

FIG. 4.5 SECTORAL PATTERN OVER TIME
- SSTC CATEGORIES



On the other hand, consumer industries, namely light industries and textile industry, enjoyed a sharp rise in 1985-87 as a result of the consumer boom brought about by the economic reforms. But in 1987-88, the trend slipped down, indicating a possible short-term consumer market stagnation and the re-introduction of some planning measures. But the overall ranking of light industries has managed moving from the 7th place in 1978-85 to the 4th place in 1987-88.

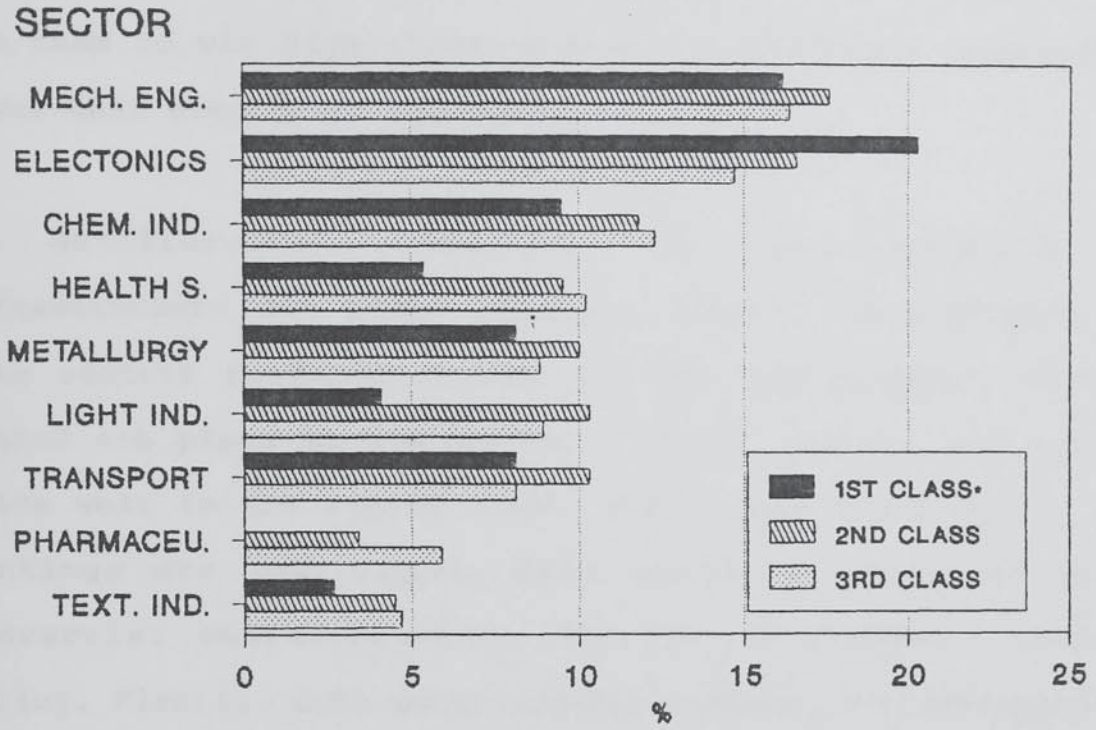
Health Service and Medical Equipment & Pharmaceutical industry, improved their ranking gradually, in relation to other industries. The ranking of health service has shifted from the 6th place in 1978-85 to the 3rd place in 1987-88,while medical equipment & pharmaceutical industry improved slightly

from the 8th place to the 7th place over the same period. This is because health-related industries are politically treated as the successful symbol of socialism, they always stay high on government agenda. Although there exist many problems, in many aspects, the Chinese health service is regarded as technically advanced even when compared with developed countries. For example, People's Hospital of Beijing Medical University, Shanghai Jiaotong University, Research Institute of Electrical Engineering of CAS and Shanghai Medical University has successfully developed a new method of international reputation, to remove renal stones - "The Hydro-electric Wave Technique of Breaking Renal Stones". This new technology won a first-class award in 1987.

4.2.1.2 Sectoral Differences by Degree of Novelty (SSTC)

As shown in Figure 4.6, three basic industries, namely mechanical engineering, electronic industry and chemical industry hold overall dominant positions. The electronic industry has been more successful in winning high classes awards, ranked the 1st (20.3%) in the special & first classes. Then its share falls to 16.6% of the second class and 14.7% of the third class. On the contrary, chemical industry performed better in low classes of award, taking 12.3% of the third class, only 9.5% of the special & first class. The mechanical engineering sector seems fairly consistent in all classes of award, with relatively better performance in the second class.

FIG. 4.6 SECTORAL PATTERN BY CLASS
- SSTC CATEGORIES



* SPECIAL CLASS AWARDS INCLUDED

The situation could interpreted as the result of sectoral characteristics and government innovation policy in combination. The electronic industry is a new industrial sector in China and enjoys high level State investments. Many of the State projects are large undertakings expanding into new technologies. This gives the industry more chances of winning high class awards. For example, the above-mentioned "high-speed digital integrated circuits" was a big State-funded project. It aimed at a major breakthrough in integrated circuits production in order to eliminate reliance on expensive imports, which were regarded as constraints to the development of Chinese electronic industry. But mechanical engineering and chemical industry, are relatively well-developed sectors in China. They receive less State investments, when compared with electronic

industry. Many innovations are based on existing technologies, rather than opening a brand new technical fields. The chances for them to win high class awards are therefore comparatively lower than electronic industry.

Metallurgical industry and transportation are infrastructure for other sectors. Figure 4.6 indicates that both sectors performed better in the high classes. Both are ranked 4th place in the special & first classes, and both did quite well in the second class. But in the third class, their rankings are low. Again, this could be explained by the industrial characteristics and the government innovation policy. Firstly, both metallurgical industry and transportation received high priority of development. Secondly, the nature of the industry decides that innovations in both industries tend to be big projects involving large-scale capital investments. As a result, they are more likely to win high class awards, rather than lower class awards. Typical examples are "The GY Low-tension Linear Rolling Machine and Its technical Application in the Renovation of Medium and Small Rolling Machines" and "The Design and Construction of 27,000T Bulk Freighter". Both won first class awards in 1987.

Compared with other industries, consumer related industries generally occupied much lower positions in high classes. But in the lower classes, their positions improved considerably. For example, the Light Industries' position reached the 4th position in the second class and 5th in the

third class. The Health Service maintained a steady increase, from 5.4% in the special & first classes to 10.2% in the third class. Similarly, textile industry and pharmaceutical industry had increased shares in the second class and the third class. Due to their technical nature, innovations in consumer and service industries are expected to be much smaller in scale and often less technically intensive. Consequently, in these industries, more awards were won in the low classes, rather than in the high classes.

4.2.2 Pattern Based on Generic and Sub-generic Classifications

In the above section, the pattern of technological innovations was presented according to the SSTC classification, which is a combination of industrial structure and ministerial categories. A new classification scheme based on generic and sub-generic technologies is used here to examine patterns of technological innovation from a different angle.

4.2.2.1 Generic Differences Over Time

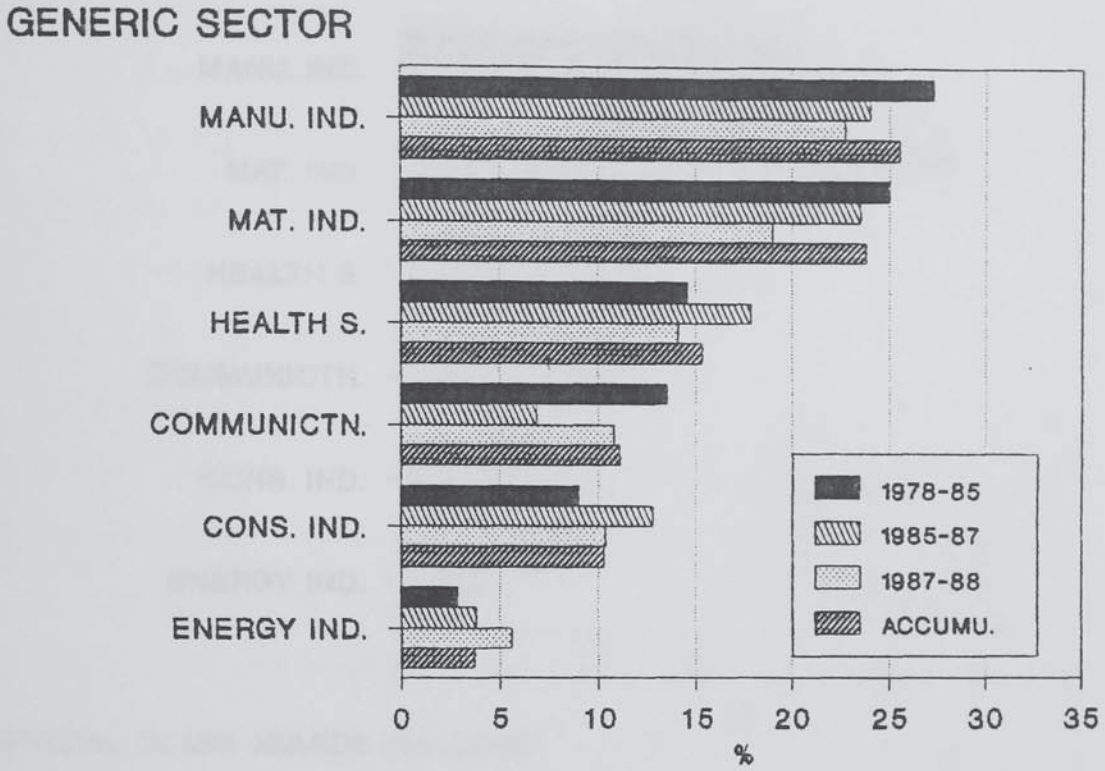
At the generic level, manufacturing industries and material industries take the overwhelming lead in all three periods, namely 1978-85, 1985-87 and 1987-88. However, their absolute shares have been declining. On the one hand, it is predictable that the two generic sectors would take the overall lead, as they are the basic industries like in other economies. The fact that their shares have been declining, on the other

hand, may suggest that the industrial structure in China is in transformation. Emphasis has gradually shifted away from traditional manufacturing industries. Other industries have gradually expanded in terms of innovation output.

Energy industries are the only sector showing constant growth over the three periods, from 2.9% in 1978-85 to 5.6% in 1987-88, nearly doubled. Although the absolute volume remains small, when compared with other sectors, the sustained growth suggests that the sector has been quite successful under the government high priority support. Many awards were related to the construction of hydro-power stations, like the Gezhouba Dam on the Yangtze River, which won a special award in 1985.

Other sectors listed in Figure 4.7 did not show any consistent increase or decease. The communications fell sharply in 1985-87, but picked up quickly in 1978-88. The poor innovation output performance in 1985-87 was caused by gaps in the State planning. Many projects in communications planned in the 70s were completed in the early 80s. The completion of those projects fulfilled the short-term demands at the time. The State subsequently removed some of its support. As a result, the innovation rate in the period 1985-87 dropped sharply. However, it was soon realised that the provision of infrastructure became acutely inadequate as the economic reform reached its peak in mid-80s. Policy started to shift back and more State funding was channelled to the communication sector. The rate of innovation increased consequently in 1987-88.

FIG. 4.7 GENERIC PATTERN OVER TIME



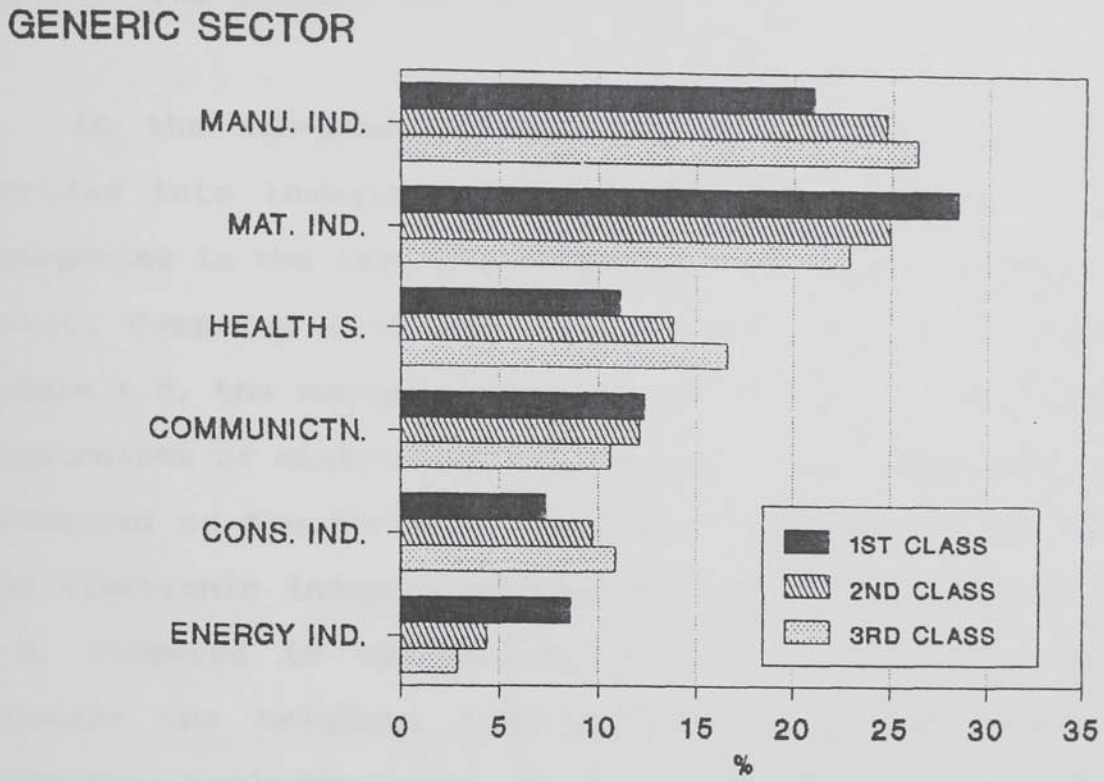
SEE TABLE 3.5 FOR DETAILED BREAKDOWN

For consumer-related sectors, the health service reached a peak in 1985-87 to 17.9%, then fell to the similar level in 1987-88 as in 1978-85. The consumer industries showed a similar pattern, jumping from 9.0% in 1978-85 to 12.8% in 1985-87, then down to 10.4% in 1987-88. This seems to suggest that innovations in consumer-related industries were most active in 1985-87, when economic reform were at its full speed. As the pace of economic reform slowed down after 1987, innovation rate in consumer-related industries dropped accordingly.

4.2.2.2 Generic Differences by Degree of Novelty

Figure 4.8 shows that when analysis is based on the class of award, infrastructure related sectors, namely materials

FIG. 4.8 GENERIC PATTERN BY CLASS



* SPECIAL CLASS AWARDS INCLUDED

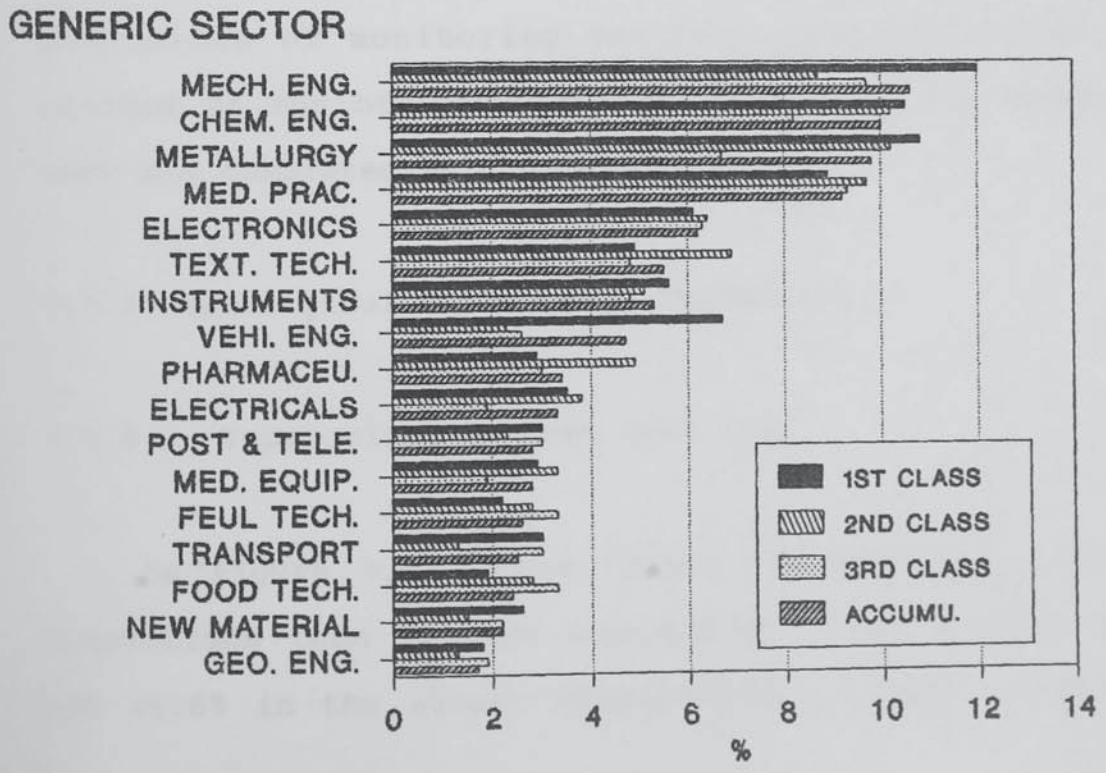
industries, communications and energy industries, had better performance in the first class. High priority of development and heavy investments given by the State in these sectors undoubtedly influenced the sectoral performance significantly.

On the other hand, manufacturing industries, consumer industries and the health service had higher rates of innovation in the lower classes. These sectors are usually not listed as a national priority of development, except for some manufacturing industries. As a result, most of them received less State investments. Innovations are therefore tended to be relatively small scale with lower degree of technical novelty. The technical characteristics of some mature manufacturing industries also limited the chances of big technological breakthrough.

4.2.2.3 Sub-Generic Difference Over Time

At the sub-generic level, generic sectors are further divided into industries, which are more comparable to the categories in the SSTC classification, though differences still exist. Compared with the SSTC classification presented in Figure 4.5, the sub-generic sectors in Figure 4.9 eliminate the constraints of ministerial boundaries. Innovation patterns are presented on the basis of industrial technology. For example, the electronic industry is only at the fifth place in Figure 4.9, compared to the second place in Figure 4.5. This is because the original SSTC definition of the electronics industry includes many items which are technically not electronic, but made by units under the Ministry of Electronic Industry. Similar problems exist in other SSTC categories.

FIG. 4.9 SUB-GENERIC PATTERN OVER TIME



However, unlike at the generic level, it is difficult to find a systematic pattern at the sub-generic level. It seems that traditional manufacturing industries are at the top of the list. At the same time, it is interesting to see textile technology is also in the front. This may somewhat explain the competitiveness of Chinese textile products in the world market. In the case of Sino-British trade, textile products have been the biggest trading category for a number of years.

4.3 Pattern of Typological Difference

4.3.1 Categorisation of Innovation Types

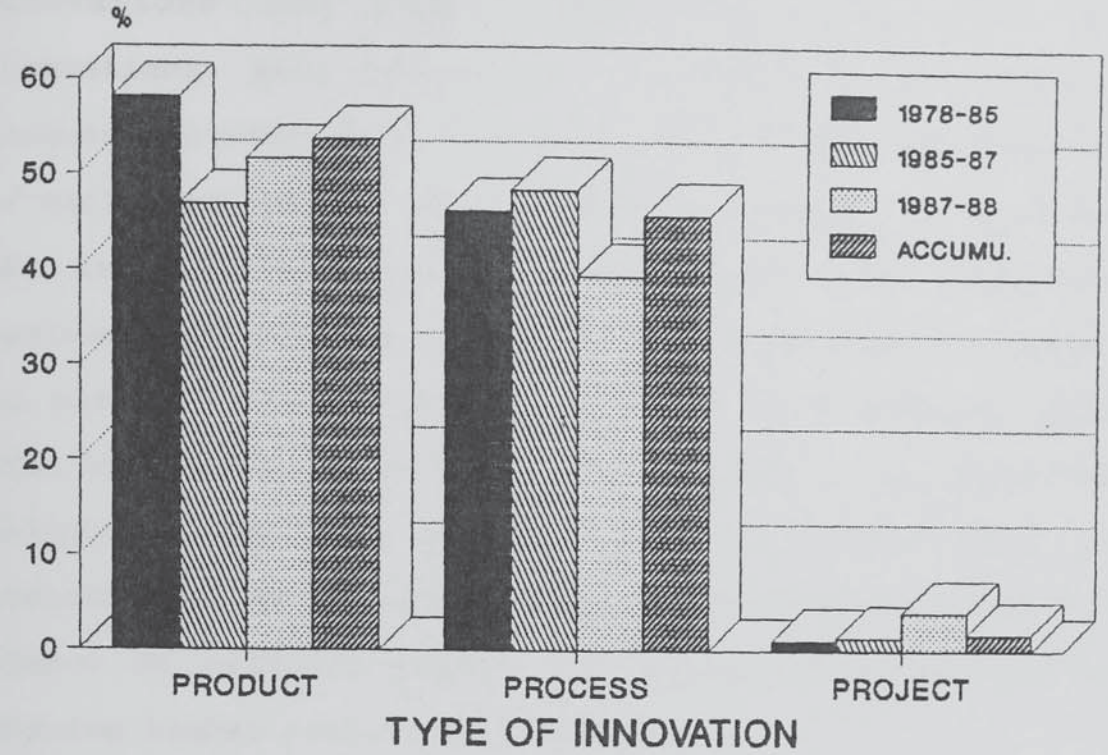
In addition to the broadly accepted innovation typology, namely product and process innovations, a third type - project is brought in to refer to big industrial undertakings, because big state funded industrial projects are one of the best indicators of monitoring sectoral priority of development claimed in the official innovation policy. The classification work was completed by the author.

4.3.2 Typological Patterns of Innovation

4.3.2.1 Typological Pattern over Time

As Figure 4.10 shows, there are generally more product innovations than process innovations. They account for 53.7% and 45.8% in the sample respectively. Except in 1985-87, the

FIG. 4.10 TYPOLOGICAL PATTERN OVER TIME



NOTE: SOME INNOVATIONS ARE BOTH PRODUCT & PROCESS INNOVATIONS

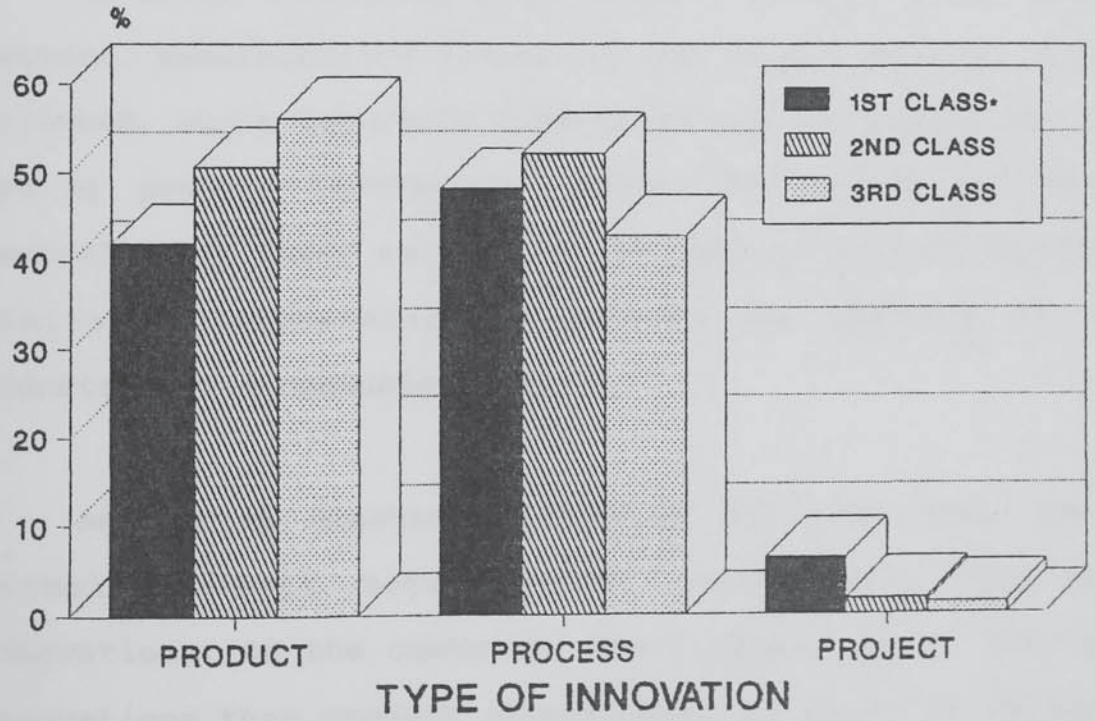
rate of product innovations was considerably higher than that of process innovations. The rate of industrial projects increased significantly from only 1.1% in 1978-85 to 4.1% in 1987-88. This marked a continuous government commitment in financing big industrial projects. Especially in the mid-1980s, the rate of industrial projects jumped from 1.3% in 1985-87 to 4.1% in 1987-88.

4.3.2.2 Typological Pattern by Degree of Novelty

As shown in Figure 4.11, there are more process innovations in the higher classes, particularly in the special and first classes, while more product innovations are found in the third class. But this is not to suggest that process

innovations are more technically novel than product innovations. Here the second criterion of the award scheme becomes decisive, i.e. the scope of economic benefits/returns. As mentioned earlier, all innovations awarded in the scheme are new technologies which have been applied in production and achieved economic results. Process innovations are much easier to diffuse into companies using the same process technology than completely changing to a new product line. Their economic returns appear to be swifter and bigger than product innovations. As a result, process innovations stand a better chance of bringing bigger and quicker economic benefits and winning higher awards consequently.

FIG. 4.11 TYPOLOGICAL PATTERN BY CLASS



NOTE: SOME INNOVATIONS ARE BOTH PRODUCT & PROCESS INNOVATIONS
• SPECIAL CLASS INNOVATIONS INCLUDED

Industrial projects are concentrated mostly in the special & first class awards, since most of them are State funded industrial projects of national economic or political significance. In addition, most of them are designated to be equipped with the latest new technologies. Upon the completion of those projects, it would be surprising if they failed to win national awards for both economic and technical, and sometimes political reasons. A good example is Baoshan Steel Complex near Shanghai. Although there were many debates about the choice of its technology and location, the first-phase construction won a first class award in 1988.

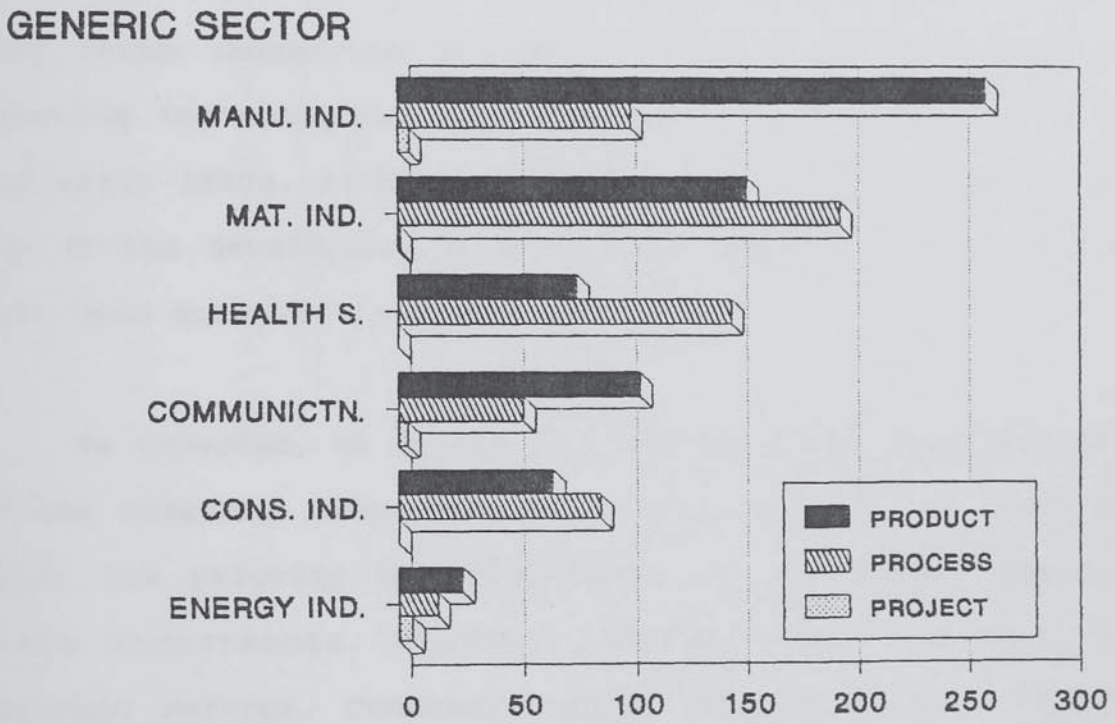
4.3.2.3 Typological Pattern by Generic Sectors

As shown in Figure 4.12, among the three most innovative sectors, manufacturing industries are highly product innovation oriented, while materials industries and the health service are led by process innovations. Again, the nature of industrial technology in these sectors can be used to explain the pattern. Similar interpretations can also be applied to energy industries and communications.

As far as consumer industries are concerned, one would normally expect more product innovations than process innovations. On the contrary, there appear to be more process innovations than product innovations, as shown in Figure 4.12. The reason might be, to qualify for the national awards for technological progress, innovations are judged by economic

benefits achieved apart from technical novelty,. Considering the scale of the sectoral economy of the consumer industries, process innovations would bring bigger and quicker economic effects. Product innovations, even if more technically advanced, appear to be less competitive in this regard, because they need longer time to acquire the market.

FIG. 4.12 TYPOLOGICAL PATTERN BY SECTOR
- GENERIC CATEGORIES



SEE TABLE 3.5 FOR DETAILED BREAKDOWN

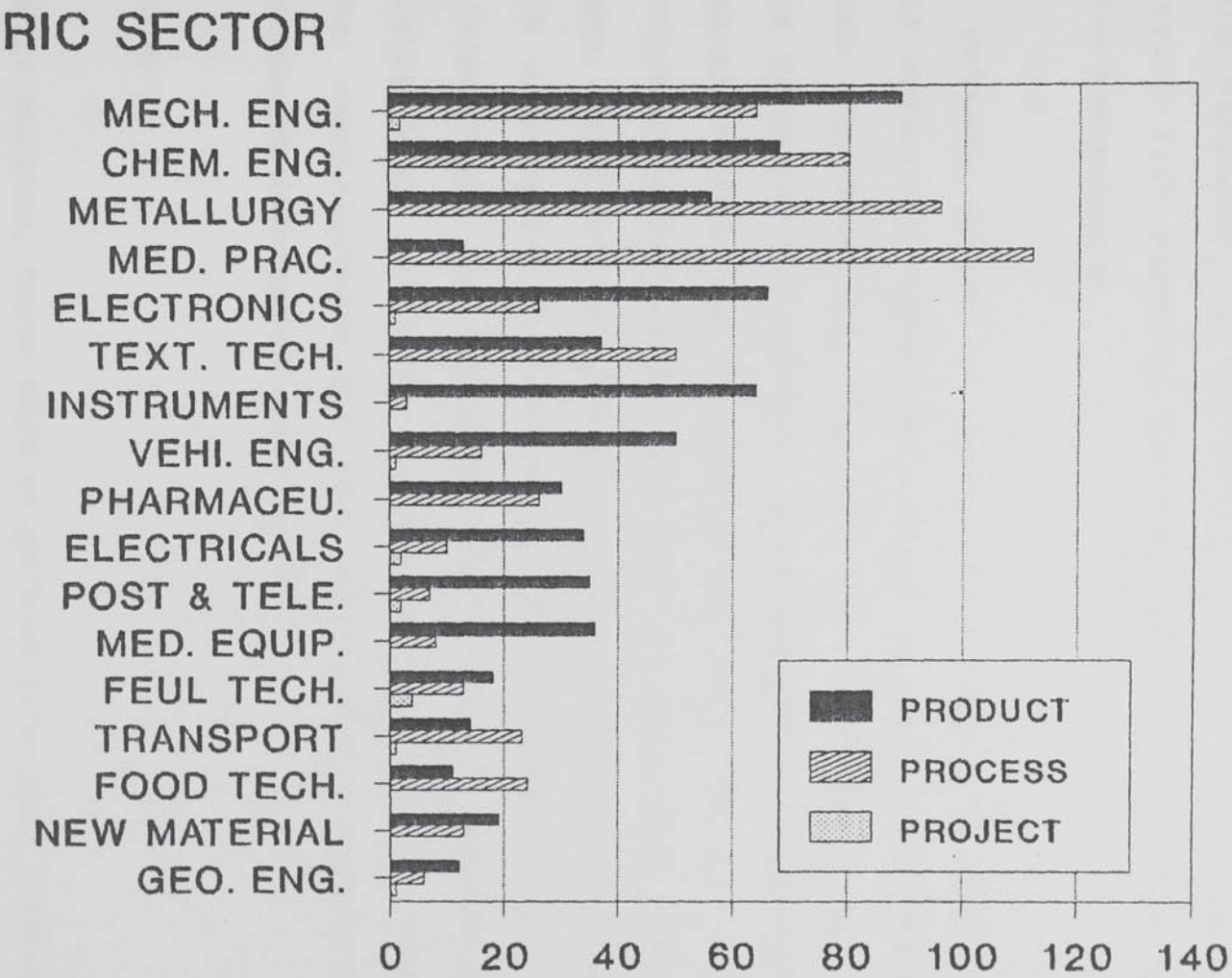
In the project category, Figure 4.12 shows that energy industries, manufacturing industries and communications take nearly all the project awards. Energy industries and communications are sectors of national development priority. They enjoyed heavy state appropriations, particularly when big projects are concerned. For the manufacturing industries, they

are the strongest sector of national economy. To sustain a steady economic growth, this sector is also allocated reasonable resources to expand its capacity, especially in the area of electronic technology. Examples of industrial project can be found in hydro-power engineering, large-scale integrated circuits and long-distance telephone system etc.

On the other hand, the share of materials industries is less than expected. This can be partly explained by the fact that these industries are now in the stage of consolidating existing technological capacity after the expansion in 1970s and early 1980s. Although the materials sector remains on the top of the development list, fewer large-scale major projects have been actually initiated in the 80s.

As expected, no awards on industrial projects were granted to the consumer industries and health service, largely due to their low priority of development and relatively small-scale state investments. However, changes have occurred in the economic reforms. Consumer-related industries have managed to encourage more innovations through both the State support and the market mechanism. Admittedly, it will take considerable time for the consumer-related industries to be able to compete with other industries in this regard.

FIG. 4.13 TYPOLOGICAL PATTERN BY SECTOR - SUB-GENERIC CATEGORIES



SEE TABLE 3.5 FOR DETAILED BREAKDOWN

4.3.2.4 Typological Pattern by Sub-Generic Sectors

Having discussed the typological pattern at the generic level, Figure 4.13 examines the typological pattern of main sub-generic technologies.

The pattern shown in Figure 4.13 suggests that the industrial nature of respective sectors influenced innovation performance significantly. Process-based industries tend to have more process innovations, e.g. chemical engineering, metallurgical engineering and medical practice. On the other hand, product-oriented industries tend to have more product innovations. Good illustrations are electronic engineering, instrument engineering and mechanical engineering. As far as project innovations are concerned, the pattern demonstrates specifically that projects are mostly located in energy industries, communications and some manufacturing industries, where government development priority lies.

4.4 Summary

In this chapter, three sets of pattern have been examined, namely geographical pattern, sectoral pattern and typological pattern. These patterns are presented in relation to two main parameters: firstly, along the time scale; and secondly by class of award. The class of award is employed as an indicator for degree of novelty here. Both parameters are brought in to assess the innovation performance of Chinese innovation system

and the impacts of government policies.

4.4.1 Geographical Pattern

As far as geographical pattern is concerned, provinces in China have been classified into three groups according to their award-winning performance, i.e. highly innovative, medium innovative and poorly innovative. Three main factors appear to be associated closely with a region's innovation performance significantly. These factors are: firstly, the level of pre-Communist industrial and economic development in the region; secondly, geographical location with regard to trading and agriculture; and thirdly, strategic choice of the government.

Along the time scale, highly innovative regions held an overall dominance. Medium innovative regions have managed to expand their share gradually. But poorly innovative regions found themselves in an unfavourable position. By class of award, highly innovative provinces are in a similar overall dominant position, but they acted more successfully in the first and second class awards. It appears that highly innovative provinces not only produce more innovations in quantity, but also generate more technically sophisticated innovations. Relatively speaking, medium and poorly innovative regions achieved better results in the third class award.

4.4.2 Sectoral Pattern

When sectoral pattern is analysed, two sets of classification system have been used in comparison. One system is the SSTC classification, which is largely based on China's industrial/ministerial structure. The other system is developed in the research with emphasis on generic categories. Generally, sectoral pattern of innovation is strongly influenced by the following factors: 1) current level of development of the sector; 2) priority for development of the sector set by the government; 3) industrial and technical characteristics of the sector; 4) influence of economic reform and the introduction of market mechanism.

Along the time scale, the sectoral pattern suggests that basic manufacturing industries i.e. mechanical engineering, electronics and chemical engineering and metallurgical industry are the top of the league. Infrastructure industries, like communication and energy gradually increased their share over the 1978-88 period. Consumer industries reached a peak in 1985-87, when economic reform was at its strongest. By class of award, the sectoral pattern shows that high class awards were frequently conferred to manufacturing and infrastructure industries, but in consumer-related industries, low class awards appear to be more dominant.

4.4.3 Typological Pattern

In the analysis of typological pattern, a "project" category specific to the planned economy context is included, in addition to the commonly used "product" - "process" typology. This category is particularly useful in assessing government investment priorities. Two factors bear significant impacts here, i.e. the priority for development set by the government and the nature of industrial technology.

Importantly, the pattern indicates that there are generally more product innovations than process innovations. This conclusion challenges the traditional view outlined in section 2.1.6, that process innovations tend to dominate in planned economy. The pattern also indicates that there are considerably more product innovations in the third class awards than that in the other two classes. While there are more product innovations than process innovations in the third class, process innovations appear to outnumber product innovations in the first and second class awards. In addition, awards conferred to project innovation largely centred in the first class and in 1987-88. Sectorally, product innovations dominated manufacturing industries, energy industries and communications. But in process-oriented industries, like chemical industry, metallurgical industry and consumer-related industries, process innovation turn out to be of greater influence.

CHAPTER 5 PATTERNS OF INNOVATING ORGANISATION

In Chapter 4, patterns of technological innovation have been presented and interpreted along a number of dimensions. They outlined a general picture of achievements of innovative activities in China in aggregate terms. This chapter shall proceed on the basis of Chapter 4 to examine the patterns of innovating organisations: who actually made these achievements and what are the relationship between different organisations in terms of contribution. This, on the one hand, compliments the aggregate measurement on innovation achievements by focusing on performance of different organisations; on the other hand, this creates a platform for later in-depth study on innovating organisations - the actors in innovation process.

5.1 Typological Pattern of Innovating Organisations

5.1.1 Categorisation of Innovating Organisations

As outlined in Chapter 2, China's R&D system followed the basic design of the Soviet model even when efforts were made recently in the reform to overhaul the system. Research institutes under the Chinese Academy of Sciences and other industrial ministries are responsible for a large portion of China's R&D resources. Universities and production units also have R&D capabilities. In addition, government organisations sometimes directly get involved in the process of innovation. But their roles are largely co-ordination, supervision and

problem shooting. In the following analysis, the roles played by these four key groups of organisation in technological innovation will be illustrated, particularly the first three groups.

5.1.2 Categorisation of Roles in Innovation Process

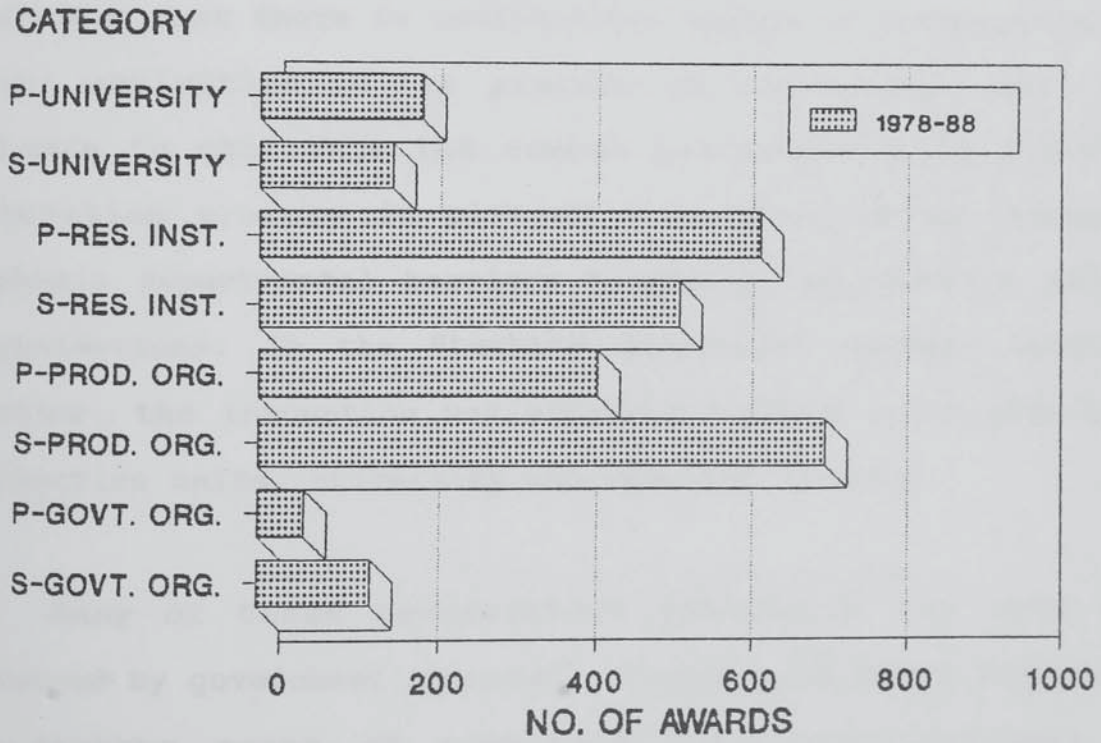
Analysis of the innovation award database shows that many awards were won jointly by more than one organisations. For example, "The 3000rpm Double Water-cooling Turbine Generator", which won a first class award in 1985, was completed jointly by Shanghai Electric Motor Factory, Zhejiang University, Harbin Electric Motor Factory and the Academy of Electrical Engineering.

In the process of innovation, different roles were played by participating units. One organisation acted as the team leader or co-ordinator, which could be either appointed by the superior administrative body in the case of planned projects, or assumed the role simply because it was the contract holder in the case of contracted research. In the above example, Shanghai Electric Motor Factory is the principal organisation responsible for the collaborative project. Other units are collaborative participants.

Thus, two primary functions can be defined in our analysis: 1) Principal Involvement, which refers to the role just outlined above. The organisation which undertakes

principal involvement is then the principal innovator. 2) Supportive Involvement, which means merely participation in and support to an innovation. Similarly, organisations which assume supportive involvements, are defined as supportive innovators. One innovation usually only has one principal innovator, but may have more than one supportive participants in the process. If we refer to the example of: "the 3000rpm Double Water-cooling Turbine Generator", Shanghai Electric Motor Factory is the principal innovator, while Zhejiang University, Harbin Electric Motor Factory etc. are the supportive innovators. The information on principal and supportive innovators is available in the published SSTC list.

FIG. 5.1 PATTERN OF INNOVATORS
- TOTAL



P-PRINCIPLE, S-SUPPORTIVE

As shown in Figure 5.1, from 1978 to 1988, research institutes acted as principal innovators in 639 innovations out of a total of 1383 (46.2%). At the same time, production units played the most important role as supportive innovators, 723 involvements out of 1611 (44.9%). Production units were also principally involved in 429 innovations (31.0%), while research institutes had 534 supportive involvements (33.1%). Universities held relatively smaller shares, with 205 principals (14.8%) and 168 supportives (10.4%).

This pattern suggests that the majority of China's technological innovations took place in research institutes and production units, with research institutes assuming more leading roles. The sheer volume of supportive involvements by research institutes and production units, on the other hand, indicates that there is considerable degree of co-operation and joint activities in the process of innovation. This fact appears to challenge the common perception held about the innovation process in planned economies, which tended to emphasis departmental barriers hindering co-operation between organisations. In the "turbine generator" example mentioned earlier, the innovation was achieved through joint efforts of production units, university and research academy.

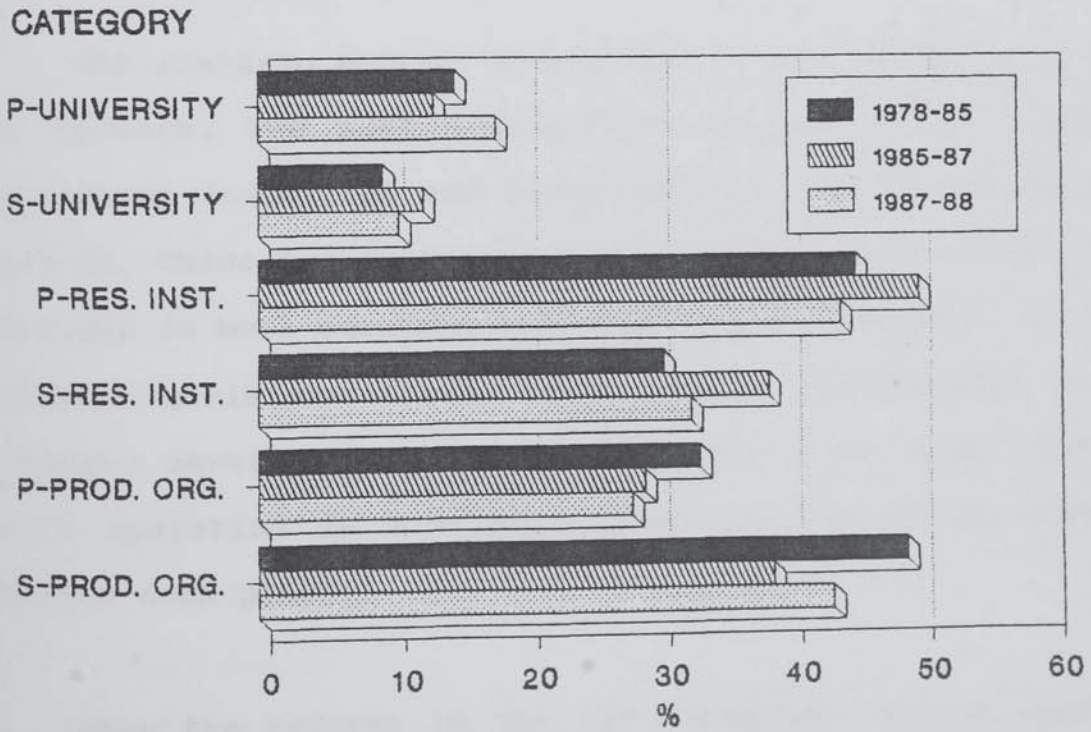
Many of these co-operative activities may have been arranged by government agencies. Direct government involvement is another means of promoting inter-organisational co-operation. In the sample, government at different levels

participated directly in 57 innovations (4.1%) as principal innovator, and also had 142 supportive involvements (8.8%). Apart from co-operation projects arranged by government agencies, the high percentage of supportive involvements indicates that spontaneous co-operations between the research and production sectors should not be underestimated.

5.1.3 Roles Played by Innovating Organisations Over Time

Figure 5.2 lists principal and supportive roles played by universities, research institutes and production units over the period 1978-1988.

FIG. 5.2 PATTERN OF INNOVATORS
- OVER TIME (1978-88)



P-PRINCIPLE, S-SUPPORTIVE

As far as principal involvements are concerned, research institutes fluctuated above 40%, reaching a peak in the 1985-87, when the reform of R&D system was introduced. The production units' share decreased gradually from 33.2% to 28.0%. Meanwhile, universities had a rise from 14.7% to 17.8%, although there was a fall in 1985-87 to only 13.1%.

The pattern of supportive involvements varied more dramatically. Production units played the most important role of this type and there was a sharp drop from 49.0% in 1978-1985 to only 38.7% in 1985-87, then recovering to 43.5% in 1987-88. Research institutes had a sharp increase from 30.4% in 1978-85 to 38.4% in 1985-87, then returning to 32.5% in 1987-88. Universities followed a similar pattern as research institutes, fluctuating between 9.3% and 12.3%.

The scenario can be interpreted as the result of a number of factors. The most influential one would be changes in government industrial and technology policy. In the period of 1978-88, China had initiated a number of radical reform policy packages in both economic and technological spheres. One of the ultimate goals was trying to bring new technologies to serve economic development. Many of those policies went into full-scale operation in mid-1980s. That is the period when most changes took place.

When the reforms in the S&T management system started in 1985, China's economy has at its best since economic reform was

introduced in 1978. Reforms in the economic sector had created a favourable environment for new technologies. Industrial enterprises were encouraged to improve production efficiency by technological means. A number of government sponsored national programmes were introduced since 1985, e.g. Technical Renovation Programme for Industrial Enterprises. Also there were specific programmes aiming at high technology, and agricultural technology and so on.

Under such a positive economic and policy environment, research institutes were granted greater autonomy in their operations. Directors of research institutes were put in charge of the running of research institutes, both organisationally, financially and academically. Research institutes were also encouraged to contact production units and get to know their needs. On the other hand, as a result of rapid economic growth, enterprises were eagerly seeking new technologies in order to compete in an increasingly competitive market place. Therefore, a sharp rise in both principal and supportive involvements of research institutes was seen in 1985-87. Because of the elimination of administrative barriers, expertise in research institutes could be easily consulted and many technical problems in production units were therefore passed onto research institutes for solution. Consequently, both principal and supportive involvements of production units decreased during that period.

However, research institutes' involvements, both principal

and supportive, dropped sharply in 1987-88. At the same time, production units kept roughly the same level of principal involvements as before, but increased a great deal in supportive involvements. If this change is correlated to government policy changes, the following interpretation could be possible.

From 1987, a responsibility system was introduced into research institutes. The new policy was that applied R&D institutes should become self-financing over a limited time period, except those in the basic research and public service area. The State would reduce its fund appropriation annually. Under the responsibility system, R&D institutes was supposed to find research projects by themselves, to pay their employees and to finance research. R&D institutes under financial pressure tended to take on projects of less risk and quick financial return. Since less attention and resources were devoted to large and technologically sophisticated projects, which are normally lengthy and risky and may not be financially more rewarding, research institutes achieved less national-level awards. Therefore, both principal and supportive involvements of research institutes declined in 1987-88. This problem was widely acknowledged among researchers and in the media. However, it may not necessarily suggest a general decline of innovation activities.

In the period of 1987-88, the production units' principal involvements fell slightly from 29.0% to 28.0%, but their

supportive involvements improved significantly from 38.7% to 43.3%. The sharp increase in supportive involvements shows that production units have gradually adapted to a facilitating role in technological innovation. It may also indicate that more practical technical problems were solved through joint efforts between research institutes and production units. As an engineer from an Xian-based research institute described, his institute was asked by a power plant to help renovate its coal grinder. In this particular project, the research institute assumed the technical leadership as the principal innovator. Since nearly all the R&D work were carried out in the power plant, the project was not a simple research contract. It was a collaborative undertaking, in which the power plant played an active supportive role. (Interview E, Appendix A)

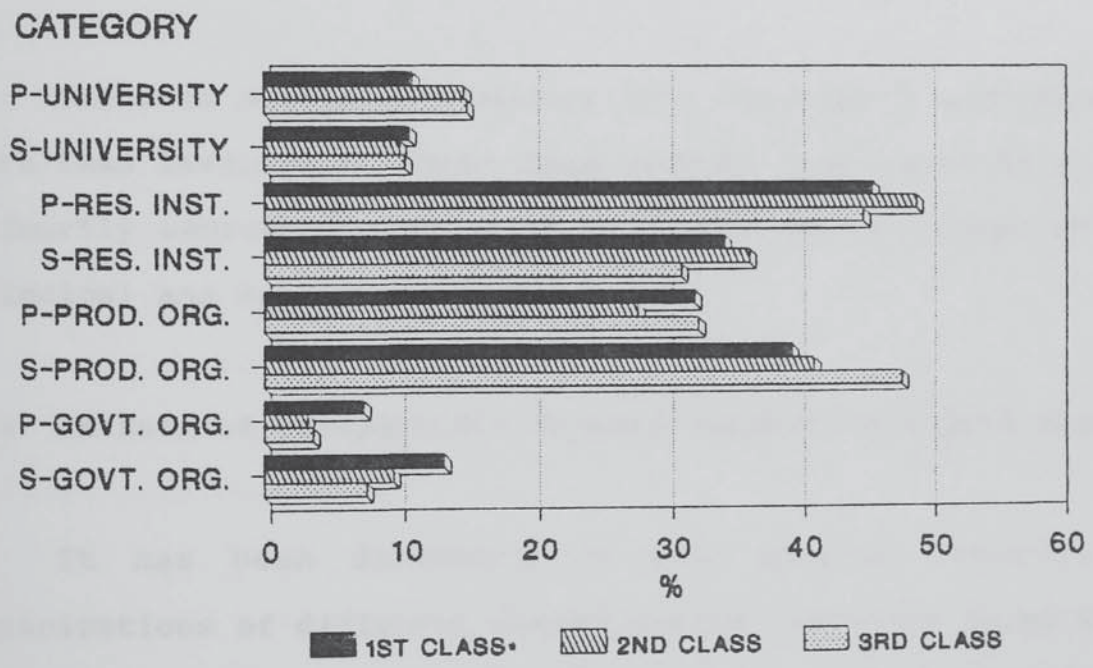
Universities are China's huge R&D reserve, particularly in basic and applied research. In the past, they played a less important role than they could do. In the reform process, the research and development potentials of universities have gradually been realised by industrial enterprises. Various forms of co-operation were undertaken. In the above-mentioned "turbine generator" example, Zhejiang University is one of the collective innovators. In some cases, universities have set up their own development companies, marketing their own technological products or providing technical services. As shown in Figure 5.2, universities play an increasingly important role as principal innovators in 1978-88 (from 13.1% to 17.8%). However, when compared with research institutes and

production units, the higher education sector's role in technological innovation is still comparatively limited.

5.1.4 Roles Played by Innovating Organisations by Degree of Novelty

As shown in Figure 5.3, roles played by innovating organisations further differentiated by degree of novelty. This is achieved through the class of award.

FIG. 5.3 PATTERN OF INNOVATORS
- BY CLASS



P-PRINCIPLE, S-SUPPORTIVE
• SPECIAL CLASS AWARDS INCLUDED

In Figure 5.3, research institutes and production units are undoubtedly the most active contributors in technological innovations in all classes of award. Generally speaking,

research institutes play more principal parts, while production units assume more supportive roles. More specifically, research institutes led in all classes as principal innovators, especially so in the second class. Production units' dominance as supportive innovators was apparent in all classes, particularly in the third class.

With regard to principal involvement, universities acted more actively in lower class awards, reaching 15.1% in the third class. But as far as supportive involvements are concerned, their shares fluctuated around 10.5% in all three classes.

There is a general tendency that government organisations were less involved in lower class awards. Their activities were primarily centred in the first class awards, in terms of both principal and supportive involvements.

5.2 Pattern of Co-operation Between Innovating Organisations

It has been discussed in the previous section how organisations of different nature played different roles in the process of technological innovation. It is also mentioned that, many of the innovations were the results of collective efforts in which more than one organisations got involved. To assess the relationship between organisations in these collective efforts, the concepts of two types of innovating roles and four types of innovating organisations introduced earlier, are

used to define the interactions among innovating organisations.

Analysis of 1393 innovations in the Database of Award-winning Innovations, showed that 767 innovations have been completed collaboratively, which account for more than 55% of the total. Such an majority, on the one hand, suggests that many innovations are achieved through joint efforts; on the other hand, it challenges the common perception that due to the departmentalised barriers associated with planned economies, co-operation between units are rare phenomena in innovation process. It may be arguable that the sample is biased, and therefore the conclusions drawn may not be fully convincing. Having acknowledged the worry, it must be pointed out that the sample here represents the first large-scale quantitative analysis on technological innovation in China, and all the entries are significant innovations representing the front-line level of Chinese technology. It is fair to argue that although there are limitations, the conclusions drawn from the current data are believed to have a solid empirical basis and are largely representative.

Over the period 1978-88, the ratio of co-operation dropped from 57.4% (1978-85) to 52.7% (1985-87), and then to 52.0% (1987-88). Nevertheless, the rate of co-operation in innovation activities remains reasonably high. It also seems that new reform measures introduced to promote co-operation between units, did not bring about higher co-operation rate as expected. But since only innovations of national significance

are measured here, the results should not be simply interpreted as that the reform failed to encourage more collaborative innovative activities. Many more co-operations may occur at lower levels, and may not be reflected in the sample.

5.2.1 Participation in Co-operative Innovations

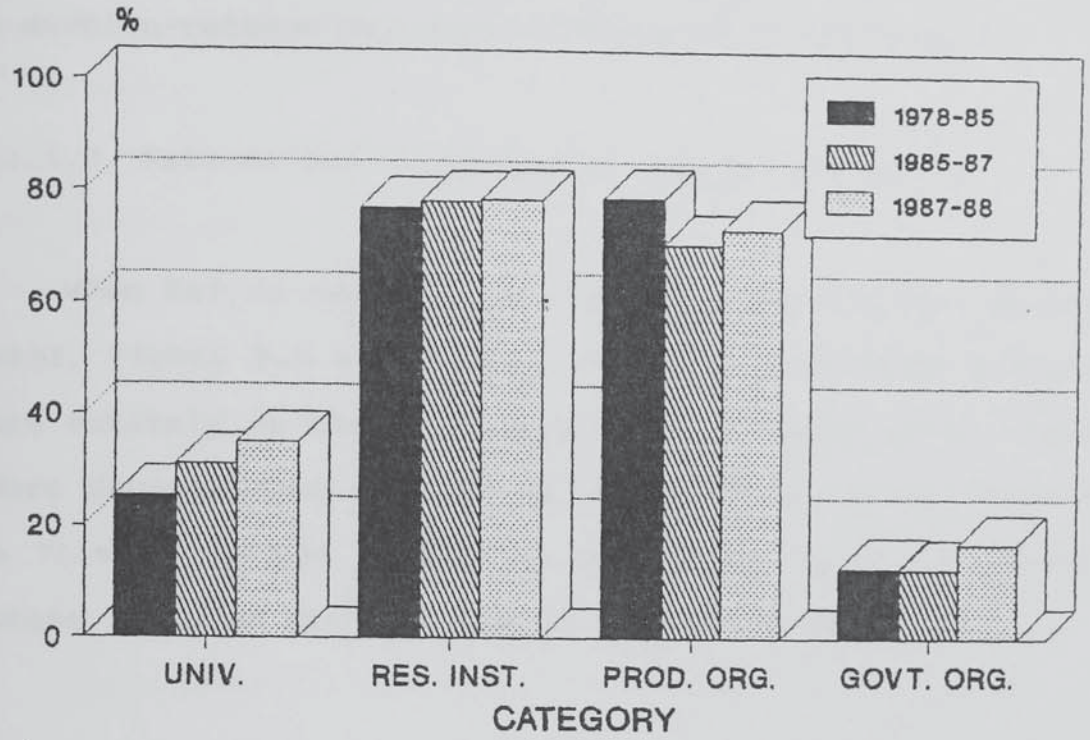
In the award-winning database, there are 767 innovations achieved jointly by more than one units. There are four main types of organisation, who participated in technological innovation. In this section, the rate of participation of these organisations are to be analysed.

5.2.1.1 Rate of Participation Over Time

As shown in Figure 5.4, the pattern confirms that research institutes and production units are the two most active participants in co-operative innovations. Research institutes have increased the rate of participation gradually over time. Under the reform policy, research institutes have been encouraged to extend horizontal links in order to serve the economic development better. On the other hand, under the increasing pressure for financial independence, research institutes have no other choice, but to seek for industrial co-operation.

While the rate of participation by research institutes shows a gradual increase, universities also upgraded their

FIG. 5.4 PATTERN OF PARTICIPATION
- OVER TIME (1978-88)



rate of participation significantly, from 25.4% (1978-85) to 35.0% (1987-88). This confirms the argument raised earlier that universities, as one of China's main R&D contingents, are playing an increasingly more important role in technological innovation, and becoming more and more closely linked to industrial enterprises.

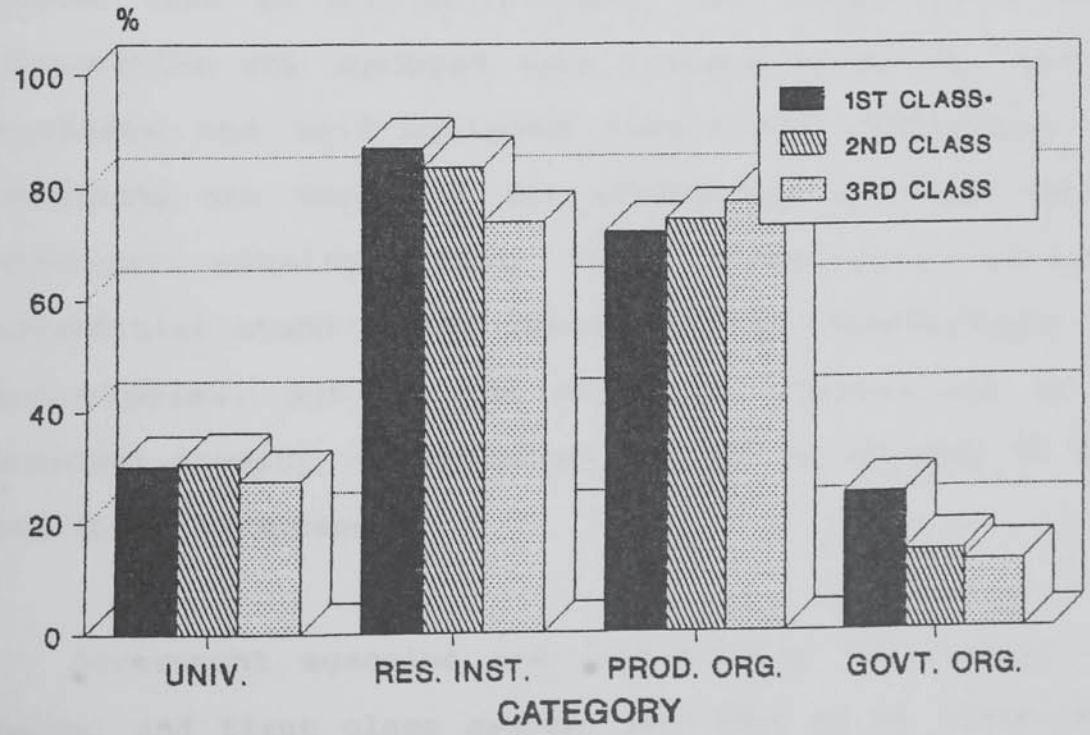
It is important to note that production units' participation was higher in 1978-85 than in 1985-87 and 1987-88. This may be explained by the fact that increased participation of universities and research institutes has taken up some of production unit's share. Over the time, some production units may have developed their own R&D capabilities. Some technical problems are solved in-house. For example,

Shanghai Machine Tool Factory has its own research institute, which conducts new product development, design and other production-related R&D work. (Interview I, Appendix A)

5.2.1.2 Rate of Participation by Degree of Novelty

When 767 co-operative innovations are analysed by class of award, Figure 5.5 shows that research institutes participated more actively in higher classes than in lower ones. There is a sharp decline from the second class to the third class (83.4% to 73.6%). On the contrary, production units performed more active in lower classes than in higher classes.

FIG. 5.5 PATTERN OF PARTICIPATION
- BY CLASS



* SPECIAL CLASS OF AWARDS INCLUDED

Clearly, innovations, which had won higher class awards tended to be technically more sophisticated, therefore requiring more input of technical expertise and resources, which under most situations only research institutes could be able to provide. Hence, high rates of participation of research institutes in higher classes are understandable. Accordingly, innovations that won lower class awards tended to be less sophisticated in technical terms, and sometimes they could be dealt with by production units alone. As a result, research institutes are less involved and production organisations become more active in lower classes.

Compared with research institutes and production units, the universities' rates of participation are much lower. Figure 5.5 indicates that universities did relatively better in higher classes than in the third class. The reason could be that universities are equipped with trained personnel, up-to-date knowledge and well-equipped laboratory facilities. These conditions are essential for innovations of high degree of technical novelty. With these favourable advantages, universities stand better chances making breakthroughs in new technologies. But in the cases of innovations of lower technical novelty, universities may not be so easy to benefit from their advantages.

Government agencies are particularly influential in the special and first class awards, but less so in lower classes. Admittedly, many innovations won special or first class awards

are big in scale, capital intensive or strategically important. Therefore, they require high level State assistance or direct involvement of a government department. For example, the development of "Computer Data Processing System for the Third National Population Census" was directly supervised by the State Planning Commission.

5.2.2 Forms of Co-operation

Having illustrated the participation by different organisations in co-operative innovations generally, a group of specific patterns are developed below to give a clearer picture of collaborative activities.

5.2.2.1 Homogeneous Co-operation

Homogeneous co-operation refers to co-operation between organisations of the same nature in the completion of an innovation. For example, "the Integrated Solar Drier" developed by Guangzhou Research Institute of Energy and Guangzhou Research Institute of Agricultural Machinery is a typical homogeneous co-operation. There are three main categories of homogeneous co-operation, i.e. between universities, between research institutes or between production units. Figure 5.6 and 5.7 outline the rates of homogeneous co-operation over time and by class of award respectively.

FIG. 5.6 PATTERN OF COOPERATION
- HOMOGENEOUS (1978-88)

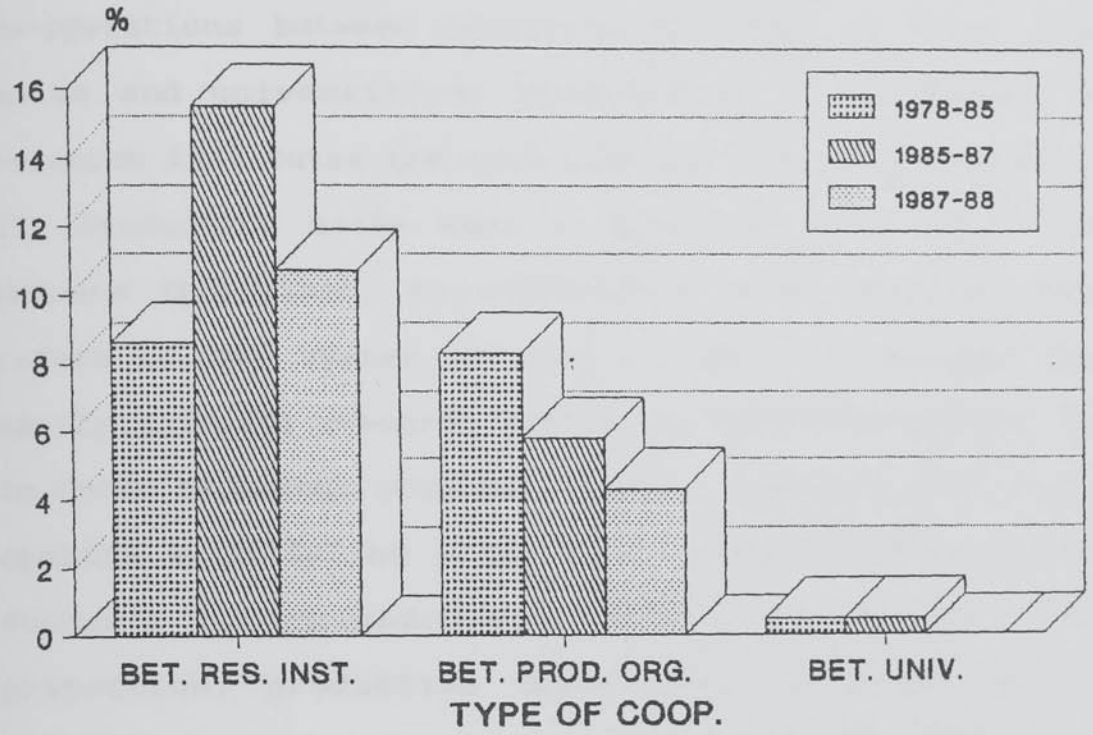
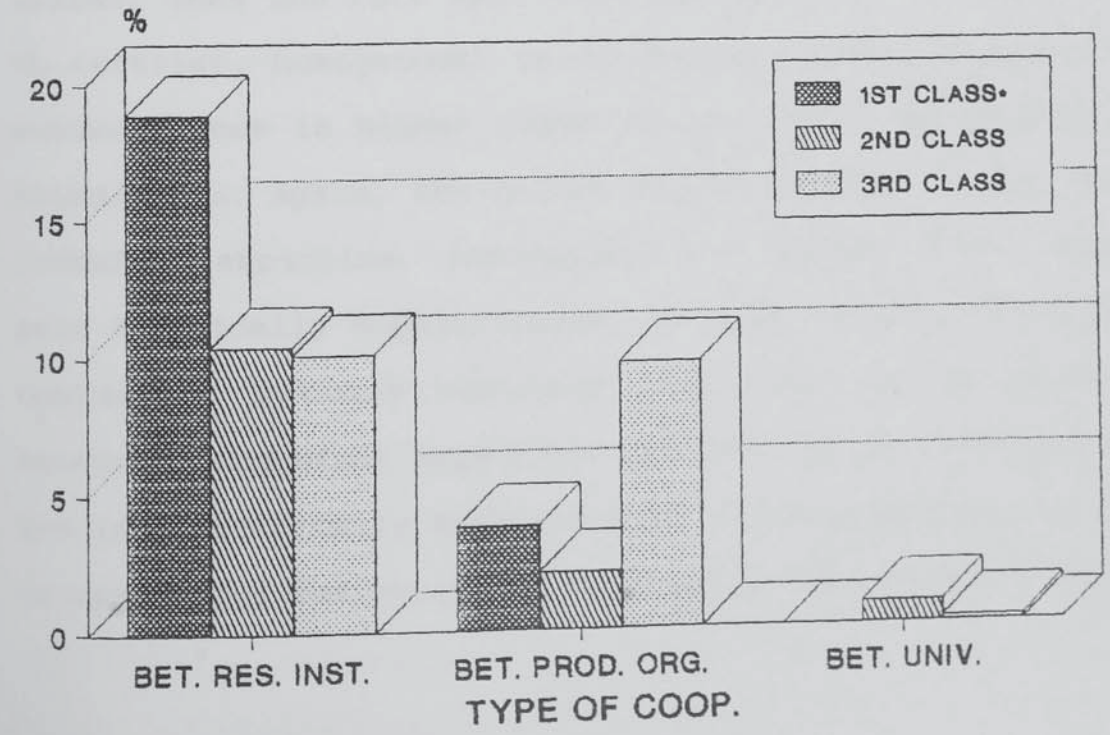


FIG. 5.7 PATTERN OF COOPERATION
- HOMOGENEOUS (BY CLASS)



• SPECIAL CLASS AWARDS INCLUDED

As shown in Figure 5.6, there are very limited homogeneous co-operations between universities, compared with production units and universities. Homogeneous Co-operations between research institutes are most commonly seen, especially in 1985-87. Production units have a declining rate of co-operation between themselves. An explanation could be that, since the reform of S&T system started in 1985, production units can easily approach research institutes with appropriate expertise to solve technical problems. Simply, there is less need to co-operate with fellow production units. Moreover, since the economic reform encourages market competition, for self-protection, production units have to block the flow of technical information from reaching their competitors.

Figure 5.7 shows that homogeneous co-operations between research institutes concentrated in the special and first class awards. Then the rate went down dramatically in lower classes. In contrast, homogeneous co-operation between production units occurred less in higher class awards, but concentrated in the third class. Again, the reason can be related to the needs for technical expertise. Innovations won higher class awards are more technically sophisticated, so that in many cases only co-operations between research institutes could provide the necessary technical expertise and facilities. When innovations are less technically sophisticated and more production related, co-operations between production units then become sufficient.

5.2.2.2 Heterogeneous Co-operation

Heterogeneous co-operation refers to collaborative activities between organisations of different type in the innovation process. For example, "the TBJL Medium-wave Synchronous Broadcasting Stimulater" jointly designed by Harbin Broadcasting Equipments Factory and Shandong Research institute of Broadcasting and Television is an example of heterogeneous co-operation. Among four types of organisation mentioned earlier, three of them, namely research institutes, production units and universities, are the actual R&D performers in technological innovation. Interactions between these three types of organisation are of most interest, as far as heterogeneous co-operations are concerned.

Two types of co-operations are the primary forms, i.e. co-operation between universities and production units, and co-operation between research institutes and production units. Figure 5.8 and 5.9 give the rates of heterogeneous co-operation over time and by class of award respectively.

As shown in Figure 5.8, co-operations between research institutes and production units account for more than 50% of the collaborative innovations in the period from 1978 to 1988. They are the most important form of heterogeneous co-operation. Over the period from 1978 to 1980, co-operation between universities and production units showed a steady increase from 18.1% in 1978-85 to 25% in 1987-88. This suggests that while

FIG. 5.8 PATTERN OF COOPERATION
- HETEROGENEOUS (1978-88)

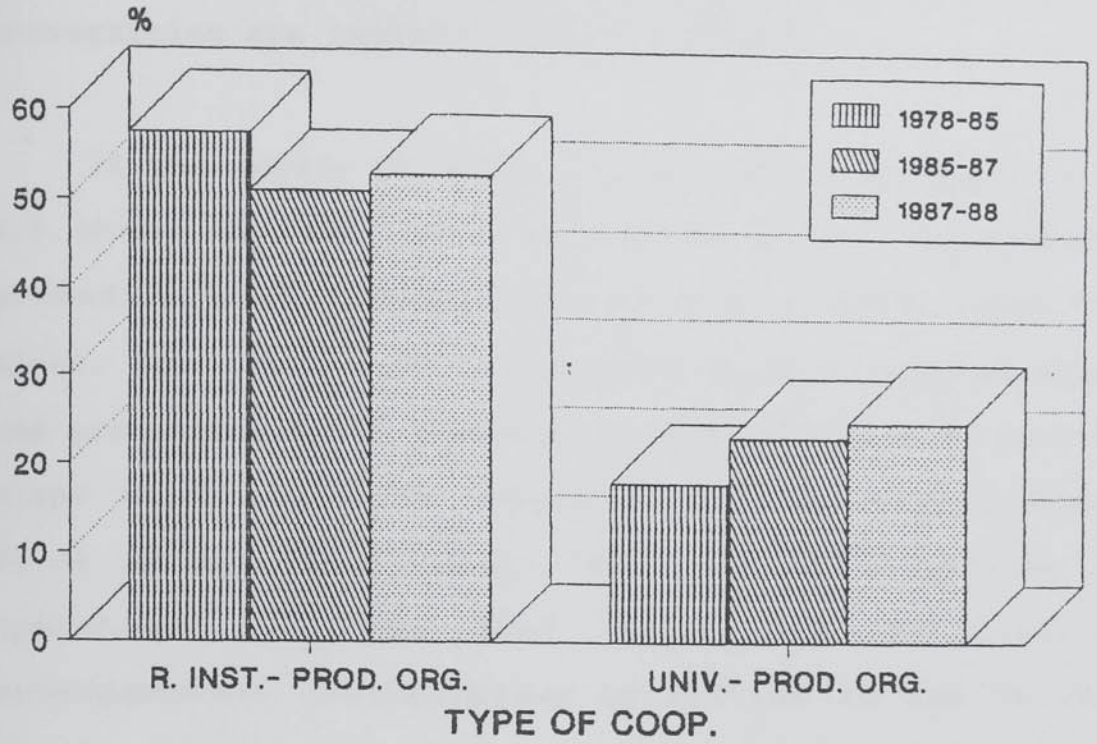
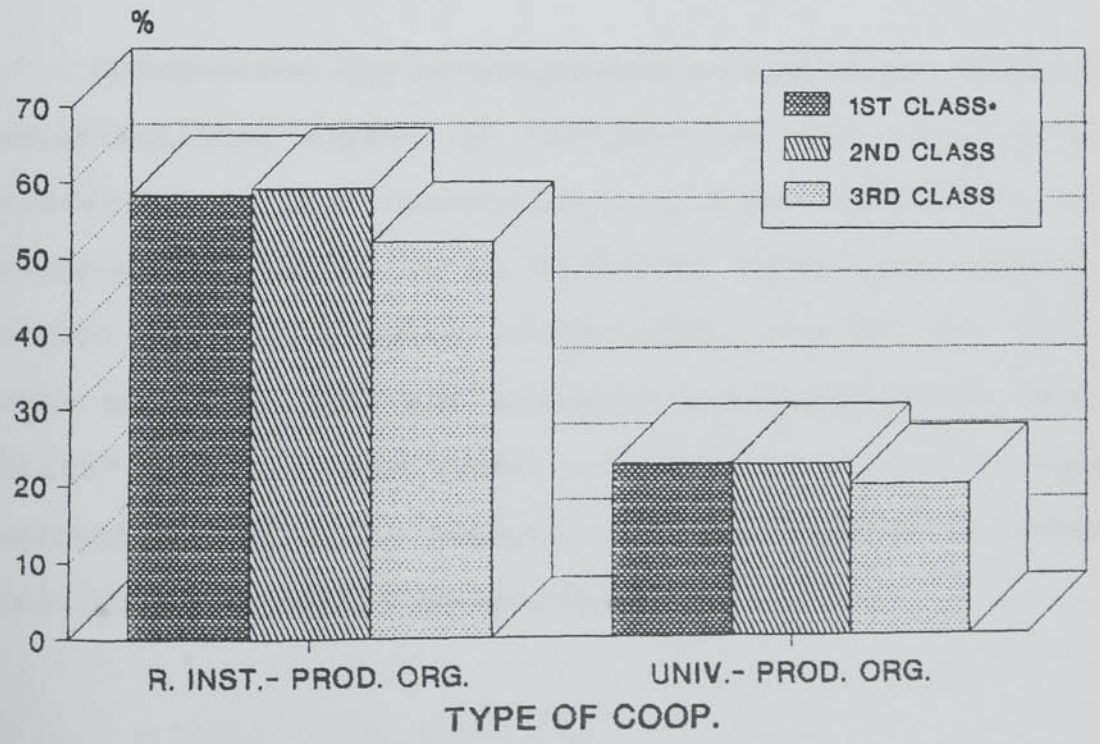


FIG. 5.9 PATTERN OF COOPERATION
- HETEROGENEOUS (BY CLASS)



* SPECIAL CLASS AWARDS INCLUDED

research institutes remain as the dominant innovation force, universities are expanding their influences.

If the degree of technical novelty is brought in, Figure 5.9 shows the rate of co-operation between universities and production units decreased gradually from higher class to lower class. But the rate of co-operation between research institutes and production units increased slightly from 58.5% in the first class to 59.3% in the second class, but dropped sharply to 52.2% in the third class. The trend of both forms of co-operation indicates that there are relatively less heterogeneous collaborative activities in the third class awards, because relatively low level of technical novelty and sophistication associated with these innovations.

5.2.2.3 Inter-Region & Intra-Region Co-operation

Homogeneous and heterogeneous co-operations illustrate the organisational aspect of co-operation. But organisations co-operating in one innovation could be located in the same geographical region or in different localities. Hence, inter-region and intra-region co-operations are the two basic forms when co-operations are assessed geographically. The "solar drier" example mentioned earlier is a intra-region co-operation, while the example of "broadcasting simulator" is a case of inter-region co-operation.

FIG. 5.10 PATTERN OF COOPERATION
- GEOGRAPHICAL (1978-88)

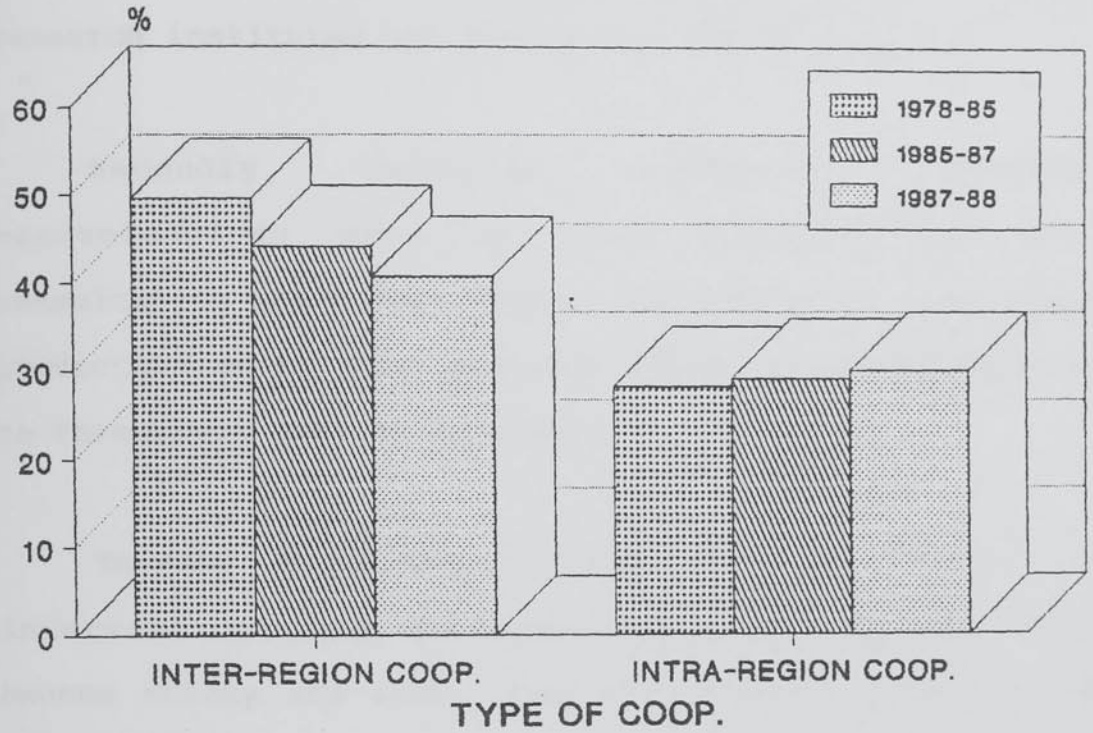


Figure 5.10 shows that the rate of inter-region co-operation has been declining over the three periods from 1978 to 1988, while the rate of intra-region co-operation has been picking up steadily. But inter-region co-operations remain a more important form of co-operation than intra-region co-operations.

There are a number of possible reasons for the increase of intra-region co-operations. Firstly, under the current economic reform, both research organisations and production organisations enjoyed decentralised autonomy. In theory, they could look for co-operative partners all over China. However, each province in China is geographically roughly equal to the United Kingdom, and each province has its own self-sustained

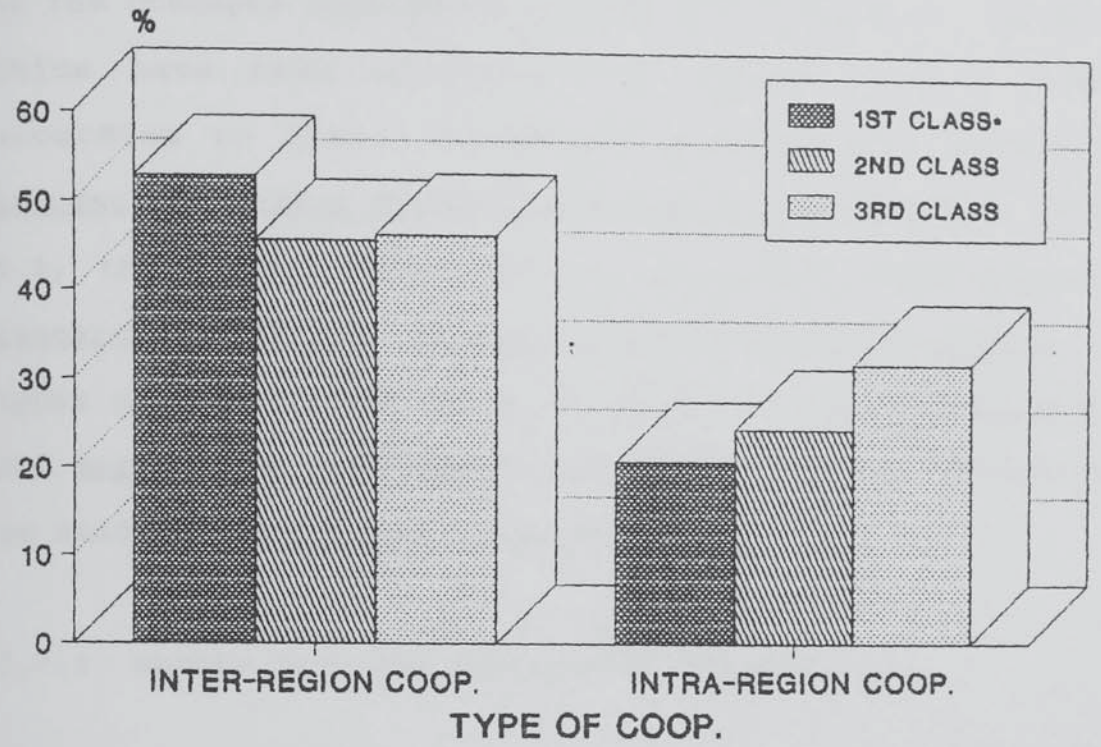
economic and technical systems. As a result, when an organisation is looking for partners, local companies or research institutes are the first ones to contact.

Secondly, technical information services and communications are far from comprehensive. For easy consultation and communication, both research organisations and production units find partners which are geographically close to themselves easy to approach.

Thirdly, inter-region activities, are likely to involve interventions from different local governments. Things can become sticky and slow, when more bureaucracies are involved. If collaborative units are all in the same region, such problems become much easy to overcome. From the local government side, they also prefer innovations to be made in their own jurisdictions. Therefore awards could be won under the provinces' name.

Figure 5.11 shows that there are more inter-region co-operations than intra-region co-operations in all classes of award. Inter-region co-operations take a dominant share in the special & first class awards (52.8%), then fluctuate around 46% for the second and third class awards. The rate of intra-region co-operations stays low in the first class (20.8%), then expands steadily to 24.5% in the second class, then 31.9% in the third class. The pattern suggests that inter-region co-operations happened more in innovations of higher technical

FIG. 5.11 PATTERN OF COOPERATION
- GEOGRAPHICAL (BY CLASS)



• SPECIAL CLASS AWARDS INCLUDED

novelty, as resources or expertise in one region may not be sufficient to tackle these innovations. Meanwhile, due to comparatively low technical novelty, intra-region co-operations become increasingly important in innovations that won lower class awards.

5.3 Geographical Pattern of Innovating Organisations

In the above sections, patterns of innovating organisation were examined along two parameters, i.e. the types of organisation and the forms of co-operation. In this section, patterns of innovating organisation in relation to their geographical locations are to be assessed.

Before moving on to analysis, it is useful to refresh some of the concepts introduced earlier. In Chapter 4, provinces in China have been arranged into three general categories according to their innovation performance, namely highly innovative, medium innovative and poorly innovative. In section 5.1, three main categories of innovating organisation, i.e. research institutes, universities and production units, and two types of role in innovation process, i.e. principal involvement and supportive involvement are defined. These categories will be used in the following analysis.

5.3.1 Number of Units Involved Geographically

Chapter 4 suggests that some geographical regions are more innovative than the others in terms of innovation awards. But the analysis was conducted on an aggregate basis. It remains unclear how organisations of different nature contributed to innovation performance in each geographical region. Table 5.1 gives the number of award-winning organisations in each province.

It can be found in Table 5.1 that award-winning research institutes and production units concentrated in the highly innovative regions. Only few located in the poorly innovative regions. The medium innovative regions overlapped somewhere in between.

	Univ.	Res. Inst.	Prod. Units
Highly Innovative:			
Beijing	30	238	91
Shanghai	20	94	153
Liaoning	8	40	79
Jiangsu	12	25	81
Sichuan	14	43	50
Shaanxi	8	22	24
Shandong	4	21	56
Hubei	6	18	35
Tianjin	8	13	43
Heilongjiang	8	19	35
Guangdong	10	21	32
Hunan	3	18	27
Medium Innovative:			
Hebei	4	7	30
Henan	1	24	27
Jilin	4	11	18
Zhejiang	5	15	27
Anhui	5	13	15
Gansu	2	9	16
Shanxi	2	9	10
Guizhou	1	3	9
Neimonggu	0	7	9
Poorly Innovative:			
Yunnan	1	6	7
Fujian	1	8	4
Jiangxi	0	6	13
Guangxi	2	7	5
Xinjiang	0	2	3
Qinghai	1	2	2
Ningxia	0	1	1
Xizang	0	0	0

Table 5.1 Geographical Pattern of Award-winning Organisations

This pattern could be interpreted from a number of angles. Firstly, research and production organisations in the highly innovative regions possess superior R&D resources than their counterparts in medium and poorly innovative regions. Secondly, there are simply more research and production units in the highly innovative regions in absolute numbers, thus, more opportunities for them to win awards. Thirdly, the highly innovative regions are economically developed areas. The demands for new technology in these areas are high, which in

turn stimulates technological innovation. Fourthly, in a system where central planning is still in action, State research projects are more likely to be assigned to the research or production units in the highly innovative regions, because of their R&D strength.

In addition, Table 5.1 shows that in the highly and medium innovative regions, R&D capacity and innovativeness of a specific region are determined by the total aggregate strength of the three types of innovating organisations, i.e. research institutes, production units and universities. For example, in some provinces like Shandong, Hunan and Henan, only a few universities were involved. But research institutes and production units showed strong presence.

Table 5.1 also shows a big gap between the medium and the poorly innovative regions in terms of the number of award-winning units involved. However, such a difference becomes less obvious between the highly and the medium innovative regions. Some regions in the medium innovative group gathered reasonable number of various innovation units, e.g. Henan, Zhejiang, Hebei, Jilin and Anhui. This indicates their R&D potential and the possibility of improving their performance significantly. But the performance of the poorly innovative regions and some of the medium innovative regions with insufficient R&D potentials are unlikely to make significant changes in a short time. A polarised pattern may continue with regard to geographical innovation performance.

5.3.2 Rates of Participation Geographically

The number of organisations involved is an useful measure to assess innovation capacities of a specific region. However, one organisation may have participated in a number of innovations. The number of participations by a specific type of organisation will define its contribution to innovation performance more precisely.

It has been made clear in the previous discussions that research institutes are the main principal innovators and production units are the main supportive innovators in aggregate terms at the national level. At the regional level, whether such a statement remains true depends on the specific regions in discussion. As can be seen in Table 5.2, research institutes in Beijing and Shanghai are undoubtedly the main principal innovators, outnumbering universities and production units, partly because Beijing and Shanghai hosted a large number of research institutes. There are differences between Beijing and Shanghai - the two national R&D centres. While in Beijing, universities are more active than production units, in Shanghai, production units are more innovative than universities. But in some industrially developed regions, production units outnumbered the research institutes in terms of both principal and supportive involvements. These regions are Liaoning, Jiangsu, Shandong, Tianjin and Heilongjiang in the highly innovative group, and Hebei, Zhejiang, Gansu and

Guizhou in the medium innovative group, and Jiangxi in the poorly innovative group. Moreover, except in Beijing and Hunan, production units in all highly and medium innovative regions have played more supportive roles than research institutes have.

	Univ.		Res. Inst.		Prod. Units	
	P	S	P	S	P	S
Highly Innovative:						
Beijing	40	45	274	217	33	77
Shanghai	40	23	109	86	80	115
Liaoning	8	14	34	25	41	69
Jiangsu	10	9	28	21	33	61
Sichuan	12	14	34	27	25	36
Shaanxi	24	12	17	11	10	18
Shandong	4	0	14	12	19	45
Hubei	12	5	14	9	14	38
Tianjin	9	3	11	6	17	30
Heilongjiang	7	8	11	9	18	31
Guangdong	11	6	15	12	10	23
Hunan	2	2	11	19	16	16
Medium Innovative:						
Hebei	2	4	7	5	17	21
Henan	1	0	10	19	9	23
Jilin	5	5	9	9	8	10
Zhejiang	10	7	2	14	9	18
Anhui	3	2	7	8	5	10
Gansu	2	1	5	6	6	12
Shanxi	0	2	5	4	4	9
Guizhou	2	0	3	1	6	4
Neimonggu	0	0	7	1	2	7
Poorly Innovative:						
Yunnan	0	1	1	5	5	5
Fujian	0	1	5	4	2	2
Jiangxi	0	0	0	6	7	6
Guangxi	1	1	4	3	1	4
Xinjiang	0	0	2	0	0	4
Qinghai	0	1	0	2	2	0
Ningxia	0	0	1	0	1	0
Xizang	0	0	0	0	0	0

Note: P -Principal Involvement, S -Supportive Involvement

Table 5.2 Geographical Breakdown of Participation

This suggests that at the national level due to the existence of national R&D centres like Beijing and Shanghai, research institutes have made more technical innovations and acted as major principal innovators in aggregate terms. But as far as each individual region is concerned, production units become increasingly more important. Among 12 highly and 9 medium innovative provinces, production units overtook research institutes as the main principal innovators in 6 and 4 provinces respectively. It can be concluded that, except Beijing and Shanghai, in other geographical regions, the roles played by research institutes and production units in technological innovation are only of marginal difference.

In addition, although universities have become an important force in technological innovation, their overall contribution still lags behind research institutes and production units. Only in a few exceptional regions, universities' performances as principal innovators are better than production units, e.g. Beijing, Shaanxi, Guangdong and Zhejiang. This suggests that the absolute number of universities in a region has strong influence on the performance of the higher education sector in that region.

5.4 Summary

This chapter covers three sets of pattern analysis in relation to innovating organisations, namely, typological pattern, co-operation pattern and geographical pattern. Like

in Chapter 4, time and class of award are used as parameters in the analysis.

Essentially, four types of organisations are brought into discussion here. They are research institutes, production units (or industrial enterprises), universities and government organisations. The first three types of organisations are usually engaged in actual technical research. But government organisations' role in technological innovation is largely co-ordination and supervision.

In addition, two primary functions in technological innovation are defined, i.e. principal involvement and supportive involvement. They are employed to differentiate contributions by participating organisations.

5.4.1 Typological Pattern

As analysis suggested, research institutes and production units are the major innovators, in terms of both principal involvement and supportive involvement. But research institutes appear to be more active as principal innovators, while production units are more involved as supportive innovators. At the same time, government organisations tend to be largely supportive. Universities, on the other hand, gradually improved their position as principal innovators.

When the pattern is related to the class of award, it can

be found that research institutes held leading positions as principal innovator in all classes, particularly in the second class, while production units took the lead as supportive innovator in all class. Pattern analysis also shows that production units as supportive innovators and universities as principal innovators are more active in low classes of award. Regardless of principal and supportive involvements, government organisations have been primarily engaged in first class awards.

Two factors are thought to have contributed to the pattern significantly. Firstly, the design of R&D system in China determines the dominance of research institutes as principal innovators and production units as supportive innovators. Secondly, economic reform and the introduction of market competition into the innovation system since 1978 have brought important impacts on technological innovation.

5.4.2 Co-operation Pattern

As far as co-operations between innovating organisations are concerned, there are several types of co-operation, i.e., co-operation between organisations of the same nature, co-operation between organisations of different nature; co-operation between organisations within or across region.

Analysis indicates that there is a high percentage of innovations achieved by collaborative effort, and research

institutes and production organisations are the most frequent partners in co-operation. The pattern analysis reveals that research institutes participated more actively in higher class awards, but production units participated more in the lower class awards. Government organisations are mainly involved in innovations won the first class awards.

Among homogeneous co-operations, research institutes, are most frequently involved, especially in 1985-87. In addition, co-operation between research institutes are mainly in first class award-winning innovations. The rate of co-operation between production units has been declining consistently over 1978-88. But it remains much higher than that of universities. Of those co-operations between production units, they concentrated in the third class.

Heterogeneous co-operations are considerably more frequently seen than homogeneous. Among all co-operative innovations in the sample, more than 50% involved co-operations between research institutes and production units. Despite the dominance of co-operation between research institutes and production units, the rate of co-operation between universities and production units increased steadily over 1978-88. When heterogeneous co-operations are assessed against the class of award, the rates of co-operation remain roughly stable. There are only slight drops in the third class, regardless of university - production unit or research institute - production unit co-operations.

It is important to find that there are more inter-region co-operations than intra-region co-operations. But the rate of inter-region co-operation has been declining over the period 1978-88, whereas the rate of intra-region co-operation has been increasing steadily. If the class of award is taken into consideration, the pattern shows that inter-region co-operations outnumbered intra-region co-operations in all class categories, especially in the first class. But from the first class to the third class, the rate of intra-region co-operations increases considerably.

Identical factors, as in the typological pattern, determined the pattern of co-operation. Firstly, the design of Chinese R&D system determined the unique collaborative relationship between research institutes and production units. Secondly, the reform towards a market economy and the reform of R&D system have brought about important changes. But those changes may not be entirely expected. In general, a high rate of co-operation has been achieved over the period 1978-88. It seems to suggest that there are considerable amount of co-operation among organisations in a planned economy, as far as technological innovations of national significance are concerned.

5.4.3 Geographical Pattern

Geographical pattern analysis in chapter 4 defined three

groups of region according to their award-winning performance. On the basis of the grouping, analysis in this chapter identified roles played by organisations of a different nature in each region.

Except in Beijing, the number of award-winning production units exceeded research institutes in all regions. There are high concentrations of research organisations in Beijing and Shanghai - China's two national R&D centres. Their existence greatly altered the overall patterns of technological innovation at the national level. But at the regional level, in most of the highly innovative provinces and many medium innovative provinces, production units overtook research institutes as both principal innovators and supportive innovators. The production units' role, when assessed at regional level, becomes much more important than the national pattern suggested.

This analysis shows that differences in innovation performance are caused by a number of factors. Firstly, some regions are technically more superior. Secondly, some regions have more R&D units. Thirdly, some regions have reached higher level of economic development so that the demands for new technology are greater. But the pattern analysis suggests that the overall R&D capacity of a region is the aggregation of R&D strength and potentials of research institutes, production units and universities in the region.

CHAPTER 6 INNOVATION IN APPLIED R&D INSTITUTES

Having analysed the second parameter - achievements in our research framework through the patterns of technological innovation and innovating organisations, in this chapter, efforts will be devoted to the analysis of R&D institutes - the main actors in the innovation process.

The original function of R&D institutes in planned economies was narrowly defined. R&D institutes were structurally separated from the production units and expected to play a rather isolated academic role, which is to provide scientific and technical solutions to problems raised by production units and to pursue scientific and technical research assigned by the State.

6.1 Internal Structure and Management

6.1.1 Internal Structure of R&D Institute

R&D institutes in China are usually designed to serve a specific technical field within a defined industrial sector, based either on technology or product line. The name of a R&D institutes normally gives this information, e.g. Guangdong Research Institute for Rubber Ageing.

The full name of a R&D institute also gives additional information, including geographical location and hierarchical

position in the R&D system. For example, Shenyang Research Institute of Industrial Rubber Products, Ministry of Chemical Industry, tells us that the institute is located in Shenyang; its superior is the Ministry of Chemical Industry and its main research area is technologies related to industrial rubber products.

Again, the name of Shanxi Provincial Research Institute of Chemical Technology suggests that this institute is supervised by the Shanxi provincial government; it is certainly located in the province and its research area is chemical technology. However, even if a R&D institute is directly attached to industrial ministry, its operation remains strongly influenced by the local government over administrative, personnel and welfare issues.

Sometimes the name of a R&D organisation tells you roughly the size. This is differentiated by the wording of "Academy" or "Institute". In general, an academy is bigger than an institute, and sometimes consists of a dozen of institutes.

In other cases, the name of a R&D organisation does not give much specific information. For example, the name of the No. 601 Research Institute of the Ministry of Aeronautic and Aerospace Industries only indicates that the institute is under the Ministry of Aeronautic and Aerospace Industries. and nothing on its location and research areas is given. In this case, it can be assumed that this R&D institute is largely

involved in defence-related research.

The internal structure of Chinese R&D institutes shows a high degree of similarity, regardless which sector an institute is located. The common structure is shown in Figure 6.1.

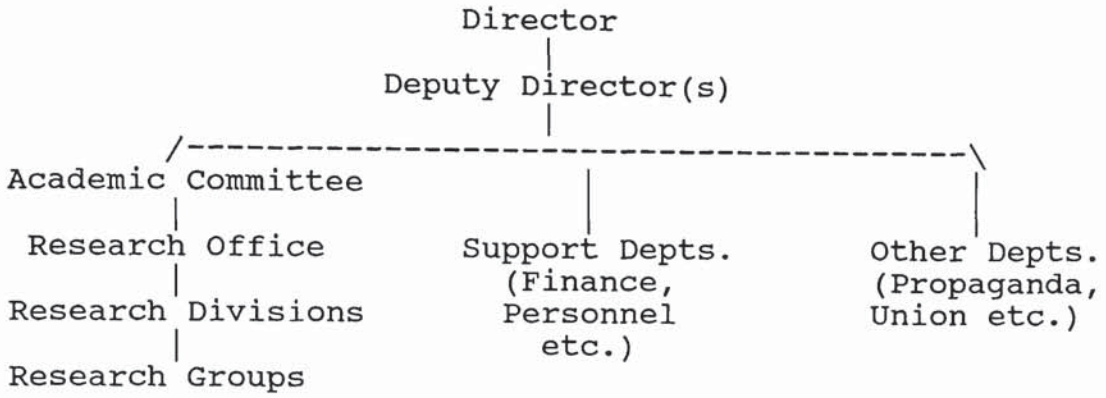


Figure 6.1 Internal Structure of a R&D Institute

A R&D institute is normally headed by a director and assisted by a number of deputy directors. Under the current director's responsibility system, the director is assumed to take overall charge over the running of the institute. Deputy directors have responsibilities in one of the basic functions.

There are three main groups of departments in an institute. The first group includes research divisions/units, arranged according to technical fields, product families or research directions. Each division has a number of research groups or project teams, working on different research topics. These research groups can be either permanent or temporary, depending on the situation. In addition to research divisions, some institutes have a Central Laboratory or Division for

Testing and Measuring to provide basic experimental equipments to the whole institute. For example, Shenyang Research Institute of Metallurgy has one testing laboratory and three research divisions, which specialise in magnetic materials, material processing and physical chemistry respectively. (Interview A, Appendix A)

The second group of departments are functional or administrative departments, such as Finance, Personnel and Logistics etc., to facilitate academic divisions. Since these departments have control over resources, they have more practical decision making power over many issues.

The third group consists of a number of political departments, whose tasks are mainly concerned with the Party, the youth league, propaganda and security etc. They can be regarded as the extension of political control of the Party into S&T communities. In all circumstances, the Party branches still assert influences through established networks, although it is claimed that the Party's intervention over research management has been declining.

6.1.1.1 The Office of Research Management

In terms of research management, the Office of Research Management or the Research Office is the most important department. It is normally directly led by the technical deputy director or the chief engineer. Its roles are to <u>supervise</u>

research projects in the institute, co-ordinate external and internal communications, draft research plans of the institute and organise project appraisals, and sometimes keep research archives and literatures. The last function in some research institutes may be taken care of by the Office of S&T Information.

Personnel in the Office of Research Management do not participate any practical research. However, they all have technical background and research experience, who are supposed to bring expert views on research planning and management.

The importance of the Office of Research Management in R&D institutes is generally declining in the current reform. But, It remains the centre for co-ordinating research activities within R&D institutes. According to a senior engineer from Guangzhou, both horizontal projects from the market and vertical projects from the superior, have to register with the Office of Research Management. Particularly, for horizontal projects, the Office is in many cases the legal representative able to sign any contract on behalf of the institute. (Interview M, Appendix A)

6.1.1.2 The Academic Committee

The second important group in research management is the Academic Committee. While the Office of Research Management runs the administrative side of research management, the

Academic Committee is responsible for the academic aspect of research activities. The Committee does not exist as a formal department. Its members are senior research staff drawn from research divisions/groups. Working closely with the Office of Research Management, the Committee's main tasks involve reviewing research proposals and budgets, working out research schedules and plans, evaluating research results and recommending awards to higher authorities.

However, the importance of the Academic Committee varies considerably from one R&D institute to another. Its position depends largely on how influential the committee members are within the organisation. According to a research associate from Beijing, "people of fame and prestige played important role in the decision making process at the institute level. They decides how resources to be located within the institute". (Interview H, Appendix A)

6.1.1.3 Research Divisions & Groups

Research divisions and groups are the actual performers of technical research. A R&D institute may have a number of research divisions. Each division may have several research groups. Research divisions are usually permanent units, specialised in a general research direction. But research groups are not necessarily permanent. They can be organised for specific projects. Group members may also be drawn from several divisions. The responsibility of research group head

involves much practical work. According to a research group head from CAS, her duty includes "preparing feasibility reports, research proposals, application for budgets and annual reports, as well as organising group members and supervising research". (Interview H, Appendix A)

6.1.2 Innovation Management in R&D Institutes

6.1.2.1 Management of Research Project

Innovation management in R&D institutes is a very complicated issue. The approach adopted by different institutes varies considerably, especially when the reform introduced responsibility system into R&D institutes. Since innovations are mostly accounted for on the basis of individual research projects, innovation management can be therefore regarded largely as a project-based process.

For top-down projects, the Academic Committee and the Office of Research Management are in overall charge. They jointly administer allocation of projects, formation of research groups, monitoring of research progress, control of budget and final evaluation upon completion. The Office of Research Management serves as the secretariat of the Academic Committee responsible for day-to-day running of innovation management. But many decisions have to be made by the Academic Committee. (Interviews C, D, L & M in Appendix A)

Since the introduction of market mechanism into R&D system, horizontal contracts began to form a considerable portion of institutes' projects. As far as these projects are concerned, the Office of Research Management no longer has the overall control. Since the majority of these horizontal research projects are found by research divisions or groups on their own initiatives, the management responsibilities are largely delegated to the hands of research divisions or groups. However, research groups are required to register their research projects with the Office of Research Management in order to obtain necessary supports from the institute. An engineer from Hunan explained one important reason, "this is because transaction of money has to go through the Academy's bank account, research units do not allow to have their independent bank account. But some big research projects still require the co-ordination of the research office. The Main purpose of the research office now is as a communication channel, with less real power". (Interview D, Appendix A; also see Interview A & C)

As far as technical research is concerned, it is up to the head of research group to supervise the research progress and solve day-to-day problems. The change is less dramatic in this aspect.

6.1.2.2 Innovation Management in Wider Perspective

Chinese R&D institutes have additional obligations which

their Western counterparts do not have. R&D institutes have to act as a societal unit. Its role includes provision of housing, children education, and sometimes even food and heating. On the other hand, various constraints make researchers depend heavily on their institutes.

At the organisational level, R&D institutes act as the caretaker to their employees, but their own degree of independence is, also limited. First of all, R&D institutes, even those directly supervised by the ministries, are controlled by local government, where they are based. Although ministerial R&D institutes are not administratively subordinate to local governments, but they are required to inform local industrial bureaux their intended decisions. (Interview M, Appendix A) On big finance and personnel issues, R&D institutes have to report to the local bureaux for approval, even those ministerial institutes are not exempted entirely. If any decision deviates significantly from what expected by the authorities, administrative means may be adopted to alter the decision. (Interview M, Appendix A)

R&D institutes depend heavily on local government. For example, they need their approval for land planning for both research and housing purposes; they need their assistance to provide electricity, water, medical services; and so on. All these services are administered by different local bureaux. In order to establish their own territory with relative independence, some R&D institutes have built their own

hospitals, schools, shops, post offices, cinema and apartment blocks etc. An R&D institute becomes a miniature society. The rationale behind this empire building activity is to reduce their dependence on outside units. But in so doing, it enlarges the scale of operation of R&D institutes. Many funds, which could have been spent on research, have to be diverted to these supportive services. (S&T Daily, 17/2/89, p2) Many directors of R&D institutes have complained that they have spent more time and energy on welfare services and personnel matters than on research management. On the other hand, they all agree that the provision of a relatively worry-free environment for employees is essential for scientific research. (NRCSTD, 1986)

The problem of dependence exists at the individual level too. A good example is that the reform policy encourages free mobility of scientific and technical personnel, especially from urban to rural areas and from developed to less developed areas, but the majority of them are unable to move. The problems they encounter are very practical.

Firstly, housing is the most acute problem. Since many R&D institutes offer housing to their employees, if employees no longer work in the institute, their accommodation will be subsequently withdrawn. While in most organisations, housing is arranged according to the length of service, new employees are unlikely to get preferential treatment.

Secondly, the resident registration system causes further

problems if you move from one locality to another, particularly when family members are concerned. Failure to secure resident registration will bring about a series of problems, like children's education and even the supply of rationed goods.

Thirdly, as far as salary and career promotions and many other welfare benefits are concerned, the length of continuing service with the same organisation is one of the determining factors. The longer, the better. Unless these uncertainties are clarified and secured, the majority of research staff would not risk the loss of their current benefits to transfer to a new unit.

This seems to suggests that in a society, where salaries have been undermined by other visible or invisible benefits, people's behaviour will be heavily influenced by the provision of those benefits. If the reform of R&D system is to achieve its anticipated objectives, additional measures have to be introduced to alter the operating environment at large.

6.2 Reform of R&D Funding System and Sources of Research Project

6.2.1 Reform of R&D Funding System

Significant changes have been observed in the way R&D institutes operate in the S&T reform since early 1980s. The "Decision of the Central Committee of CPC on the Reform in S&T

Management System" reinforced those changes. Under the central directive, a series of policies were implemented. The most influential one was the reform of the R&D funding system, upon which other changes are based.

It is the intention of the reform policy that R&D institutes should become less dependent on the State and support their own existence through market competition. It is hoped that through market interactions, R&D institutes and production units would come more closely together and bring new technologies into industrial applications more quickly and effectively. To achieve such an objective, the State introduced radical measures to change the existing R&D funding system. In general, State support will no longer be available to all R&D institutes in the form of State appropriations, rather they will be available in an indirect fashion, i.e. through national foundations or project open bids.

In the past, research institutes received an aggregate sum of money from the State, which covered salaries, overhead expenses and research expenses. In the reform, research institutes are categorised into three groups according to their research activities. For the first group, research institutes still receive full scale State appropriations as before. Research institutes in this group are mostly engaged in the fields of agriculture, basic technical service and public service etc. Because the nature of their research, it would be impossible for them to become financially self-sufficient

without the State assistance. Even so, an engineer from the Institute of Standardisation and Planning, Ministry of Broadcasting and Television said, "although we continue to receive State funding, the amount is declining in real terms, we also need to look for additional funding from other channels". (Interview 8, Appendix A)

The second group of research institutes continue to receive funding from the State, but only to the extent that staff salaries and overhead expenses are met. Purchase of expensive new equipments needs separate budget application. But purchase of common equipments is included in the overhead expenses. Research institutes in this group have to find research projects by themselves, either bidding for State projects or signing contracts with industrial users. For these institutes, although the State has guaranteed salaries and overhead expenses, they have to earn sufficient income to cover bonus, welfare expenses and development fund. Research areas of these institutes are mostly between basic research and applied research.

The last group of research institutes, mostly applied R&D institutes, face the most dramatic change. The State funding will be gradually phased out in a given period. Eventually, the State will no longer provide any direct appropriation. Applied R&D institutes will have to generate income from research projects to finance their staff salaries, overhead expenses, as well as provide bonus, welfare fund and development fund. In a

word, these institutes are expected to become economically independent units. Applied R&D institutes are the focus of the following discussion..

6.2.2 Available Channels of Research Project

Although research institutes in the first group can still survive with the State aid, research units in the other two groups have to compete for research projects in the market to support themselves.

Simon and Rehn's study on Shanghai's electronic industry found that projects flow into the city by multiple channels, such as State commissions and industrial ministries. At the local level, projects are mainly initiated by local industrial bureaux. "In addition, a number of projects are self-initiated at the level of the work unit." (Simon & Rehn, 1988, pp121-122) These self-initiated are frequently contracts signed between research units and potential industrial users. Under the new competitive circumstances, there are a number of channels through which R&D institutes may generate their income.

6.2.2.1 Vertical Contracts

Firstly, the institute can still obtain research projects from the State, including both the central and the local governments, on a contractual basis through competitive bidding. This type of contract is frequently called "vertical

contract". Vertical research contracts are generally from the following sources: SSTC national plans, ministerial projects, defence-related projects from the State S&T Commission for National Defence and local economic plans.

These vertical contracts remain centrally-controlled in nature. This is reflected in two aspects: firstly, the centralised R&D planning process remains largely as in the past, and secondly, imperfect competition operates in the allocation of research projects. Both aspects are determined by the planned nature of Chinese R&D system. This is reflected by the fact that the position of a R&D institute in the R&D hierarchy determines its degree of access to research projects and other R&D resources. It is commonly seen that projects are more likely to be granted to direct subordinate research units under the authorities, even other research units may be more suitable or qualified.

Professionally, the centralised R&D system is designed in such a way that some research organisations are established as the centres for certain industry/technology, equipped with better research facilities and personnel. Naturally, when a competitive mechanism is introduced, these research units are in a much stronger position than others units in winning contracts. (Interviews G, J & K, Appendix A) Imperfect competition also sectorally exists in relation to government industrial/technology policy. When certain industrial sectors are chosen as priorities to develop, more projects are approved

and more R&D resources are channelled to these sectors. As a result, R&D institutes in these sectors get research contracts much easier.

6.2.2.2 Horizontal Contracts

Secondly, an R&D institute can look for research projects at the open "market" place, i.e. contracted research. This type of contract is often referred as "horizontal contract". Contracts of this type vary a great deal in their technical contents. Many of them are not necessarily technically intensive, but to provide technical service, consultancy or training.

In terms of competition, the market mechanism plays a greater role in horizontal contracts. However, due to the lack of effective and efficient infrastructure, such as technical information network and legal framework, many research contracts are not won through "real" market competition, but through personal or organisational connections. As admitted by an engineer from Beijing Academy of Iron and Steel, "research groups look for horizontal contracts largely through personal contacts with factories and visits, not through technology markets". (Interview C, Appendix A)

Moreover, the ability of a R&D institute to attract research contracts is affected by its technical specialisation. A R&D institute in applied industrial technology may find more

comfortable to adapt to the new competitive environment. But institutes engaged in specialised area or basic research may find rather difficult to do so. On horizontal research projects, a research assistant from Wuhan Research Institute of Physics, CAS, said, "people don't like to do it, as it is not the same basic research people used to do before; and people simply don't know how to find contracts". (Interviews G, Appendix A; also Interview D & K)

Taking into consideration the existing technical levels of Chinese industrial enterprises and their motive for quick economic returns in the reform, research institutes who can offer appropriate and/or incremental technologies to increase short-term productivity and cut costs, are most favoured by production units. In return, these projects brought quick economic income to R&D institutes and research individuals, thus helping the institutes to realise the target of self-financing. Consequently, in many research organisations, "Short, simple and quickly profitable" projects are most favoured.

Such a two-way demand cycle determines the presence of short-sighted behaviour in economic and technological activities in the reform. Many concerns have been expressed that if such short-term behaviours are to continue, China will lose its momentum of technological development in the coming century. Many researchers have urged the need to maintain a proper balance between long-term and short-term research and

between, basic and applied research. (Interview A, F, K & C, Appendix A)

It must be pointed out that in the current reform emphasis is overwhelmingly placed on economic performance. The yardstick is whether a R&D institute has become financially self-sufficient within the given time span. Management of many R&D institutes have to play safe, to make sure this requirement is fulfilled the minimum requirement.

As a result, many R&D institutes adopted a rather practical approach in their innovation management: a) to fulfil reasonable amount of vertical projects "assigned" by the State (sometimes it may not be assigned, but bided for), provided they carry enough funding. This will send good images to the superior level and secure certain amount of funding; b) to achieve as much "real" economic benefits as possible by completing quick and profitable horizontal projects; c) to maintain, if financial resources permit, the running of selected long-term research projects, in order to sustain technical competitiveness in the future. For example, Shenyang Research Institute of Metallurgy of CAS has a deliberate policy of funding research into frontier new material technologies. At the same time, developing horizontal links is positively encouraged. (Interview A, Appendix A)

6.2.2.3 Science Foundation Projects

The third major source of research funding comes from the National Natural Science Foundation. The direction of funding is largely towards basic scientific research, with a reasonable portion towards technical research. There are 7 broad areas of funding, namely mathematics and physics, chemistry, biological science, geological science, information technology, material and engineering science, and management science.

The Foundation is administrated by a national committee. But much of the day-to-day running is dealt with by the Chinese Academy of Sciences and its subordinate research institutes. Applications for funding from the Science Foundation are subject to peer review, which normally involves experts invited nation-wide. But in some cases, an institute of national prestige in the field may significantly influence the results of examining research proposals. As a research assistant from Wuhan Research Institute of Physics said, "on the examination board of Physics Section of the Science Foundation, 8 out of 15 board members are from Beijing Research Institute of Physics. According to the rules, if more than half of the board members are in favour, an application is approved. As a result, the Beijing Institute always got more money than us". (Interview G, Appendix A)

Apart from the conventional provision of research funds, with the State assistance, the National Science Foundation has

set up a selection of National Open Laboratories attached to prestigious R&D institutes or universities nationwide. The running of National Open Laboratories are supervised by their own committees, whose members consist of famous experts nationwide in the specific fields. These laboratories receive special grants, covering research expenses and equipment purchases. Research projects are chosen by the committee and open for bid to research organisations all over the country. Since the Open Laboratories have the most advanced equipments and better research conditions, people tend to come to the Open Laboratories to do their research. According to a researcher from Wuhan Research Institute of Physics, the host organisations of open laboratories, have become the national centres of specific academic fields. (Interview G, Appendix A; also Interview L)

6.2.2.4 Self-Initiated Projects

Finally, R&D institutes could develop their own research projects. At this level, due to financial constraints, self-initiated projects tend to be small in size. There are several incentives for R&D institutes to develop research projects on their own initiatives. Firstly, R&D institutes regard some research projects as necessary long-term technological reserves. Some of the research results will either be directly applied in or lead to other innovations later. This largely happens in the area of new frontier technology, such as laser, superconductivity etc.

Secondly, some projects are carried out with known marketable potentials, however, external finance could not be obtained beforehand. R&D institutes have to finance the projects by themselves first. But for these projects, from very beginning, it is known that research results of these projects will be marketed, either by selling the research results to production organisations, or by exploring initial profits through pilot in-house production, then transferred to industrial organisations for large-scale production under agreement later. This usually involves new product and process development. It is equally worth noting that some production units have created or expanded their in-house R&D departments. Some even achieved national technical level. (Interview I, Appendix A)

The third type is that a R&D institute may recommend a research project to a production company or other potential users. Potential recipients then agree to support the research. Since the projects have secured client and finance, the burden on the R&D institutes is much less than the first two categories. But this requires close understanding between the R&D institute and its potential customers. So this type of research project normally occurs among old partners. (Interviews I, J & L, Appendix A)

6.3 Incentives for Technological Innovation

It has been discussed in Chapter 1 that the structure of centralised R&D system largely followed the concept of technology push. R&D institutes and industrial companies and their functions are arranged in a linear pattern, rather than a reactive fashion. In addition, the State bureaucracies always assume control over the running of both the market and the research.

Although in the current reform there are indications that the Chinese R&D mechanism based on technology-push concept, started to shift towards a more market-sensitive, demand-pull one, there remains various constraints derived from the old structure. In the current Chinese R&D system, the state planning and decision making through administrative channels are pervasive throughout the innovation process. It can be envisaged that a mixture of "technology-push" and "demand-pull" R&D mechanism will co-exist in China to find an appropriate balance.

6.3.1 Interacting through the Market

Like in all economies, demands for new technology and supplies of new technology are admittedly the two dominant factors in the process of technological innovation. But the fundamental issue in the Chinese context is how these two factors interact to each other through the newly introduced

market mechanism. In the past and at the present time, the main generator of new technological knowledge is the formal research sector, i.e. the research institutes, while the main agent to convert this new technological knowledge into products and services is the production sector. These two sectors have been traditionally communicating to each other through the planning mechanism.

In recent years China has realised the importance of market mechanism in the process of technological innovation, and the problems of bringing market elements into the centralised R&D system. Various attempts have been made to establish market-based interactions between R&D institutes and industrial companies Among the measures introduced, the most influential ones are:

a) The opening-up of the technology market. The content of technology market is not clearly defined. In fact it refers to all kinds of commercial activities related to movement of technology. Technology Fairs are one of the most commonly seen features of the technology market. At these fairs, R&D institutes and enterprises can contact each other much easier;

b) The set-up of local/regional technical service and consultancy centres. These centres are frequently under the umbrella of local/regional government, but financially independent. These centres do not carry out technical research themselves, but serve as a mediator between technology

suppliers and users.

c) The emerge of joint research-production ventures, which incorporated R&D institutes and production companies into new business entities. These ventures are operationally similar to large companies in the West in some aspects. But such mergers are not achieved through financial acquisitions, and in fact need to be approved by respective superior government departments.

But these measures received different reactions, although in the official press it is always highly positive. According to interviews conducted in Shanghai by Simon & Rehn, "it seemed that most of the research and production units indeed viewed technology markets as an excellent opportunity to realise higher financial revenues. On the other hand, interviewees also made clear that reliance on contracts and technology markets as a major funding source could not be achieved by administrative acts, but would have to be integrated into a whole set of reform measures." (Simon & Rehn, 1988, p149)

One fundamental problem of Chinese reform is that on the one hand, the government realised the necessity of an independent market system to encourage innovation activities, on the other hand, the government is extremely reluctant to release all the authority of control. A compromise formula is thus designed - "The State adjusts the market, while the market governs the economy". This concept is commonly accepted in all

government ranks. It is the result of this belief that the Chinese government has introduced many guidelines and regulations etc. to maintain their confidence of control. It is true that many old regulations were abolished at the same time, and the environment for market-based free interactions did improve. But the general feeling of R&D institutes is, as put by an engineer from Anshan, that "there are too many regulations to confine the operation of research institutes, but too few to really regulate the market". (Interview 11, Appendix A) In recent years, the volume of transactions through the technology markets/fairs has fallen considerably. Simon & Rehn believe "the main cause appears to have been excessive bureaucratic regulations". (Simon & Rehn, 1988, p149)

To solve the problem of excessive bureaucratic regulations, the Chinese government since mid-1980s has speeded up the process of S&T legislation. Technology Contract Law, R&D Institution Law, S&T Foundation Law etc. have been drafted. Some have already come into force, such as Patent Law. (White Paper No.2, 1987, pp82-94) But to change completely from reliance on regulations to reliance on legislation, more efforts need to be made.

On the other hand, policy makers seem to expect that once R&D institutes and enterprises are allowed to operate "freely" in the market, they will do so and demands for new technology will spontaneously emerge and grow. This is only partly true. Because, in all likelihood, if market demands for new

technology are to emerge and grow, there must be sufficient infrastructure to facilitate such demands. Particularly, if new technology is to reach industrial applications through market interactions, sufficient working capitals/funds must be available at the demand side.

In China, industrial enterprises are obviously the main demand side of the game. In the current reform, they have been granted more operational power over day-to-day running, finance and personnel matters. Enterprises could even retain a portion of profits and provisions of depreciation write-offs at their own disposal, provided they have met the responsibility targets, agreed by the superior bureau and enterprises. But profits retained by the enterprises are generally small and pre-determined for many specific purposes. For example, bonuses and other material benefits occupied a large share in order to keep the morale of employees. As a result, the amount, which could be spent on in-house R&D or purchasing new technology from outside, are scarcely insufficient. This partly interprets the reason why horizontal contracts are largely small in scale. After all, the lack of sufficient financial resources at the demand side greatly hinders the market mechanism into expected full play.

In order to help the industrial enterprises to realise the importance of new technology, the State Economic Commission introduced the Technical Transformation Programme in industrial enterprises: firstly, to upgrade the technical level of

industrial enterprises; secondly, to make enterprise managers realise to the potential of technological innovation and its impact on product and process innovation; thirdly, to provide additional funds for industrial enterprises to acquire new technology from R&D institutes.

Funds for technical transformation come from the central or local governments in the form of both loans and grants. These funds, however, are only to help enterprises absorb some of the start-up costs for taking advantage of emerging market opportunities. Just as the changes in R&D funding system are designed to encourage research institutes to seek potential buyers of their technology, the Program for Technical Transformation is aimed at motivating enterprises to look for potential partners in the R&D community, who can help them solve technical problems, develop a new product, or improve the quality of an existing product. More importantly, the government hopes this could change the behaviour of industrial enterprises and create a demand-pull effect for new technology, thus improving the links between research institutes and production units.

Another big problem in the use of market interaction is the lack of a rational price structure. There have been quarrels since the very beginning of commercialised technology transfer. Both R&D institutes and enterprises complained about unfair pricing.

On the enterprise side, company managers are used to the situation where new technology was transferred from R&D institutes under the arrangement of central planning free of charge. The transition from free transfers to commercialised transfers caused conceptual resistance, particularly when detailed price negotiations are concerned.

On the R&D institute side, institute directors are under increasing pressure to achieve financial self-sufficiency. But they similarly are not used to the commercialised competition. The prices they ask for may not be entirely rational.

In many cases, problems concerning transfer prices have to be settled through administrative interventions. This suggests that State intervention remains superior to any market forces, and sometimes are the only effective way. It may require some time before competitive market norms could be widely accepted and fully established.

6.3.2 Incentives for Innovating

It has been argued the Chinese R&D system was constructed on the notion of technology push. Market demands were less considered. This situation has been changing since the beginning of economic reforms. The Chinese government has put its emphasis on establishing financial independence of R&D institutes, by gradually reducing direct appropriations. This has greatly changed the way many R&D units and staff used to

operate. This certainly alters the traditional incentives for innovating, where political incentives used to prevail. But to make R&D institutes change their old ways of doing things and become more responsive to market needs, new incentives must be given in appropriate directions, in order to create positive motivation environment and generate more innovations.

In R&D institutes, there exist two levels of incentives: firstly, organisational incentives - which induce a R&D institute to be innovative; and secondly, individual incentives, - which encourage individual researchers to be innovative.

6.3.2.1 Organisational Incentives for Innovating

At the organisational level, R&D institutes, under the pressure of economic reform, are mostly concerned with achieving maximum economic performance, so that they can become financially independent. This is also what is expected by the State. Generating more technical innovations and then transferring them for a fee in the market is an inevitable way for such a goal.

Apart from the emphasis on economic performance, research organisations have been trying very hard to achieve recognitions, which consist of three key elements: recognition by the superior government bodies, recognition in the market and recognition by the academia. Three recognitions are placed

with different priorities.

Generally, the first two types of recognition have been given more weights than the last one. There are a number of considerations for R&D institutes to have their innovation activities recognised by superior government bodies. The primary concern is that the government bodies at different levels still control of the majority of research funds. Although those funds are now allocated through open bidding, if a R&D institute is favoured by the government through its established performance, the institute is more likely to win the bidding.

The availability of such "vertical" research funds would contribute considerably to the overall financial situation of the institute. Good images can also be created through personal links and through political channels. However, the fundamental basis remains the sound research capability and high research performance. From this point of view, good track record of innovation is crucial to establish such a recognition.

Apart from the recognition by the government bodies, R&D institutes require market recognition. Market recognition puts an R&D institute in a much stronger position when competing in the market place. Market recognition means reputation in research quality, influence in the market, and trust of production companies. Obviously such a recognition can only be achieved through quality R&D work and successful transfers,

which, in turn, provide the institute with much needed "horizontal" research funds. In the situation where there is an increasing dependence on the market, R&D institutes have to fight hard to establish the market recognition. Although various formal and informal links are important in this aspect, the basis to achieve this recognition is to generate more innovations and expand influence in the market.

Compared with market recognition and the recognition by government bodies, recognition within the academia is considered as a means, rather than an objective. If an R&D institute holds a prestigious status in a technical field, it would be easier for the institute to attract research contracts, both vertically and horizontally.

However, when a specific innovation is concerned, the three types of recognition and their impacts are integrated together. Each of them comprises an important part of organisational incentives for innovating. As economic reform proceeds, incentives for R&D institutes to be innovative become increasingly complex. What R&D institutes strive to achieve through three types of recognitions, is to maximise their control over a rapidly changing environment and to increase their independent techno-economic capacity.

Another incentive for innovation comes from R&D institutes' direct involvement in production. As severe problems exist in the mechanism of transferring new technology

from R&D institutes to production enterprises, many R&D institutes have responded to these problems by establishing their own independent production facilities. R&D institutes are actually putting research results into production by themselves, rather than persuading enterprise managers to buy their research results. This forms an alternative route for new technological innovations to reach the market place. (Guangming Daily, 12/10/89, p2)

6.3.2.2 Individual Incentives for Innovating

At the individual level, impacts brought about by the economic reforms are apparent. Individual researchers are no longer inspired by the glamour of political propaganda and ideological indoctrination. Many interviews in this research suggest that material incentives have become the primary incentives in R&D communities. (See interviews in Appendix A)

Although its influence has been declining, political incentive has not yet been phased out completely. Since the early 1980s, scientists and engineers have been encouraged to apply for Party membership. Many people since then have joined the Party. The motivation to be a Party member is a complicated matter. The most important factor is that, being a Party member brings immediate benefits. On the one hand, Party membership offers a useful shelter against risks of future political uncertainty; on the other hand, it provides advantageous position for promotion both professionally and/or managerially.

In addition, a Party member would be considered politically reliable, and therefore would enjoy other favourable material and non-material treatments. Having experienced years of political hardship, scientists and technologists, for one reason or another, may find such an "umbrella" is attractive and useful.

However, the main criterion used by the Party in the economic reforms to select its new recruits, is the so-called "Red and Expert" principle. In addition to political loyalty - "Red", a candidate has to be professionally competent. In recent years, the "Expert" side has been given increasingly more weight in the selection process. A candidate has to show acceptable professional achievements in order to be regarded as qualified. Political stimulus nowadays is used differently as a tool to encourage professional achievements. In R&D institutes, this means encouragement for more technological innovations.

People may not all necessarily appreciate this kind of political incentive. Thus, other forms of incentive for innovation become active. The most commonly used form of material incentive is cash bonuses. In almost all R&D institutes, a percentage of profits are set aside as cash bonuses upon the completion of research projects. An engineer from Chenxing Research Institute of Manufacturing Technology said, in his institute, the bonuses have become an integral part of the salary. (Interview F, Appendix A) In addition to cash bonuses, material rewards are realised through various

allowances and even through consumer goods, if such consumer goods are in short supply in the market, the distribution of physical goods would be far more effective than cash bonuses. Another important reason to use consumer goods is that the State has always tried to cap the amount of cash which are distributed as bonuses. Transforming money into physical goods is an easy alternative to escape from official capping and win support of sub-ordinates.

In addition to political rewards and material incentives, another identifiable incentive for innovating is associated with professional pursuit. For some researchers, solving technical problems brings professional satisfaction. Sometimes, they simply just want to do more in their own fields. Otherwise they feel uncomfortable. Like an research assistant from Research Institute of Acoustics of CAS put it, "sometimes it is a matter of academic interest or preference. People just want to do what they like to do". (Interviews L, Appendix A; also Interview H)

Part of the professional satisfaction is realised by professional promotion which is widely acknowledged as another important incentive for innovating. Promotion is judged upon individual contributions to research work, research achievements and research ability. This is mainly assessed through the number of awards won, the number of research projects completed, the number of practical problems solved, the number of patents held, and the number of papers published

etc. (Interview H & J, Appendix A)

6.4 General Attributes of Surveyed R&D Institute and Analysis

In addition to interviews, questionnaire survey was conducted to explore some general attributes of award-winning R&D institutes. There are a number of key elements addressed in the questionnaire: firstly, the size of the institutes in terms of total employees; secondly, the ratio of research personnel; thirdly, the total number of awards won by the institutes at or above the provincial level; fourthly, the hierarchical position of the institute in the R&D system; and finally the technical level of the institute.

6.4.1 General Attributes of R&D Institute

Two industries, Mechanical engineering and chemical industry were chosen for a questionnaire survey. Questionnaires were distributed to 46 R&D institutes in mechanical engineering and 44 in chemical industry. All of them are winners of national awards for S&T progress included in the database analysis. The return rates are 65.2% (30) for mechanical engineering and 45.6% (21) for chemical industry respectively. (See Appendix B for list of surveyed R&D institutes).

R&D institutes surveyed varied considerably in size. 30 R&D institutes in mechanical engineering and 21 in chemical industry, who replied the questionnaire survey, can be

classified into three groups, namely small, medium and large, according to their sizes respectively. In mechanical engineering, the groups are less than 500 employees, between 500 and 1500 employees and above 1500 employees. In the chemical industry, group boundaries turn out to be different, shifting upwards to less than 1000 employees, between 1000 and 2500 employees and more than 2500. Figure 6.2 and 6.3 show how R&D institutes fall into these boundaries. Another important point worth noting is that Chinese research organisations tend to be bigger by Western standard. Even small ones could have several hundreds of employees.

	Small	Medium	Large
Mech. Eng.	9 (<500)	19 (500-1500)	2 (>1500)
Chem. Eng.	12 (<1000)	8 (1000-2500)	1 (>2500)

Table 6.1 Size of R&D Institutes Surveyed

Although Chinese R&D institutes tend to be very big in terms of total employee, the ratio of research personnel varies considerably, which in fact is a better indicator of research capacity. Some institutes have quite high ratios of research personnel, highest 83.4% in chemical engineering and 79.7% in mechanical engineering, whereas some units possess rather low ratios of research related personnel, lowest 28.6% in chemical engineering and 38.1% in mechanical engineering.

The total number of awards won by a R&D institute at or above the provincial level over 1978-1988 is used as an

indicator of research performance. Again, surveyed institutes shows significant differences. Some institutes claimed over 100 awards. In marked contrast, some institutes claimed only a few.

Administratively, the majority of these research institutes are under the jurisdictions of industrial ministries or provincial bureaux. Only some of them are led by the Chinese Academy of Sciences. Table 6.2 outlines their relationship with superior bodies.

	Ministries	Provinces	CAS
Mech. Eng.	21	8	1
Chem. Eng.	9	10	2

Table 6.2 Administrative Links of Surveyed R&D Institutes

Furthermore, the majority of these surveyed institutes claimed that they are technically in the leading or upper positions. Only a few indicated they are in the middle reach. Their claims are used as an indicator of their comparative technical level in the industry. The actual breakdown is shown in Table 6.3.

	Leading	Upper	Middle
Mech. Eng.	23	6	1
Chem. Eng.	9	8	4

Table 6.3 Technical Level Claimed by R&D Institutes Surveyed

6.4.2 Analysis and General Findings

6.4.2.1 Unit Size vs. Researcher Ratio

As shown in Figure 6.2 and 6.3, R&D institutes clustered into natural groups. The trend indicates that small R&D institutes tend to have relatively higher ratio of research staff, while the large institutes tend to have lower ratio of research staff, with the medium-sized institutes spanning in between. It is important to note that in Figure 6.2 and later figures, the regression line is plotted on the basis of correlation coefficient. Its existence is merely to help viewing the figure, it does not suggest any statistical trend.

6.4.2.2 Unit Size vs. Research Performance

Size is often used as a parameter to measure and compare innovation performance among organisations. Based on the size groups defined earlier, Figures 6.4 and 6.5 correlate unit size to research performance, using total number of awards won by a R&D institute as a measure. Again, a rather group associated pattern is shown. Small R&D institutes scored rather poorly, except one case in chemical industry, whereas medium-sized R&D institutes performed rather well with the highest award-winning records in both sectors. More importantly, the pattern does not seem to suggest that large R&D institutes have any particular advantages in terms of award winning.

FIG. 6.2 UNIT SIZE VS RESEARCHER RATIO
MECHANICAL ENGINEERING

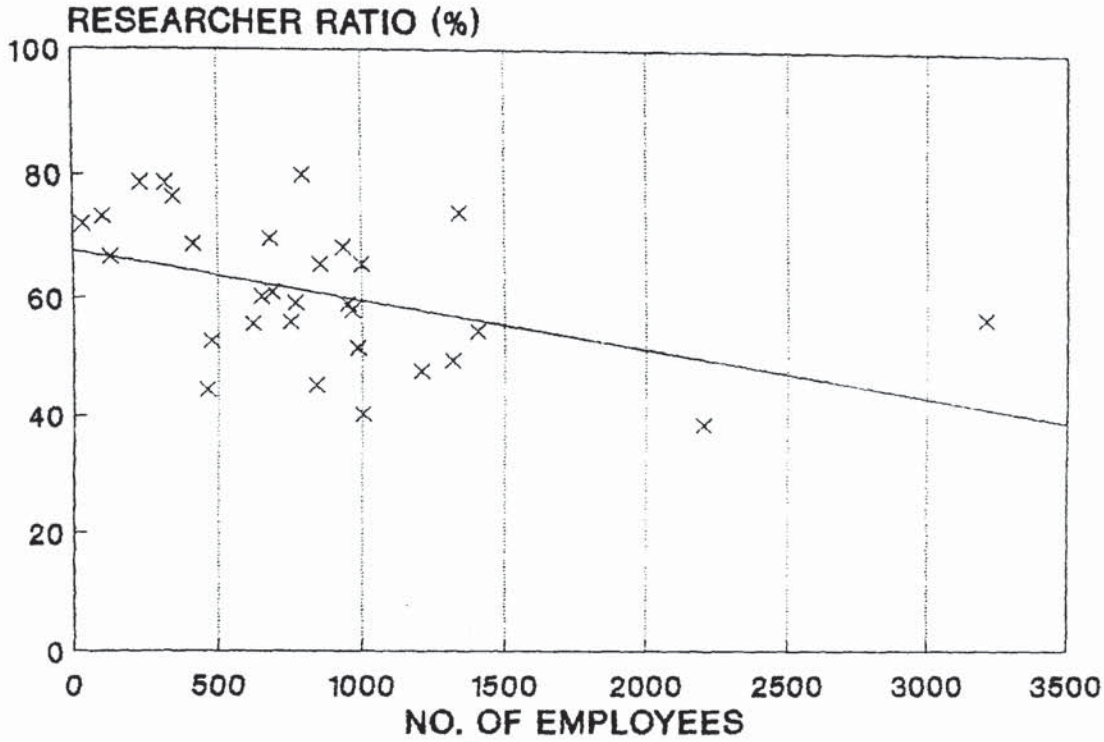


FIG. 6.3 UNIT SIZE VS RESEARCHER RATIO
CHEMICAL ENGINEERING

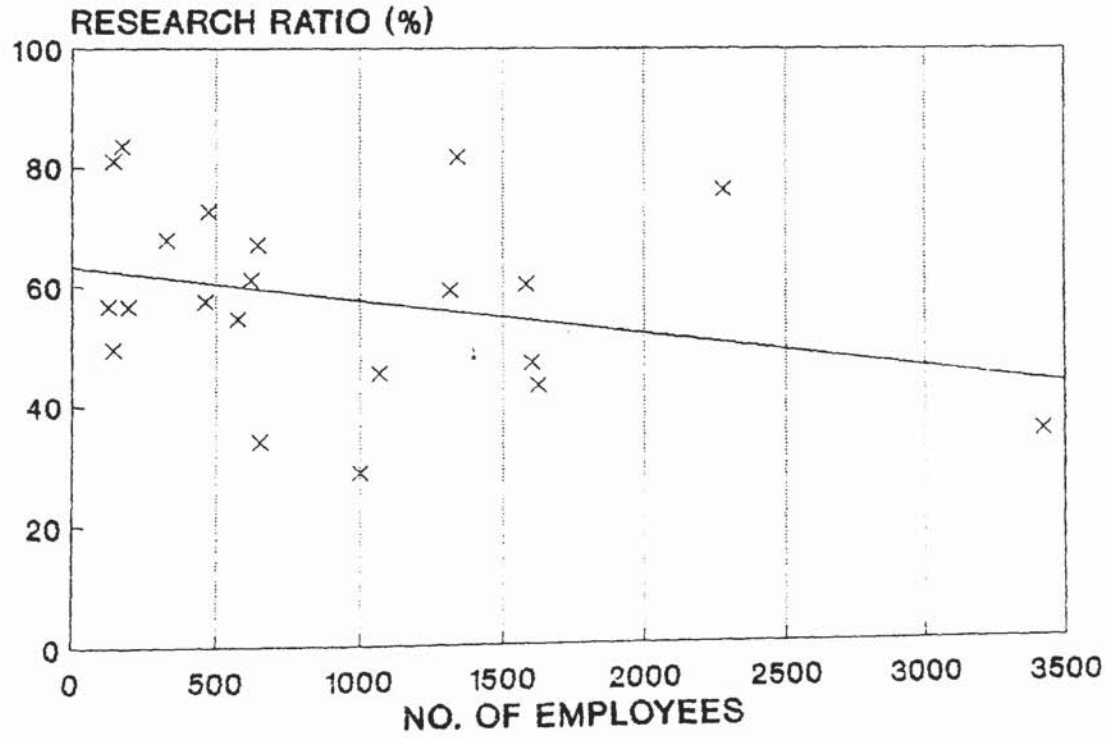


FIG. 6.4 UNIT SIZE VS PERFORMANCE
MECHANICAL ENGINEERING

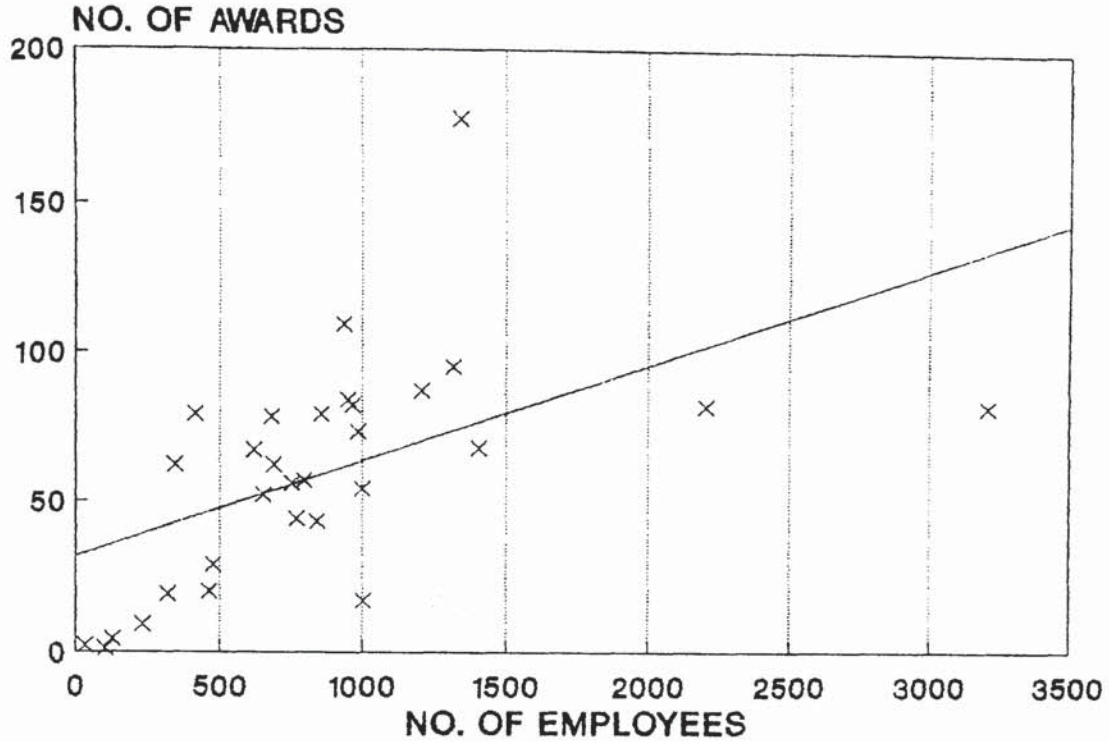
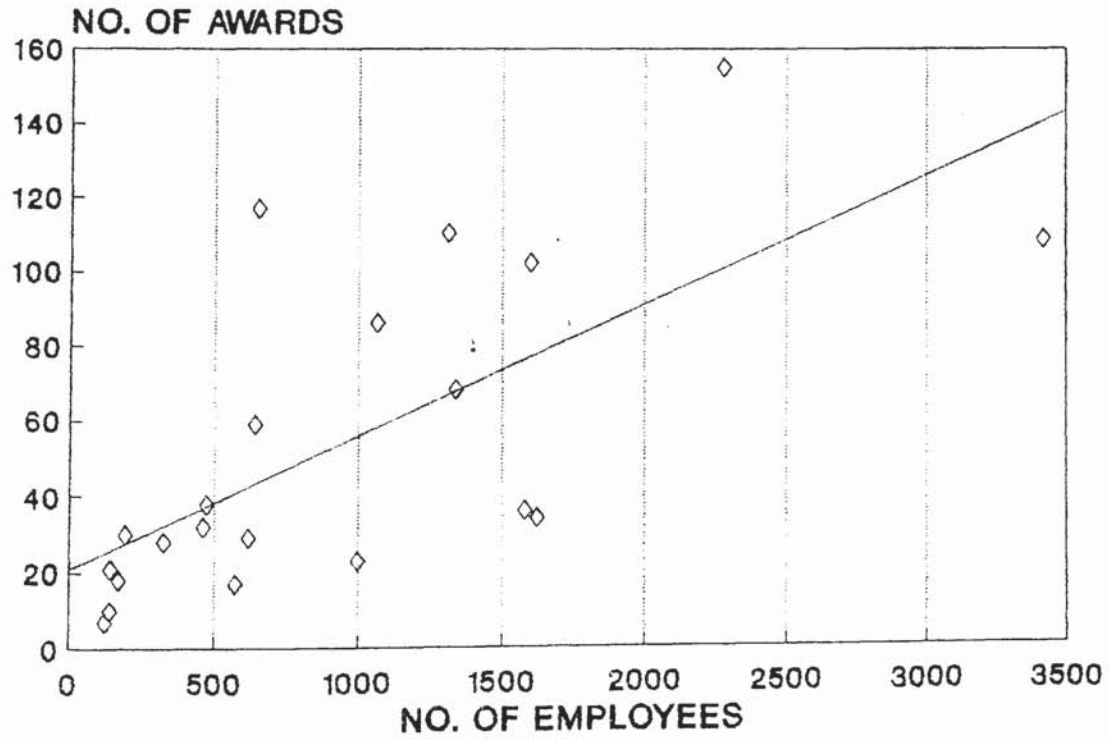


FIG. 6.5 UNIT SIZE VS PERFORMANCE
CHEMICAL ENGINEERING



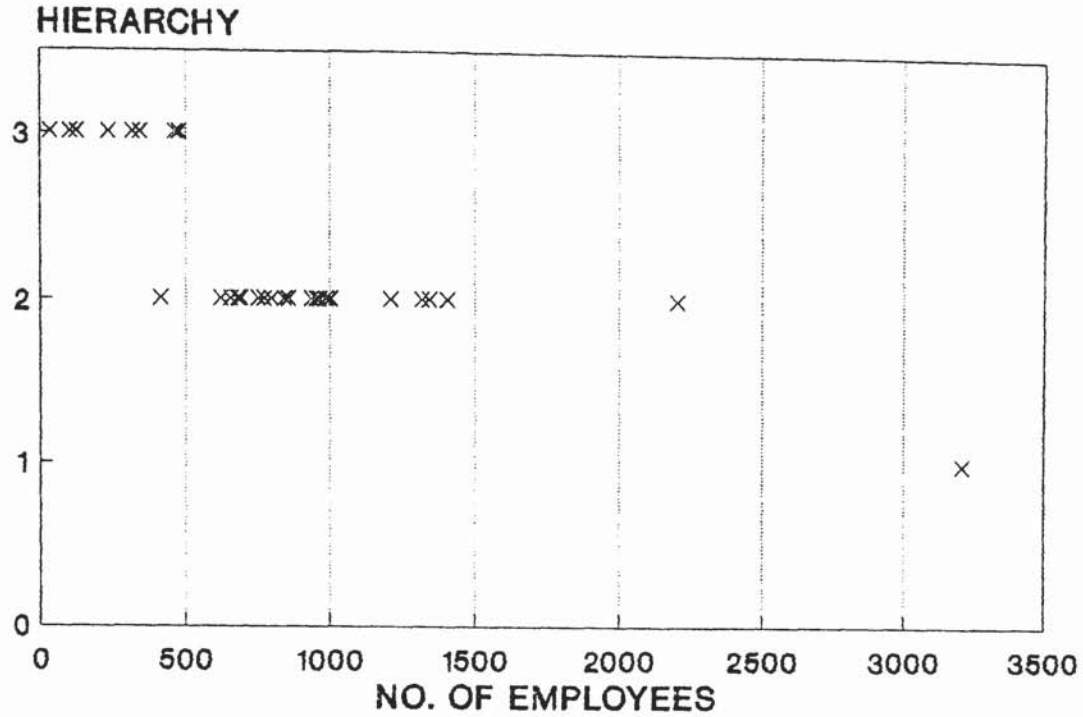
6.4.2.3 Unit Size vs. Hierarchy

Information obtained from the questionnaire survey suggests that R&D institutes attached directly to industrial ministries and the Chinese Academy of Sciences (CAS) are bigger in size. AS shown in Figure 6.6 and 6.7, the distinction is very clear in mechanical engineering. Small R&D institutes, are mostly led by local governments, whereas big and medium-sized institutes are directly supervised by either the CAS or industrial ministries. Data of the chemical industry indicate a similar trend, though the pattern is less clear cut. Small and medium-sized R&D institutes are supervised by both industrial ministries and local governments, as well as the CAS. However, the ministerially-led units are usually bigger than the local ones.

6.4.2.4 Unit Size vs. Technical Level

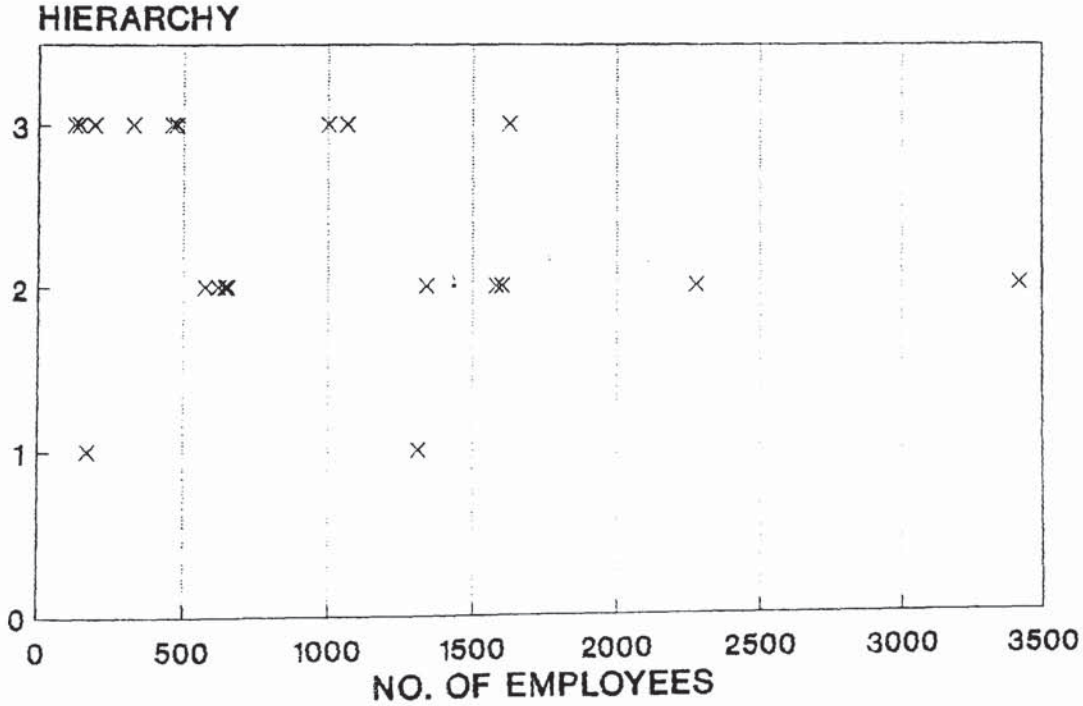
Figure 6.8 and 6.9 indicate that most large and medium-sized R&D institutes claimed that they are holding leading positions in terms of technology. A few institutes in the medium-sized group claimed an upper-middle technical level. But small R&D institutes vary a great deal in this aspect. In mechanical engineering, institutes are centred around leading and upper-middle positions, whereas in chemical industry the claims are more evenly spread over three positions. Most of those R&D institutes claiming middle position are local units. But it is important to remember that all these research

FIG. 6.6 UNIT SIZE VS HIERARCHY
MECHANICAL ENGINEERING



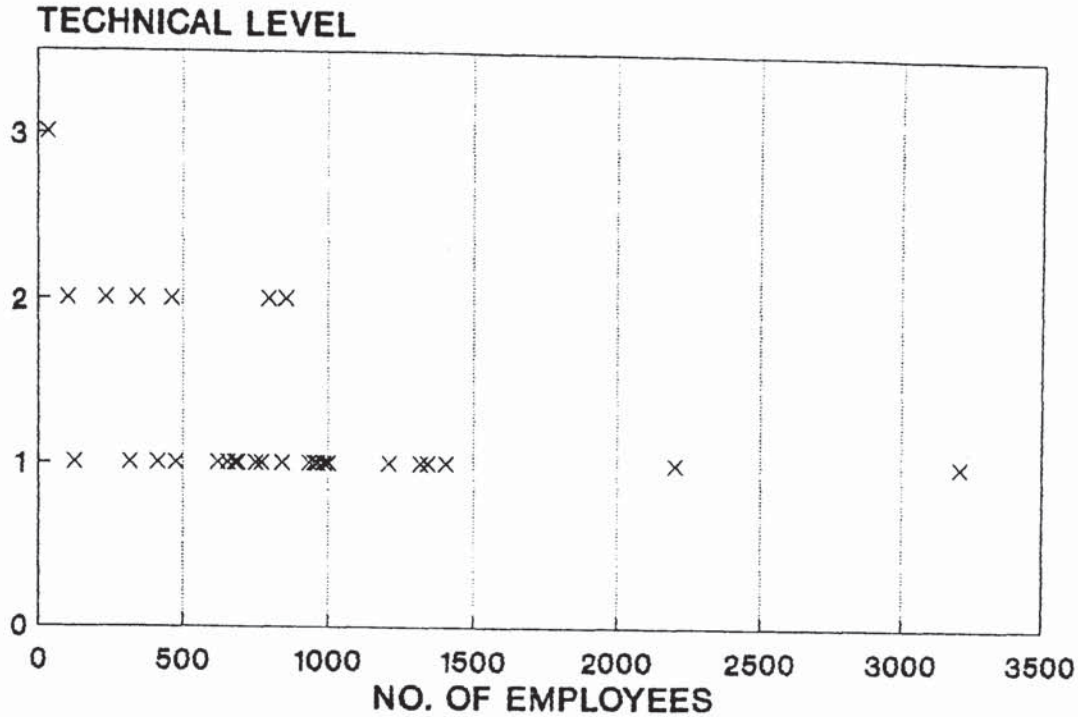
1 - CHINESE ACADEMY OF SCIENCES
2 - MINISTRIES 3 - PROVINCES

FIG. 6.7 UNIT SIZE VS HIERARCHY
CHEMICAL ENGINEERING



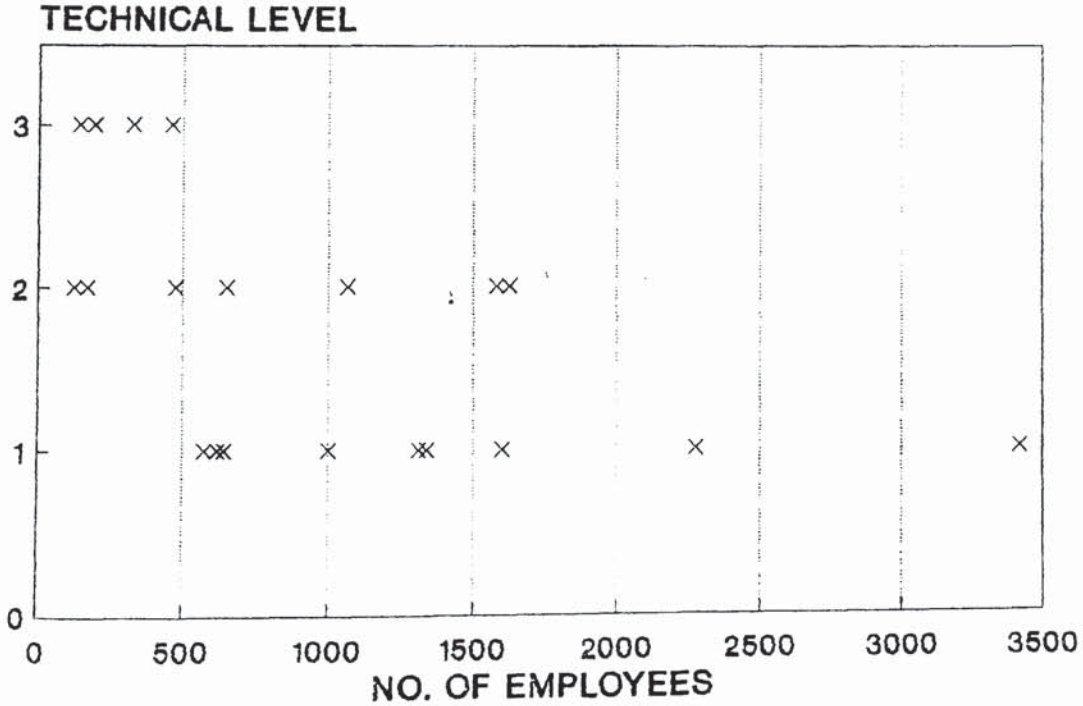
1 - CHINESE ACADEMY OF SCIENCES
2 - MINISTRIES 3 - PROVINCES

FIG. 6.8 UNIT SIZE VS TECHNICAL LEVEL
MECHANICAL ENGINEERING



1 - LEADING 2 - UPPER-MIDDLE
3 - MIDDLE

FIG. 6.9 UNIT SIZE VS TECHNICAL LEVEL
CHEMICAL ENGINEERING



1 - LEADING 2 - UPPER-MIDDLE
3 - MIDDLE

institutes have won awards above the provincial level, thus they are technically advanced, when compared with other research units in China. As a result, none of them placed itself on below average choices.

6.4.2.5 Research Performance vs. Researcher Ratio

It has always been difficult to measure the correlation between research performance and researcher ratio. In theory, it may appear to be that the higher ratio of researchers that an institute has, the better performance is expected. This view is proved untrue in the survey. The trends in Figure 6.10 and 6.11 suggest there is no definite relationship between research performance and researcher ratio. Although small R&D institutes have rather high researcher ratios, their lack of other resources made them extremely difficult or even impossible to achieve high performance. Figure 6.10 and 6.11 show that R&D institutes with researcher ratio around 60% for mechanical engineering and 40% for chemical industry tend to have better research performance. Once the ratio goes up to 70%-80%, R&D institutes have either very good performance or a rather poor record.

6.4.2.6 Research Performance vs. Hierarchy

Among a number of factors, the position of an institute in the R&D system determines its access to information, finance, qualified personnel and other supports. As a result, a research

FIG 6.10 PERFORMANCE VS RESEARCHER RATIO
MECHANICAL ENGINEERING

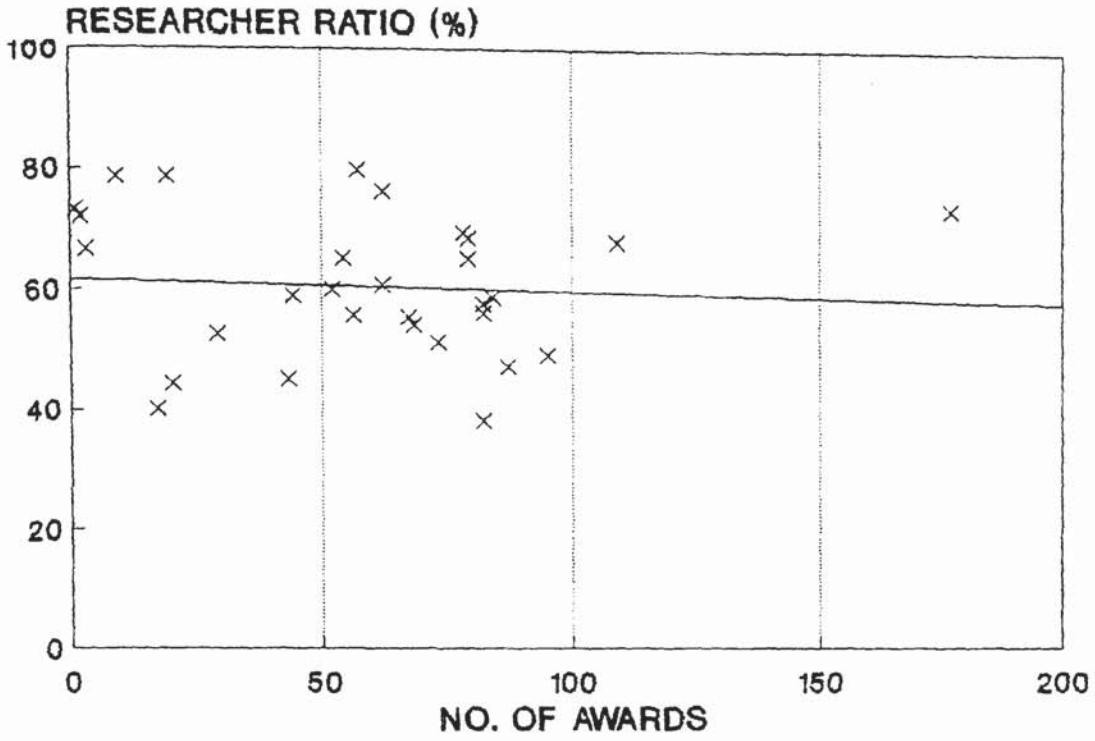


FIG 6.11 PERFORMANCE VS RESEARCHER RATIO
CHEMICAL ENGINEERING

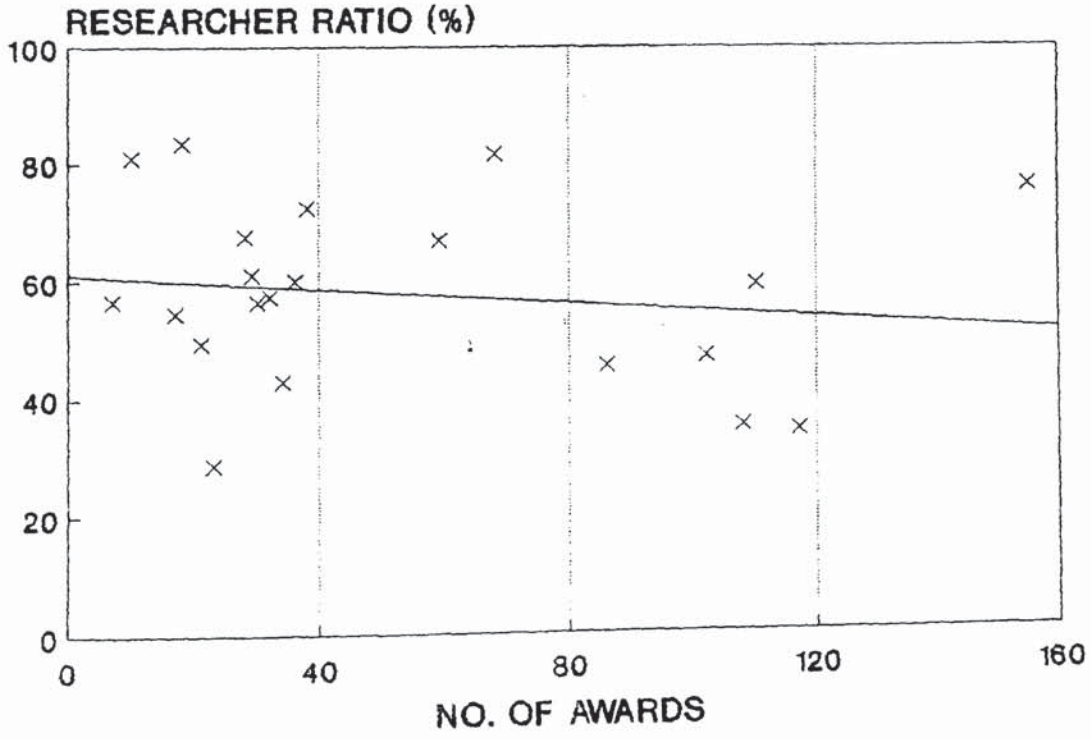
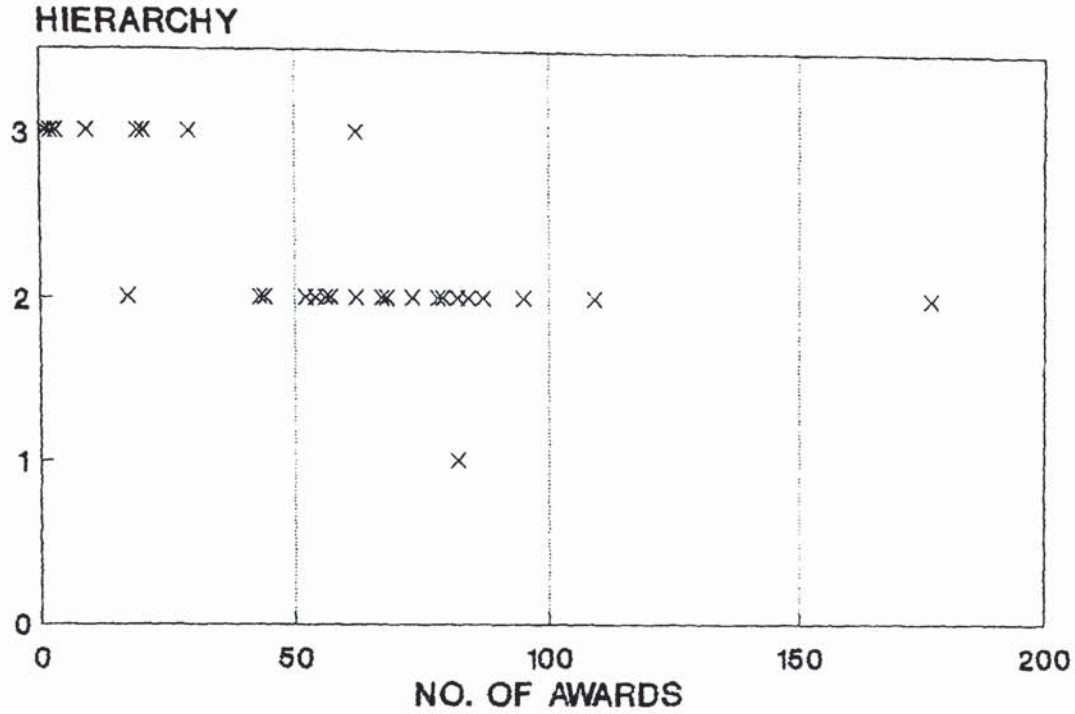
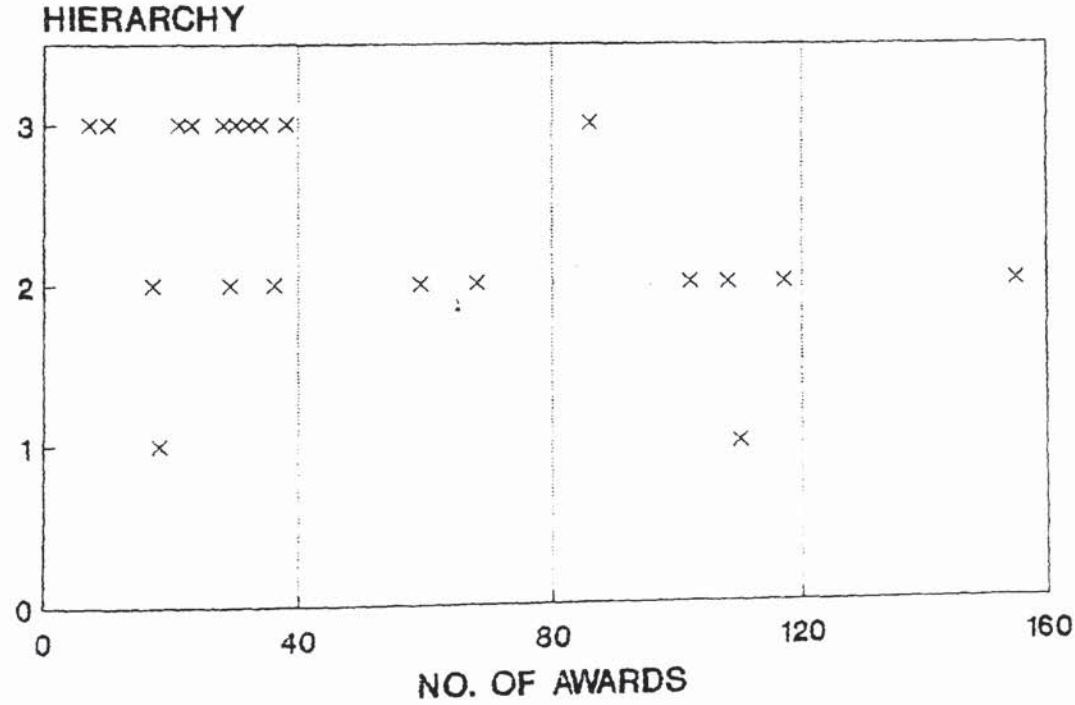


FIG. 6.12 PERFORMANCE VS HIERARCHY
MECHANICAL ENGINEERING



1 - CHINESE ACADEMY OF SCIENCES
2 - MINISTRIES 3 - PROVINCES

FIG. 6.13 PERFORMANCE VS HIERARCHY
CHEMICAL ENGINEERING



1 - CHINESE ACADEMY OF SCIENCES
2 - MINISTRIES 3 - PROVINCES

institute's hierarchical position significantly influences its research performance. Figures 6.12 and 6.13 give a clear account. Except one case in mechanical engineering and chemical industry respectively, there is a significant gap between what ministerial institutes had achieved and what was achieved by local institutes. The scenario is strongly in favour of research units directly attached to industrial ministries.

6.5 Summary

In this chapter, we focused our discussion on the most important actors in the innovation process - i.e. the applied R&D institutes. Three main issues were particularly discussed. They are the innovation management, the impacts of reform and the incentives for innovating. In addition, some general attributes of R&D institutes were also assessed.

Generally, the introduction of market competition into R&D system offered R&D institutes and individual researchers new incentives to commercialise their research results. It also encouraged production units and their managers to generate demands for research results which could facilitate the production process.

Although the R&D system has shifted towards market-oriented, the central planning mechanism remains at work. The centralised planning system still controls the bulk of China's R&D resources. It will be some time before the market

competition and the state planning could find their appropriate balance.

On the other hand, the introduction of the market mechanism into the R&D system does not mean equal competition for every R&D institute, nor does it guarantee a positive response from R&D institutes and production units. It is evident in the research that demands for new technology and incentives for innovation are far from adequate. On the demand side, industrial enterprises suffered from the drawbacks of shortage of funds for technology procurement, lack of managerial support, irrational price structure and frequent government interference.

For R&D institutes, the most significant change was the reform of the R&D funding system, which was intended to make R&D institutes become financially independent. Under such unprecedented pressure, survival became the R&D institutes' first priority. The insecurity of research funding has led R&D institutes to adopt a "quick, small and profitable" policy, which may damage the long-term competitiveness of Chinese R&D strength. In addition, R&D institutes have also suffered from irrational technology transfer prices and depend heavily on their technical fields.

In terms of organisational structure, R&D institutes have undergone less dramatic changes in the reform. The only important change is that research divisions/groups have

generally been granted more autonomy over project management. The once all-in-charge Office of Research Management becomes a co-ordinating body.

One rationale behind China's S&T reform is to use market demand to accelerate the innovation process. This, in fact, couples two separate stages: firstly to make new technology available, and secondly to disseminate and assimilate new technology across the industrial system.

To make new technology available, there must be sufficient and effective incentives to encourage R&D institutes to innovate. There exist two levels of incentives: organisational and individual. For R&D institutes, the incentives include recognition by superior government bodies, recognition in the market and recognition by academia. A good combination of these three factors would provide an R&D institute with a competitive position to attract research projects and generate necessary income. But to achieve all these, solid R&D work is the essential pre-requisite. In fact, these incentives could be regarded as either aims or means. They played an important dual-role in the process of innovation.

As far as research individuals are concerned, their incentives for innovating are more practical. Material incentives become more influential and dominant than political rewards and career or professional pursuit. Due to the diversity of individuals involved in the innovation process,

different people may be motivated by different combination of these factors. However, one thing is certain. Political incentives have lost past dominance.

There is also an unique "dependence" problem in China, the reform has so far failed to solve. The "dependence" problem is reflected by the fact that R&D institutes tried to reduce dependence on outside units, by incorporating many non-research operations. On the other hand, the way Chinese society is organised, forced all members of the society to rely on the units they are attached to, for various welfare and social needs. The impacts are counter-productive to the introduction of free market competition. Especially, the mobility of research personnel is severely constrained. This could be partly explained by the fear of losing social/political control among Chinese leadership, who, on the one hand, are happy to see economic results of the reform, on the other hand, reluctant to accept market economy on a full scale. Unless this obstacle is overcome, the introduction of free market competition could only achieve partial success.

As far as general attributes of R&D institutes are concerned, results from a questionnaire survey in mechanical engineering and chemical industry, suggest that smaller R&D institutes tend to have a higher ratio of research staff than their larger counterparts. But R&D institutes with a higher researcher ratio did not necessarily have better innovation performance. There seems to exist a sectorally dependent

optimal researcher ratio for R&D institutes. Large R&D institutes are not necessarily more innovative. In fact, medium sized R&D institutes had the best innovation performance. Larger R&D institutes are mostly directly supervised by industrial ministries and CAS, and they appear to be technically superior to local R&D institutes. Furthermore, these CAS and ministerial R&D institutes are more innovative than their local counterparts.

CHAPTER 7 CONCLUSIONS AND PROSPECTS

7.1 Research Framework in Retrospect

It has been argued at the beginning of the thesis, that the idealised pure market economy and planned economy simply do not exist in practice. All economies in the world are, in fact, certain configurations of markets and hierarchies. Each individual country, due to its own political and economic conditions, adopted various combinations of market and planning mechanisms in the running of the economy. Some combinations are apparently more conducive to economic and technological development than other combinations.

On the other hand, there is no fixed combination of these elements. With the development of the economy, technology, society and political system, there are frequent demands to change the existing combination and find a new one. In the process of change, government plays an important role. In many countries, governments have used direct and/or indirect measures in an attempt to lead the change. These measures may not be entirely successful. Some could be counter-productive. To shift from one existing balance of market and hierarchy to a new one, may involve institutional change, depending on how radical the changes are going to be. In the case of incremental changes, market self-adjustments and some degrees of government regulation may be sufficient. But radical changes, like the reforms in Soviet Union and China, are so dramatic that a

complete new combination needs to be constructed.

In order to measure these changes, a research framework of three dimensions was proposed. The three dimensions are:

Arrangements - the R&D system and its reform;
Achievements - Performance of the R&D system;
Actors - Innovating organisations in the R&D system.

Arrangements - these refer to the linkages between the market and planning mechanisms. This is often represented through visible institutional and organisational forms, and various invisible communication and regulation channels. However, these linkages are likely to change, through the formation, modification and dissolution of various institutional structure and regulations. Through these changes, a new mixture of market and planning mechanism is achieved.

Achievements - these refer to the performance of an innovation system. Admittedly, this is largely determined by the arrangements prevailing in a system. However, similar or identical institutional arrangements may not have similar innovation performance. This may be related to social, political or even cultural constituents of the system. This may also be related to the fact that innovation performance is perceived and measured in different ways. Often, the innovation output indicators, such as patents, awards etc. are used for

assessment.

Actors - these include a collection of organisations and individuals in the innovation system. Organisations and individuals communicate and exchange with each other through the arrangements of the system. Different organisations assume differently roles in the system. Even organisations of identical nature under the same arrangements may behave markedly different. So an organisation's behaviour is partly determined by the environmental arrangement and partly by its own response. So do research individuals. The behaviour of innovation actors can be examined from different angles. But research and industrial organisations are frequently at the centre of the study.

In the present research, the above-mentioned research framework has been used to analyse the innovation system in China. It provides an analytical framework to explore a rather complicated system. In the following section, the main findings of the research are summarised along the three dimensions.

7.2 Conclusions

7.2.1 Arrangements

Today, China is experiencing dramatic changes in its innovation system. The final outcome of these reforms are hard to identify at this stage. But it is likely that the Chinese

R&D system and its way of functioning after the reform will be changed remarkably. If we look at the later part of the 19th century and the first half of 20th century, when the technological performance of Germany and the United States overtook that of Britain, their success was related the major institutional changes in the R&D system. Both countries had developed new ways of organising R&D activities and technical research into production and marketing. This resulted in the emerge of clusters of innovation, which, in turn, greatly enhanced the economic development. (Freeman, 1982; Rothwell, 1985)

Similarly, from a historical perspective, the current reforms in China may lay the foundation for future technological take-off. But in a period marked by radical changes in the technological basis of the economy, existing organisational and institutional structures may form the major obstacles to the transformation. As a result, institutional, social and political changes may be necessary to ensure economic and technological changes to take place on full scale.

In the process of establishing and restructuring the innovation system, the reforms were characterised by radical changes. Under such circumstances, the task of the government becomes extremely complex and important. There is a need to drastically transform the existing innovation system to meet the new demands. The difficulties for the government are to stimulate the renewal of the old system and to establish new

frameworks, which are supposed to integrate the market competition, planning and sometimes political interests together. But in the process to achieve all this, the government has to sustain some kind of system which already exists; support the establishment of other new institutions at the same time, negotiate between groups of interest; and introduce other measures of change. To do this skilfully and without causing too much socio-economic disturbance certainly requires hard manoeuvring and careful thinking.

From this point of view, the ongoing reform of the R&D system in China is to find an appropriate balance of market and planned aspects of technology, to create sufficient incentives to spur innovation, and to ensure enough funds to support key new technology. To shift away from the original command system, reforms of the operating system, the organisational structure and the personnel system were introduced. Although these serious efforts made progress, the Chinese R&D system still bore the birthmark of a centralised system. Research and production functions are largely separated, with R&D capacities concentrated in vertical compartments. However, there are increasing signs that such departmental barriers are reduced by horizontal contacts through the market-place.

As a result of changes in R&D funding, R&D institutes are forced to develop horizontal links. But since the State still controls a large portion of national S&T budget, planning and national and local plans for technological development remain

of significant importance. Research projects are competed through open bidding. But it is important to make clear that, at the same time when market competitions are introduced into the innovation system, there continue to be coherent plans at the national level to promote innovations in high technology, agricultural technology etc. The existing planning process is largely consultative, except plans for defence and strategic projects.

As far as government support for innovation is concerned, it is analytically useful to distinguish different kinds of efforts. First of all, government is responsible for funding basic research and education. Secondly, government channels funds through various procurement arrangements and contracts. A third kind is government direct investment in certain programmes, such as electronics and bio-technology. The government can also use selected industrial policy to encourage innovation in specific industries. There seem a number of tasks the reforms are trying to achieve: 1) to increase the flexibility of R&D and industrial structure by means of both planning control and market competition; 2) to enhance the horizontal information flow within and between research and production organisations through market mechanism; 3) to identify and support crucial areas of future technological advance at national and organisational level; 4) to retain the capacity to mobilise large amount of capital and technical resources in pursuit of strategic priorities.

7.2.2 Achievements

Thanks to the availability and abundance of systematic data of National Awards for S&T process in China, performance of the Chinese R&D system is measured through a series of patterns generated through database analysis, which offered constructive insights not previously avoidable.

There are two sets of pattern analysis in the research. The first one focused on innovation itself; the second one on innovating organisations.

7.2.2.1 Patterns of Technological Innovation

The pattern analysis, from the output end, shows that a province's innovation performance appears to be strongly influenced by three key factors, i.e. the pre-Communist level of economic development, government strategic choice and the province's geographical location. All highly innovative provinces benefits from various combinations of these factors. The coastal provinces and provinces in the north-east, in general, enjoyed high level of pre-Communist level of industrial development and advantageous geographical location for international transport, their innovation performance is less determined by government policies. But for these provinces in the hinterland, like Sichuan and Shaanxi, their innovation performance relied heavily on government selected development policy, since they generally achieved lower level of industrial

development in the pre-Communist era. However, for poorly innovative provinces, all these three factors appear to be disadvantageous to them, even there have been considerable efforts to alter the situation. As a result, it is not surprising to see that a small group of highly innovative provinces made the majority of innovations. They produce not only more innovations, but also more sophisticated innovations.

Sectorally, an industrial sector's innovation performance, is largely determined by the other set of three key factors, i.e. its level of technological development, its position on the government priority list for development and the technical nature or industrial characteristics of the sector. Each sector has its own combination of these three factors, though the importance may vary. For example, electronic industry, typically, enjoyed a high development priority status and being a sector of experiencing rapid technological change, whereas mechanical engineering represents a mature industry, which has achieved considerable level of technological development. On the other hand, consumer industries, due to their industrial nature, tend to make innovations on a smaller scale. Since the introduction of the market mechanism into the R&D system, sectoral performance became subject to market competition. But it appears that sectoral innovation performance remains heavily influenced by these factors.

Admittedly, there are many other factors which may affect innovation performance both regionally and sectorally, e.g.

technical information network, density of research institutes and universities etc. But the above-mentioned factors appear to be more influential. One important pattern revealed in the pattern analysis is that there are generally more product innovations than process innovations. This conclusion disagrees with the common perception suggested by a number of previous studies that centrally planned economies tend to have more process innovations than product innovations. (See Gomulka, 1986; Poznanski, 1985; Fischer, 1989; Amamn & Cooper, 1982) However, despite of the dominance of product innovations, process innovations appear to outweigh product innovations in high class awards, where the economic benefits brought about by the innovation may be given favoured consideration. On the other hand, the sectoral product/process innovation mix depends considerably on technical or industrial characteristics of the sector. For example, manufacturing industries tend to have more product innovations than process innovations. In addition, it is important to mention that a third type of innovation category - Technological Projects - are used to monitor government selected development priorities. The pattern analysis shows that government priorities did have an important impact on sectoral innovation performance, especially on big industrial undertakings.

7.2.2.2 Patterns of Innovating Organisations

It has been identified in the analysis that research institutes are the most important innovators in technological

innovation. While research institutes played more principal roles, production units' roles were largely supportive. It is also found that universities have gradually increased their influence, and government agency's direct involvement in innovation activities are generally low and mostly in large projects.

The dominance of research institutes as principal innovators and production units as supportive innovators, is largely due to the design of R&D system in China. Under the system, R&D institutes are separated from production units and equipped superior technical facilities and expertise. Their innovation performance is expected to be better. But it is important to notice the impacts brought about by the S&T reforms. Production units and universities have become increasingly active in technological innovation.

Irrespective of the separation of research institutes and production units, the result of analysis indicates that there is a considerable amount of co-operation in innovation activities. Co-operations occurred between organisations of different or same nature, and within or across regional boundaries. Co-operation between research institutes and production units is the most common form. Inter-region co-operations are more frequent than intra-region ones. But the reform of the R&D system has encouraged more co-operative activities, within the same region.

The pattern analysis suggests that two national R&D centres, Beijing and Shanghai, where a large number of R&D organisations and R&D resources are concentrated, contributed significantly to national S&T development. But due to their existence, the overall patterns of technological innovation are greatly altered. In some provinces, the research institutes' dominance as principal innovators becomes less evident, or is even overtaken by production units. In fact, a region's innovation performance is determined by the combined strength of R&D institutes, production units, and higher education institutions.

7.2.3 Actors

The analysis of innovation performance demonstrates that research institutes, especially applied R&D institutes, are the main innovators in Chinese R&D system. However, our understanding of innovation in these research institutes appears to be far from satisfactory. In order to explore innovation in applied R&D institutes, two separate empirical studies were carried out. Research institutes in mechanical engineering and chemical industry were surveyed by questionnaire. Semi-structured interviews were also conducted.

Applied R&D institutes were the focus of the ongoing reforms in R&D system. The most significant change occurred in the area of R&D funding. Direct State appropriations to applied R&D institutes are gradually phased out. They are supposed to

generate their own financial income to support staff and research projects. There are a number of channels of research projects, such as vertical contracts from central or local government agencies, since they still control a large portion of R&D budgets, and horizontal contracts developed with industrial users through the market, as well as projects from the National Science Foundation. Some institutes even initiated their own research projects.

While there were fundamental changes in the way research projects are funded, changes in the internal structure of R&D institutes occurred as well, but to a lesser degree. The Research Office, which used to be the powerful channel of central planning, now no longer controls everything. Much of its power has been delegated to the research groups, in the hands of project leaders. Some research institutes have adopted the responsibility system, which opens the way to both external and internal market competition.

There has been increased personnel mobility within R&D institutes. Research group leaders are given the freedom to choose group members. Unselected personnel are allocated into non-research units run by the institute like shops etc. However, as far as personnel mobility in broad terms is concerned, there remain severe constraints. The decentralisation of control appears to be confined to the organisation as a unit and in selected areas, such as finance and research management. From a societal point of view, the

State has always been reluctant to relax its control, especially when individual mobility is concerned. There is an unique "dependence trap" for both research individuals and research institutes. For individuals, the society is organised in a fashion that one has to be attached to a work unit or mass unit, in order to get basic welfare and social rights. For research institutes, in order to meet the non-research needs of their employees, they have to incorporate many additional operations. As a result, research management in China is not as simple as the management of research laboratories. It is the management of a mini-society.

Similarly, there are two sets of incentives for innovating. For R&D institutes, the fundamental motivation comes from the fact that they have to become financially self-sufficient. The key to that is to secure and expand research projects from various channels. As a result, incentives for R&D institutes includes recognition by superior government agencies, recognition in the market and recognition by academia. Through these recognitions, R&D institutes can establish the reputation to win both horizontal and vertical research contracts. For research individuals, incentives for innovating can be material, political and professional. But it has been identified that material incentives, both monetary and non-monetary, are the most important forms of motivation. Political incentives have largely lost dominance compared with the pre-1978 period. In most cases, these elements of incentives act simultaneously at both the organisational and

individual levels. It is important to note that, to be a national award winner, is regarded by both research institutes and individuals, as a way to gain advantageous position in competition and win other associated benefits.

In addition, results from the questionnaire survey in mechanical engineering and chemical industry, suggest that medium-sized R&D institutes tend to have higher innovation performance. R&D institutes directly attached to industrial ministries and the CAS have achieved better performance than local R&D institutes. R&D institutes with a higher proportion of research staff may not be necessarily more innovative. There appear to be sectorally dependent optimal ratios for different industries.

7.3 Summary and Prospects

This research reveals that there are consistent efforts to encourage technological innovation in China. The government introduced various policy initiatives to alter the environment and institutional arrangements for innovation. National plans for technological developments in various industrial sectors were put into action. The most significant changes are the introduction of market competition and the change of R&D funding system.

At the same time when the market mechanism is favoured, the Chinese government still retains the planning mechanism. It

seems that the Chinese are trying to find an appropriate balance of market and planning by trial and error. Sometimes this is painted with the colours of the so-called "socialist market economy of Chinese characteristics" or "the State governs the market, the market then guides the economy". Such slogans can be interpreted from different angles. On the one hand, it may indicate the the political leadership simply does not understand the meaning of market economy or is not quite sure where the reforms are headed for. On the other hand, it may be argued that these slogans are just political formulations for things to be done without causing too much problem at the beginning.

However, it is less urgent to judge which interpretation is correct. For the present discussion, the most important point is that there is no single type of arrangement, which will be universally optimal for innovation activities in all economies. Technical innovativeness requires a mixture of different kinds of market and planning elements to facilitate its realisation. This involves changes in institutional structure, legislation, fiscal and tax leverage, and changes in associated social structure. From this point of view, the ongoing Chinese reforms of R&D system represent attempts to achieve an optimal mix. But, so far, these attempts have achieved limited success. Reforms to the political and social systems are necessary to facilitate and support the further success in the economic and S&T arenas.

On the other hand, it has to be admitted that this research is only able to assess an innovation system in transition with reference to certain dimensions. There are many open opportunities for further research and discussion. With rapid changes in world economic system, e.g. the East European countries and newly industrialised countries in Asia, future research could be carried out comparatively to assess theoretical implications. After all, the complexity and diversity of innovation systems in different socio-economic contexts, and their common goal to achieve economic development through technological innovation, create many opportunities for future research.

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APPENDIX A INTERVIEWS

Interviews in this research were all arranged through informal channels. The aim is to obtain first-hand individual views on innovation activities in R&D institutes. 38 people were interviewed in total. Most of them are researchers from R&D institutes in China. At the time of interview, they were visiting British universities. Among 38 interviewees, 28 were from applied and developmental research institutes, 8 from basic and applied research institutes, 2 from others. 24 of the institutes are under industrial ministries, 11 belong to Chinese Academy of Sciences and 6 are supervised by provincial governments.

Demographically, 25 out of 38 interviewees are between the age of 30 to 50, with other 6 younger than 30 and 7 older than 50. Academically, 9 of them are at the senior level, equivalent to principal engineer rank in the UK. One of them was a chief engineer. 17 interviewees are experienced engineers, while the other 12 are at relatively junior levels.

Technically, the industrial sectors these research institutes represent are Mechanical Engineering (8), Electronics (6), Chemical Engineering (5), Metallurgy (5), Energy (5), Bio-technology (2), Basic Science (4), Textile (1) and Others (2).

Geographically, these research institutes are located in the following pattern: 11 in Beijing, 7 in Liaoning, 3 in Sichuan, Hubei, Shanghai, and Jiangsu, and 1 in Hunan, Shaanxi, Henan, Guizhou, Gansu, Heilongjiang, Tianjin and Guangdong respectively.

Better results are expected from these informal arrangements. Firstly, all of them were first-line researchers in R&D institutes. Some of them were research group leaders. They knew how research projects are managed from the beginning to the end. Their views are not mere "parrot interpretations" of the official policies, but reflect how reform policies in S&T system are perceived by the S&T community at large. Secondly, what is more important is that since all the interviewees were away from their work units, they felt free to express their opinions and make comments on policy issues, particularly when they were assured that their identities will not be disclosed. Although the degree of openness varied from person to person, information obtained from these interviews are generally believed to be of high quality. It was agreed that the names of the interviewees will not be disclosed to any third party without prior consent, so a numbering system is used in the thesis to refer to a particular interview. 13 interviews were translated and summarised.

APPENDIX A - I INTERVIEW CHECK LIST

General Information

1) Interviewee's general information:

   Title, Position, Work Experience etc.

2) Organisation's general information:

   Name, Location, Number of Staff, Number of Research Staff, Research Standard Roughly, History, Superior Body and Relation, Internal Structure, R&D Management and Control, Research Direction etc.

Research Information

1) Project and funding sources, funding scales and methods, how to apply and distribute, co-ordination at the ministerial level.

2) Project time table, Supervision of research project, examination of research results, forecast of economic benefit, application for national / ministerial / provincial awards.

3) Formation of research group, selection of researcher, in-group collaboration and collaboration with other department, research group's degree of independence, budget control, distribution of cash awards and bonus.

4) In the reform, changes occurred in terms of R&D management, responsibility, collaboration person-person relationship, conflict of interests, staff mobility and welfare constraints.

5) Views on incentives for innovating, effects of award schemes and problems, material incentives and other forms of incentives.

6) Personal comments on government S&T policy, problems and achievements.

APPENDIX A - II LIST OF INTERVIEWS

Interview		Title	Date	Location	Organisation
1	(A)	RA	3/8/89	Liaoning	Shenyang Research Institute of Metallurgy, CAS
2	(B)	C.Eng	3/8/89	Beijing	Beijing Academy of Nonferrous Metallury, China Corporation of Non-ferrous Metals
3		A.Eng	9/8/89	Beijing	Institute of Rail Vechicles, Academy of Railway, Ministry of Railway
4	(C)	C.Eng	3/8/89	Beijing	Beijing Academy of Iron and Steel, Ministry of Metallurgy
5	(D)	C.Eng	3/8/89	Hunan	Changsha Academy of Mining & Metallurgy, Ministry of Metallurgy
6	(E)	A.Eng	3/8/89	Shanxi	Xian Institute of Thermal Engineering, Ministry of Energy
7		C.Eng	9/8/89	Henan	Institute of Energy, Henan Academy of Sciences
8		C.Eng	9/8/89	Beijing	Institute of Standardization & Planning, Ministry of Broadcasting and Television
9	(F)	C.Eng	9/8/89	Sichuan	Chenxing Research Institute of Manufacturing Technology, Northern Industrial Company, Ministry of Machine Building and Electronic Industry
10		RA	5/8/89	Liaoning	Shenyang Research Institute of Computer, CAS
11		C.Eng	6/8/89	Liaoning	Anshan Research Institute of Thermal Energy, Anshan City
12	(G)	RA	12/8/89	Hubei	Wuhan Research Institute of Physics, CAS
13	(H)	AR	12/8/89	Beijing	Beijing Research Institute

					of Bio-Physics, CAS
14		A.Eng	13/8/89	Liaoning	Liaoning Research Institute of Textile Technology, Ministry of Textile Industry
15		RA	13/8/89	Hubei	Institute of Economic, Hebei Academy of Social Sciences
16		RA	13/8/89	Sichuan	South-West Research Institute of Physics, Ministry of Nuclear Industry
17	(I)	CDEng	14/8/89	Shanghai	Research Institute of Grinder, Shanghai Machine-tool Factory
18	(J)	S.Eng	14/8/89	Liaoning	No. 601 Research Institute, Ministry of Aeronautical and Aerospace Industry
19		C.Eng	16/8/89	Beijing	Research Institute of Biological Environment, Chinese Academy of Environmental Sciences, State Administration of Environment
20		S.Eng	16/8/89	Beijing	Beijing Research Institute of Vaccum Electronics, Ministry of Mechine Building and Electronic Industry
21	(K)	S.Eng	16/8/89	Jiangsu	China Ship Science Research Centre, China Corporation of Ship Building
22		C.Eng	20/8/89	Liaoning	Shenyang Research Institute of Computer, CAS
23		C.Eng	21/8/89	Guizhou	Guiyang Research Institute of Geo-Chemistry, CAS
24		C.Eng	21/8/89	Gansu	Lanzhou Research Institute of Geology, CAS
25		AR	22/8/89	Beijing	Research Institute of Chemistry, CAS
26	(L)	RA	22/8/89	Beijing	Research Institute of Acoustics, CAS
27		C.Eng	30/8/89	Hebei	Research Institute of Quartz, Chinese Academy of Building Materials

28	S.Eng	30/8/89	Jiangsu	Nanjing Research Institute of Electronic Devices, Ministry of Machine Building and Electronic Industry
29	C.Eng	31/8/89	Shanghai	Shanghai Research Institute of Materials, Ministry of Machine Building and Electronic Industry
30	S.Eng	31/8/89	Liaoning	No. 606 Research Institute, Ministry of Aeronautical and Aerospace Industry
31	C.Eng	31/8/89	Hubei	No. 609 Research Institute, Ministry of Aeronautical and and Aerospace Industry
32	PG	3/9/89	Hellong-jiang	Research Institute of Petro-Chemistry, Heilong-jiang Academy of Science
33	RA	4/9/89	Jilin	Changchun Research Institute of Optical Machinery, CAS
34	C.Eng	4/9/89	Beijing	Beijing Academy of Petro-Chemical Sciences, China Petro-Chemical Corporation
35	C.Eng	5/9/89	Shanghai	Shanghai Research Institute of Ship Desiel Engines, China Corporation of Ship Building
36	C.Eng	5/9/89	Jiangsu	Suzhou Research Institute of Thermal Engineering, Ministry of Energy
37	RA	5/9/89	Sichuan	Chengdu Research Institute of Organic Chemistry, CAS
38 (M)	S.Eng	8/9/89	Guangdong	Guangzhou Research Institute of Rubber Aging, Ministry of Chemical Industry

Key

PG - Postgraduate
AR - Research Associate
A.Eng - Assistant Engineer
CDEng - Chief Design Engineer
RA - Research Assistant
C.Eng - Engineer
S.Eng - Senior Engineer

Note: Interviews with bracketed letters are summarily transcribed and translated. (see Appendix A - III) Other interviews are available in the form of cassette.

APPENDIX A - III INTERVIEW SUMMARIES

INTERVIEW A

Organisation: Shenyang Research Institute of Metallurgy
Chinese Academy of Sciences
(6 Wenhua Road, Sec 2, Shenyang)

Period: 1982-1987.10

Summary:

The institute is directly supervised by Chinese Academy of Sciences. There is a Shenyang Branch of CAS. But it does not have any financial of administrative power over the running of the institute.

Total employees are around 1200. Among them 700 are research personnel.

The main research area is material science. The original set-up of this institute in Shenyang was because it's close to AnShan. It was primarily concerned with the research of metallic materials. Now it has diversified into research of non-metallic materials.

Structure

Directors (Secretary)
|
Sections (Section for Research Management)
|
Administrative

Function of SRM

SRM is responsible for the research activities in the institute, co-ordinating communications vertically and horizontally, collecting research results, organising project evaluation, planning and applying projects. Main responsibility is co-ordination. Other sections are propaganda, security etc. There are more than 20 research units.

Division of R&D (No.1, No.2, No.3 - different fields)

Before the reform tasks of R&D divisions were to develop research results into products, pilot production and develop process technology for factories, diffusion of new technology. In the reform, in addition to the previous two functions, they were also involved in production of final products and sell directly to users.

No.3 Division of R&D - Magnetic materials, computer control etc. (New one)

No.2 - Foundry, processing

No.1 - Material testing

Material testing laboratory - Take care of major testing equipment, serve the whole institute.

Below Divisions are research units. The size of research unit varies from 60-70 to 10-20.

Case

Material used for the turbine blades of engine. Started in 1975. Now competition is more based on the economic benefits and intellectual property rights, whereas in the past it was more concerned with technical level. This project was a sub-project of a big one - development of new ship engine, administrated by SSTC.

When project reaches the Institute, SRM, directors and academic committee gather together to allocate tasks among research units. A leading group is formed to supervise the running of the project, joined by a person from SRM, and other technical peers from different backgrounds. Personnel in the SRM have technical background.

Project is normally granted to a research unit in the same/similar research direction. Tasks then assigned to researchers by the head of the research unit. When co-operation between two or more research units is required, in the past, only academic reputation is shared, now any use of equipment and manpower is charged through internal accounts.

About the finance of project, if a project is big, the leading group divides research funds between research units. A portion of the fund is retained by the SRM. Then research units have the right to use their own share for the research. But the purchase of large equipment needs approval at the Institute level.

The institute is classified as basic-applied research institute, in the reform. In the past research institute has fixed research budget from the state.

In the reform, a percentage of fixed budget in still granted to basic-applied institute. This percentage is reduced each year. (30% first year)

Horizontal links with industries are carried out on research unit basis. Unit leaders and members go out and look for contracts, mainly with existing contacts. Directors look for projects as well, but mainly with new contacts and big projects. Those projects are not supervised by SRM. Although horizontal links are developed, they are placed on the basis that state projects are completed. The institute is one of the best research organisation in the field. The number of projects

assigned from the top is scare in the reform. Main categories are SSTC Key Projects, CAS Projects, Natural Science Key Projects. There are no provincial projects.

Most of the horizontal projects are administrated by unit leaders. Research units retain a certain percentage of profit. Not much organisational change in the reform. Some technical companies were set up.

There was a debate about the balance between high-tech research and applied research. Research units in different fields hold different views. The decision was heavily influenced by the director at that time. Now the emphasis of the institute is towards high-tech. One reason is high-tech project attracts more funding. Applied research is also encouraged.

Most of the unit leaders are around 50 years old, large number had studied in Russia. Titles normally Associate Fellows or Fellows. However people played most important roles in the research are those around 30s and postgraduates. There are 120-130 postgraduates in the institute.

In the reform, researchers had more say in the decision making in the institute. Research groups have profit retains. Institute distributes bonus seasonally. Not many projects won national award. Patents and awards are considered as an academic reputation. It has weights in the academic promotion.

INTERVIEW B

Organisation: Beijing Academy of Non-ferrous Metallurgy

Period: 1983-1988.11

Summary:

The Academy was under the jurisdiction of the Ministry of Metallurgy. In 1984, it was transferred to the newly-established China Corporation of Non-ferrous Metals. Number of total employees is around 2500. There are more than 1000 research personnel. It's the No.1 in research in non-ferrous metallurgy. It has branches in Guangzhou and Baoji directly led by the CCNM.

Structure

Directors
(Director's Office)
|
Chief Engineer
(Chief Engineer's Office)
- Support Director
|
Section of Research Management
- Co-ordination of Research Budget/Fund
Technical Information etc.

There are 11 research units from extraction of metals to metal processing to metal products. Each unit has around 100 people, below units are groups. Heads of units are normally Senior Engineers, a large percentage of them had studied in Russia. Most of them are between the age of 40-50. Very few young people reached this status.

Function of SRM

Before the reform:

Project funding was handled by the section of Finance. SRM supervises research progress. Progress reports of research projects were made periodically by research units to SRM.

During the reform:

Horizontal contracts also need to report to SRM, as the Academy will draw a portion of income from the contract total. Research groups don't have bank accounts. All external transactions have to go through the Academy's account.

Research groups sometimes are formed by self-grouping. Group leader, who is normally the contract-finder, has the right to choose group members and the use of research budget. Group members can be selected within the academy, from different units. Normally, a project group is attached to a research unit.

People of different research interests pursue different types of project. Some prefer small, quick, practical projects. Others prefer those of high academic values. It seems that small, quick and practical projects are more preferred now than those of high academic values.

Horizontal Projects channel :

correspondence, bidding meeting, exhibition, etc.

Vertical project channel :

A research planning meeting is held annually at ministry or corporation level. Directors of research institutes attend. In the meeting, a number of research project proposals are formed. They bring them back to the institutes, preparing a research plan. If the plan is approved, research budget is then allocated. Job is assigned to a research group. SRM supervises the progress of the research, also evaluation. The evaluation depends very much on the end-users. Specialists outside the Academy are invited for the examination. Researchers will give a presentation.

In the reform, the academy expanded its capacity of small-scale production. The main reason is to gain income. Research group has small-scale production equipments/line. Academy has a intermediate production factory, at which research results of research groups are further developed and modified before introducing into industries. Some research groups have a number of production lines.

People - most important in the research are aged between 30-40. Senior engineers supervise and co-ordinate. They rarely do first-hand research.

Organisational Change

In the reform, they try to restructure the old Academy-Institute-Unit-Group structure. It is now a kind of Academy-Group structure. People didn't leave very much. People have difficulties in finding accommodation welfare if they resign.

Bonus

Cash award - research personnel involved. Not sure whether discounted by the Academy or not. Effectiveness of award depends largely on the reasonable distribution of benefits. If it's not fair, it hinders research motivation. Project-finders, in theory, have more shares in profit. But, in practice, in order to avoid conflicts, they don't want extra. Patents are registered under individual's name. If any income appeals, they Academy declared a portion, as research used academy's equipments etc.

INTERVIEW C

Organisation: Beijing Academy of Iron and Steel

Period: 1983-1988.10

Summary:

The Academy was founded in 1952 as a research institute, it changed its name to Academy in 1958.

Structure

Before the -reform: 21 Research Units (in the past)

In the reform: 1. Institute - financially independent (1)
2. Division - financially relatively independent - several units. (2)
3. Unit - as before, adopting responsibility system.

Material research:

- Iron & Steel
- Some non-ferrous
- Fire-proof, hard-melting materials
- Aluminium
- Magnetic materials etc.

Project running

Now every concern is about money. Research units have responsibility (profit) quota to the Academy.

Both horizontal and vertical projects exist. According to top-down projects, horizontal contracts and academy's research plans, research groups are set up. Some groups focus on horizontal contracts. Some concentrate on top-down projects. Two types of project can be seen in one research group.

Very small amount of profits can be distributed to research groups as cash bonus.

Bonus:

20% of the net profit - total
4% - Academy
8% - Unit
8% - group
distributed to individuals within the group (No set rules)

Intra-Academy Co-operation

Before the Reform

A system of internal cheque book was employed, only as a way

of management. If you don't have "money" in the group account, academy will allocate money to you.

During the Reform

Any issue of internal cheque means real deduction of your research budget. Now research groups all try to save money. Some tests or analyses, if it's not essential, are not carried out. As a result, the inter-group co-operation in research is decreasing.

Department of Research Management

In the past, most projects are top-down. They are administrated by the DRM research budgets are allocated through DRM. DRM knows all the running of research projects and supervise research progress.

Now, those horizontal contracts, need to be approved (stamped) by the DRM, but they don't have much decision-making power over contract details. But Institute and Divisions can accept contracts on their own. DRM still have co-ordinating role, when co-operations between research units are required. Research groups control their own research progress.

Project Result Examination

When a project is finished, a report is drafted and handed to the Ministry, asking for examination. If the Ministry accepted, a group of experts forms a panel of examination. The panel members, however, are invited by the research group. As they are in the same field, and have many contracts in the past, such an examination seldom fails. Only end-users sometimes put difficult questions, particularly about technical problems.

Inter-organisation co-operation

If two or more organisations are involved, in a project they will have discussion first, like division of labour. If responsibilities are equally divided, they will be partners. Otherwise, the one with more responsibility shall be the principal, and the others become participants playing supportive roles.

If a partner is a production unit, it is likely that this project is industry based. The majority of research work are done by research institute. Production unit offers plant equipments. Big enterprises have their own research units, some are of quite high level.

Search for Contracts

Since 1986, fixed research budget is reduced each year, about 20% annually. By 1990, Academy is expected to be self-financed.

Group members hunt for contracts largely through contacts th factories and visits, and not through technical markets. laries of group members are now provided by project earnings. sh bonus are commonly distributed evenly. It has been nsidered to award project-finder some commission fees. There no regulation yet.

Cash award is normally not deducted by the academy. But, oup leaders distribute award among people involved. Otherwise, ere will be difficulties in future co-operation.

Leaders at unit level, are largely trained in Russia, casionally with young representatives. Group leaders are stly graduates of 60s.

Patents and awards are treated as personal achievements. ey have academic promotion.

p-down projects

1) Projects are decided at the ministry. A planning meeting is held to allocate projects. Funds distributed.

2) Some projects are decided and announced. Institute put in applications to compete. After examined by experts committee, projects are then granted.

Report contents include:
a) equipments available
b) previous research
c) research schedule
d) budget proposal

Certain percentage of research grant goes to the Academy, ome go to the Unit and the rest goes to the group. The actual reak-up is not exactly sure.

INTERVIEW D

Organisation: Changsha Academy of Mining & Metallurgy

Period: ?

Summary

The Academy was established in 1955. It was Shanghai Research Institute of Silicate, CAS. Part of the institute moved to Changsha in 1956, because the non-ferrous metal mine reserve is rich in Hunan. A group of people were sent to Russia for training in 1956. Now those people are major force. The total number of employee is more than 1400. There are about 800 research personnel.

In the past, there were 14 research units. Mining engineering is responsible for mine selection, refining, material analysis, explosion, and pipe engineering.

Section of S&T

Before the reform, it was useful. Now, it's a rubber-stamp. In the past, all the projects are allocated by the section of S&T. Now projects are found by research units in their own channels. However, they have to report to the SST, as any transaction of money has to go through Academy's account. It's only for the purpose of registration, the SST doesn't concern the details. In case of big projects, representative of the SST is invited to attend and sign contracts. The main purpose of the SST is now as a communication channel, no real power.

Before the reform

Research proposal is handed to the superior. If it is approved, budget is decided by the superior, as well. It's a two-way process. The people in charge in the ministry visit institutes to learn their requirements. Also, people from SST/SRM go to Beijing to report problems/achievements regularly. Through consultation, allocation of budget projects for research are decided.

During the reform:

The State will cut the fixed research budget to zero in 5 years in the following pattern: 1st year 30%, 2nd year 50%, 3rd year 75% and so on. This means that budget for each research project is small. Most importantly, State does not guarantee individual's salary. In the past, salary and fixed research budget were channelled down separately. Now, they are combined. If you finish the project quicker than planned, bonus will be awarded from the unused budget.

Before the reform, there was no bonus. A group of people at the top in the Academy or Ministry prepared a plan. Most likely they refer to the western experience. A proposal/model was

distributed to each research unit for discussion. For example, if a project group consists of 2 people and the total budget is Y10,000. Bonus is calculated as follows:

(1) Y10,000 to Institute. 8% retained by the Institute as "commission fee". Y9,200 left.

(2) deduct salary, research expenses etc. Y3,000 left.

(3) Bonus. 16% - of the saving. Y480 to individuals. The rest are divided between the institute (bigger) and the Unit (smaller).

Comments

(a) Only useful/competent people can be selected into research groups. This results in employment problem. This is due to historical surplus of manpower, many of which were recruited through "Guanxi" in the past.

(b) Only a small percentage can be used as bonus. So they don't save, spend all or claim it in other forms, not in cash. e.g. travel.

(c) Conflicts between groups over the use of equipments etc. Many general equipments purchased owned by the institute within the past, now located in certain research group are seen as group assets. Use of those equipments are charged. Research in material science, only advanced instruments make it possible to find, results of high academic value. If use of those equipments are two expensive, they can't afford it. They have to use simpler instruments and simpler methods. This leads to poor quality of research.

(d) In the past, the more qualified personnel, the better. More research can be done. More papers can be written. The institute was assessed by its supervisor in that way. Number of paper - indicator - more investment

(e) In many cases, project allocations are through personal connections. Also, institutes in Beijing have geographical advantages than other provincial counterparts.

Complaint

Commission fee Institute has very tough measures on research personnel, but 8% is charged for the sake of this tough control. Sure, administrative staff need to be supported. However, what are the regulating measures to ensure the quality of their management. This percentage does not even provide general service/use of general equipments. Use of those equipments are charged, only cheaper than guest users.

Administrative staff are paid "average-bonus" which is sometimes higher than research staff. The policy management method doesn't protect the motivation of front-line research

people. It can't ensure successful running of a research organisation. Because they are the basic force. The relationship can't be like "managing - being managed", should be a supportive, helpful one. The chance of winning award sometimes ties in the uncertainty of scientific research.

The institute is classified as applied-research. If one person is engaged in two research projects, his salary is only deducted once. He has more opportunities of claiming saving award. Commission fees exist, but never made publicly. Normally made in the transaction between two parties. (users - institutes) Finding projects depends much on research fields. There are also problems in the budgeting of research funding of top-down projects. Some projects are allocated four times more funds than required.

People trained in Russia are now mostly Unit Heads. People graduated in early 60s now are group leaders. It is an old institute, rigid, young people have less chances of promotion. Many of them go to rural counties to do technical consultancy. No organisational changes.

INTERVIEW E

Organisation: Xian Research Institute of Thermal Engineering

Period: 1985.8-1986.11

Summary:

There are 800-900 employees. 50% of which are research personnel. The institute was moved from Beijing.

Research units include turbine, boiler, material, computer, and chemistry. Office of S&T co-ordinates research projects, especially inter-unit ones.

Case

Responsibility system was introduced in the institute, most of the projects are contracted to research/project groups. Group members are selected by group leaders. If the project is small, people are selected within the research unit or research group.

The project was "the overhaul of coal grinder used in power plant". Coal grinder is used to produce coal power. Those machines were bought from Russia in the 50s and had been worn badly. But the cost of full replacement is too high. The factories look for a way of remedy/repair. The factory and the research (material) unit jointly draft a report to the ministry. The partner in the factory is the technical department. The project was approved by the ministry as ministry-level project. Budget was allocated. The factory had a smaller share. Money divided by the ministry directly.

Bonus

After deducting all the research expenses, net profit is distributed among the institute, OST, unit and the group. Project time schedule is proposed in the report to the ministry, also the budget of expenditure. Two to three months were spent in the factory to get data. Other work was carried out in the institute.

Examination

Firstly, the result was examined by the testing group in the research unit. If it's OK in the test, production trial goes ahead. The real performance has to be assessed in the factory.

The research group leader was over 50. Besides, there was a middle-aged person, two young persons, and one testing person. There were five people in total.

People at unit leader level are mostly university graduates of early 60s. Unit head performs as an administrator, and seldom involved in research. Deputy heads are more academic.

Research grant was firstly placed in an internal account for this project. Group leader has complete control over spending. Net profit was divided as mentioned before. Distribution of bonus within the group is group leader's job.

Co-operation

With the factory, we have to do our experiment during the overhaul period, as equipments are free at the time. But people are busy in all types of maintenance work. Factory seems that they don't take time seriously.

In the Reform

Every unit and group is trying to find projects. They are given autonomy in the project running. In the past projects sources are merely from office of S&T. Now if you don't find by yourself, OST won't take care.

The institute is classified as applied research. State will not provide all the running expense. People in the institute are permitted to have secondary job, e.g. to be a technical advisor of a factory. There is a formality to be completed. But not common. There has to be an adoption period for this now policy. Research people now face enormous pressure of finding projects to support themselves. This gives a new group dynamic. Those who can find project become more influential in the institute. There are also problems of forming research groups, such as who is going to be included. There is a case where in a group, head and deputy head had conflicts. The progress of the research is hindered. So people prefer to have people of common interests in the group.

INTERVIEW F

Organisation: Chenxing Research Institute of Manufacturing Technology, Northern Industrial Company

Period: 1982.9-1987.5

Summary:

Total employee amounted to 500. Qualified personnel include 140 Engineers and 32 Senior Engineers. Among them, 50 Engineers and 20 Senior Engineers are engaged in research. There are 240 qualified research personnel in total. Moved from Beijing in 1965 (Army Institute), abolished in 1973 and re-assembled in 1975 (third line).

Military-related research Academies/Institutes have similar structures:

Directors
|
Directors' Office
(Processing documents, correspondence, administration)
|
Department of Research Management
1) Report of Research Result
2) Project Examination and Report Recording/Filing, Statistics
|
Research Units - According to Research Directions
|
Research Groups

Internal Project Allocation

Sources include Defence S&T Commission, Ministry, Science Foundation, Provincial S&T Commission, and Municipal City S&T Commission. Project allocation depends on the nature of the project, complexity of the project financial resources, and existing expertise.

a) For example, a project of adaptive control of machine tools. Naturally, it is allocated to manufacturing technology group. If the group requires computer expert, people from computer group can be included.

b) Big project requires people from many related branches. A special research group is set up and headed by either a deputy-chief-engineer or a head of research unit. This group will work on this project, until completion. After completion, members return to their original units. After 1987, institutes have to apply for projects. Feasibility reports and research plans are handed to the Ministry. In every second-half year, all research groups/units draft their research plans. These plans are summarised by Department of Research Management. After summary, plans are given to the director. He then brings those selected

plans to Beijing. People in the Bureau of S&T in the Ministry, according to the research projects proposed, and the total research budget available, roughly work out budgets for each projects. Negotiations and modifications are made by both sides. These projects then brought back to the institute. DRM then allocates those projects to research units/groups. Those projects are assessed quarterly.

Bonus

1 Vertical Project

About bonus, state has regulations. 70% of the net profit of research goes to the Institute, and 30% goes to the Unit. Among the 30%, 5% is for overhead charge and 25% for the group. Furthermore, 2% taken from the 70% Institute's retains is for research budget saving bonus i.e. 68% net to the Institute.

2. Horizontal Contracts

a) "Hard" project - use of institute's equipments. 8%-9% of the net profit goes to the Group. (Unit wants 5% of 8-9%) The rest goes to the Institute.

b) "Soft" project - design, service, sub-contract. 15%-20% goes to the Group (variable). The rest goes to the Institute. For example, they help a factory to set up a new production line, they design all the equipments and find a contract to make those equipment.

Defence Research for Civilian Use

It depends on the nature of those institutes. Some are easy. Some are difficult. Those defence product-oriented institutes are hardly to change (bullets, rockets). Those institutes are normally big, that increase its difficulty. They belong to military Products Bureau. But those supervised by S&T Bureau are more dynamic.

Policy encouraged the transfer for military institute. (1) Newly developed products - tax-free for 3 years. (2) Small or medium scale pilot production - tax-free for 3 years. (3) But 5% product development tax is not exempted.

In the reform, co-operations cross ministry boundary with civilian partners are frequently seen. Since Seventh Five Year Plan, defence budget is cut. On the one hand, expense in defence industry is cut; on the other hand, employee number in defence industry is increasing at 7% annually. As a result, many defence-related institutes/factories are short of projects and funding.

In Sichuan, a major base of Chinese military base, organisations who can support themselves in the military-civilian transfer, are rarely seen, because major product lines can't be withdrawn, only allowed to be sealed. Besides, those

organisations are big. Small-scale production has minor effect. They need large-scale production, which requires capital investment. But this is what is lacked of.

Reform

There are two reasons why horizontal links are developed: (1) Government policy made institutes have to find their own way out. (2) Institutes are looking for better benefits.

This leads to a situation - people all look for horizontal practical projects. Very few people stay on the vertical projects. By doing so, it can bring more material income, quick return, and avoid many organisation/personal conflicts.

However, military-related projects are normally completed on-time. All horizontal contracts have to report to the DRM. Although DRM does not interfere the running of projects. Those reports are used as indicators to measure the performance of individual researchers, e.g. promotion, academic title, wage etc.

In general, people of 40-50, graduated between 60-65, are now heads of research units/institutes. But in those big institutes (product institutes) directors and unit heads are often those trained in Russia. In my research institute, there is a gap of middle-age people, because of the abolishment of the institute in 1973. Many Worker-Peasant-Soldier graduates, now are at unit/department ranks, aged 35-40. Because people graduated after 1977 prefer doing research, and because WPS graduates had poor training, they naturally pursue administrative route, instead of academic. Heads of research groups are normally graduates around 1965 and most of them are senior engineers.

In product institutes, there is almost no such a gap. Research work is performed by those middle-aged researchers. In this institute, young people are more active in research. Old people serve as group leader co-ordinating the group in general.

There are "local" regulations about how to adminster horizontal contracts. Ideally, those projects should be headed by the project-finder who performs as a contractor. This is rarely seen, because it is difficult to manage. So now, (1) 3%-5% of net profit is given to project-finder as a reward (commission). Then DRM takes over the project, allocates to unit. (2) If the project-finder is a group leader or similar, then he is naturally the project leader. Group members for specific project can be recruited across units within the institute.

State has a regulation that people engaged in military-related (third line) industry can't move "freely". For new graduates, only after 2 years, they can move. Although the official policy looks like encouraging people move from military-industry to civilian industry, it is impossible in practice. The common practice is that researchers leave their personal files

and residents' registrations in the institute, and sign contracts with factories outside or provide technical service to factories. Every year, certain amount of money (a portion of their earnings) is handed to the institute.

Many young people don't care their personal file, resident's registration etc. They just go away. This causes conflicts between provinces. So state sets another regulation. Sometimes, if you want to change employment, new employers have to pay Y5000 to the previous organisations.

Co-operation

For projects from the Defence STC, ministry signed contracts with the DSTC. This type of projects are normally co-ordinated by Bureau of S&T in the Ministry. Quarterly progress reports are required from each participant organisations. Or, a principal organisation is appointed by the ministry. The DRM of this organisation performs as an organiser and responsible for co-ordination. In both cases, participant organisations are chosen by the ministry.

Co-operation normally went on very well as those organisations had co-operated before. Of course, it is slightly difficult to co-operate with a new organisation which you don't know much.

Examination, Application for Award

Examination and application are through DRM. If you want a ministry level examination, the project has to pass institute-level examination. Application for award is based on the project examination.

Examination criteria includes (1) Economic Benefits (2) Technical level/novelty, creativity, complexity, and (3) Comparison with International Standard.

Calculation of Economic Benefits

Example: a process improvement of a product

Calculating: material saving, wage saving, overhead saving, time saving.

a) Suppose the same annual production quantity - saving (Factory)

b) National market demand for that product - saving (National)

Cash award is not simply delivered to the research group. It has to be distributed among all concerned people. All the administrative and supportive departments are entitled a portion. 50% left is the most. Also, it is very difficult to allocate reasonable percentages to different departments. It is normally set by institute leader. People are not interested in award-winning generally. What they concern most is the class of award,

not the material benefit. Every time the distribution of cash award results in conflicts.

Classification of Institutes

Defence-related institutes was classified into basic, applied as well. For those of applied research nature, fixed administrative budget sets stable for 5 years. But number of employee increases. In fact, the state cut investment. If any increase in wage, those funds are provided by military - civilian income by horizontal contracts. Institutes in different research area differ greatly in income. Some rich institutes can set their own internal wage standards. But those standards only apply within the institute. It is normally add 1 or 2 grades on top of normal wage set by the state.

INTERVIEW G

Organisation: Wuhan Research Institute of Physics, CAS

Period: 1983.9-1988.5

Summary:

There are about 500 employees. About 50% of whom are qualified personnel. The institute was built in early 1950s, formerly called Research Institute of Nuclear Energy. Research area include theoretical physics National open laboratory, acoustics, magnetic resonance.

Structure

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                    Directors
                        |
            /-----------------------\
            |                       |
Departments (administrative)   Units (Research)
                                    |
                                  Groups
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But in open laboratory, there is no clear groups, only research directions.

Research Funding

In the past, research budgets are granted according to the number of employees, Y8000 per employee-year. The use of those research budgets is decided by the institute for research in the institute. If big projects are assigned, additional budgets will be granted.

In the reform, fixed research budget (calculated on number of employee) is abolished, only administrative expenses are given. This means institutes have to apply research projects from the Natural Science Foundation or find horizontal contracts. Because we are engaged in theoretical scientific research, very few industrial users are found, with an exception of the Acoustics section, since the section is able to provide computer service.

Our institute is not too difficult, because the State invested a sum of money to built a National Open Laboratory. More money than before, but the distribution is uneven. Some research units are rich; the others are not. The research of the institute overlaps with other institutes, and less competitive. Particularly, in the examination Board of physics section of Science Foundation, 8 out of 15 are from Beijing Research Institute of Physics. According to regulation, an application is approved, if more than 50% of the board members support. As a result, Beijing Research Institute of Physics gets more grants than us. Therefore, many research groups in my institutes are severely under-financed.

Horizontal Links - Sources

1. Seventh Five Year Plan national projects
2. Provincial key projects
3. Contracts with enterprises

About the last type

a. People don't like to do it, as it is not basic research
b. People don't know how to find contracts

Only those in the Acoustic section may be involved.

Application for Science Foundation Projects

Many applications were made. Very few succeeded. Research groups make a proposal, discussed and examined at unit and institute levels, making estimates whether capable of winning grants. For theoretical research, small amount of money can do nothing. But if the application is over Y100,000, there is no chance to get approved at the Board. So only small applications can be selected. This is a mistake. Although the State spent a lot of money to set up the Science foundation, e.g. Y6-700 million in 1984, there were no big projects approved. Whereas money are spent on small projects of insignificant impacts. It is a waste. No special research capacity can be built. Papers are published, but not many are significant break-throughs.

Project Management

Self-generated projects - when application is made to Science Foundation, research group is already in its prototype. In the application, the number of senior researchers, junior researchers and postgraduates are included. There is a sharp contrast among those middle-aged persons (35-50). Some with ability are now research fellows or associate research fellows. Those lack of ability are merely research assistants. When research group is going to form, they are left out. So, the composition of research groups is normally old-prestigious persons and young-hardworking people.

In the reform, research groups are formed regardless unit boundaries. In the past, it's normally within unit boundary.

There has never been a case a project is given automatically. There is a list of projects in the Seventh Five-Year plan. According to the list, institutes make their applications competitively. Sometimes, a big project is allocated to an organisation, the institute may be asked to co-operate, complete sub-projects.

Problems in co-operation

1. competition over finance

2. Conflicts over other benefits
3. Not because of lack of experts, interests must be placed equally. Otherwise co-operation never goes well.

Department of research management supervises the use of research grants, according to regulations of science foundation. There is a time limit when a project is approved. Reports are required periodically by the Foundation.

Project Evaluation

Upon the completion of a project, project leader invites the people he/she gets on with well in the field, to give evaluation. 5 or more professor / associate professor level people are required for evaluation. Examiners may also think if I give him an easy time this time, he may return the same to me next time. Hence, many project evaluations are merely a formality. So, many evaluations contain unreliable information. There is a need of a supervising system of project evaluation.

All the projects, including horizontal contracts, have to go through DRM, because the institute is charging a administrative fee from each project. The money is used to support administrative staff. If less projects, then higher percentage.

Basic Research - Applied Research

Under normal situation, research grants are enough. There is a difference between applied research and basic research. For applied projects, you have to show people your results are working. But for basic research, criteria are much more flexible, also unpredictable.

As two types of research exist in the same institute, the institute designed its own policy, balancing the income between research people. Salaries are still paid by the state, in most CAS institutes. Many results of basic research can't be sold easily.

Staff

Directors at the institute level are all of senior titles, graduated in early 60s. Unit leaders the same group of people. In my opinion, people working really hard are postgraduate students because (1) the desire of achieving a degree and (2) less burden or constraints of family etc. Real work is done by those young people. But very few young researchers are independently in charge of research projects.

National Open Laboratory

CAS & SSTC invest jointly. In fact, it is another type of research foundation. Funds for a group of related areas are collectively allocated to one organisation which is academic leader in the field. The organisation administers the

reallocation of research funds. The open laboratory is headed by a director. An academic committee administers its running. Committee members are famous experts in the field nation-wide. Those people decide how to allocate the money.

The host organisation is allocated a special grant for the purchase of equipments. But research grants are distributed nationally. As the open laboratory has most advanced equipments, people from all over the country come to the laboratory to do their research. So research grants are largely spent in the host institute. Open laboratory charged the use of equipments, as it has to cover the running costs and depreciations. In published papers, acknowledgements are made to the open laboratory. The open laboratory, to certain extent, is a national research centre of an academic field. In a way, it has an advantage, as the research grants are not given to individual research institutes, expertise nation-wide are gathered in the open laboratory, competitive and selective.

Awards and Incentives

CAS has regulations/codes of awards. Institutes choose a few from completed projects and apply for awards - my institute applies to the section of physics, CAS. After examining and balancing, decisions are made. But it is felt that balancing is more dominant. Cash award is distributed within research group through balancing and negotiating. Institute and unit don't take any.

The winning of award, benefits may be different to individuals. (1) for those in need of academic promotion - title, (2) less consideration of material incentives.

Number of published papers is used as an indicator to measure research performance, particularly useful in academic promotion. It is also indirectly linked to political incentives (e.g. model researcher, party membership), also welfare (housing).

There is a problem about free flow of S&T personnel. Commonly, those who can find jobs outside are those desperately kept by the institute. Flow is not too easy, not the job per se. The social constraints had more impacts e.g. wife's job, children's school, and resident registration etc. Some people had additional jobs. It is a common case that people move to an organisation with lower prestige. In contrast, if you want to move up, things become difficult.

We have relation with provincial STC as well. We are directly led by CAS. But, personnel appointments are also reported to the provincial department of organisation, but approved by CAS.

INTERVIEW H

Organisation: Research Institute of Bio-physics, CAS

Period: 1975-1986

Summary:

Total employee 700. Research personnel 300-400. The institute was founded in 1958. Main research areas are bionics, cytology, bio-molecules etc. Since 1976, heads of the institute became more academic. Before that political cadres were in control.

Department of Research Management

It allocates research budgets. it organises research seminars. Most of them are specialists. It keeps all the records of research projects and communications up and down, application for awards etc. Balancing disagreements between different groups.

Duty of group head: (1) feasibility report / proposal, (2) application for grants / equipments, (3) selecting group member, and (4) annual summary report / plan for next year. Interpersonal relationship is very difficult to deal with accordingly to my experience.

Before the reform

The formation of research group was on a democratic basis. Those capable and experienced people can compete to be group heads. People who are willing to join the group, join on a free basis. I didn't want to be group leader, as my family background is not politically good enough. But people followed me academically. So I was made group leader. But I wasn't bossy, just be co-operative and equal. The research group was in existence before, led by another person.

Although it was said that project proposal needs to be examined by research committee etc., in practice, it wasn't like that. The procedures were I got a couple of forms to fill, what to do, how many people needed, how much money needed, what equipments needed and how long to complete, potential / implication of expected results.

When I filled in the forms, I handed them to the Unit Director. There is an academic committee in the unit, also a counterpart in the institute. At unit level, it may be a temporary one. After approved by the Unit Director, application then passed to the institute. Department of S&T doesn't have much power. Unit Directors actually had more decision-making power. Institute Director may balance a little bit. Peer opinions are more influential. They decide in their specialised fields. Money was allocated from CAS to institutes, then re-allocated within the institute. In the allocation process,

people of fame, prestige played important roles. Decisions depend more on personal influence than on technical / scientific contents. Famous people have more shares.

At that time, bonus was fixed, about Y5/month. People didn't pay much attention to it. R&D company and experiment factory earned money by selling products. This income could be a source of bonus. There wasn't much left-over from the research budget. More money are used for more work. It is hardly to say any material motivation behind. Purely, people in basic scientific research just want to do more in their own fields, at least more publications. We thought we had to do something, otherwise we felt uncomfortable. It seems that in the past academic responsibility of scientists played a major role.

Project Appraisal

Research results are normally presented in the form of published paper. Normally it is accepted by public. Unless another group of people pursuing research in the same area question the validity - debate. Formal examination is rarely needed. If any people feel doubtful, they can come and discuss. There was a case mistakes were made by an authoritative person. I discovered. There was a debate, but in a friendly consultative atmosphere. The mistakes were largely because of the unavailability of modern equipments, and inaccurate research methods.

Research Group

Research group, once has been formed. It will remain on a permanent basis. Research topics are proposed by group leaders and discussed among members. General research direction is fixed, but specific projects may change year by year. This involves minor personnel changes. Also trainees came from other organisations/universities when related research opportunities came up. Completion of new projects may bring the birth of new research group. In some research groups, post-graduates played important roles but not in all, as only approved senior research fellows can recruit post-graduates. In principle, group leaders are normally also academic leaders. it also depends on interpersonal relationships of the person.

A case: a person, although he is very good at research, but people dislike him. Nobody is willing to join his group. He is left alone and has to be allocated in a research group. This causes problems for the research group leader - how to manage such a group member. Sometimes, it is very difficult to balance for the group leader. In practice, group leader has inadequate power over personnel management / or authority, particularly to those with equal or more experiences. Group leaders are merely "servant", not much legalised power, but do many administrative work. However, Unit Directors make decisions with reference to what group leaders suggest.

Awards

Applications are handed to Unit's academic committee discussion. Decision-making power lies much in the hands of unit director. Then applications are handed to the institute committee, balancing between different units by those "peers" representing different units.

Cash awards were distributed evenly between group members. It was difficult to distinguish who did more. Problems also existed in the authorship of project. Sometimes quota is given by the superior. This sometimes caused conflicts. Those did more work may not be even mentioned.

Material incentive is not important to us. Award winning helps in the promotion, not too much. The most important factor is interpersonal relationship.

Promotion criteria

(1) number of publication in the 1st class journals
(2) age
(3) interpersonal relationship & balancing
(4) clan relations / useful to the leaders

For senior titles, it is more objective. A score system is employed.

(a) ability of trading post-graduates
(b) how many and what projects had been done. What role played.

Individuals make applications to a committee, then applications are passed to experts in the field. This also depends on personal relationship with those peers in the field. If those peers are in favour, institute committee will discuss the matter seriously. The institute has the right to grant AR, CAS grants SR.

INTERVIEW I

Organisation: Research Institute of Grinding Machine
Shanghai Machine Tool Factory

Period: 1973-1987

Summary:

The factory was built in early 1950. Total employee in the institute: 48. Main tasks are Design (Blue prints, Technical assurance), R&D (Problem solving in manufacturing process), and Journal (national) "Grinding and Grinding Machine".

In the past, design of a new model is decided by the superior, as a task. The institute had to fulfil it. Now, power is delegated to the factory in the reform. The factory can sign contracts with domestic and foreign customers. Now part of the work is from the ministry, the other part relies on the market customers come directly to us. If they want general machine tools, we can make it according to standard design. If they want special machine tools and bring their technical requirements, we have to design a new model to meet the request. Upon signing contracts, technical personnel from both sides will discuss the technical feasibility. If it is technically achievable, negotiating about payments. Then a formal contract is signed. Also deliver date is fixed. This type of product tends to be more expensive. Particular attention was paid to overseas market. A service / sales company was set up in the United States.

Customer orders are channelled to the Department of Sales & Planning of the factory first. There are two sections in the department, one dealing domestic orders, the other dealing with overseas orders. Processed information is then passed to department of planning of the institute. All technical issues are supervised by factory's chief engineer. Department of Sales & Planning serves as a bridge between the Research Institute and the chief engineer.

Upon an order, chief engineer organises technical meetings. Different design proposals are discussed in the meeting. Those proposals are prepared by the institute. From them, a optimised one or combined one is chosen. Other departments of the factory, (workshops, supplies etc.) also participate the discussion, presenting their views. In the meeting, decisions about what components to be bought or made are made. Technical (manufacturing) capability is also reviewed. After discussion, a final proposal is fixed. Work goes through to next stage - design.

The factory is the largest grinding machine factory in China, possibly in the world. R&D section is divided into groups, focusing on problems solving. Design section is divided into hydraulic system, electrical control etc. Mechanical group is normally the responsible/co-ordinating group, as it does

overall design.

The institute is led by the Chief Engineer. It actually replaces the technical Department commonly seen in other factories. In addition, the institute has design ability, not only problem-solving. Most of the technical problems are forwarded to the design section. Production problems encountered in the design process are handed over to R&D section to solve. R&D section solves two types of problem. (1) process technology in the production, and (2) technical performance testing, as many parameters can only be defined when a real machine is built. Chief design engineer is responsible for all technical issue at design stage. There are more than 20 research units in the institute, electrical, hydraulic mechanical etc., and a special meter design group. We also produce hydraulic components and meters for other factories (selling). new graduates from university have to practice for 3-5 years, before they can be independently in charge of something. In the institute, people of 35-45 are backbone in the research, graduated before the cultural revolution. Young people don't satisfy their current job most of them try to go abroad. Very few of them can work independently.

Except problem solving, we also carrying out prior technical investment research, collecting technical information, researching into the potential area. We may not use the technology now, but the technology is kept as a reserve for future development. This is part of long-term plan.

Factory has both short-term and long-term plans. About what models to be developed etc. management system at my factory is not bad. Effectiveness is not bad, efficiency needs to be improved. Factory's total employee - 6000 to 7000.

Technology Management System

Every workshop has a technical group. The main tasks of those technical group are to provide technical assistance over equipments, process technology etc. If they encounter problems they can't solve. They hand the problems to the research institute in three ways: 1) contact research institute immediately; 2) make a note, hand in later in a technical meeting; and 3) contact chief engineer. Those contacts can be verbal or written.

Technical groups in workshop mainly solve problems in the manufacturing process. At factory level, there is a department of production technology, parallel to the research institute. The size is small. Once a design is drafted by the research institute, drawings are passed to department of process technology.

Based on design, DPT studies the manufacturability of design and design all the required auxiliary equipments (moulds and fixtures). Tooling workshop make those auxiliary equipments, prior the production of products.

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                    Research Institute
                          |
          Department of Production Technology
     /-----------------------------------------\
  Workshop              Tooling            Other Department
     |                                          |
  Operation                                   Supplies
```

Sometimes, people from Research Institute go along with supply people to find suitable parts for technical reasons.

People in the research institute frequently go out to do national technical survey, finding out advantages and disadvantages of competitors' products, technical performance of both domestic products and imported products. Information office of the institute is mainly translating international journals.

Application for Awards

If a product is commonly regarded as good, factory apply to the Ministry for award. Ministry will send people down, to examine the product. Upon approval, award is given. Awards can be national and Shanghai municipal. About cash award, in some cases, institutes decides how to distribute the money. sometimes, factory decides how to. The main concern is not to hurt people's motivation - balancing among all the people concerned.

In theory, and according to the State policy, bonus should be awarded in relation to contribution. In practice, it is very difficult to do so. Every organisation has its own regulation to solve the problem. According to my opinion, reward, on the one hand, is material benefit, on the other hand, should be academic promotion. Promotion can't be according to age. It's not fair as people's ability differs even they received the same education.

Award-winning is a proof of ability. It is considered in academic promotion. In some cases some people who didn't have any university education are more competent than those graduated from universities. They should be awarded.

About bonus, in new product development, bonus only given to those who participated. As salary is generally low among research people, factory had its own policy. On the basis of completing factory's tasks, people are allowed to use their spare time to do other contracts. If spare-time research uses equipments, institute will charge a percentage of profits. Both sides have benefits. But first of all, factory's tasks must be guaranteed.

Bonus varies among departments. Each department/workshop

distribute bonus independently as, workshops are also allowed to have horizontal links. In general, research people get less bonus than workers.

We don't co-operate very much with other organisations. Sometimes, universities contact us to solve certain problems. At the present, if a research project doesn't have any practical use / economic benefits, the State would not need it. Although theoretical research is necessary, applied research is more important. Knowledge creates material wealth. This is what we wanted. Otherwise, it's no use. As we have strong expertise, we normally do research by ourselves, except sometimes we ask university people to do theoretical calculation etc. For all co-operation, a contract has to be signed, who is in charge, who is supportive, how to manage finance etc.

Product Evaluation

Department of Quality Control, plus heads of technical groups in all workshops come to examine a new product. Design people don't attend. If it is OK. Municipal bureau will send people to inspect the performance/quality. End users also come to make comments. Sometimes, people from other machine tool factories are invited to the evaluation meeting. The scale depends on what level the evaluation is (factory or municipal or ministry). In sum, people in charge of technical issues present, outside experts present, users present.

INTERVIEW J

Organisation: No. 601 Research Institute
Ministry of Aeronautics & Aerospace Industry

Period: 1962-1987

Summary:

At first, No. 601 Research Institute belonged to Ministry of Aeronautics. It is for the design of aircraft. At the beginning of "new China", before 1960, aeronautic industry was aided by Soviet Union. When Sino-soviet relation became tense. Military commission decided to set up their own defence research institutes. No.6 Academy was one of them, established in 1960.

General Information

Half of the employees are technical personnel. The other half are workers.

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Technical Deputy-Director (of the Institute)
                    |
            Chief Design Engineer
                    |
          Deputy Design Engineer
   (In charge of different technical aspects -
Structure, aerodynamics, System Testing etc.)
                    |
              Research Units
   (About 10, in different specialised areas)
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Technical management in the institute is administrated by Department of Research Management. Within the department, there is a section of organising and planning to organise, and co-ordinate research activities of units, e.g. drafting plans and organising meetings.

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Department of Research Management-----\
                    |          Section of Organising
                    |                & Planning
                    |             Head & Deputies
                Director
                    |
          Section of S&T Information
      /-----------------------------------\
Drawing, Reports                       Library
    Archives
```

Project Generation (Before the reform)

If we went to design a new model, our institute made the proposal first, taking into consideration of the need of the Air Force and international trend and the production capability of factories. We first had a rough idea, then we went to the Air force to consult with pilots to see what are their needs because

they knew aircraft best. When we reached consensus, we took our notes to the Headquarters of the Air Force to report our idea to commanders. Then we discuss over some details. After this, we report our investigation to the Ministry leaders. Through repetitive consultations, an agreement is reached. Then report is submitted to the military commission, when the report is approved, real design and research work can be carried out. Of course, formal document will be given by the superior to the institute.

Feasibility study

When we discussed the technical feasibility, making more detailed proposals, Unit of General Design is the main body responsible for this work. Incorporating experts from other specialised units. Those people are divided into groups, working on related parts of the feasibility report:

1. General sketches (3-D & profile)
2. Technical requirements (quantitative) on overall performance
3. Technical requirements for components
4. Calculation of weight

This report is handed to superior for approval. If it is approved, we bring it to the Air Force for consultation. If OK, we come back and start working according to the proposal.

Draft Design Stage

Schematic diagram:
-component design
-wings/body
-hydraulic system
-control system

This stage is more detailed than previous one in technical sense. All the drafts will be signed by responsible persons. Chief Engineer and deputies are in charge of this stage. Sometimes we go to production units, consulting issues about production. The persons we contact are those in change of manufacturing technology and old workers to find out problems concerning production.

Production design stage

Then we start detailed design, drawing all the parts, components. Drawing are then sent to factories for production. If any problems related to design are encountered in the production, institute has a technical service team for problem solving. Factory first run pilot production. Only a few aircraft are made for experiments. - all sorts of technical/performance tests. Many problems will be solved at this stage.

The final examination is by the Ministry's Aviation Examination Committee and the Air Force. Performances of the

aircraft must conform to requirements. If OK, they will sign the certificate.

Co-operation

Such a big project can't be done by one ministry. Inter-ministry co-operation is necessary, for example, electronic devices - Ministry of Electronics, materials - Ministry of Metallurgy. Although my institute is to design aircraft, we don't design everything. Many components are designed and manufactured by other organisations, for example, engine and hydraulic components. Except routine contacts, the ministry organises meeting periodically. All the organisations related are assembled. Since we are in charge of overall design, our institute gives technical requirements to other co-operative participants. Contracts are signed based on consultation. This type of meeting will be held several times according to the progress of design.

About completion of contracts on time, depends much on the industrial basis of Chinese industries. Although in the contracts, it is stated the technical specifications and time scale. Sometimes, you simply can't achieve it. Most important thing is technical performance, which is most crucial to the aircraft. So time constraint is rather soft. If one problem delays progress, a technical problem-solving group is set-up, trying everything to solve the problem. Cost is not considered at that time. If the project is approved, finance will be guaranteed until it is finished.

After several design-production cycles, several models of aircraft were built. We realised that we must have a special organisation to formulate technical performance specifications for new models. Therefore, the Air Force set up a technical group. Our ministry also sets up an institute (No. 620) to do pre-design feasibility studies.

The main tasks are to examine what kind of aircraft we need, what performance the aircraft is expected, taking into consideration of military applications, international comparison etc. In the past, those tasks are done by design institutes. Now a special institute ensure systematic study.

About finance, in the reform, every project is granted fixed budget. Design work are planned on the basis of financial ability. To develop a new model, the state needs to invest several billion yuans. Ministry gives the budget to principal organisation. The distribution of research budget is by the principal responsible organisation, (normally No. 601 Research Institute). Supportive organisations are responsible to the principal organisation, rather than the ministry. In the principal organisation, this is a chief design engineer in overall charge. In supportive organisations, there are chief design engineer of sub-systems. Initially, money are registered on our account in total, but transfer to other organisation later. For vertical projects, we just follow what plan has

already regulated.

In my institute, horizontal linked can be developed at both institute and unit levels. However, any contract must report to the institute. Profits from horizontal contracts are divided between institute - unit and individuals. The amount of income varies among units, depending on their research areas.

Research Personnel

Total employee of 601 is around 2000. 50% of which are research personnel. The compositions of research personnel, are different between old and new institutes. No. 601 is an old one, 7-8 people graduated in early 50s. They are chief and deputy chief engineers. A group of people trained in Russia in early 1960s. They also are at senior levels. But many of them have been assigned other jobs, leaving the institute. At unit level, people graduated before 1965 and some graduated after 1965, before 1970 are research back-bones. New graduates after 1977. are research assistants.

Academic Promotion

The ministry issued official document, about promotion. Detailed standards and methods are given in the document.

The main criteria are the contribution in technical work. (1) performance, (2) technical level/ability, and (3) foreign language. Judged by (1) awards winning, (2) problems solved, (3) patents, and (4) papers published.

However, it is very difficult to follow these criteria in practice, particularly when specific persons are concerned. So in practice, age (or employment period) has to be taken into account. There is always a quota of promotion assigned to research units, making practical work extremely difficult. Institute had to have its own localised policy.

Perception on Awards

I got three awards. I think the money is minor. I am more concerned about the class of award, as it indicates how big your contribution is. It is also a confirmation of my research work. It also brings honour and proud. Material benefits are there, but it is not everything.

Before the reform, employees' salary are supplied by the State. Now a new policy is piloted in my institute, at experiment stage. Some applied research institutes under Ministry of Aeronautics are only given a portion of administrative expenses. The percentage given is decreased every year. Eventually institutes are expected to be self-financing. There are two ways of finance. First one is to apply for state research projects. The other is to develop horizontal links/civilian products.

Bonus

There is a basic institute bonus. This bonus has nothing to do with research unit's horizontal links. It is provided to all. The distribution of this bonus is based on individual's work performance (classes). But there is not much difference between people. Another type of bonus is from the income of horizontal links.

Aircraft Company

Recently, a number of aircraft companies are formed in Chinese aeronautical industries. In fact, it is nothing new to the industry. There was a debate about independence/separation of research institutes and production factories from the right beginning. When research institutes were set up, people had different opinions. Some insisted that research institutes should be separated from production. It is better for research work. Some other people insisted that research must be related to practice. Integration can ensure better application of research results. So from the far beginning, from top leaders to middle management, there was different points of view. However, in defence related industries, research academies were set up independently and led directly by SSTCND. But since 1965, those academies were passed to industrial ministries. Research institutes are still separated from factories. Even now some aircraft companies are created. It is merely a name. management is not strong enough (loose). Factories and institutes under its name still run on their own tracks. They haven't been closely integrated into an entity.

INTERVIEW K

Organisation: China Ship Science Research Centre
China ship Building Corporation

Period: 1968-1985

Summary:

The institute was a pilot base for S&T reform. Reform stated in 1982. Prior to other institutes. At that time more than 60 institutes were chosen as piloting bases.

The institute was established in late 1950s, part of the construction programme of defence research. Soviet experts joined in planning at early stages. The location was chosen by Soviet experts. Close to Tai Lakes geological conditions are good. But living conditions were poor. This choice was not changed, even when Sino-Soviet relation went bad. By 1965, experiment facilities were nearly ready. (Investment Y10 million at that time) The experiment base is the biggest in East Asia, one of the six biggest in the world. Before 1965, the institute was led by the Navy. After 1965, defence academies are passed to industrial ministries, the institute is led by Ministry of Ship Building. (No. 7 Academy - No. 6 Machine Building Ministry.)

Since its establishment, it went through all sorts of political movements, frequent change of management, the efficiency of research is not satisfactory. Total employee more than 1600. Engineers are 800+. Senior Engineer 200+. Before the Cultural Revolution, there were more than 10 PhDs, who came back from Europe and Russia. Since 1960, good graduates were selected from universities all over China, as it was defence related. Our institute is doing research on overall performance of ships. We had experts in every field relating to ship building.

Research Divisions:

1. Ship Fluid Dynamics - several units
2. Ship Structure - several units
3. Testing and measurements - several units
4. Computing

Our institute is only analysing ship performance and related technical issues. But we don't design ships. CSBC has a number of institute specialised in design. One is No. 708 Research Institute in Shanghai, which designs civilian ships and military auxiliary ships, and small military vessels. No. 701 Research Institute in Wuhan designs conventional submarine and large military ships. No. 719 Research Institute in Wuhan designs nuclear submarines.

Design institutes formulate design proposals. They can refer to past designs, but they have to do model simulations, to verify their design proposals. They had to come to our institute

to do those performance experiments. Before the reform, those related tasks (both design and experiment) are delivered in one-go from the top to the academy. We don't design, but we study the technical performance of a design, verify the validity of a new design. We do model simulation before the manufacture, once the first ship is made, we will do overall experiment of this new ship.

Project Generation

90% of the research projects before the reform were top-down projects. There is a special institute in the No. 7 Academy - Research Institute for Feasibility Studies. It serves as a think-tank of the academy. It contacts people in the Navy Headquarters. The original need for a new type of ship is from the Navy. But the need is in an abstract form. Research institute for Feasibility Studies translates the interpretation of the need from Navy into technical terms. this process requires repetitive consultations over technical details. Once a project is decided, Navy will supply the research fund. Before research tasks are given to research institutes, technical deputy directors and Head of Department of Research Management of those institute will be invited to Beijing to attend planning meeting. In the meeting, the whole project is divided between institutes.

There were two considerations in the process of division of tasks. One is that the division should be "systematic", to increase research efficiency and the other is that everybody has something to do, sharing research budgets. Two things mixed together made the job-allocation a bargaining process.

When jobs have been allocated to respective institutes, institutes will hold planning meeting. Technical deputy director and Head of DRM gather Heads of research units plus some influential figures together. Firstly, tasks will be briefed. Then they will discuss the job allocation within the institute, the persons in charge, units involved, budget allocation etc. After the meeting, section of planning will draft a formal document and pass it to research units. At the unit level, unit head organises several research groups and supervises the progress of research.

Financial resources are not as abundant as in the aeronautical industry because the Navy is not on the top list of national defence. However, if the pre-calculated budget is not enough, the ministry/Navy had no choice, but to add investment. This results in a situation, research efficiency is not taken seriously.

Most of the research projects are lagged behind schedule, except those directly supervised by the ministry. In theory, all the work are co-ordinated by the Department of Planning of the Academy. Academy Deputy-Directors divided jobs between them. 20+ institutes are supervised by respective deputies. Although the system is designed like this, if the project is delayed by material supply or other uncontrollable factors, the Academy had

to allow the revision of previous schedule. Gradually, this became a common practice, no pressure at all. Whereas, those big projects of strategic and political significance are ensured everything. Nobody dared to delay.

Department of research management has several sections.

1. Technical section
2. Planning section
3. Achieve section
4. Education section

This department is in charge of all technical issues.

Co-operation

If it goes beyond the ministry boundary, the ministry co-ordinates co-operation. A meeting in held. People from other ministries are invited. In most cases, people from SSTCND will address the meeting, also solve conflicts in the co-operation.

Research Personnel

Nearly all units' heads and most institute's directors are graduates of early 60s. There are some graduates of 50s. Old generation is kept for the reason of international contacts. New graduates in 1980s are normally group members, not capable of leading a research group. So there is a big gap there in terms of research personnel. 40-50+ are back-bone of the research institute.

There was no organisational change, when the ministry changed its name to corporation. The biggest change affecting research institutes was the changing-hands from SSTCND to the ministry. The recent name change didn't change the allocation of research projects and budgets. The possible change is the corporation may have profit considerations. It may affect the investment in research.

Financing

The State Council had a policy. Applied research institutes shall be self-financing by 1990. It gave a lot of pressure on institutes. In the past, my institute needed at least 3-4 million Yuan to run each year. Now this budget is decreased annually. Institute has to find more horizontal contracts to support itself. Thus, institute turns this pressure onto research units, giving a quota of profits to be fulfilled.

In my opinion, research work now is overwhelmingly led by money. For the long-run, a specialised institute lost its ground for existence. To survive, we have to find other projects to do, instead of doing ship research. What's the point calling a ship research centre? An easy alternative is to do ocean engineering, - offshore platform etc. This depends much on natural resources.

The survey data in South China Sea do not look promising. Ship building industry is globally declining. We have to find new way out. But for such a specialised institute with old people as main body, it's very difficult to change the knowledge structure and orientation.

Not many horizontal links were developed. We tried to help factories to demolish old ships. It's low technology. Factories don't care our new methods. They prefer labour-intensive method. It's cheap. We tried to do civilian product design for example, some people designed small tourist boats. However, when they made money, they wanted to separate from the institute - another problem!

Award

About award system in China, the basic policy is not from the reality but from the project per se. This is to say the possibility of award winning depends on the importance of the project. Small projects have less chance. On the other hand, big projects can only come from the State. One case was we did an experiment together with the navy, all the experiment papers were locked up in the safe. But we are given an award. There was no formal examination, only approved by a few people in charge. The other case was an experiment of vessels again. It was very big, jointly by a number of ministries. The experiment was merely to obtain some data for future design reference. There was nothing novel in terms of technology. However, it is big, so award is given.

In addition, if the project is led/participated by famous people, you bear more chance of award winning, regardless of technology. - Peer

In terms of awards, it seems that economic benefit prevails as the only criterion. I think both economic benefit and opinions of experts in the same profession should be taken of equal importance. Economic benefit is one indicator, not the only one. Economic benefit is a short-term indicator. It is not fair to give awards merely according to short-term effects.

Two project done in my group obtained awards, one ministerial, one academy, Y8000 in total. Institute - 20-30%, Unit - some %. When it reached the group, everybody has to be given a share. I got Y500, as I was the group leader. I was happy at the beginning. Later I realised I was talked about at back by many people. There is no formal regulation on the management of cash award. In my institute, cash award is treated the same as income from horizontal contracts.

Internal responsibility system was introduced at unit level. Transactions between units are through "internal cheques". Charges are made for the use of equipments etc. It is in a way, balancing the income unevenness within the institute, especially those service units, e.g. computing, testing. They can't find contracts outside. They have to earn their living through other

major units.

Bonus Implications

Some think academic research is important and bonus is not important. Some may think academic research doesn't count; they do what can make money. The latter type often go out to help factory solve problems. A certain percentage of his income will be handed in to the unit/institute. 1/5 - 1/4 people are more or less involved in such secondary job. This may be one reason why township enterprises are so active in Jiangsu province.

My feeling is that the management system is so confused. Conflicts exist everywhere. In a sense, research must be constrained by economic means. On the other hand, a country's S&T research can't be merely guided by economic force. It should have an overall long-term strategy.

The policy shift is always sudden and radical. I hope, a balance should be found. The whole system needs better co-ordination. Institutes must be ensured other supportive policies. At present, they are left alone, struggling for survival. Directors spend most of their time to find projects, almost no time on research management / long-term planning. The location of institute's industry, and research end-products decides largely an institute's survival ability. Biased investments in certain industries in the past result in another problem of uneven income. Some organisations with better equipments are bound to be better off.

I prefer incremental change. One-off policy can't success. If other supportive policies and environments are not following, radical policy is bound to fail. In addition, policy is too simplified. It had no theoretical standing.

INTERVIEW L

Organisation: Research Institute of Acoustics, Chinese Academy of Sciences

Period: 1983-1988.9

Summary:

Research Institute of Acoustics was originally part of the Research Institute of Electronics. This section was set up in early 60s. It was for the co-operative ocean research with Soviet Union. It was for the Navy. In 1964, the institute was formally founded. Headquarters is in Beijing, about 600 people. We had three work bases. North Base is at Qingdao. East Base is in Shanghai. South Base is in Hainan Island. Those stations focus on hydro-acoustics. Other research areas covered are air acoustics, biological acoustics etc.

In general, there are three major research areas: hydro-acoustics, air acoustics and ultra-sonics and infra-acoustics. Such a division follows the natural development of the subject and its applications. Including three Bases, total employee exceeds 1000, one of the biggest in the world.

In the past, research projects were mainly tasks assigned by the State through CAS.

Department of Research Management (functions)

Academically, it is supervised by the academic committee of the institute. The committee administers the set-up of project, progress of research, budget and feasibility study, and finally evaluation. In the institute, the committee is the academic authority. The task of DRM is to assist the academic committee, functioning like a secretariat. The whole process of innovation management appeared to be managed by the DMR. But the decision-making power lies in the hands of academic committee.

Project Categories

1. Academic Nature

   - Applied project
   - Basic research
   - Industrial contract (mixture of applied and basic)

2. Scale

   - Big (Million)
   - Medium (Above 10,000)
   - Small (Below 10,000)

3. Finance

   - State (CAS receives money directly from SPC)

- Military
- Science Foundation
- Industrial

In the past SSTC is only a empty framework, always having power conflicts with CAS. CAS is real body of research.

When CAS receive research budget, it is distributed among divisions. Institute of Acoustics belongs to Division of Mathematics & Physics. The distribution is influenced by many human factors. The number of senior (2-3) research fellows indicates the research ability of an institute. Personal influence is another important factor.

Now, there are more financial channels, expanding horizontal links. CAS had a policy that majority of research emphasis should be place on projects related to economic constructions. Under this policy, you have to contact industrial and agricultural organisations. There are problems: (1) demand for research is limited, and (2) financial resources are limited. Funds for R&D are scarce. This determines that research funds obtained from horizontal links may not be economical for organisation like CAS, with high-level research personnel and facilities. - "Scientist's point of view"

In my institute, or in CAS in general, research personnel are the majority. I'm not sure about the percentage. However, my experience is that personnel at research assistant level are badly needed. Now, recruitment of post-graduate students is a way to solve the problem. But it has its limitations. (1) study only 2-3 years, (2) young people want to go abroad. Whereas, many projects are running longer than 7-8 years or even longer. The continuity of research is an existing problem.

Difference (Before the reform & in the Reform)

It depends very much on the tradition and situation of the institute. If an institute is in theoretical research, organisation, personnel composition are managed along that line, it will be very difficult for the institute to adapt the new situation. Many of CAS institutes are of this nature. Of course, there are some institutes, whose research areas are closely related to technologies e.g. material, electronics etc. They naturally adapt the new situation easily.

From my opinion, before 1986, although the policy encouraged that change, real movements were rarely seen. However, in recent year, due to administrative pressures - employee quota fixed, cut in funding etc. the institute / people in the institute, have to find their own ways out. Meanwhile, some people who were already conducting industrial related research. This policy change provides a good chance to make benefits, either for individuals or for the research units. In a words, the direction of research is changed due to external pressure. Since CAS was set-up as a pure research organisation, there is an inertia in its research orientation along its original design.

The changes resulted from internal pressure are minor/rare. Academic interest or preference of research people is another important factor. Sometimes, people don't care loss in material terms. They just want to do what they like to do.

Generation of Vertical projects

1 General problems encountered nation-wide in the process of economic construction and S&T development. They are summarised as research projects and assigned by the State.

2 CAS projects - CAS has its own development plan. There is also issue about division is research. CAS must be internationally competitive in a number of key fields. So CAS has its own key research projects. More facilities and investments, are channelled into certain institutes

3 Institutes have their own projects too. Mainly to develop key research projects within academic disciplines.

These three kind of projects are vertical projects, since they have nothing to do with other administrative organisation. The first one is more comprehensive.

Horizontal Links

1 CAS as a national research entity, it had natural connections with industrial organisations in the past. Some research projects were brought up through those connections.

2 Institutes as research entities, they also have their own connections - projects.

3 Research groups also had such connections.

All three types are direct contacts between CAS and industrial and agricultural organisations. It doesn't entail any governmental / administrative intervention and is not included in any State plans.

Natural Science Foundation

There are Science Foundation at different levels, National, CAS and sometimes the institutes. To apply for funding from those foundations, your application report has to be supported by the references from a number of experts, and discussed by the selection committee. If they think OK, your application then is approved.

This depends on sometimes much who are your referees. People in the profession have known each other before. Guanxi plays a rather important role. Actual use of research funds varies a lot among institutes. (1) Fund is placed in the Department of Finance, research group has an internal account. Any expenses related to research are deducted from your account. Certain percentage of administrative charge is made by Department

of Finance. (2) Research group has its own bank account, managing its own funding.

Inter-organisation Co-operation

Several Forms

1 Co-ordinated by government body, e.g. SSTCND

2 Co-ordinated by the principal organisation e.g. an institute in CAS is technical leader.

There is an organisational incentive to be project co-ordinator. This is because co-ordinator can claim more contribution towards the project. This means co-ordinator may have more share in the benefits generated by research results.

However, to be co-ordinator, the organisation must be not only technically strong, but also have strong administrative power to ensure the management over finance, and personnel etc. There is a balance there.

Sometimes, co-ordination is jointly done by technical and administrative bodies. In case of cross-Ministry projects, projects are divided into sub-projects and open to society for bidding / sub-contracting.

Conflicts exist in terms of intellectual property right, award winning etc. It is very difficult to find a perfect way to solve the problem. There are two considerations: financial incentives, and academic / organisational incentives.

So, in practice, the form of co-ordination depends on the administrative power, academic / technical ability and interests compromise between partners.

Incentives

It relies much on the government policy. Government policy uses various incentive schemes to guide. However, the actual effects are another story. Actual incentives are represented in the following aspects : academic titles, housing benefits, bonus, and ability to attract more research funds.

There hasn't a perfect integrated award package towards individuals because nearly all research projects are completed through co-operation between individuals and organisations. Sometimes, it is difficult to justify who contributed more. So, this brings unfairness in awarding. The problem lies that you have to make sure researchers feel the award is fair among them. If this problem is solved, it will make research management and research much easier.

Cash Awards

Cash awards are distributed by project leaders. This

practice had its problem. Since it is based on project leader's simple judgement, it inevitably has bias and unreasonable elements. He will award those he thinks they did more contribution. This may result in conflicts. However, at the moment, it is a relatively effective way.

Under egalitarian tradition, incentive awards are compensated among group members. If one person is awarded academic promotion, other members may be compensated through more material benefits, Otherwise, conflicts may occur within the group.

Awards Application

Department of Research Management first examine the contents of the projects. If the projects are self-generated academic committee organises examination. If the projects are from CAS or higher, examination group is formed by inviting experts nation-wide. With the aid of department of research management, examination group holds an examination meeting. An examination report is made at the meeting, containing the following aspects.

Quantitative - economic benefits, performances
Qualitative - national comparison, international comparison, theoretical contribution etc.

This report is the basis for applying award. Cash awards are passed to the research group through administrative channels. Certain percentages are kept by the institute. Amounts to research group vary from case to case. Then group leader distributes within the group. There is no formalised regulations.

INTERVIEW M

Organisation: Guangzhou Research Institute of Rubber Aging

Period: 1963-1988

Summary:

Before the Reform

Research projects are granted by the Bureau of S&T, ministry of chemical industry.

The generation of research projects can be:

i) Basic research - applied for by the institute, then approved by the ministry or formulated at the ministry level.

ii) Applied research - two important meetings are held annually.

a) Production Organisations - hand in their technical problems (preparation)
b) Planning & co-ordination meeting of research organisations - allocate research projects and funding.

Those projects have "soft" limits on funding and time span except those priority projects. This leads to a common situation that projects are always delayed, as additional funding can be obtained next year. In an extreme case, a project has been dragged on for 17 years.

In case of big and complex projects, co-operation between organisations are needed. Then, ministry plays a co-ordinator's role. Projects are divided into smaller pieces, either by technical nature or technological / production sequences. Funds are also distributed to different organisation accordingly. If a co-operative project wins the national award, then cash award is first granted to the primary innovator. The redistribution of cash award is done by consultation between organisations. The choice of partners remains in the hand of ministry.

For those projects of high priority, normally a special office is set up to administer its progress. Much tighter controls over time schedules are applied through periodical checks. As a result those projects are normally completed on time.

During the Reform

Many horizontal channels are opened up. Projects are still granted from the top, but much tighter control on budget and time schedules are employed. Competition for those projects becomes obvious. Research organisations are encouraged to develop

connections with production organisation. Incomes generated by this form of activities are permitted to be kept by the institutes. Each research institute has its own rules of income distribution. Generally, 10% of net income is given to the "project finder", 30% is handed over to the institute, remains are distributed within the research group. There exist many conflicts over cash distributions.

In the 1985 reform, research institutes are re-classified according to their primary activities into two major groups:
i) Basic research category (Shi-Ye)
ii) Applied research category (Qi-Ye)

For the first category, administrative / operational funds are still provided by the government, while for the second category, this funding is cut by a certain percentage annually. Eventually, those institutes will become self-financing. There are overlaps in the classification. In general, all institutes are expected to generate their own funds one way or another to different degrees. At the same time, planning process still exists. Planning meeting is still held every year to allocate top-down projects.

In the decentralisation process, central policy is interpreted differently by research institutes. In some cases, research divisions are granted overall autonomy of dealing projects. In other cases, research groups have more say, while research divisions only assume co-ordinating functions.

Administrative Structure

Although the institute is directly under the Ministry of Chemical Industry, the ministry in fact only administers the institutes project allocation and funding. In this aspect, the institute reports directly to the department of S&T in the ministry. But, as the institute is geographically located in Guangdong, the provincial Bureau of chemical industry, supervises the personnel and administrative aspects of the institute. Other local bureaux also have impacts on the institute's activities, e.g. Bureau of finance, Bureau of S&T personnel.

Generally, the reform in S&T arena granted more power to research institutes. This shift causes many internal problems concerning the running of institute. On the one hand, the institute has to motivate its personnel to find more additional income. On the other hand, the institute also needs to keep its academic orientation. The distribution of income is always a hot debating topic, as a result of difference in long-term and short-term views, or people of different interests.

Office of S&T Research

Office of S&T Research plays an important role in organisational context. Previously, it was a co-ordinating and administrative body to ensure the completion of projects assigned by the ministry. Now, it's administrative role has declined, but

it still co-ordinates research activities in the institute. Particularly, in the stage of project feasibility studies and project evaluation. It co-operates with the academic committee of the institute. When external co-operations are needed, office of S&T Research plays representative role of the institute.

APPENDIX B QUESTIONNAIRE SURVEY

APPENDIX B - I QUESTIONNAIRE

A) General Information

1) Organisation's Full Name:

2) Superior Administrative Body:

3) Number of Total Employees:
   a) Research Personnel:
   b) Administrative & Support Staff:

4) Technical Level in the Industry (Self Assessment)
   a) Leading
   b) Upper-middle
   c) Middle
   d) Lower-middle
   e) Low

5) Number of Awards Won at or above the Provincial Level:
   a) Provincial Awards:
   b) Ministerial Awards:
   c) National Awards:
   d) Total:

B) Project Information
(Choose one of the award-winning project, answer the following questions, preferably national awards)

1) Project Name:

2) Project Source:
   a) National Project
   b) Ministerial Project
   c) Self-generated Project
   d) Others (Please specify)

3) Funding Sources:
   a) State Allocation
   b) Self-financing
   c) In Combination (If possible, specify %)

4) Is this project completed jointly with other units?
   a) Yes. (If yes, answer question 4A-4D)
   b) No. (If no, answer question 5)

4A) Please list co-operative partners and their superior bodies.

4B) Choice of Partners:
   a) Specified by the superior body in advance.
   b) Chosen by the Principal Organisation.
   c) Both

4C) Division of Labour
- a) Decided by the superior body
- b) Achieved through consultation between partners

4D) Co-operation and Information Flow in the Research
- a) Very Satisfied
- b) Satisfied
- c) OK
- d) Not Too Difficult
- e) Difficult

5) Research Group
- a) Total Member:
- b) Technical Composition:
  - i) Senior
  - ii) Junior
  - iii) Technical Support
- c) Age Composition:
  - i) >45
  - ii) 30-45
  - iii) <30
- d) Group Leader
  - i) Position
  - ii) Title
  - iii) Age

6) Project Management
- a) Co-operation with Other Depts in the Institute
  - i) Very Satisfied
  - ii) Satisfied
  - iii) OK
  - iv) Not Too Difficult
  - v) Difficult
- b) Specify the Degree of Difficulty of the Following Issues (Most Difficult and Least Difficult)
  - i) Technical
  - ii) Personnel
  - iii) Financial
  - iv) Intra-group Co-operation
  - v) Intra-institute Co-operation
  - vi) Inter-institute Co-operation
  - vii) Relationship with Superior Bodies
  - viii) Others (Please specify)

C) Comments

1) Please comment on existing award system and its impacts on researchers' motivation?

2) What improvements can be achieved in terms of incentives for innovating?

3) What government reform policies since 1978 have brought about significant changes into research management?

APPENDIX B - II LIST OF SURVEYED R&D INSTITUTES

Mechanical Engineering

1. *Shanghai Research Institute of Coal Mine Machinery, Chinese Academy of Coal Industry, Ministry of Railway

2. *Changchun Research Institute of Optical Machinery, Chinese Academy of Sciences

3. *Wuhan Research Institute of Material Protection, Ministry of Machine Building & Electronic Industry

4. *Shanghai Research Institute of Material Protection, Ministry of Machine Building & Electronic Industry

5. *Hefei Research Institute of General Machinery, Ministry of Machine Building & Electronic Industry

6. Shanghai Research Institute of Electrical Engineering, Ministry of Machine Building & Electronic Industry

7. *Harbin Research Institute of Welding, Ministry of Machine Building & Electronic Industry

8. *Tianjin Research Institute for Electrical Transmission Design, Ministry of Machine Building & Electronic Industry

9. *Guangzhou Research Institute of Machine Tools, Ministry of Machine Building & Electronic Industry

10. *Beijing Research Institute of Mechanical & Electrical Engineering, Ministry of Machine Building & Electronic Industry

11. Beijing Research Institute of Automobile Parts

12. Hunan Research Institute of Agricultural Machinery

13. Zhejiang Research Institute of Agricultural Machinery

14. *Shanghai Research Institute of Instruments and Meters, Shanghai Bureau of Telecommunication & Instruments

15. Zhengzhou Research Institute of Machinery

16. *Xian Research Institute of Heavy Machinery, Ministry of Machine Building & Electronic Industry

17. *Jinan Research Institute of Casting and Forging Machinery Ministry of Machine Building & Electronic Industry

18. Beijing Academy of Mechanical and Electrical Engineering

19. Chengdu Research Institute of Tool

20. *Guangzhou Research Institute of Agricultural Machinery, Guangzhou Agricultural Machinery Company

21. Guangxi Research Institute of Agricultural Machinery

22. *Hubei Research Institute of Machinery Hubei Bureau of Machine Building

23. *Shenyang Research Institute of Casting Ministry of Machine Building & Electronic Industry

24. Yantai Research Institute of Manufacturing Technology

25. *Shandong Research Institute of Internal Combustion Engine, Shandong Bureau of Machine Building

26. *Beijing Research Institute of Machine Tool, Ministry of Machine Building & Electronic Industry

27. Guilin Research Institute of Electrical Engineering

28. *Lanzhou Research Institute of Petroleum Machinery, Ministry of Machine Building & Electronic Industry

29. *Nanjing Research Institute of Agricultural Mechanisation, Ministry of Agriculture, Husbandry and Fishery

30. *Shenyang Research Institute of Instrument & Meter Technology, Ministry of Machine Building & Electronic Industry

31. *Zhengzhou Research Institute of Grinding Material and Tools, Ministry of Machine Building & Electronic Industry

32. *Shanghai Research Institute of Grinders, Shanghai Bureau of Machine Building & Electronic Industry

33. *Shanghai Research Institute of Machine Tool, Shanghai Bureau of Machine Building & Electronic Industry

34. *Shanghai Research Institute of Mould Technology, Shanghai No.2 Bureau of Light Industries & Shanghai Jiaotong University

35. Tianjing Research Institute of Engineering Machinery

36. Tianshui Research Institute of Pneumatic Tools

37. *Luoyang Research Institute of Bearing, Ministry of Machine Building & Electronic Industry

38. *Chinese Academy of Agriculture Machinery,
Ministry of Machine Building & Electronic Industry
& Ministry of Agriculture, Husbandry & Fishery

39. *Beijing Research Institute of Automation,
Ministry of Machine Building & Electronic Industry

40. *Shanghai Research Institute of Automatic Meters,
Ministry of Machine Building & Electronic Industry

41. Shandong Design Academy of Machinery

42. *Beijing Research Institute of Lifting & Handling Machinery
Ministry of Machine Building & Electronic Industry

43. *Shenyang Research Institute of Tractors
Shenyang Bureau of Agricultural Machinery

44. *No. 2 Design Academy of Ministry of Machine Building & Electronic Industry

45 Academy of Mechanical Engineering,
Ministry of Machine Building & Electronic Industry

46. Shanghai Research Institute of Electrical Cable

Note:

* Institutes marked with "*" responded in the questionnaire survey.

Chemical Engineering

1. Lanzhou Research Institute of Chemistry & Physics, CAS

2. Changchun Research Institute of Applied Chemistry, CAS

3. *Beijing Design Academy, China Corporation of Petro-Chemicals

4. *South-west Academy of Chemical Engineering, Ministry of Chemical Industry

5. *Academy of Petro-Chemical Engineering, China Corporation of Petro-Chemicals

6. Fushun Academy of Petro-Chemical Engineering, China Corporation of Petro-Chemicals

7. North-west Research Institute of Rubber Products

8. *Shanghai Research Institute of Organic Chemistry, CAS

9. Shanghai Research Institute of Silicate, CAS

10. *Shanghai Research Institute of Organic Fluro-Materials, Shanghai Bureau of Chemical Industry

11. *Beijing Academy of Chemical Engineering Beijing Chemical Industrial Company

12. *Academy of Nanjing Chemical Industrial Company

13. Liming Academy of Chemical Engineering

14. *Hangzhou Research Institute of Chemical Engineering Hangzhou Chemical Industrial Company

15. No. 6 Design Academy, Ministry of Chemical Industry

16. Chenguang Academy of Chemical Engineering, Ministry of Chemical Industry

17. *Shanghai Academy of Chemical Engineering Ministry of Chemical Industry

18. Tianjing Academy of Chemical Engineering

19. Research Institute of Industrial Latex, Ministry of Chemical Industry

20. Jinxi Academy of Chemical Engineering

21. *Sichuan Research Institute of Chemical Engineering, Sichuan Bureau of Chemical Industry

22. *Research Institute of Chemical Engineering, Sichuan

Chemical General Factory, Sichuan Bureau of Chemical Industry

23. *Xinjiang Research Institute of Chemistry, CAS

24. Changsha Research institute of Chemical Engineering

25. Shaanxi Research Institute of Chemical Engineering

26. Heilongjiang Research Institute of Petro-Chemical Engineering

27. *Shanghai Research Institute of Petro-Chemical Engineering
China Corporation of Petro-Chemicals

28. Fujian Design Academy of Petro-Chemical Engineering

29. *Anhui Research Institute of Chemical Engineering
Anhui Bureau of Petro-Chemical Industry

30. *Shenyang Academy of Chemical Engineering
Ministry of Chemical Industry

31. *Ningxia Research Institute of Chemical Engineering
Ningxia Petro-Chemical Industrial Company

32. *Hebei Research institute of Petro-Chemical Engineering
Hebei Bureau of Petro-Chemical Industry

33. Research Institute of Industrial Carbon Black,
Ministry of Chemical Industry

34. *Research Institute of Industrial Coating,
Ministry of Chemical Industry

35. Academy of Jilin Chemical Industrial Company

36. *Academy of Chemical Machinery, China Chemical Machinery Co
Ministry of Chemical Industry

37. Zhuzhou Research Institute of Chemical Engineering

38. *Research Institute of Industrial Alkaline,
Ministry of Chemical Industry

39. *Liaoning Research Institute of Chemical Engineering
Liaoning Bureau of Petro-Chemical Industry

40. Shenyang Research Institute of Industrial Rubber Products

41. Sichuan Design Academy of Chemical Engineering

42. Research Institute of Catalyst,
Shanghai Petro-Chemical General Factory

43. Xiangtan Design Academy of Chemical Engineering

44. Research Institute of Metallic Chemistry, Academy of Railway

Note:

* Institutes marked with "*" responded in the questionnaire survey.

APPENDIX B - III General Attributes of R&D Institutes

Chemical Engineering

Inst. *	No. of Employee	Researcher Ratio %	No. of Awards	Hierarchy #	Tech. Level+
CE-3	1338	81.4	68	2	1
CE-4	1580	59.9	36	2	2
CE-5	2275	75.6	155	2	1
CE-8	1310	58.9	110	1	1
CE-10	998	28.6	23	3	1
CE-11	1623	42.8	34	3	2
CE-12	1065	45.1	86	3	2
CE-14	192	56.3	30	3	3
CE-17	3419	34.8	108	2	1
CE-21	473	72.3	38	3	2
CE-22	124	56.5	7	3	2
CE-23	169	83.4	18	1	2
CE-27	617	60.9	29	2	1
CE-29	460	57.2	32	3	3
CE-30	1600	46.7	102	2	1
CE-31	142	49.3	21	3	3
CE-32	141	80.9	10	3	3
CE-34	650	33.8	117	2	2
CE-36	642	66.7	59	2	1
CE-38	572	54.4	17	2	1
CE-39	326	67.5	28	3	3

Note:

* Check Appendix B - II for exact names under the same number.

Hierarchy:
1 - Chinese Academy of Sciences
2 - Ministries
3 - Provinces

+ Technical Level:
1 - Leading
2 - Upper-middle
3 - Middle

Mechanical Engineering

Inst. *	No. of Employee	Researcher Ratio %	No. of Awards	Hierarchy #	Tech. Level+
ME-1	853	65.1	79	2	2
ME-2	3207	56.1	82	1	1
ME-3	619	55.3	67	2	1
ME-4	963	57.5	82	2	1
ME-5	935	67.9	109	2	1
ME-7	687	60.6	62	2	1
ME-8	1404	54.1	68	2	1
ME-9	1000	40	17	2	1
ME-10	750	55.6	56	2	1
ME-14	474	52.3	29	3	1
ME-16	984	51.1	73	2	1
ME-17	950	58.6	84	2	1
ME-20	32	71.9	2	3	3
ME-22	341	76.2	62	3	2
ME-25	125	66.4	4	3	1
ME-26	2200	38.1	82	2	1
ME-28	839	44.8	43	2	1
ME-29	412	68.4	79	2	1
ME-30	768	58.8	44	2	1
ME-31	651	59.8	52	2	1
ME-32	315	78.4	19	3	1
ME-33	460	44.1	20	3	2
ME-34	231	78.4	9	3	2
ME-37	1206	47.2	87	2	1
ME-39	1339	73.5	177	2	1
ME-40	1315	49	95	2	1
ME-41	999	65.1	54	2	1
ME-43	679	69.4	78	2	1
ME-44	100	73	1	3	2
ME-45	795	79.7	57	2	2

Note:

* Check Appendix B - II for exact names under the same number.

Hierarchy:
1 - Chinese Academy of Sciences
2 - Ministries
3 - Provinces

+ Technical Level:
1 - Leading
2 - Upper-middle
3 - Middle

APPENDIX B - IV QUESTIONNAIRE SURVEY RESULTS

	Chemical Engineering	Mechanical Engineering
Projects:		
Total Number of Projects:	39	56
Project Sources:		
National Project:	8	13
Ministerial Project:	19	26
Provincial Project:	2	6
Self-Generated Project:	13	11
Project Finance		
State Allocation:	27	40
Self-Financing:	21	24
Co-operation		
No. of Co-operative Projects:	26	40
Forms of Co-operation:		
Partners Set by the State:	6	13
Chosen by the Principal:	13	17
Both:	7	11
Division of Labour in Co-op.:		
Set by the State:	4	14
Through consultation:	22	26
Satisfaction about Co-op.:		
Very Satisfied:	6	8
Satisfied:	13	26
OK:	5	5
Not too difficult:	2	0
Difficult:	0	1
Satisfaction about Internal Co-op.:		
Very Satisfied:	4	6
Satisfied:	16	36
OK:	15	11
Not too difficult	4	3
Difficult	0	0

Most & Least Difficult Problems:

	Most Dif.	Least Dif.	Most Dif.	Least Dif.
Technical:	13	2	23	3
Personnel:	11	5	3	10
Finance:	4	4	19	2
Intra-group Co-op.:	2	11	1	10
Intra-Institute Co-op.:	0	9	1	12
Inter-Institute Co-op.:	2	2	4	3
Superior Body:	0	13	0	26

APPENDIX C DATABASE

APPENDIX C - I SAMPLE DATABASE RECORDS

AWARDS FOR INVENTIONS/S&T PROGRESS OF THE
PEOPLE'S REPUBLIC OF CHINA

RECORD NO: 359 DATE OF INPUT: 02/15/89

INNOVATION: The optimization of design of asynchronous motors

PRODUCER: Dongbei Institute of Electrical Engineering

LOCATION: LNS COLLABORATION: N NATURE: PD

INDUSTRY CODE: ME CLASS OF AWARD: 3

MINISTRY CODE: MHP TYPE OF AWARD: PG

AWARD NUMBER: 22 DATE OF AWARD: 07/15/85

GENERIC: 8 SUB-GENERIC: 82 TECHNICAL: 03

AWARDS FOR INVENTIONS/S&T PROGRESS OF THE
PEOPLE'S REPUBLIC OF CHINA

RECORD NO: 360 DATE OF INPUT: 02/15/89

INNOVATION: CK3263 digital control capstan lathe

PRODUCER: Shenyang No.3 Machine Tool Factory

LOCATION: LNS COLLABORATION: N NATURE: PD

INDUSTRY CODE: ME CLASS OF AWARD: 3

MINISTRY CODE: LNS TYPE OF AWARD: PG

AWARD NUMBER: 23 DATE OF AWARD: 07/15/85

GENERIC: 8 SUB-GENERIC: 81 TECHNICAL: 11

AWARDS FOR INVENTIONS/S&T PROGRESS OF THE
PEOPLE'S REPUBLIC OF CHINA

RECORD NO: 534 DATE OF INPUT: 03/17/89

INNOVATION: Y-7 molecular sieve catalyst

PRODUCER: Academy of Petro-chemical Sciences, China Petroleum & Chem

LOCATION: BJS COLLABORATION: Y NATURE: PD

INDUSTRY CODE: CE CLASS OF AWARD: 2

MINISTRY CODE: PCC TYPE OF AWARD: PG

AWARD NUMBER: 1 DATE OF AWARD: 07/15/85

GENERIC: 2 SUB-GENERIC: 22 TECHNICAL: 08

AWARDS FOR INVENTIONS/S&T PROGRESS OF THE
PEOPLE'S REPUBLIC OF CHINA

RECORD NO: 511 DATE OF INPUT: 03/01/89

INNOVATION: H100-9/0.97 centrifugal compressor

PRODUCER: Xian Jiaotong University; Kaifeng Pneumatic Factory

LOCATION: SXS COLLABORATION: Y NATURE: PD

INDUSTRY CODE: ME CLASS OF AWARD: 3

MINISTRY CODE: SCE TYPE OF AWARD: PG

AWARD NUMBER: 11 DATE OF AWARD: 07/15/88

GENERIC: 8 SUB-GENERIC: 81 TECHNICAL: 07

APPENDIX C - II DATABASE ANALYSIS PROGRAMMES

PROGRAMME: COOP

```
***** THIS IS A MENU PROGRAMME CONTROLLING THE DIRECTION OF
***** CO-OPERATION SERACHING, BY YEAR OR ALL

CLEAR
SET TALK OFF
A = SPACE(1)
@ 4,5 SAY "DO YOU SEARCH A SPECIFIC YEAR OR ALL (Y/A)?" GET A
READ
DO CASE
  CASE A = "Y"
    DO COOPYR
  CASE A = "A"
    DO COOPALL
ENDCASE
RETURN


***** SUB-PROGRAMME: COOPYR
***** THIS IS A PROGRAMME TO MEASURE THE COOPERATION BETWEEN
***** ORGANISTIONS, BY REGION AND BY NATURE

CLEAR
SET TALK OFF
SELECT C
USE PRODUCER INDEX PROD_NO
SELECT B
USE INTERMED INDEX INTER_RC
SET RELATION TO PRODUCERNO INTO PRODUCER
SELECT A
USE AWPROG INDEX AWPROG_R
SET RELATION TO RECORDNO INTO INTERMED

SET FIELDS TO RECORDNO, COLLABRATN, B->RECORDNO, B->;
  CONTRIBUTN, B->PRODUCERNO, C->PRODUCERNO, C->;
  LOCATION, C->ORGAN_TYPE, DATE, CLASS

YR = SPACE(4)
@ 4,5 SAY "INPUT THE YEAR FOR SEARCHING (19xx)" GET YR
READ

STORE 0 TO CLS
DO WHILE CLS <= 3
STORE 0 TO RIPO, UNPO, RUP
STORE 0 TO RIONLY, UNONLY, POONLY
STORE 0 TO RI, UN, PO, GMT, COOP
STORE 0 TO INCP, OUTCP, INOUTCP
GO TOP
DO WHILE .NOT. EOF()
  IF COLLABRATN = "Y" .AND. YEAR(DATE) = VAL(YR) .AND.;
    CLASS = CLS
```

```
SELECT 2
  SEEK A->RECORDNO
  STORE 0 TO K, M, N, P
  STORE 0 TO INCOOP, OUTCOOP
  LCTN = SPACE(3)
  DO WHILE RECORDNO = A->RECORDNO
      SELECT 3
        IF K = 0 .AND. M = 0 .AND. N = 0
          LCTN = LOCATION
        ELSE
          IF LOCATION = LCTN
            INCOOP = INCOOP + 1
          ELSE
            OUTCOOP = OUTCOOP + 1
          ENDIF
        ENDIF
        DO CASE
          CASE ORGAN_TYPE = "RI"
              K = K + 1
          CASE ORGAN_TYPE = "UN"
              M = M + 1
          CASE ORGAN_TYPE = "PO" .OR. ORGAN_TYPE = "SO"
              N = N + 1
          CASE ORGAN_TYPE = "GA" .OR. ORGAN_TYPE = "GO"
              P = P + 1
        ENDCASE
      SELECT 2
      SKIP
  ENDDO

    IF K > 0 .AND. N > 0
      RIPO = RIPO + 1
    ENDIF
    IF M > 0 .AND. N > 0
      UNPO = UNPO + 1
    ENDIF
    IF K > 0 .AND. M > 0
      RUP = RUP + 1
    ENDIF

    IF K >= 2 .AND. M = 0 .AND. N = 0
      RIONLY = RIONLY + 1
    ENDIF
    IF M >= 2 .AND. K = 0 .AND. N = 0
      UNONLY = UNONLY + 1
    ENDIF
    IF N >= 2 .AND. K = 0 .AND. M = 0
      POONLY = POONLY + 1
    ENDIF

    IF K > 0
      RI = RI + 1
    ENDIF
    IF M > 0
      UN = UN + 1
    ENDIF
```

```
        IF N > 0
          PO = PO + 1
        ENDIF
        IF P > 0
          GMT = GMT + 1
        ENDIF
      COOP = COOP + 1

        IF INCOOP = 0 .AND. OUTCOOP > 0
          OUTCP = OUTCP + 1
        ENDIF
        IF OUTCOOP = 0 .AND. INCOOP > 0
          INCP = INCP + 1
        ENDIF
        IF INCOOP > 0 .AND. OUTCOOP > 0
          INOUTCP = INOUTCP + 1
        ENDIF
    SELECT 1
    ENDIF
  SKIP
ENDDO

SET PRINT ON
?
? "THE CURRENT YEAR IN SEARCH IS  "
?? YR
? "CURRENT CLASS IN SEARCH IS  "
?? CLS
? "NO OF AWARDS JOINTLY WON    "
?? COOP
? "NO OF AWARDS WITH UNIV PARTICIPATION  "
?? UN
? "NO OF AWARDS WITH INSTITUTE PARTICIPATION  "
?? RI
? "NO OF AWARDS WITH COMPANY PARTICIPATION  "
?? PO
? "NO OF AWARDS WITH GOVERNMENT PARTICIPATION  "
?? GMT
?
? "NO OF UNIVERSITY & COMPANY COOPERATIONS  "
?? UNPO
? "NO OF INSTITUTE & COMPANY COOPERATIONS  "
?? RIPO
? "NO OF UNIV, INST & COMPANY COOPERATIONS  "
?? RUP
?
? "NO OF AWARDS BY UNIVERSITIES ONLY  "
?? UNONLY
? "NO OF AWARDS BY INSTITUTES ONLY  "
?? RIONLY
? "NO OF AWARDS BY COMPANIES ONLY  "
?? POONLY
?
? "NO OF AWRADS BY INTER-REGION CO-OP ONLY  "
?? OUTCP
? "NO OF AWARDS BY INTRA-REGION CO-OP ONLY  "
```

```
?? INCP
? "NO OF AWARDS BY INTER- & INTRA- CO-OP  "
?? INOUTCP
? "=========================================================="
?
SET PRINT OFF
CLS = CLS + 1
ENDDO
CLOSE DATABASES
RETURN

***** SUB-PROGRAMME: COOPALL
***** THIS IS A PROGRAMME TO MEASURE THE COOPERATION BETWEEN
***** ORGANISTIONS, BY REGION AND BY NATURE

CLEAR
SET TALK OFF
SELECT C
USE PRODUCER INDEX PROD_NO
SELECT B
USE INTERMED INDEX INTER_RC
SET RELATION TO PRODUCERNO INTO PRODUCER
SELECT A
USE AWPROG INDEX AWPROG_R
SET RELATION TO RECORDNO INTO INTERMED

SET FIELDS TO RECORDNO, COLLABRATN, B->RECORDNO, B->;
  CONTRIBUTN, B->PRODUCERNO, C->PRODUCERNO, C->;
  LOCATION, C->ORGAN_TYPE

STORE 0 TO RIPO, UNPO, RUP
STORE 0 TO RIONLY, UNONLY, POONLY
STORE 0 TO RI, UN, PO, GMT, COOP
STORE 0 TO INCP, OUTCP, INOUTCP
GO TOP
DO WHILE .NOT. EOF()
  IF COLLABRATN = "Y"
    SELECT 2
      SEEK A->RECORDNO
      STORE 0 TO K, M, N, P
      STORE 0 TO INCOOP, OUTCOOP
      LCTN = SPACE(3)
      DO WHILE RECORDNO = A->RECORDNO
          SELECT 3
            IF K = 0 .AND. M = 0 .AND. N = 0
              LCTN = LOCATION
            ELSE
              IF LOCATION = LCTN
                INCOOP = INCOOP + 1
              ELSE
                OUTCOOP = OUTCOOP + 1
              ENDIF
            ENDIF
            DO CASE
              CASE ORGAN_TYPE = "RI"
                  K = K + 1
```

```
            CASE ORGAN_TYPE = "UN"
                M = M + 1
            CASE ORGAN_TYPE = "PO" .OR. ORGAN_TYPE = "SO"
                N = N + 1
            CASE ORGAN_TYPE = "GA" .OR. ORGAN_TYPE = "GO"
                P = P + 1
          ENDCASE
        SELECT 2
        SKIP
    ENDDO

      IF K > 0 .AND. N > 0
        RIPO = RIPO + 1
      ENDIF
      IF M > 0 .AND. N > 0
        UNPO = UNPO + 1
      ENDIF
      IF K > 0 .AND. M > 0
        RUP = RUP + 1
      ENDIF

      IF K >= 2 .AND. M = 0 .AND. N = 0
        RIONLY = RIONLY + 1
      ENDIF
      IF M >= 2 .AND. K = 0 .AND. N = 0
        UNONLY = UNONLY + 1
      ENDIF
      IF N >= 2 .AND. K = 0 .AND. M = 0
        POONLY = POONLY + 1
      ENDIF

      IF K > 0
        RI = RI + 1
      ENDIF
      IF M > 0
        UN = UN + 1
      ENDIF
      IF N > 0
        PO = PO + 1
      ENDIF
      IF P > 0
        GMT = GMT + 1
      ENDIF
    COOP = COOP + 1

      IF INCOOP = 0 .AND. OUTCOOP > 0
        OUTCP = OUTCP + 1
      ENDIF
      IF OUTCOOP = 0 .AND. INCOOP > 0
        INCP = INCP + 1
      ENDIF
      IF INCOOP > 0 .AND. OUTCOOP > 0
        INOUTCP = INOUTCP + 1
      ENDIF
  SELECT 1
  ENDIF
```

```
  SKIP
ENDDO

CLEAR
@ 1,5 SAY "NO OF AWARDS JOINTLY WON     "  GET COOP
@ 2,5 SAY "NO OF AWARDS WITH UNIV PARTICIPATION" GET UN
@ 3,5 SAY "NO OF AWARDS WITH INSTITUTE PARTICIPATION" GET RI
@ 4,5 SAY "NO OF AWARDS WITH COMPANY PARTICIPATION" GET PO
@ 5,5 SAY "NO OF AWARDS WITH GOVERNMENT PARTICIPATION" GET GMT

@ 7,5 SAY "NO OF UNIVERSITY & COMPANY COOPERATIONS" GET UNPO
@ 8,5 SAY "NO OF RESEARCH UNIT & COMPANY COOPERATIONS" GET RIPO
@ 9,5 SAY "NO OF UNIV, INST & COMPANY COOPERATIONS" GET RUP

@ 11,5 SAY "NO OF AWARDS BY UNIVERSITIES ONLY" GET UNONLY
@ 12,5 SAY "NO OF AWARDS BY INSTITUTES ONLY" GET RIONLY
@ 13,5 SAY "NO OF AWARDS BY COMPANIES ONLY" GET POONLY

@ 15,5 SAY "NO OF AWRADS BY INTER-REGION CO-OP ONLY" GET OUTCP
@ 16,5 SAY "NO OF AWARDS BY INTRA-REGION CO-OP ONLY" GET INCP
@ 17,5 SAY "NO OF AWARDS BY INTER- & INTRA- CO-OP" GET INOUTCP
CLOSE DATABASES
RETURN
```

PROGRAMME: GENECOUN

```
***** THIS IS A PROGRAMME TO COUNT AWARDS BY GENERIC TECHNOLOGY
***** BY GENERIC CODE, BY YEAR, BY CLASS & BY SUB-GENERIC CODE

USE AWPROG
CLEAR
SET TALK OFF
GENECODE = SPACE(1)
@ 4,5 SAY "INPUT GENERIC CODE" GET GENECODE
READ

GO TOP
STORE 0 TO GENE85, GENE87, GENE88, GENECOUNT
STORE 0 TO GENE85S, GENE851, GENE852, GENE853
STORE 0 TO GENE87S, GENE871, GENE872, GENE873
STORE 0 TO GENE88S, GENE881, GENE882, GENE883
STORE 0 TO GENES, GENE1, GENE2, GENE3
STORE 0 TO GENESUB1, GENESUB2, GENESUB3, GENESUB4, GENESUB5
STORE 0 TO GESUB851, GESUB852, GESUB853, GESUB854, GESUB855
STORE 0 TO GESUB871, GESUB872, GESUB873, GESUB874, GESUB875
STORE 0 TO GESUB881, GESUB882, GESUB883, GESUB884, GESUB885

DO WHILE .NOT. EOF()
IF GENECODE = GENERIC
  DO CASE
    CASE YEAR(DATE) = 1985
        DO CASE
            CASE CLASS = 0
                GENE85S = GENE85S + 1
            CASE CLASS = 1
                GENE851 = GENE851 + 1
            CASE CLASS = 2
                GENE852 = GENE852 + 1
            CASE CLASS = 3
                GENE853 = GENE853 + 1
        ENDCASE
        GENE85 = GENE85 + 1
        DO CASE
            CASE SUBSTR(SUBGENERIC,2,1) = "1"
                GESUB851 = GESUB851 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "2"
                GESUB852 = GESUB852 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "3"
                GESUB853 = GESUB853 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "4"
                GESUB854 = GESUB854 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "5"
                GESUB855 = GESUB855 + 1
        ENDCASE

    CASE YEAR(DATE) = 1987
        DO CASE
            CASE CLASS = 0
                GENE87S = GENE87S + 1
```

```
            CASE CLASS = 1
                GENE871 = GENE871 + 1
            CASE CLASS = 2
                GENE872 = GENE872 + 1
            CASE CLASS = 3
                GENE873 = GENE873 + 1
        ENDCASE
        GENE87 = GENE87 + 1
        DO CASE
            CASE SUBSTR(SUBGENERIC,2,1) = "1"
                GESUB871 = GESUB871 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "2"
                GESUB872 = GESUB872 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "3"
                GESUB873 = GESUB873 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "4"
                GESUB874 = GESUB874 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "5"
                GESUB875 = GESUB875 + 1
        ENDCASE

    CASE YEAR(DATE) = 1988
        DO CASE
            CASE CLASS = 0
                GENE88S = GENE88S + 1
            CASE CLASS = 1
                GENE881 = GENE881 + 1
            CASE CLASS = 2
                GENE882 = GENE882 + 1
            CASE CLASS = 3
                GENE883 = GENE883 + 1
        ENDCASE
        GENE88 = GENE88 + 1
        DO CASE
            CASE SUBSTR(SUBGENERIC,2,1) = "1"
                GESUB881 = GESUB881 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "2"
                GESUB882 = GESUB882 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "3"
                GESUB883 = GESUB883 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "4"
                GESUB884 = GESUB884 + 1
            CASE SUBSTR(SUBGENERIC,2,1) = "5"
                GESUB885 = GESUB885 + 1
        ENDCASE
    ENDCASE
    GENECOUNT = GENECOUNT + 1
ENDIF
SKIP
ENDDO

GENES = GENE85S + GENE87S + GENE88S
GENE1 = GENE851 + GENE871 + GENE881
GENE2 = GENE852 + GENE872 + GENE882
GENE3 = GENE853 + GENE873 + GENE883
```

```
GENESUB1 = GESUB851 + GESUB871 + GESUB881
GENESUB2 = GESUB852 + GESUB872 + GESUB882
GENESUB3 = GESUB853 + GESUB873 + GESUB883
GENESUB4 = GESUB854 + GESUB874 + GESUB884
GENESUB5 = GESUB855 + GESUB875 + GESUB885

SET PRINT ON
?
? "CURRENT GENERIC SECTOR IN SEARCH IS  "
?? GENECODE
? "   SPECIAL     FIRST     SECOND      THIRD     TOTAL"
? "AWARDS IN THIS SECTOR IN 1985 BY CLASS"
? GENE85S, GENE851, GENE852, GENE853, GENE85
? "AWARDS IN THIS SECTOR IN 1987 BY CLASS"
? GENE87S, GENE871, GENE872, GENE873, GENE87
? "AWARDS IN THIS SECTOR IN 1988 BY CLASS"
? GENE88S, GENE881, GENE882, GENE883, GENE88
? "AWARDS IN THIS SECTOR IN TOTAL BY CLASS"
? GENES, GENE1, GENE2, GENE3, GENECOUNT

?
? "AWARDS IN THE SECTOR IN 1985 BY SUB-CODE"
? "    SUB-1      SUB2      SUB3      SUB4      SUB5"
? GESUB851, GESUB852, GESUB853, GESUB854, GESUB855
? "AWARDS IN THE SECTOR IN 1987 BY SUB-CODE"
? GESUB871, GESUB872, GESUB873, GESUB874, GESUB875
? "AWARDS IN THE SECTOR IN 1988 BY SUB-CODE"
? GESUB881, GESUB882, GESUB883, GESUB884, GESUB885
? "AWARDS IN THE SECTOR IN TATOL BY SUB-CODE"
? GENESUB1, GENESUB2, GENESUB3, GENESUB4, GENESUB5
? "=========================================================="
?
SET PRINT OFF
CLOSE DATABASES
RETURN
```

PROGRAMME: GEOCOUNT

```
***** THIS IS A PROGRAMME TO COUNT INNOVATIONS GEOGRAPHICALLY
***** BY REGION, BY YEAR & BY CLASS

USE AWPROG
CLEAR
SET TALK OFF
GEOREGION = SPACE(3)
@ 2,4 SAY "ENTER GEOGRAPHICAL REGION" GET GEOREGION
READ
GO TOP
STORE 0 TO GEO85S, GEO851, GEO852, GEO853
STORE 0 TO GEO87S, GEO871, GEO872, GEO873
STORE 0 TO GEO88S, GEO881, GEO882, GEO883
STORE 0 TO GEOCNT85, GEOCNT87, GEOCNT88, GEOCOUNT
STORE 0 TO GEOS, GEO1, GEO2, GEO3
DO WHILE .NOT. EOF()
IF LOCATION = GEOREGION
  IF YEAR(DATE) = 1985
    DO CASE
        CASE CLASS = 0
          GEO85S = GEO85S + 1
        CASE CLASS = 1
            GEO851 = GEO851 + 1
        CASE CLASS = 2
            GEO852 = GEO852 + 1
        CASE CLASS = 3
            GEO853 = GEO853 + 1
    ENDCASE
  GEOCNT85 = GEOCNT85 + 1
  ENDIF
  IF YEAR(DATE) = 1987
    DO CASE
        CASE CLASS = 0
            GEO87S = GEO87S + 1
        CASE CLASS = 1
            GEO871 = GEO871 + 1
        CASE CLASS = 2
            GEO872 = GEO872 + 1
        CASE CLASS = 3
            GEO873 = GEO873 + 1
    ENDCASE
  GEOCNT87 = GEOCNT87 + 1
  ENDIF
  IF YEAR(DATE) = 1988
    DO CASE
        CASE CLASS = 0
            GEO88S = GEO88S + 1
        CASE CLASS = 1
            GEO881 = GEO881 + 1
        CASE CLASS = 2
            GEO882 = GEO882 + 1
        CASE CLASS = 3
            GEO883 = GEO883 + 1
```

```
    ENDCASE
  GEOCNT88 = GEOCNT88 + 1
  ENDIF
GEOCOUNT = GEOCOUNT + 1
ENDIF
SKIP
ENDDO
GEOS = GEO85S + GEO87S + GEO88S
GEO1 = GEO851 + GEO871 + GEO881
GEO2 = GEO872 + GEO882 + GEO852
GEO3 = GEO853 + GEO883 + GEO873

SET PRINT ON
?
? "CURRENT REGION IN SEARCH IS  "
?? GEOREGION
?
? "  SPECIAL    FIRST     SECOND     THIRD      TOTAL   "
?
? "AWARDS IN THE REGION IN 1985"
? GEO85S, GEO851, GEO852, GEO853, GEOCNT85
? "AWARDS IN THE REGION IN 1987"
? GEO87S, GEO871, GEO872, GEO873, GEOCNT87
? "AWARDS IN THE REGION IN 1988"
? GEO88S, GEO881, GEO882, GEO883, GEOCNT88
? "TOTAL AWARDS IN THE REGION  "
? GEOS, GEO1, GEO2, GEO3, GEOCOUNT
? "==========================================================="
?
SET PRINT OFF
CLOSE DATABASES
RETURN
```

PROGRAMME: INDCOUNT

```
***** THIS IS A PROGRAMME TO COUNT INNOVATIONS SECTORALLY
***** BY REGION, BY YEAR & BY CLASS

USE AWPROG
CLEAR
SET TALK OFF
INDSECT = SPACE(2)
@ 2,4 SAY "ENTER INDUSTRIAL SECTOR" GET INDSECT
READ
GO TOP
STORE 0 TO IND85S, IND851, IND852, IND853
STORE 0 TO IND87S, IND871, IND872, IND873
STORE 0 TO IND88S, IND881, IND882, IND883
STORE 0 TO INDCNT85, INDCNT87, INDCNT88, INDCOUNT
STORE 0 TO INDS, IND1, IND2, IND3
DO WHILE .NOT. EOF()
IF INDUSTRY = INDSECT
  IF YEAR(DATE) = 1985
    DO CASE
        CASE CLASS = 0
          IND85S = IND85S + 1
        CASE CLASS = 1
            IND851 = IND851 + 1
        CASE CLASS = 2
            IND852 = IND852 + 1
        CASE CLASS = 3
            IND853 = IND853 + 1
    ENDCASE
  INDCNT85 = INDCNT85 + 1
  ENDIF
  IF YEAR(DATE) = 1987
    DO CASE
        CASE CLASS = 0
            IND87S = IND87S + 1
        CASE CLASS = 1
            IND871 = IND871 + 1
        CASE CLASS = 2
            IND872 = IND872 + 1
        CASE CLASS = 3
            IND873 = IND873 + 1
    ENDCASE
  INDCNT87 = INDCNT87 + 1
  ENDIF
  IF YEAR(DATE) = 1988
    DO CASE
        CASE CLASS = 0
            IND88S = IND88S + 1
        CASE CLASS = 1
            IND881 = IND881 + 1
        CASE CLASS = 2
            IND882 = IND882 + 1
        CASE CLASS = 3
            IND883 = IND883 + 1
```

```
    ENDCASE
  INDCNT88 = INDCNT88 + 1
  ENDIF
INDCOUNT = INDCOUNT + 1
ENDIF
SKIP
ENDDO
INDS = IND85S + IND87S + IND88S
IND1 = IND851 + IND871 + IND881
IND2 = IND852 + IND872 + IND882
IND3 = IND853 + IND873 + IND883

SET PRINT ON
?
? "CURRENT INDUSTRY IN SEARCH IS  "
?? INDSECT
? "    SPECIAL     FIRST      SECOND     THIRD      TOTAL"
? "AWARDS IN THE INDUSTRY IN 1985  "
? IND85S, IND851, IND852, IND853, INDCNT85
? "AWARDS IN THE INDUSTRY IN 1987  "
? IND87S, IND871, IND872, IND873, INDCNT87
? "AWARDS IN THE INDUSTRY IN 1988  "
? IND88S, IND881, IND882, IND883, INDCNT88
? "TOTAL AWARDS IN THE INDUSTRY "
? INDS, IND1, IND2, IND3, INDCOUNT
? "==================================================="
?
SET PRINT OFF
CLOSE DATABASES
RETURN
```

PROGRAMME: NATCOUNT

```
***** THIS IS A PROGRAMME TO COUNT AWRADS BY INNOVATION TYPE
***** BY REGION, BY YEAR & BY CLASS

USE AWPROG
CLEAR
SET TALK OFF
INNTYPE = SPACE(2)
@ 2,4 SAY "ENTER INNOVATION TYPE" GET INNTYPE
READ
YR = SPACE(4)
@ 4,4 SAY "ENTER THE YEAR FOR SEARCHING (19XX)" GET YR
READ

GO TOP
STORE 0 TO SUB11, SUB12, SUB13, SUB14
STORE 0 TO SUB21, SUB22, SUB23, SUB24, SUB25
STORE 0 TO SUB31, SUB32, SUB33
STORE 0 TO SUB41, SUB42, SUB43
STORE 0 TO SUB51, SUB52, SUB53, SUB54, SUB55
STORE 0 TO SUB61, SUB62, SUB63
STORE 0 TO SUB71, SUB72, SUB73, SUB74
STORE 0 TO SUB81, SUB82, SUB83, SUB84
STORE 0 TO SUB91, SUB92, SUB93, SUB94, SUB01
STORE 0 TO NATYRS, NATYR1, NATYR2, NATYR3, NATCNTYR

DO WHILE .NOT. EOF()
IF NATURE = INNTYPE .AND. YEAR(DATE) = VAL(YR)
    DO CASE
        CASE CLASS = 0
            NATYRS = NATYRS + 1
        CASE CLASS = 1
            NATYR1 = NATYR1 + 1
        CASE CLASS = 2
            NATYR2 = NATYR2 + 1
        CASE CLASS = 3
            NATYR3 = NATYR3 + 1
    ENDCASE
  NATCNTYR = NATCNTYR + 1
  DO NAT-SUB1
ENDIF
SKIP
ENDDO
DO NAT-SUB2
CLOSE DATABASES
RETURN


***** SUB-PROGRAMME: NAT-SUB1
***** THIS IS A SUBROUNTINE OF NATCOUNT.PRG.
***** THE FUNCTION IS TO COUNT AWARDS BY SUB-GENERIC CODE.

DO CASE
   CASE SUBGENERIC = "11"
```

```
  SUB11 = SUB11 + 1
CASE SUBGENERIC = "12"
  SUB12 = SUB12 + 1
CASE SUBGENERIC = "13"
 SUB13 = SUB13 + 1
CASE SUBGENERIC = "14"
 SUB14 = SUB14 + 1
CASE SUBGENERIC = "15"
 SUB15 = SUB15 + 1

CASE SUBGENERIC = "21"
  SUB21 = SUB21 + 1
CASE SUBGENERIC = "22"
 SUB22 = SUB22 + 1
CASE SUBGENERIC = "23"
 SUB23 = SUB23 + 1
CASE SUBGENERIC = "24"
 SUB24 = SUB24 + 1
CASE SUBGENERIC = "25"
 SUB25 = SUB25 + 1

CASE SUBGENERIC = "31"
  SUB31 = SUB31 + 1
CASE SUBGENERIC = "32"
 SUB32 = SUB32 + 1
CASE SUBGENERIC = "33"
 SUB33 = SUB33 + 1

CASE SUBGENERIC = "41"
  SUB41 = SUB41 + 1
CASE SUBGENERIC = "42"
 SUB42 = SUB42 + 1
CASE SUBGENERIC = "43"
 SUB43 = SUB43 + 1

CASE SUBGENERIC = "51"
  SUB51 = SUB51 + 1
CASE SUBGENERIC = "52"
 SUB52 = SUB52 + 1
CASE SUBGENERIC = "53"
 SUB53 = SUB53 + 1
CASE SUBGENERIC = "54"
 SUB54 = SUB54 + 1
CASE SUBGENERIC = "55"
 SUB55 = SUB55 + 1

CASE SUBGENERIC = "61"
  SUB61 = SUB61 + 1
CASE SUBGENERIC = "62"
 SUB62 = SUB62 + 1
CASE SUBGENERIC = "63"
 SUB63 = SUB63 + 1

CASE SUBGENERIC = "71"
  SUB71 = SUB71 + 1
CASE SUBGENERIC = "72"
```

```
    SUB72 = SUB72 + 1
   CASE SUBGENERIC = "73"
    SUB73 = SUB73 + 1
   CASE SUBGENERIC = "74"
    SUB74 = SUB74 + 1

   CASE SUBGENERIC = "81"
     SUB81 = SUB81 + 1
   CASE SUBGENERIC = "82"
    SUB82 = SUB82 + 1
   CASE SUBGENERIC = "83"
    SUB83 = SUB83 + 1
   CASE SUBGENERIC = "84"
    SUB84 = SUB84 + 1

   CASE SUBGENERIC = "91"
     SUB91 = SUB91 + 1
   CASE SUBGENERIC = "92"
    SUB92 = SUB92 + 1
   CASE SUBGENERIC = "93"
    SUB93 = SUB93 + 1
   CASE SUBGENERIC = "94"
    SUB94 = SUB94 + 1

   CASE GENERIC = "0"
    SUB01 = SUB01 + 1
ENDCASE
RETURN


***** SUB-PROGRAMME: NAT-SUB2
***** THIS IS A SUBROUNTINE OF NATCOUNT.PRG.
***** THE FUNCTION IS TO PRINT OUT RESULTS OF ANALYSIS.

SET PRINT ON
?
? "CURRENT INNOVATION TYPE IN SEARCH IS "
?? INNTYPE
? "CURRENT YEAR IN SEARCH IS "
?? YR
? "AWRADS OF THE INNOVATION TYPE BY CLASS IN "
?? YR
? NATYRS, NATYR1, NATYR2, NATYR3, NATCNTYR
?
? "1 - AGRICULTURE, HUSBANDRY, FISHERY & FORESTRY  - "
?? SUB11 + SUB12 + SUB13 + SUB14
? "11 - AGRICULTURAL TECHNOLOGY  -  "
?? SUB11
? "12 - HUSBANDRY TECHNOLOGY  -  "
?? SUB12
? "13 - FISHING AND FISHING FARMING  -  "
?? SUB13
? "14 - FOREST TECHNOLOGY  -  "
?? SUB14
?
? "2 - MATERIAL INDUSTRIES  -  "
```

```
?? SUB21 + SUB22 + SUB23 + SUB24 + SUB25
? "21 - METALLURGICAL ENGINEERING  -  "
?? SUB21
? "22 - CHEMICAL ENGINEERING  -  "
?? SUB22
? "23 - BUILDING MATERIALS  -  "
?? SUB23
? "24 - GEO-ENGINEERING(EXCEPT FUEL)  -  "
?? SUB24
? "25 - OTHER MATERIALS  -  "
?? SUB25
?
? "3 - ENERGY INDUSTRIES  -  "
?? SUB31 + SUB32 + SUB33
? "31 - FUEL EXTRACTION AND PROCESSING  -  "
?? SUB31
? "32 - POWER GENERATION  -  "
?? SUB32
? "33 - POWER DISTRIBUTION  -  "
?? SUB33
?
? "4 - CONSTRUCTION  -  "
?? SUB41 + SUB42 + SUB43
? "41 - CIVIL ENGINEERING  -  "
?? SUB41
? "42 - ENGINEERING PROJECTS  -  "
?? SUB42
? "43 - ENVIRONMENTAL PROTECTION  -  "
?? SUB43
?
? "5 - TRANSPORT AND COMMUNICATION  -  "
?? SUB51 + SUB52 + SUB53 + SUB54 + SUB55
? "51 - POST AND TELECOMMUNICATION  -  "
?? SUB51
? "52 - AEROSPACE AND AERONAUTIC ENGINEERING  -  "
?? SUB52
? "53 - VEHICLE ENGINEERING  -  "
?? SUB53
? "54 - TRANSPORTATION  -  "
?? SUB54
? "55 - PUBLIC MEDIA  -  "
?? SUB55
?
? "6 - HEALTH SERVICE  -  "
?? SUB61 + SUB62 + SUB63
? "61 - MEDICAL PRACTICE  -  "
?? SUB61
? "62 - MEDICAL EQUIPMENT  -  "
?? SUB62
? "63 - PHARMACEUTICAL INDUSTRY  -  "
?? SUB63
?
? "7 - SERVICES  -  "
?? SUB71 + SUB72 + SUB73 + SUB74
? "71 - INFORMATION & GENERAL STANDARDS  -  "
?? SUB71
```

```
? "72 - SOCIAL AND ECONOMIC RESEARCH  -  "
?? SUB72
? "73 - OTHERS  -  "
?? SUB73
? "74 - THEORETICAL RESEARCH  -  "
?? SUB74
?
? "8 - INDUSTRIAL MANUFACTURING  -  "
?? SUB81 + SUB82 + SUB83 + SUB84
? "81 - MECHANICAL ENGINEERING  -  "
?? SUB81
? "82 - ELECTRICAL ENGINEERING  -  "
?? SUB82
? "83 - ELECTRONIC ENGINEERING  -  "
?? SUB83
? "84 - INSTRUMENT ENGINEERING  -  "
?? SUB84
?
? "9 - CONSUMER MANUFACTURING  -  "
?? SUB91 + SUB92 + SUB93 + SUB94
? "91 - FOOD & DRINK TECHNOLOGY  -  "
?? SUB91
? "92 - TEXTILE TECHNOLOGY  -  "
?? SUB92
? "93 - HOUSEHOLD/DOMESTIC PRODUCTS  -  "
?? SUB93
? "94 - OTHERS  -  "
?? SUB94
?
? "0 - DEFENCE AND SECURITY  -  "
?? SUB01
? "======================================================"
?
SET PRINT OFF
RETURN
```

PROGRAMME: PDCOUNT1

```
***** THIS IS A PROGRAMME TO ANALYSE AWARD WINNERS
***** BY ORGANISATION TYPE, BY CONTRIBUTION & BY REGION
***** AND IN TOTAL

CLEAR
SET TALK OFF
SELECT B
USE INTERMED INDEX INTER_PD
SELECT A
USE PRODUCER INDEX PROD_NO
SET RELATION TO PRODUCERNO INTO INTERMED

SET FIELDS TO PRODUCERNO, LOCATION, ORGAN_TYPE, B->;
  PRODUCERNO, B->CONTRIBUTN

STORE 0 TO UNIV, RESINST, PROD, GMNT, SERV, GMNTAX
STORE 0 TO UNIVP, RESINSTP, PRODP, GMNTP, SERVP, GMNTAXP
STORE 0 TO UNIVS, RESINSTS, PRODS, GMNTS, SERVS, GMNTAXS

REGION = SPACE(3)
@ 4,5 SAY "INPUT THE REGION FOR SEARCHING" GET REGION
READ

GO TOP
DO WHILE .NOT. EOF()
  IF LOCATION = REGION
    DO CASE
      CASE ORGAN_TYPE = "UN"
        UNIV = UNIV + 1
      CASE ORGAN_TYPE = "RI"
        RESINST = RESINST + 1
      CASE ORGAN_TYPE = "PO"
        PROD = PROD + 1
      CASE ORGAN_TYPE = "GO"
        GMNT = GMNT + 1
      CASE ORGAN_TYPE = "SO"
        SERV = SERV + 1
      CASE ORGAN_TYPE = "GA"
        GMNTAX = GMNTAX + 1
    ENDCASE

  SELECT B
  SEEK A->PRODUCERNO
  DO WHILE PRODUCERNO = A->PRODUCERNO
    IF CONTRIBUTN = "P"
      SELECT A
      DO CASE
        CASE ORGAN_TYPE = "UN"
          UNIVP = UNIVP + 1
        CASE ORGAN_TYPE = "RI"
          RESINSTP = RESINSTP + 1
        CASE ORGAN_TYPE = "PO"
          PRODP = PRODP + 1
```

```
        CASE ORGAN_TYPE = "GO"
          GMNTP = GMNTP + 1
        CASE ORGAN_TYPE = "SO"
          SERVP = SERVP + 1
        CASE ORGAN_TYPE = "GA"
          GMNTAXP = GMNTAXP + 1
      ENDCASE
    ELSE
      SELECT A
      DO CASE
        CASE ORGAN_TYPE = "UN"
          UNIVS = UNIVS + 1
        CASE ORGAN_TYPE = "RI"
          RESINSTS = RESINSTS + 1
        CASE ORGAN_TYPE = "PO"
          PRODS = PRODS + 1
        CASE ORGAN_TYPE = "GO"
          GMNTS = GMNTS + 1
        CASE ORGAN_TYPE = "SO"
          SERVS = SERVS + 1
        CASE ORGAN_TYPE = "GA"
          GMNTAXS = GMNTAXS + 1
      ENDCASE
    ENDIF
    SELECT B
    SKIP
  ENDDO
  SELECT A
  ENDIF
SKIP
ENDDO

CLEAR
SET PRINT ON
?
? "CURRENT REGION IN SEARCH IS "
?? REGION
?
? "NUMBER OF UNIVERSITIES INVOLVED - "
?? UNIV
? "NUMBER OF UNIVERSITY INVOLVEMENTS AS PRINCIPAL - "
?? UNIVP
? "NUMBER OF UNIVERSITY INVOLVEMENTS AS SUPPORTIVE - "
?? UNIVS
?
? "NUMBER OF RESEARCH INSTITUTES INVOLVED - "
?? RESINST
? "NUMBER OF RESEARCH INSTITUTE INVOLEMENTS AS PRINCIPAL - "
?? RESINSTP
? "NUMBER OF RESEARCH INSTITUTE INVOLVEMENTS AS SUPPORTIVE - "
?? RESINSTS
?
? "NUMBER OF PRODUCTION UNITS INVOLVED - "
?? PROD
? "NUMBER OF PRODUCTION UNIT INVOLVEMENTS AS PRINCIPAL - "
?? PRODP
```

```
? "NUMBER OF PRODUCTION UNIT INVOLVEMENTS AS SUPPORTIVE - "
?? PRODS
?
? "NUMBER OF SERVICE UNITS INVOLVED - "
?? SERV
? "NUMBER OF SERVICE UNIT INVOLVEMENTS AS PRINCIPAL - "
?? SERVP
? "NUMBER OF SERVICE UNIT INVOLVEMENTS AS SUPPORTIVE - "
?? SERVS
?
? "NUMBER OF GOVERNMENT AGENTS INVOLVED - "
?? GMNT + GMNTAX
? "NUMBER OF GOVERNMENT INVOLVEMENTS AS PRINCIPAL - "
?? GMNTP + GMNTAXP
? "NUMBER OF GOVERNMENT INVOLVEMENTS AS SUPPORTIVE - "
?? GMNTS + GMNTAXS
? "==========================================================="
?
SET PRINT OFF
CLOSE DATABASES
RETURN
```

PROGRAMME: PDCOUNT2

```
***** THIS IS A PROGRAMME TO COUNT AWARD WINNERS
***** BY ORGANISATION TYPE, BY CONTRIBUTION
***** BY YEAR & BY CLASS

CLEAR
SET TALK OFF
SELECT C
USE PRODUCER INDEX PROD_NO
SELECT B
USE INTERMED INDEX INTER_RC
SET RELATION TO PRODUCERNO INTO PRODUCER
SELECT A
USE AWPROG INDEX AWPROG_R
SET RELATION TO RECORDNO INTO INTERMED

SET FIELDS TO RECORDNO, DATE, CLASS, B->RECORDNO, B->;
  PRODUCERNO, B->CONTRIBUTN, C->PRODUCERNO, C->ORGAN_TYPE

YR = SPACE(4)
@ 4,5 SAY "INPUT THE YEAR FOR SEARCHING (19XX) " GET YR
READ

STORE 0 TO UNIVP, RESINSTP, PRODP, GMNTP, SERVP, GMNTAXP
STORE 0 TO UNIVS, RESINSTS, PRODS, GMNTS, SERVS, GMNTAXS

N = SPACE(1)
@ 6,5 SAY "INPUT THE CLASS FOR SEARCHING (0/1/2/3/A)" GET N
READ
IF N = "A"
  STORE 0 TO M
  DO WHILE M <= 3
    DO PD2-SUB1
    M = M + 1
  ENDDO
ELSE
  M = VAL(N)
  DO PD2-SUB1
ENDIF
CLOSE DATABASES
RETURN

***** SUB-PROGRAMME: PD2-SUB1
***** THIS IS A JUDGING SUBROUNTINE OF PDCOUNT2.PRG
***** THE FUNCTION IS TO ANALYSE AWARD WINNERS BY YEAR,
      BY CLASS
***** BY CONTRIBUTION AND BY ORGANISATION TYPE

GO TOP
DO WHILE .NOT. EOF()
  IF YEAR(DATE) = VAL(YR) .AND. CLASS = M
    SELECT B
      SEEK A->RECORDNO
```

```
      DO WHILE RECORDNO = A->RECORDNO
        IF CONTRIBUTN = "P"
          SELECT C
            DO CASE
              CASE ORGAN_TYPE = "UN"
                UNIVP = UNIVP + 1
              CASE ORGAN_TYPE = "RI"
                RESINSTP = RESINSTP + 1
              CASE ORGAN_TYPE = "PO"
                PRODP = PRODP + 1
              CASE ORGAN_TYPE = "GO"
                GMNTP = GMNTP + 1
              CASE ORGAN_TYPE = "SO"
                SERVP = SERVP + 1
              CASE ORGAN_TYPE = "GA"
                GMNTAXP = GMNTAXP + 1
            ENDCASE
        ELSE
          SELECT C
            DO CASE
              CASE ORGAN_TYPE = "UN"
                UNIVS = UNIVS + 1
              CASE ORGAN_TYPE = "RI"
                RESINSTS = RESINSTS + 1
              CASE ORGAN_TYPE = "PO"
                PRODS = PRODS + 1
              CASE ORGAN_TYPE = "GO"
                GMNTS = GMNTS + 1
              CASE ORGAN_TYPE = "SO"
                SERVS = SERVS + 1
              CASE ORGAN_TYPE = "GA"
                GMNTAXS = GMNTAXS + 1
            ENDCASE
        ENDIF
        SELECT B
      SKIP
      ENDDO
  SELECT A
  ENDIF
  SKIP
ENDDO

SET PRINT ON
?
? "CURRENT YEAR IN SEARCH IS "
?? YR
? "CURRENT CLASS IN SEARCH IS "
?? M
?
? "NO OF UNIVERSITY INVOLEMENTS AS PRINCIPAL - "
?? UNIVP
? "NO OF UNIVERSITY INVOLVEMENTS AS SUPPORTIVE - "
?? UNIVS
?
? "NO OF RESEARCH INSTITUTE INVOLVEMENTS AS PRINCIPAL - "
?? RESINSTP
```

```
? "NO OF RESEEARCH INSTITUTE INVOLVEMENTS AS SUPPORTIVE - "
?? RESINSTS
?
? "NO OF PRODUCTION UNIT INVOLVEMENTS AS PRINCIPAL - "
?? PRODP
? "NO OF PRODUCTION UNIT INVOLVEMENTS AS SUPPORTIVE - "
?? PRODS
?
? "NO OF SERVICE UNIT INVOLVEMENTS AS PRINCIPAL - "
?? SERVP
? "NO OF SERVICE UNIT INVOLVEMENTS AS SUPPORTIVE - "
?? SERVS
?
? "NO OF GOVERNMENT AGENTS INVOLVEMENTS AS PRINCIPAL - "
?? GMNTP + GMNTAXP
? "NO OF GOVERNMENT AGENTS INVOLVEMENTS AS SUPPORTIVE - "
?? GMNTS + GMNTAXS
? "============================================================"
?
SET PRINT OFF
RETURN
```

APPENDIX C - III SELECTED LIST OF AWARDS - MECH. ENG. (SSTC)

C INNOVATION	INNOVATOR
1985	
1 3000rpm double water-cooling turbine electricity generator	Shanghai Electric Motor Factory Zhejiang University Harbin Electric Motor Factory Academy of Power Engineering
1 #900mm high accurate worm and and worm gears, and sphere calibrating/index worm gears	Chongqing Machine Tool Factory
1 Super B3-707 double line taper ball bearings and B-706 single line taper ball bearings used on precision coordinate boring lathes	Luoyang Bearing Factory
1 The driving techniques and development of phase-variable, single-roll rolling mills	Zhongnan University of Technology Dongbei Light Alloy Processing Factory Hot Rolling Workshop, Wuhan Iron and Steel Corporation BaojiCereal and Oil Machinery Factory
1 The complete set of equipments for 3.5m thick coal mining	Xian Coal Mining Machinery Factory Zhenzhou Coal Mining Machinery Factory Xibei Coal Mining Machinery Factory Shanghai Research Institute of Coal Mining Machinery, Academy of Coal Industry Luan Mining Bureau
1 The calculating method, programme and application for diesel engine air supply mechanism	Fudan University
2 Production technology of high precise gears	Changchung Research Institute of Optical Machinery, Chinese Academy of Sciences
2 Under water linear explosive cutting technique	Huadong Institute of Technology Guangzhou Research Institute of Sea Rescue Equipments
2 The conversion of 1.2m fixed-energy cyclotron to	Shanghai Research Institute of Nuclear Science, Chinese Academy

	30 M eV(P) isochronous variable-energy cyclotron	of Sciences
2	FD2-100WYC and FD-1.4-50WYC windmills	Xilinguole Perfecture Research Institute of Wind Power, Inner Mongolia Fengxi Machinery Factory Nanjing Institute of Aeronautics Baotou Electric Motor Factory
2	5MN electic-hydraulic standard servo-dynamoeter	Chinese Academy of Metrological Sciences Chendu Academy of Mesurement and Testing Shanghai Heavy Machine Tool Factory
2	AU-110 small air-driven, high-speed centrifugal pumps	Wuhan Research Institute of Physics, Chinese Academy of Sciences Wuhan Research Institute of Virology, CAS
2	4-frequencies annular laser angle sensors and annular laser anglulometer	Chinese Academy of Metrological Sciences Kungming Machine Tool Factory Qinghua University Suzhou No.1 Optical Instrument Factory
2	Dynamic measurement of conjugate gear engagement accuracy and the equipment for technical analysis	Xian Jiaotong University Hanjiang Machine Tool Factory Wuhan Freezer Factory
2	Built-up and polishing electroplating technique and additives	Wuhan Research Institute of Material Protection, Ministry of Machine Building
2	The experimental study of the steam corrosion and wear to stainless-steel wheels of turbine	Kungming Electric Motor Factory Shanghai Research Institute of Materials
2	Experiment of 35T/h coal-burning, ebullating boiler for electricity generation	Yiyang Experimental Factory for Comprehensive Utilisation of Coal Power Shanghai Design Institute of Electrical Generators Shanghai Boiler Factory Hunan Academy of Power Survey and Design Huazhong Institute of Technology
2	Energy-saving fans and grills for electric motors	Department of Electric Motro Engineering, Qinghua University

		Maintanence Workshop of Shoudu Iron and Steel Cooporation Tong County Micro-electric Motor Factory Beijing General Electric Motor Factory Beijing Heavy Elctric Motor Factory
2	The design and production of QY200-14/31 hydraulic support frames and accessories	Beijing Research Institute of Mining, Academy of Coal Industry Section of Technical Research, Academy of Coal Industry Xibei Coal-mining Machinery Factory Beijing Coal-mining Machinery Factory Songzao Mine Bureau
2	New design method of compressor loop valves	Xian Jiaotong University Shanghia Compressor Factory Hefei Research Institute of General Machinery
2	ZW-40 marshland bagger	Chongqing Air Compressor Factory
2	Linear asynchronous motor	Shanghai University of Technology
2	Jet moulding and its equipments	Harbin University of Technology Wuhan Forging Factory Harbin Steel Factory
2	high accuracy gear calibrator series	No.6354 Research Institute, China Ship Building Corporation
2	75 KVA cobalt rare-earth, magnetogenerator	Dongfang Electric Motor Factory Shenyang Institute of Mechanical and Electrical Engineering No.1409 Research Institute, Ministry of Electronic Industry Qinghua University
2	The research of flow passing components of multi-satge centrifugal water pump blades	Beijing Postgraduate School, Huadong Petrolium Institute
2	Y-series small three-phase asynchronous motors	Shanghai Research Institute of Electrical Accessories Dalian Electric Motor Factory Shanghai Electric Motor Company
2	Techniques for the improvement of welding quality of boilers	Harbin Research Institute of Welding Harbin Boiler Factory Shanghai Research Institute of

		Materails, Ministry of Machine Building
2	?	No.6 Research Institute, Ministry of Nuclear Industry
2	20MnTiB cold-forging hi-strength bolt	Academy of Railway, Ministry of Railway Daye Steel Factory Shanghai Standards Company Research Institute of Bridge, Bureau of Bridge, Ministry of Railway Department of Mechanical Engineering, Qinghua University
2	High accuracy evolvent inspection instrument	Chengdu Academy of Measurement and Testing
2	The research of aluminium of improved conductivity for electrical engineering	Shanghai Research Institute of Cable Shenyang Cable Factory Fushun Aluminium Factory
2	YA7232B worm abrasive wheel grinder	Shanghai Machine Tool Factory
2	Special oil field air supply equipment	No.8 Engineering Company, Ministry of Petrolium Industry Lanzhou Refinery Liaohe Oil Prospecting Bureau
2	WT-300 mobile drilling machine for both oil and gas fields	Bureau of Geophysical Oil Prospecting Beijing Petroleum Machinery Factory Jianghan No.3 Petroleum Machinery Factory
2	WK-10 digger	Taiyuan Heavy Machinery Factory
2	AD transistor electrical transmission equipments	Tianjin Design Institute of Electrical Transmission
2	Welded stainless steel sieve tube	Zhuzhou Mining Sieve Factory
2	BQF supersonic inner-flow air grinder	Shanghai Electrical and Chemical Factory
2	ZCE1 - 4500/700 BDI3000KW silicon controlled rectifier for precise speed control system	Shanghai General Rectifier Factory
2	High precision, circular	Guangzhou Research Institute of

	induction, synchronous motors	Machine Tool Kungming Machine Tool Factory
2	3001 multi-purpose gear calibrator	Harbin Measurement Instrument and Cutting Tool Factory
3	Double ball bearings outer slot cutting grinder	Harbin Bearing Factory
3	The analysis of three dimensional flow field in turbines by using quasi-orthogonal coordinates	Fudan University
3	R&D of the cold-forming moulds of GCr15 taper bearing rings	Huazhong Institute of Technology Qinghua University Xiangyang Bearing Factory
3	Qu80-Qu132 three-phase asynchronous motors	Shanghai Yuejin Electric Motor Factory
3	Multi-tangential small hole air supply and double air layers bearings	Xian Jiaotong University Wu County Oxygenerator Factory, Jiangsu
3	Experment equipments for the testing of hydraulic pumps, motors and systems	Beijing Institute of Technology
3	?	Sichuan No.1 Meter Factory Beijing No.603 Factory Tianjing Silicate Factory Tianjing Optical Glass Factory
3	Integrated double-chamber vacuum heat-treatment furnace	Shoudu Machinery Factory
3	DS21 0.5 scale three-phase threeway electric meter	Shanghai Electric Meter Factory
3	Rare-earth high chrome-nickel-nitrogen, high chrome-manganese-nitrogen heat-resisting steel	Unit of Casting, Shangdong University of Technology Xing County Electric Furnace Accessory Factory, Shangdong
3	High accuracy forging of diesel engine synchron gears	Beijing General Gear Factory Beijing Research Institute of mechanical and Electrical Engineering Wuhan Automobile Gear Factory
3	Research and application of long-life, heavy-load WC	Beijing Research Institute of Powder Metallurgy

	cemented carbide	
3	SN10-10 I.II.III series in-door, high-voltage, oil-saving safety breaker	Xian High-voltage Electrical Instrument Factory Tianjing Switch Factory
3	QKSG800-1200-550/498 underwater high-voltage electric pump	Heifei Electric Motor Factory Shanghai Research Institute of Electrical Equipments, Ministry of Machine Building
3	QWP65, 50 spring water sprayers	Bangbu Fire Brigade, Anhui Bangbu Fire-fighting Equipment Factory Bangbu Heavy Industry Bureau
3	TX6113B horizontal boring lathe (#300mm)	Kungming Machine Tool Factory
3	EJ30 rock-profile tunnel digger	Shanghai Research Institute, Academy of Coal Industry Maintanence Worshop, Pingxiang Mining Bureau Shanghai No.1 Petroleum Machinery Factory Wangping Coal Mine, Yanbei PLA 00612 Division
3	SJ-65x30, SJ-FM1600 plastic film blowing moulding machine	Dalian Rubber and Plastic Machinery Factory
3	No.1 sheet metal cold-rolling lubricant	Research Institute of Refining, Luoyang Petro-chemical Engineering Co., China Petroleum and Chemicals Corporation Wuhan Iron and Steel Corporation Wuhan Sebo-chemical Factory No.10 Workshop of Shanghai Iron and Steel Corporation
3	The optimization of design of asynchronous motors	Dongbei Institute of Electrical Engineering
3	CK3263 digital control capstan lathe	Shenyang No.3 Machine Tool Factory
3	Modification and improvement of irrigation pumps	Hunan Research Institute of Agricultural Machinery Research Institute of Irrigation Machinery, Jiangsu College of Technology Zhejiang Research Institute of Machine Building Chaling County Pump Factory, Hunan

3 Solid calcium silicate - acetylenic gas bottle	Tangbao Company, Shanghai Bureau of Light Industry Shanghai High-pressure Container Factory Shanghai Wusong Chemical Factory
3 ? CERTAIN EQUIPMENT TO DO WITH THE RECYCLE OF NATURAL GAS	No.609 Research Institute, Ministry of Aeronautical Engineering Zhongyuan Bureau of Oil Exploration Daqing Oilfield, Ministry of Petroleum
3 DWX15-200, 400, 630 frame automatic switches	Changzheng No.9 Electrical Instrument Factory, Guizhou
3 XH754 horizontal manufacturing centre	Qinghai No.1 Machine Tool Factory
3 The production technology of high stability stabilitron by P-N junction socketing	Shanghai Research Institute of Instruments and meters
3 XA series single-stage centrifugal pumps	Fuoshang Water Pump Factory
3 Semi-automatic feather selecting and dedusting machine	Leather and Fur Processing Factory, Hubei Animal Products Import and Export Corporation
3 YJK35 enlargement printing equipment	Qinghuangdao Research Centre of Audiovisual Technology
3 TUZ-1300 horozontal, vibrational, centrifugal drier	Luoyang Research Institute of Mining Machinery, Ministry of Machine Building Academy of Coal Selection, Ministry of Coal Industry Zhuzhou Mining Sieve Factory Matou Coal Selection Factory, Fengfeng Bureau of Mining
3 D3-1.7/0.5 geothermal turbines	Qingdao Steam Turbine Factory
3 Fundamental research on fatigues in design	Zhengzhou Research Institute of Machinery, Ministry of Machine Building Dongbei Institute of Technology Shanghai Research Institute of Materials, Ministry of Machine Building

3	1200T hydraulic brick press	Xian Research Institute of Heavy Machinery Taiyuan Mining Machinery Factory
3	Series camera lenses for film industry	Beijing No.608 Factory
3	Four large axial pumps used in the Luan River diversion project	Tianjing Generator Factory Research Institute of Energy and Irrigation, Chinese Academy of Agricultural Sciences
3	Forging technique of connecting rods	Jilin University of Technology Boshan Forging Factory No.5 Academy of Research and Design
3	BM-100 digger for thin coal pits	Heilongjiang Research Institute of Coal Industry Research Institute, Shuangyashan Bureau of Mining, Heilongjiang Jixi Coal Machinery Factory
3	SGZ-1600/10TH on-load, dry-cooling, adjustable transformer	Shenyang Transformer Factory
3	DD680 and DD650 coaches	Dangdong Automobile Factory
3	Automatic worm testing instrument for steel balls	Shanghai Steel Ball Factory
3	Circular optical grating and its application	Shanghai Institute of Mechanical Engineering
3	Changjiang special bus chassis	Changzhou Automobile Factory Jilin University of Technology Xian College of Highway Engineering
3	Automatic control and optimisation of smelting process	Jinan Research Institute of Forging and Casting Machinery Wuxi Machine Tool Factory Nanjing Institute of Technology Harbin University of Science and Technology Beijing Academy of Mechanical and Electrical Engineering
3	Standard series herculite insulator	Nanjing Electric Ceramic Factory
3	R&D of micro-computer controlled 100T scale	Tianshui Hongshan Experiment Equipment Factory Hunan University Suzhou Meter Component Factory

		Institute of Standards, Ministry of Railway Fushun Steel Factory
3	?	Shanghai Gexin Electric motor Factory
3	Fast purification of the cleaning water in casting workshops	Qinghai Shanchuang Machine Tool Casting Factory
3	Integrated solar power drier	Guangzhou Research institute of Energy, Chinese Academy of Sciences Guangzhou Research Institute of Agricultural Machinery
3	? A PAINT	Tianjing Insulating Material Factory
3	R&D of the SJD-51 DC-potential surface crack detector	Shanghai Jiaotong University Huaqiao University Shanghai Defectoscope Factory
3	Guilin-2 rice combine harvester	Guangxi Research Institute of Agricultural Machinery Guilin Prefectural Combine Harvester Factory, Guangxi
3	Medium module carbide gear hobbing cutter	Chengdu Research Institute of Cutting Tools Chungqing Machine Tool Factory Shanghai Research institute of Materials Beijing Gear Factory
3	BJH201A double-chamber carburetor	Beijing Automobile Factory Beijing Research Institute of Automobile Components
<u>1987</u>		
1	?	Xian Jiaotong University
1	R&D of high accuracy shaft series and high accuracy lathes	Beijing Research Institute of Machine Tools
1	YDJC-9000/2250 50Hz experimental transformer end-to-end connection equipment	Shenyang Transfomer Factory Wuhan Research Institute of High Voltage
1	Q1-53A stator base horizontal lathe	Qiqihar No.1 Machine Tool Factory

2	The research and diffusion of silver-saving switches and related electrical products	Shanghai Research Institute of Electrical Accessories Guilin Research Institute of Electrical Accessories Beijing Low-voltage Electrical Factory Suzhou Electrical Factory Guangzhou Electrical Alloy Factory Control Group of Silver in Electrical S
2	The experimental temperature-rise control system of 500KV power transmission in Shenyang Transfomer Factory	No.7 Research Academy, State Commission of Machine Building
2	The uniform curing of of casting components and the reinforcing pouring mouth	Shanxi Institute of Mechanical Engineering Qingchuang Machine tool Factory Xian Nodular Cast Iron Factory
2	The 10KV axial water turbine group at Baigou Power Station in Guangdong	Tianjing Generator Factory Tianjing Hydraulic Control Equipment Factory Tianjing Research Institute of Electric Transmission Guangzhou Research Institute of Machine Tools Harbin Institute of Electrical Engineering
2	3204 gear shape and direction calibrator, 3480 automatic attachable large gear pitch calibrator and 3406 automatic gear pitch calibrator	Harbin Measurement Instrument and Cutting Tool Factory
2	Noise control of carpenter saws and planers	No.9 Research academy, China Ship Building Corporation
2	ZJ45 petroleum drilling machine	Lanzhou Petro-chemical Machinery Factory Baoji Petroleum Machinery Factory Jinan Diesel Factory Lanzhou Research Institute of Petroleum Machinery Chuandong Exploration Co. Sichuan Petroleum Bureau
2	High accuracy taper valve system	Xian Research Institute of Heavy Machinery Shanghai No.1 Iron and Steel Factory

		Zhejiang xiangshan No.2 Hydraulic Components Factory
2	Studies of components of rotating plough and their compatibility with tractor	Nanjing Research Institute of Agricultural Mechanisation Jiangsu College of Technology Jiangsu Taicang No.1 Agricultural Machinery Factory
2	The study of the arch structure of the chain furnace and its second air supply	Xian Jiaotong University Beijing Boiler Factory
2	The optimisation of technical parameters in optical cool-machining	Shenyang Research Institute of Instruments and Meters Technology Zhengzhou Research Institute of Abrasive Materials and Equipments Jiangxi Optical Instruments Factory Jiangnan Optical Instruments Factory Nanjing Instrument Machinery Factory cont
2	The experimental testing techniques of coal mining machine and its rotating components	Shanghai Research Institute, Academy of Coal Industry
2	The study of cracks in high temperature welding	Harbin Research Institute of Welding Harbin Boiler Factory
2	The production technology of silico-aluminium alloy pistons	Shandong Binzhou Piston Factory
2	Dual-direction angular ball bearings	Harbin Bearing Factory
2	The quench of large diameter cool-rolling rollers by using 50Hz double inductors	Beijing Research Institute of Mechanical and Electrical Engineering Xingtai Metallurgical Machinery Factory
3	The research of profile grinding equipments for piston rings	Shanghai Machine Tool Factory Shanghai Research Institute of Grinders Shanghai Internal Combustion Engine Accessories Factory
3	Research of casting coatings	Qinghua University

3 High accuracy shaft system and micro-feeding systems	Shanghai Research Institute of Machine Tools
3 New welding techniques for mining ring chains	Zhangjiakou Coal Mining Machinery Factory, Ministry of Coal Industry Harbin University of Technology
3 Positive electrode oxygenation of aluminium alloy bars	Guangdong College of Technology Guangzhou Aluminium Alloy Products Factory
3 Four parameters instantaneous voltage recovery technique	Xian Research Institute of High Voltage Equipments
3 K009 calibrator of main shaft rotating accuracy	Shanghai Research Institute of Machine Tools
3 Research and application of new non-polluting sulphor-nitrogen-carbon gasification techniques	Wuhan Research Institute of Material Protection
3 The research of laser surface intensfication of perforator in stamp printing	Qinghua University Beijing Research Institute of Mechanical and Electrical Engineering Beijing Stamp Factory
3 The cutting techniques of hard-machining components of petroleum machines	Academy of Petroleum Prospecting and Exploration Ministry of Petroleum Industry Qinghua University Shanghai University of Technology Jianghan Petroleum Bureau Yumen Petroleum Bureau
3 The technical research of five projects on pump sealing in Shengli Oil Refinery	Huadong Institute of Petroleum Shengli Oil Refinery, Qilu Petro-chemical Company
3 PXO1200/150 light hydraulic rotating bucker	Shenyang Heavy Machinery Factory
3 The study of the reduction of smoke pollution and fuel consumption of 190 diesel	Jinan Diesel Factory
3 R&D of 492QA2 gasoline engine	Research Institute, Beijing Internal Combustion Engine Factory
3 The multi-layer vibrating mud sieve	Changqing Bureau of Petroleum Prospecting

3 The moulding technology of long optical fibre and related equipments	Shanghai Research Institute of Cable
3 Two-phase flow pump	Gung County Two-phase Flow Pump Factory, Henan
3 The improvement of mechanical and electrical durabilities of small capacity AC relays	Shanghai Research Institute of Electrical Accessories Shandong Yantai Electrical Accessories Factory
3 The study of strength and life of cool-melting moulds	Huazhong Institute of Technology Shanghai No.5 Standards Factory, Shanghai Standards Company
3 The research and application of mechanical principles of hobbing gear cutter	Dalian Institute of Technology Guangdong Shaoguan Tool Factory
3 1700/#610 five-stage continous cold-rolling collectin/holding machine	Harbin Jilian Machinery Factory Wuhan Iron and Steel Corporation
3 XMZ2500/1500 automatic filter	Tangshan Branch of the Academy of Coal Industry
3 The mechanical emergency safety brakes of the press	Shananghai Research Institute of Moulding Shanghai Jiaotong University Shanghai Lighter Factory
3 DG750-180 electric driven, hydraulic speed-adjustable water pumps	Beijing Electrical Equipment General Factory
3 Electric carry-scraper	Maanshan Academy of Mining Nanchang General Machinery Factory Yangzhou Metallurgical Machinery Factory Ganglushan Iron Mine, Daye Ferrous Metal Company
3 Jet burning kiln	No.7 Research Academy, Ministry of Machine Building Suzhou Electric Ceramic Factory
3 CTJY10.2 hydraulic stripping shovels and YYGJ80A hydraulic rock driller	Changsha Academy of Mining and Metallurgy Iron Mine of Shanghai Meishan Metallurgical Company Hebei Xuanhua Pneumatic Machinery Factory

3	The practical study of multi-function cutting liquid and LPG-1 high effect grinding liquid	Guangzhou Research Institute of Machine Tools Shanghai Pujiang Bearing Factory Shanghai Gaoqiao Chemical Factory Beijing Measurement Instrument and Cutting Tool Factory Luoyang Bearing Factory
3	3MZ1310A fully-automatic grinding lathe for the inner slots of ball bearing rings	Shijiazhuang Special Bearing Equipment Factory Wafangdian Bearing Factory
3	The experimental study of double-turbine hydraulic distance controllers	Tianjin Research Institute of Engineering Machinery
3	Liquified petroleum gas tanker series	No.523 Factory
3	The study of impact energy of stripping shovels by acoustic emission	Tianshui Research Institute of Pneumatic Equipments Changsha Academy of Mining and Metallurgy
3	The multi-direction forging of tube joints and related equipments	Huazhong Institute of Technology Wuhan Automobile Standard Components Factory
3	GJY114 high-frequency straight tube welding machine, and GJZ diameter shaper	Shijiazhuang Special Bearing Equipment Factory
3	?	Hunan University
3	The research of high speed bearings used in the high speed camera	Luoyang Research Institute of Bearings
3	6NF-13.2 detachable steel-roller rice mill	Hunan Research Institute of Agricultural Machinery Zhejiang Wuyi Agricultural Machinery General Factory Henan Shangcheng Machinery Factory Hunan Chenzhou Rice Mill Factory
3	The in-operation testing of major technical parameters of well underwater pumps	Chinese Research Institute of Agricultural Machinery
3	Multi-layer, high-performace, wave-like expansion washer	Maintanence Worshop, Liaoyang Petro-chemical Fibre Company

3 CU-0013 Laser ring slot roughness measurement instrument	Luoyang Research Institute of Bearings
3 Microcomputer assisted automatic testing system for asynchronous motors	Shangahi Resaerch Institute of Electrical Accessories
3 The experiments and structural studies of box structures of truck crane beams	Changjiang Crane Factory Xinan Jiaotong University
3 Flangeseal crank injection pump series	Yuandong Machine Building Company

1988

1 The complete set of equipments of 500KV transmission between Jinzhou and Liaoyang	Shenyang Transformer Factory Xian Transformer and Heater Factory Shenyang High-voltage Switch Factory Xian Research Institute of High-voltage Equipments Xuchang Research Institute of Relays Dongbei Electricity Bureau cont.
1 The R&D of Jiefang CA141 5T trucks and renovation of production line	No.1 Automobile Factory
2 The analysis of drilling rod failures and the effect of inner thickened transient areas on the life of drilling rods	Material Testing Centre, Ministry of Petroleum Industry Bureau of Material Supply, Ministry of Petroleum Industry
2 Automatic high-aisle warehouse at the No.2 Automobile Factory	Beijing Research Institute of Automation, State Commission of Machine Building No.2 Automobile Factory
2 210KW high-voltage, three-cylinder, double-cooling electricity generting turbines	Harbin Turbine Factory
2 Standard single-stage harmonic gear box series	Research Institute of Standards, Ministry of Electronic Industry Research Institute of Harmonic Transmission, State Commission of S&T for National Defence No.29 Research Institute, MEI

		No.54 Research Institute, MEI
2	The R&D of MK2932B continuous locus digital-controlled grinder	Ningjiang Machine Tool Factory
2	500KV - 360 trillion IV three-phase on-load autotransformer at Gezhouba Power Station	Shenyang Transformer Factory
2	AS9/500 vertical well driller	Luoyang Research Institute of Mining, Ministry of Machine Building Luoyang Mining Machinery Factory Special Well-drilling Company, MCI Research Institute of Well Drilling, Academy of Coal Industry Shanghai Rectifier Factory
2	Y7125A large plane abrasive wheel gear grinder	Qinchuan Machine Tool Factory
2	Computer control management system of coal ports at Yingkou and Lianyungang	Shanghai Research Institute of Automation, State Commission of Machine Building Shanghai Research Institute of Electrical Accessories, CMB
2	The engineering project of 200T high-speed dynamic balance laboratory at Shanghai Gas Turbine Factory	No.2 Design Acdemy, State Commission of Machine Building Shanghai Gas Turbine Factory
2	The basic research of high-speed, heavy-load gears	Zhengzhou Research Institute of Machinery Nanjing High-speed Gear Box Factory
2	R&D of the production technology of axle bush by centrifugal casting of lead and bronze grains	Chingqing Vessel Diesel Components Factory Harbin University of Technology
2	The improvement of compressor performance and its optimal design	Xian Jiaotong University
2	The study and appliaction of aerodynamics and two phase flow techniques in high efficiency single and double stage gas turbines	Research Institute of Thermal Physics, Chinese Academy of Sciences

2	The numerical calculation of magnetic fields of electric motors	Qinghua University
3	KN4-36(PKG2) electricity generator safety cutout	Shenyang High-voltage Switch Factory
3	R&D and domestic production of VTR "0, 1, 4, 4A" series turbine compressors	China Ship Building Corporation Jiangjin Pressurizer Factory Xizhong Turbine Factory
3	The R&D of PJ-1 painting robot and its application	Beijing Research Institute of Manufacturing Automation, State Commission of Machine Building
3	CZQ6000 DC low-frequency demagnetizer	Xian Jiaotong University Jiangsu Sheyang Radio Factory Xian Aircraft Corporation
3	Production technology for the improvement of casting quality of hydraulic structure components	Yuci Hydraulic Factory Huazhong Institute of Technology
3	?	Tongchuan Mining Bureau
3	SJ-65 x 30L, SJ-FM1600L plastic film blower	Dalian Rubber and Plastic Machinery Factory
3	The testing technique of pump performance by micro-temperature difference	Huadong Institute of Chemical Engineering
3	MM52100 precision plane guide-rail grinder	Shanghai Heavy Machinery Factory
3	The study and application of three-layer composite lubricating materials	Shanghai Research Institute of Materials, Ministry of Machine Building Zhejiang Jiashan Composite Bearing Factory Wuxi Taihu Non-grease Lubricating Bearing Factory
3	H100-9/0.97 centrifugal compressor	Xian Jiaotong University Kaifeng Pneumatic Factory
3	B5OL-IA stage-3 multi-channel turbulent separating catalo-cracker	Beijing Postgraduate School, Huadong Petroleum Institute Beijing Design Academy China Petroleum and Chemicals Corporation Daqing Petro-chemical General Factory

3 Squeeze extruded cable polyethylene	Shanghai Research Institute of Cable, State Commission of Machine Building
3 The improvement of efficiency and decrease in fuel consumption of 6180 diesel and its diffusion	Shanghai Research Institute of Ship Transport Guangdong Ship Machinery Factory
3 The R&D and diffusion of S.F series energy-saving, low-noise axial air blower	No.711 Research Institute, No.7 Research Academy of the China Ship Building Corporation
3 The experimental study of reducing aging time after forging by using vaccum technology	No.2 Heavy Machinery Factory Research Institute of Big Casting and Forging Works No.1 Heavy Machinery Factory Beijing Heavy Machinery Factory Shanghai Heavy Machinery Factory
3 Needle bearing with forged rings	Suzhou Bearing Factory
3 White casting iron - steel composite casting material and realted technology	Shenyang Research Institute of Casting, State Commission of Machine Building Shandong Linyi Special Steel Factory
3 The research of basic machine parts	Shandong Bureau of Machine Building Shandong Academy of Mechanical Design Lianshan Bearing Factory Jinan Hydraulic Pump Factory Lunan Machine Tool Factory
3 CKJ5 series AC vaccum contactor	Shanghai Research Institute of Electrical Accessories Shanghai Huatong Switch Factory Tianjin Electrical Control Design Factory Shenyang Low-voltage Switch Factory Jinzhou Xinshen Switch Factory
3 The research of low-roughness, errosion-resistant plastic moulding steel	Shanghai Research Institute of Materials Daye Steel Factory
3 FWX anti-mashgas explosion belt conveyor in mining	Tangshan Metallurgical Mining Machinery Factory Beijing Research Institute of Lifting and Handling Machinery Shenyang Low-voltage Switch

		Factory
3	CAD/CAM system for pressing dies	Shanghai Jiaotong University
3	The casting techniques of high-strength, thin-wall cast iron components	Research Institute of Manufacturing Technology and Macterials, Chinese Academy of Agricultural Machinery Research Institute of Manufacturing Technology and Materials, No.1 Tractor Factory No.2 Casting Workshop of No.1 Tractor Factory
3	LPB-1000 gear-teeth crusher	No.1 worshop, Xibei Coal Mining Machinery General Factory
3	Composite-spring vibration damper in oil drilling	Daqing Petroleum College Daqing Research Institute of Oil Drilling Mudanjiang Petroleum Machinery Factory
3	MQB-400 cotton selector	Qihe County No.3 Cotton and Oil Processing Factory, Shandong Shandong Cotton and Jute Processing Machinery Factory Qihe County No.2 Cotton and Oil Processing Factory
3	JI/QHT-150 steam corp drier	Jilin Cereal and Oil Warehousing Company Lishu County Caijia Warehouse
3	Jianghuai - 500 tractor	Anhui Tractor Factory Luoyang Research Institute of Tractor
3	High-tenacity, large-section, hot-forging mould steel	Huazhong Institute of Technology Forging Workshop, No.2 Automobile Factory Shanxi Heavy Machinery Factory Inner Mogolia No.2 Machinery General Factory Qijiang Gear Factory

APPENDIX C - V SELECTED LIST OF AWARDS - CHEM. ENG. (SSTC)

C INNOVATION	INNOVATOR
1985	
1 The method of recovery of hydrogen from the releasing gas in ammonia synthesis by four-tower, constant-variable pressure absorption technique	Xinan Research Academy of Chemical Engineering, Ministry of Chemical Industry
1 Emulsified explosive used in coal mining	No.525 Factory, Zibo Mining Bureau, shandong Fushun Research Institute of Coal Research Institute of Explosive technology No.12 Factory, Fuxin Mining Bureau Kailuan N0.602 Factory
2 Y-7 molecular sieve catalyst	Academy of Petro-chemical Sciences, China Petroleum & Chemicals Corporation Catalyst Factory of Qilu Petro-chemical Company Cangzhou Petro-chemical Factory
2 R&D of KT-1501 turbine high-pressure cylinder rotor	Jinxi Chemical Machinery Factory Shanghai Institute of Mechanical Engineering Xian Jiaotong University
2 New refining process of paraffin by hydrogenation	Fushun Academy of Petro-chemical Sciences, China Petroleum & Chemicals Corporation Daqing Petro-chemical General Factory, CPCC Dongfanghong Refinery, Yanshan Petro-chemical Company, CPCC
2 Rubber seals for hydraulic supporters	Xibei Research Institute of Rubber Products Taiyuan Branch, Academy of Coal Industry
2 CH-784 anti-corrosion coating for carbon steel water cooler	Hebei Cangzhou Chemical Fertiliser Factory Tianjin Paint General Factory
2 The application of P507 extracting agent in the separation of rare-earth elements	Shanghai Research Institute of Organic Chemistry Shanghai Yuelong Chemical Factory

2	Thermal insulating technique in steam-pipe network	Research Institute of Mechanics, CAS Shanghai Research Instituite of Silicate, CAS Yanshan Petro-chemical Company Shanghai Research Instituite of Engineering Physics, CAS
2	The application of "738" baby silkworm protecting hormone and the skin casting-off hormone in sericulture	Shanghai Research Institute of Organic Chemistry Research Institute of Sericulture, Chinese Academy of Agricultural Sciences Research Institute of Silkworm and Mulberry, Zhejiang Academy of Agricultural Sciences
2	Non-electrical detonation system with plastic detonation tube	Huadong Institute of Technology No.9644 Factory No.474 Factory
2	Polytetrafluoroethylene and copolymers of fluoroethylene	Shanghai Research Institute of Organic Fluoro-materials
2	KEWENLING - a pesticide with triazole structure	Shanghai Research Institute of Agricultural Pesticides
2	Development and application of new varieties of organo-silicates	Shanghai Resin Factory
2	An acidic mordant dye	Tianjin No.2 Dye Chemicals Factory
2	The application of carbon steel thermal tube and thermal transducer in the recycle of heat	Nanijing Institute of Chemical Engineering Research Institute of Engineering Thermal Physics, CAS
2	The technology of 1000 ton polypropylene production line by utilising refining gas as raw material	Beijing Academy of Chemical Engineering Rubber Workshop of Yueyang Petro-chemical General Factory Design Academy of Nanjing Chemical Industrial Company
2	Innovated production technology of hydrogen peroxide by anthraquinone method	Liming Academy of Chemical Engineering
2	Methylated "YILIULIN" - an organophosphorous agricultural chemicals	Huazhong Normal University Research Institute of Plant Conservation, CAS Qingdao No.2 Agricultural Chemical Factory

2	A new design method of methanol synthesising reactor	Huadong Institute of Chemical Engineering
2	Catalytically eliminating carbondioxide by using hot solution of potassium alkali containing two activators	Academy of Chemical Enginnering, Nanjing Chemical Industrial Company Wulashan Chemical Fertiliser Factory Qixiashan Chemical Fertiliser Factory
2	Eliminating process of carbon dioxide and hydrogen sulfide by using propenyl carbonate	Academy of Chemical Engineering, Nanjing Chemical Industrial Company Hanzhou Research Institute of Chemical Engineering No.6 Design Academy, MCE Shandong Bohai Chemical Fertiliser Factory
2	"481" catalyst and the process of hydrogenation of ligroin for export	Fushun Academy of Petro-chemical Sciences, China Petroleum and Chemicals Corporation Research Institute of the refinery of Jinling Petro-chemical Company, CPCC
2	Automated system for stocking and transporting petroleum products in Daqing Petro-chemical General Factory	Daqing Petro-chemical General Factory, CPCC No.6 Research Institute, MEI Design Academy, Office of Daqing Ethylene Project, CPCC
2	Jin 1876 catalyst used for hydroisomerisation of xylene	Academy of Petre-chemical Sciences, China Petroleum and Chemicals Corporation No.3 petroleum Factory, Fushun Petro-chemical Company, CPCC No.1 Chemical Workshop, Shanghai Petro-chemical General Factory, CPCC
2	"Zhongxi sha mie ju zhi" - a synthetic agricultural chemical with the similar function as Dalmatian chrysanthemum	Zhongxi Pharmaceutical Factory Shanghai Research Institute of Agricultural Chemicals
2	Sulfonated resin-containing deep-drilling mud	Sichuan Petroleum Bureau Xinan Petroleum Institute Huadong Petroleum Institute Huabei Petroleum Bureau Qinghai Petroleum Bureau

3	Rubber sealing belt for float-top oil tank	Guilin Rubber Product Factory
3	Development of impact-resistant rigid polyethylene drain pipes for in-door use	Shanghai Shengde Plastic Factory
3	Development and application of a series of fluorocarbon synthetic rubbers	Shanghai Research Institute of Organic Fluoro-materials Chenguang Academy of Chemical Engineering, MCI
3	Automobile inner tube made from isobutene-isoprene rubber	Shanghai Dazhonghua Rubber Factory
3	T804 low temprature diesel fluidity promoter and its application	Academy of Petro-chemical Sciences, CPCC: Beijing Organic Chemicals Factory Daqing Petro-chemical General Factory
3	GSD horizontal, continuous, vaccum, belt filtrator	Shanghai Academy of Chemical Engineering
3	R&D and application of rolled waterproof ethylene-propylene rubber sheet	Beijing Academy of Chemical Engineering Baoding No.1 Rubber Factory Beijing Research Institute of Construction Engineering Beijing No.6 Rubber Factory
3	Research, production and application of organosilicone gel	Chenguang Academy of Chemical Engineering
3	R&D of alumina absorbant	Tianjin Academy of Chemical Engineering
3	Research and industrial application of a catalyst used for liquid-phase hydrogenation of C3 fraction eliminating propyne and propadiene	Beijing Academy of Chemical Engineering No.1 Chemical Factory, Liaoyang Petro-chemical Fibre General Company
3	Plastic anti-corrusion jacket for metal pipes	Beijing Academy of Chemical Engineering No.1 Company of Huabei Oilfield
3	Z204 catalyst used in the two-step conversion of natural gas	Xinan Academy of Chemical Engineering

3	The study of reclaiming metallic anode coating containing ruthenium and titanium	Jinxi Academy of Chemical Engineering Tianjin Chemical Factory Gedian Chemical Factory
3	750g natural latex meteorological balloon	Research Institute of Latex Technology, MCI State Bureau of Meteorology
3	R&D of the one-step casting of hardened stainless steel vane wheel in centrifugal compressor	Sichuan Chemical Machinery Factory
3	The treatment of nitrogen oxides in the tail gas from the process of nitric acid production by using an ammonia-selective catalyst	Research Institute of Chemical Engineering, Sichuan Chemical General Factory Chengdu University of Science and Technology
3	FXN agricultural bactericide	Sichuan Research Institute of Chemical Engineering Research Institute of Elements, Nankai University
3	Totally plastics-jacketed blasting fuse and its production equipments	No.104 Factory
3	Complex fireproof composition for ship decks	Jiangnan Shipyard, China Ship Building Corporation No.708 Research Institute, CSBC Research Institute of Ocean-faring Vessels Standards, Bureau for Ship Inspection Xiangshan Light Blank Factory No.11 Research Institute, CSBC
3	R&D of a series of tyres for engineering vehicles	Henan Tyre Factory Guizhou Tyre Factory Guilin Tyre Factory
3	TM white carbon black	Tonghua No.2 Chemical Factory
3	Research, design and application of YL-3000 energy-saving turbine	Research Institute of Engineering Thermal Physics, CAS Beijing Design Academy of Petroleum, CPCC Lanzhou Oil-refining Machinery Factory
3	YJP-1 fluorescent yellow dye	Shanghai Research Institute of Organic Chemistry Kungshan Organic Chemical Factory

3	AP-17 de-emulsifying agent for crude oil	Xinjiang Research Institute of Chemistry, CAS Section of Petroleum Transport Xinjiang Petroleum Bureau
3	? shape of a spiral thermal transducer	Huanan Institute of Technology
3	The optimization technique of thermal transducer network	Qinghua University
3	The study of body-cracks of the one-step pump in the production of methylamines	Xiangjiang Nitrogenous Fertiliser Factory
3	B108 moderate-temperature conversion catalyst	Changsha Research Institute of Chemical Engineering Hunan Catalyst Factory
3	The research of complex phosphorous-potassium fertiliser	Xibei University Weinan City Government Weinan Dye Chemical Factory
3	Nylon conveyer belt	Qingdao No.6 Rubber Factory Shanghai No.11 Synthetic Fibre Factory Zhongnan Rubber Factory
3	Liquid calcium-zinc complex stabliser	Shangxi Research Institute of Chemical Engineering Changzhi Chemical Factory
3	Propylation of trimethylbenzene / preparation of pyromellitic anhydride by air gas-phase oxidation	Heilongjiang Research Institute of Petro-chemical Engineering Shanghai Coking Factory
3	Longguang bezene-free, lead-free and highly stable nitro-coating for pencil	Hengyong Pencil Coating Fcatory, Hebei
3	Organic alta-mud	No.46 Research Institute, Ministry of Electronic Industry
3	Di-2-ethylhexyl peroxidicarbonate	Tianjin No.2 Organic Chemical Factory
3	?	Liming Machinery Company
3	Evaporating equipment by mechanical compression	Academy of Nuclear Sciences
3	New technique for the refining of synthetic	Shenyang Chemical Factory

	lubricant oil by means of emulsification	
3	R&D and pilot production of CHC-1 catalyst for the production of ethylene oxide by oxidating ethylene	Shangahi Research Institute of Petro-chemical Engineering
3	3762 series catalysts for petroleum hydrocracking	No.3 Petroleum Factory, Fushun Petro-chemical Company, CPCC
3	Production technology of porous PVC resins	Beijing No.2 Chemical Factory Fuzhou No.2 Chemical Factory
3	Synthetic technology of PBT engineering plastics and its modification of fire-resistance and strength	Beijing Academy of Chemical Engineering
3	R&D of initiator "K"	Xibei Normal College Lanzhou Research Institute of Chemistry and Physics
3	R&D and diffusion of millisecond detonator permitted in coal mines	No.12 Factory, Fuxin Mining Bureau No.11 Factory, Fushun Mining Bureau
3	Phase-two thermal transducing network of evaporation in small-scale ammonia synthesisation	Fujian Design Academy of Petro-chemical Engineering
3	Process technology of synthesising trimethyl phosphite by tertialamine-ammonia method	Anhui Research Institute of Chemical Engineering Shanghai Design Academy of Pharmacy Nantong Agricultural Chemical Factory
3	All-season lubricant oil for vehicle axles	Research Institute of Metallic Chemistry, Academy of Railway Duzishan Refinery Jinxi No.5 Petroleum Factory
3	NZP-1 combustion catalyst for the treatment of organic waste gas	Hangzhou University
3	"Zhuzhuangsu" - plant growing promotor	Shenyang Academy of Chemical Engineering Qingdao Agricultural Chemical Factory Huazhong Institute of Agriculture Research Institute of Plant

		Conservation, Shandong Academy of Agricultural Sciences
3	The technology of row-connection of two synthetic reactors in small-scale nitrogenous fertiliser plants	Hebei Institute of Technology Yutian No.1 Chemical Fertiliser Factory
3	TSE-2040 polishing liquid for monocrystalline silicon plates	Tianjin No.1 Chemical Experiment Factory
3	"315" catalyst for the production of stylene by catalystical dehydrogenation of ethylbenzene	No.1 synthetic Rubber Factory, Lanzhou Chemical Company
3	Equipments for recovering CO2 from the combustion tail gas in Cishui Natural Gas Fertiliser Factory	Cishui Natural Gas Fertiliser Factory, Guizhou
3	Colour printing technology on rubber products	Guangzhou No.3 Rubber Factory
<u>1987</u>		
1	Catalytic hydrogenation of residual oil at atomospheric pressure	Beijing Design Academy, CPCC Academy of Petro-chemical Sciences, CPCC Luoyang Petro-chemical Industrial Company Shijiazhong Refinery, CPCC
1	R&D and application of TS series treating agents for cooling water	Tianjin Academy of Chemical Engineering, MCE
2	Synthetic technolgy of 2-nitrile-4-nitrophenoyl amine	Xiangtan Dye Chemical Factory Xiangtan Academy of Chemical Engineering Wuhan University Xiangtan Research Institute of Environmental Protection
2	Comprehensive development of energy-saving technology in ammonia synthesising	Zhejiang College of Technology
2	#1400mm urea synthetic tower with multi-layer liners	Chemical Machinery Factory, Nanjing Chemical Industrial Company

2	R&D of new production technology of N339 carbon black	Research Institute of Carbon Black, Mninstry of Chemical Industry
2	R&D of FH-1 humic acid resin and its application in the treatment of heavy metal waste water	Research Institute of Geography, Chinese Academy of Sciences
2	SKI-300 catalyst for dimethyl benzene isomerization	Academy of Petro-chemical Sciences, CPCC No.3 Petroleum Factory, Fushun Petro-chemical Company, CPCC Qianjin Chemical Factory, Yanshan Petrochemical Company, CPCC
2	R&D of GS-01 dehydrogenation catalyst for converting ethylbenzene into styrene	Shanghai Research Institute of Petro-chemicals, CPCC Chemical Factory of Shanghai Gaoqiao Petro-chemical Company
2	2.5% methyl sulf-phosphate pulvis and its application	Sichuan Research Institute of Chemical Engineering Fuzhou Research Institute of Agricultural Chemicals Sichuan Jianyang Agricultural Chemical Factory Jiangxi Gannan Agricultural Chemical Fcatory
2	Experimental study of synthesising butyl oxalic amide at 500 ton/year capacity	Shenyang Research Institute of Chemical Engineering, MCE Jiangsu Nantong Chemical Factory
2	Syloite anti-collapse drilling liquid	Shengli Oilfield Xinjiang Petroleum Bureau Huabei Petroleum Bureau Dagan Petroleum Bureau Huadong Petroleum Institute Yumen Petroleum Bureau Changqing Bureau of Oil Prospecting
2	New method of separating carbon dioxide from gas mixture by BV potash liquid	Huadong Institute of Chemical Engineering Shanghai Gas Company Shanghai Design Academy of Chemical Engineering Shanghai No.1 Iron and Steel Factory
2	Z109-1Y and Z109-2Y natural gas one-stage converting catalyst	Sichuan Chemical General Factory Chengdu Research Institute of Organic Chemistry, CAS Chengdu No.715 Factory

2	Scientific and economic use of fertiliser in Yixing County	Yixing County Government, Jiangsu Shanghai Academy Institute of Chemical Engineering, MCE
2	B301 converting catalyst in a wide range of temperature	Shanghai Academy of Chemical Engineering, MCE
3	The assimilation and improvement of imported technology of car radial tubeless tyre	Shanghai Zhentai Rubber Factory
3	S101-2H and S107-1H vanadium catalyst in sulfurnate acid production	Catalyst Factory of Nanjing Chemical Industrial Company
3	B110-1 and B110-2 catalysts for transforming carbon oxide	Research Institute of Nanjing Chemical Industrial Company Catalyst Workshop of Sichuan Chemical General Factory Catalyst Factory of Nanjing Chemical Industrial Company
3	Anti-corrosive coating technique for brine pipe inner surface	Research Institute of Coating Materials, MCE Sichuan Design Academy of Pertroleum Prospecting, MPI
3	Experimental study of fluorosilicate rubber at 4 ton/year capacity	Shanghai Research Institute of Organic Fluoro-materials
3	C207 ? catalyst	Research Institute of Nanjing Chemical Industrial Company
3	R&D of application of a new rubber synthesising technology - multi-stage condensation in solutions	Reseach Academy of Jilin Chemical Industrial Company Shengli Chemical Factory, Yanshan Petro-chemical Company
3	CDF - hydrophillic warping reagent for organic silica fabric	No.1 Branch of Chenguang Academy of Chemical Engineering, MCE
3	Twin-screw reactor and its application	No.1 Branch of Chenguang Academy of Chemical Engineering, MCE
3	High-pressure sealed gear pump	Beijing Chemical Machinery Factory Huzhou Natural Gas Factory
3	Simulating system of general chemical engineering process (stable or dynamic)	Computing Centre of Ministry of Chemical Industry Beijing Institute of Chemical Engineering Shanghai Academy of Chemical Engineering, MCE

		Zhejiang University Huadong Institute of Chemical Engineering
3	MDT emulsified lubricant for hydraulic frames and KNC oil-water composite fire-resistant gear lubricant	Beijing Research Institute of Mining, Academy of Coal Industry, Ministry of Coal Industry
3	Circulating technique in resin production	Academy of Petro-chemical Sciences, CPCC
3	R&D of JY mechanical seals	Academy of Chemical Machinery, Ministry of Chemical Industry
3	? an agricultural pesticide	Hunan Agricultural Chemical Factory Anhui Research Institute of Chemical Engineering Shenyang Academy of Chemical Engineering, MCE Zhuzhou Research Institute of Chemical Engineering Sichuan Academy of Chemical Engineering
3	Technical Renovation of butadiene production equipments	Tianjin University
3	Multi-stage computer control over a large-scale ammonia synthesising plant	Sichuan Chemical General Factory Shanghai Academy of Chemical Engineering, MCE Research Academy of Nanjing Chemical Industrial Company
3	High efficiency filling tower with new internal accessories	Research Institute of Chemical Engineering, Tianjin University
3	R&D of centrifugal extractor and its application	Research Institute of Nuclear Energy Technology, Qinghua University Shanghai Yuelong Chemical Factory Hangzhou No.1 Plastics and Chemical Factpry Tianjin No.2 Organic Chemical Factory Jiangsu Research Inst of Comprehensive Utilisation of Sea Wate
3	R&D and application of Dushulin - a series of organophosphor mice-killing	Liaoning Research Institute of Chemical Engineering

pesticides	
3 R&D of special high-pressure resistant soft rubber tube	Shenyang Research Institute of Industrial Rubber Products, MCE
3 Rubber membranes used in over 110kV electric transformer	Shenyang Research Institute of Industrial Rubber Products, MCE Shenyang Research Institute of Transformer, Ministry of Mechine Building
3 R&D of additives used in the crude oil transport	Daqing Petroleum Bureau Leading Office of Shengli Oilfield Beijing University
3 Intermediate appraisal of production equipments for the production of heavy soda ash by hydration	Research Institute of Soda Production, MCE
3 HP-14 oil lubricant	Academy of Petro-chemical Sciences Navy College of Engineering
3 Production technology of Steel-meridian heavy-load tyres and its application in the production of 8.25R20 meridian tyres	Shanghai Dazhonghua Rubber Factory
3 Application of HN extract agent - 1-heptane diacetamide - in absorbing phenol from waste water	Shanghai Research Institute of Organic Chemistry, CAS Wuxi Cokeing Factory Shanghai Coking Factory
3 R&D of XS-7 polyvinyl chloride resin	Tianjin Chemical Factory
<u>1988</u>	
0 Industrial production technology of poly-cis-butadiene rubber	Lanzhou Research Institute of Chemistry and Physics, CAS China Petroleum and Chemicals Corporation Changchun Research Institute of Applied Chemistry Shengli Refinery, Yanshan Petro-chemical Company, China Petroleum and Chemicals Corporation cont.
1 New production technology of ammonium phosphate by concentrating method	Sichuan Yinshan Phosphorous Fertiliser Factory Chengdu University of Science and

	through phosphate acid neutralizing slurry in di-water process	Technology Sichuan Design Academy of Chemical Engineering
1	"Lekai II" 100ASA daylight colour film	No.1 Film Factory, Ministry of Chemical Industry
2	Evaluating Regulations on the detection of Pressured Container Defects	Research Institute of Chemical Machinery, MCE Research Institute of General Machinery, State Commission of Machine Building
2	R&D of 66 kinds of electroplating solutions for non-ferrous, noble and alloy metals	Shanghai Research Institute of Organic Chemistry, CAS Engineering College of Armoured Force, PLA Heilongjiang Research Institute of Machinery
2	?	Academy of Petro-chemical Sciences Maoming Petroleum Company
2	R&D of MB-82 catalyst for the synthesis of acrylonitrile	Shanghai Research Institute of Petro-chemical Engineering, CPCC
2	The equipments and process of chloro-alcohol esterification	Tianjin University Shanghai Gaoqiao Petro-chemical Company Shanghai Research Institute of Petro-chemical Engineering Dept of Chemical Engineering, Tianjin University Unit of Organic Chemical Engineering, Dept of Chemical Engineering, Tianjian Uni
2	Simulating system of ECSS chemical engineering project	Qingdao Institute of Chemical Engineering
3	Production technology for separating carbon 4-fractions by methy-tert-butyl-ether (MTBE) method	Research Academy of Jilin Chemical Industrial Company Design Academy of Jilin Chemical Industrial Company
3	R&D of special rubber seals	Xibei Research Institute of Industrial Rubber Products, MCE
3	R&D and pilot production of CT-2 acetic ethylene catalyst and its industrial application	Shanghai Research Institute of Chemical Engineering, CPCC Research Institute of Catalyst, Shanghai Petro-chemical General Factory

		No.2 Workshop, Shanghai Petro-chemical General Factory
3	New granulating technology of polyacrylamide by pressing	No.5 Research Institute, Ministry of Nuclear Industry Jiangsu Jiangdu County Chemical Factory
3	? something to do with the condensation of diesel	Academy of Petro-chemical Sciences Harbin Refinery
3	113B and 113C undust dispersers for butanediamide	Academy of Petro-chemical Sciences, CPCC Lanzhou Refinery, CPCC Jinzhou Refinery, CPCC
3	New technology of desulfurization by selective water solution of methyethanolamine and other related technical improvement	Research Institute of Natural Gas, Sichuan Petroleum Bureau Chuandong Natural Gas Purification Factory, Sichuan Petroleum Bureau
3	Comprehensive appraisal technique of jet fuels	Academy of Petro-chemical Sciences Research Institute of Fuel of the Air Force No.621 Research Institute, Ministry of Aeronautics
3	H2500mm convex rubber vessel guardrail	Shenyang Rubber Tube Factory
3	2800 urea synthesising tower	Chemical Machinery Factory, Nanjing Chemical Industrial Company
3	CB-5 catalyst and study of its industrial application	Fushun Academy of Petro-chemical Engineering Technical Section, Shengli Refinery Catalyst Branch, Changling Refinery
3	R&D of cyano-condenser - a high performance chemical grounting material	Department of Applied Chemistry, Tianjin University
3	Technical Improvement of the production of amino-benzene through hydrogen reduction of nitro-benzene	Nanjing Chemical Factory, Ministry of Chemical Industry