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INTEGRATION OF INDUSTRIAL AND TECHNOLOGY POLICIES IN JAPAN: A PRELIMINARY VIEW*

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SUMMARY

Many observers of the industrial scene in Japan still maintain the notion that the Ministry of International Trade and Industry (MITI) plays an overwhelming role in directing the country's development. This is a total misunderstanding although with some truth in it.

This paper attempts to highlight and describe the conditions and interaction which have been favourable for Japan's industrial and technological development. In doing so it naturally becomes evident that Japan at various stages has been handling very different situations in its postwar development. First, the country was engaged in an intensive technology catch-up phase followed by a more independent development. Now, Japan is actively laying the foundation for its own and original development of new technologies, at the scientific and industrial frontier.

In reaching today's advanced position the composition and orientation of the industrial and technological actors have changed. The catch-up phase was characterized by more direct control over technology import contracts and the use of capital as a lever for directing industrial development to key technology sectors. In the intermediate period some of the government laboratories - among those MITI and the Ministry of Post and Telecommunications - shouldered a main responsibility to support the upgrading of industrial technologies.

Today, the traditional direct policy instruments have given way to more subtle support forms such as support for long-term basic research. At the same time Japan remains a homogenous and closely integrated society where a common understanding of long-term trends and commitment to required actions may be much more easily achieved than in other industrialized countries.

However, Japan is of course not a country free of conflict and the paper refers to unsuccessful cases when MITI attempted to restructure industrial sectors such as computers and automobiles. This in fact highlights the very important role played by the domestic and international markets in shaping industrial and technology policies and fine-tuning the instruments to achieve the objectives. In this process it may often have been the private companies who - through interaction with government agencies - have played a major role in setting the policies which have been so successful in promoting industrial development in Japan.

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INTRODUCTION

Japan has in the postwar period emerged as a major economic power which today accounts for 10% of the global gross national product. The country's successful economic development traces its roots to a number of different factors which include societal factors and the industrial foundation already laid before WWII. However, there should be doubt that the formulation and implementation of economic, industrial and technological policies since 1950 has played an important role. Occasionally there has been a close relationship between industrial and technology policies which partly explain the success. An attempt will in the following be made to provide an overview of some major technology policies and how they relate to the industrial policies. A few examples of successes and failures will also be described in some detail.

Technology policy includes measures which aim at domestic development of new technologies (including research) on adapting existing technologies, improving the capability of transferring technology and adapting it to local conditions as well as assessing technological developments consequences. The aim of technology policy is to improve the competitive position of domestic companies and technology policy measures consequently include instruments such as tariff protection for infant industries and allocation of capital at preferential interest rates to emerging industries. This broad definition also covers the system required to collect and analyze information required for understanding the changes in the technological environment.

Industrial policy covers a somewhat related set of instruments which in particular influence the environment. They include availability of

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*) The material contained in this report is mainly based on research carried out at the Institute for Policy Science at Saitama University during August 1983-July 1985. The author was at the time carrying out a research project with the title "Linking technology and industrial policies in high-technology sectors in Japan".

capital and interest rates, the permission to construct industrial plants, to obtain foreign licenses, and allocation of required foreign exchange for imports. The tentative definitions used above clearly indicate that there is a considerable overlap between industrial and technology policies in countries which have been able to sucessfully to promote its industrial development. This paper highlights the benefits of a competitive environment for a healthy development of industry in sectors undergoing rapid technological change.

Technology policy and industrial policy have never or seldom been discussed in separation when policy planners in Japan have been looking into the future and laying a groundwork for new achievements. The infrastructure, including the national research laboratories, has not been viewed in isolation but always as support for industrial and economic development. In fact the industrial development, or rather the market potential, domestically or internationally has played an important role in shaping the country's technology policy. Thus, it is possible to identify two major characteristics which have facilitated the integration of industrial and technology policies in Japan. First, the level of integration has not been attempted at the national level but rather at the sectorial or company level which is clearly brought out in the examples which are discussed in the report. Second, the mediators between national and private industries are mainly to be found in the government agencies, including some of the national research laboratories. These actors have often been quite successful in articulating the demand from a potential market into technology development efforts which support the industrial penetration of the emerging markets. The incentive has to be very considerable extent been shaped by the market which contrasts with the "planned economy", approach which characterizes technology development efforts in many developing countries.

INDUSTRIAL POLICY IN JAPAN

In order to understand the objectives and methods of Japan's industrial po:icy it is useful to summarize the different stages of economic development in the postwar period which can be divided into three stages.

The reconstruction period - 1945-59

Almost all industrial facilities were destroyed at the end of the war. The production of consumer goods was down to 30% of the prewar level and the manufacture of producer goods was down to an appalling low of 10%. Thus, it was seen as essential to rapidly re-establish key industries such as electric power, coal, iron and steel, and chemical fertilizer. The government as a consequence established a "priority production system" in order to allocate the limited raw materials, capital and foreign exchange resources to such key industries. The controls were gradually removed as the production base expanded. The Japanese economy had almost recovered by the mid-1950s and problems associated with material shortages had almost ceased to exist. Then followed a phase in which every means was sought to consolidate the industrial foundation and increase productivity in order to prepare the economy for international competition.

The rapid growth period - 1960-69

The major objective was to achieve rapid economic growth and at the same time open the economy to foreign competition. This was partly seen as a instrument which would promote the economic development in Japan but also demanded by the country's major trading partners. Japan joined GATT - The General Agreement on Tariffs and Trade - in 1955. The level of liberalization was in 1960 still quite low when the government adopted the Foreign Exchange and Trade Libealization Plan.

The level of trade liberalization had reached 93% in 1964 and was almost completed by 1973. The first steps toward capital liberalization were taken in 1967 but it is not until quite recently that Japan reached a high level of finance liberalization.

The strengthening of the international competiveness was seen as the major task during this transition period. At the time Japan still had to solve its balance of payment problems and catch up with the developed countries in most industrial sectors. The use of new policy measures during this period meant a transition from direct and regulatory measures to indicative and indirect ones. For this purpose a long-term vision for the industrial structure was developed in 1963 - the first one to be followed by a second one in 1971 and a third one in 1980.

The 1963 vision - prepared by the Ministry of International Trade and Industry (MITI) - encompassed criteria both for expanding the demand through changing the income elasticity and expanding the supply by increasing productivity. As a consequence the development of the heavy and chemical industries were singled out as a desirable industrial objective. Throughout the 1960s and particularly toward the end of the decade there was a rapid growth of investment - more than 20% annually - in the heavy and chemical industries. The level of investment generated further growth which was made possible by the high level of domestic savings. At the same time changes in fiscal policies and taxation further enabled the economy to sustain a rapid rate of growth. It should be noted that there was a drastic change in the energy balance with petroleum replacing coal as the chief source of energy - similar to the situation in many other countries. In Japan the energy transition necessitated structural adjustment in the coal mining industry in order to deal with the problems of mine closures and the resulting unemployment.

Consolidation period - 1970-79

The Japanese industry was able to considerable strengthen its competitiveness in the world markets through its development of heavy and chemical industries during the 1960s. At the same time the rapid build-up of these industries along the Pacific coast led to serious pollution problems in many places. The re-examination of industrial policy which culminated in the "Vision of MITI Policies in the 1970s" - prepared by the Industrial Structure Council of Ministry - should be seen in this light. It should also be noted that Japan had already by 1965 solved its balance of payments problem and has since then run a consistent trade surplus.

In the new vision, 1970, it was proposed that Japan should initiate measures in order to accomplish a shift to a knowledge-intensive industrial structure. This would then place a considerably lighter burden on the environment and also have the potential of offering a more meaningful path of modernization for the Japanese people.

Thus there was a considerable shift in the focus of industrial development during the 1970s. This decade in particular saw an increased growth in high technology sectors such as computers and numerically controlled machine tools. These and other sectors required additional resources for research and development. However, in other sectors such as textiles the activity was declining and many companies had to seek new lines of development, or disappear. This resulted partly from the transition to the floating exchange rate which led to the appreciation of the Japanese currency. At the same time the transition was also accelerated by the intensified competition from developing countries. It should also be noted that the two oil crises of the 1970s with drastic price hikes made Japan introduce on remarkably successful energy conservation measures.

Against the background presented above it is obvious that the aims of Japan's industrial policy has been shifting in order to adopt to the changes in the domestic and international economic environment. It is possible to identify five major categories of policy objectives. The first objective was to create an industrial structure which was able to efficiently meet the general needs of the population. For this purpose the market mechanisms was allowed to play a major role. The second objective was was to encourage and facilitate an international division of labour. This has meant that Japan has shifted its emphasis of industrial restructuring to areas in which it enjoys a relative advantage in land and labour productivity while at the same time reduce its involvement in labour-intensive industries.

It is also, at least in principle, accepted that Japan should pursue a horizontal division of labour with the other industrialized countries. In order to move in this direction Japan has in recent years reduced tariffs, facilitated access to its markets and simplified standard setting procedures in for certain categories of products - although far from complete. As a consequence of the consistent and increasing surplus in the balance of trade the Japanese government has actively encouraged private companies to step up direct investment in overseas markets and to participate in various forms of industrial collabaorative projects, including joint research and development.

The third objective has been to use technological breakthroughs to open up new possibilities for economic activity - a challenge which Japan shares with other advanced industrialized countries - in order to sustain the industrial vitality of the country. Japan has in this context been actively supporting the joint development of technology for which the Engineering Research Associations (ERAs) is the best known policy instrument. The ERAs are ad hoc research organizations which have been set up to develop industrial technologies which are considered important for future industrial development in Japan. The members are usually the major Japanese companies although smaller companies also participate. These collective organizations receive subsidies from the government which occasionally may - for future-oriented and risky projects - cover total costs.

The fourth objective is to promote Japan's economic security in a more comprehensive way. This would include measures to lessen the dependence on petroleum through energy conservation and the development of alternative energy sources. Another important aspect include the laying of a foundation in technological development and basic research which will safeguard the contined competitiveness of the Japanese industry under changing conditions. The fifth objective of Japanese industrial policy is to create a framework for enhancing harmony between industry and society. This would mean elimination of some of the damage to the environment and the over-concentration of industries and population in urban areas which has been characteristic of the rapid postwar industrialization in Japan. However, the basic philosophy underlying the five objectives is still to maximize the vitality of private enterprise by making efficient use of the market meachanism.

In looking at the specific details of the industrial structure policy in Japan it is important to realize that the major concern can be divided into two parts. One is the adjustment measures which aim at the scaling down of structurally depressed industrial sectors. The other is the promotion of promising industries which is the focus of the discussion to follow. Under ideal conditions, promising industries should emerge from free competition among of private firms. However, there are stages of technological development where private companies are reluctant or unable to pursue the necessary technological development. Reasons for this may the large risks involved or the limited financial and technological resources. Under such circumstances the government in Japan - through various agencies - has supported development projects which cover one or several of the following situations: 1. large risks; 2. long lead time for development; 3. large externalities through ripple effects throughout the economy; and 4. potential of satisfying important social needs.

Japan of course shares this concern with most other countries. It should be noted here that the Japanese government has not sought to nationalize private companies and has left the commercial development and marketing of products embodying the results R&D - supported by the government - to the private sector. The government support for R&D has on the whole been rather limited compared with the situation in other major industrial countries which - in contrast to Japan - support huge military development programs and usually also spend large amounts on big national projects which are often seen as carriers of national prestige. In a background paper from the Ministry of International Trade and Industry it is noted that

> "Japan's government financial assistance to private R&D projects is like a drop in the bucket. Take, for example, the government's incentives for development of the machinery and electronics industries. Since the mid 1950's, the Japanese government has been providing incentive measures for these industries under an enabling law. The major emphasis of these measures has been on (1) formulating a long-term vision of the desired future orientation of eligible industrial groups,

(2) extension of credit and tax incentives, (3) promotion of technological development, and (4) standardization of specifications and product categories. In 1978, the body of the law concerning the machinery and electronics industries was revised. As a result, the priorities and scale of government funding underwent substantial changes. The role of government was reduced to primarily formulating a long-term vision to guide the development of these industrial groups". (Features of the Industrial Policy of Japan, Japan Reporting MITI JR-5, Tokyo, March 1983, p. 13)

The existence of large amounts of bank loans as a means of indirect financing has been a distinctive feature for providing industrial funds in Japan - in particular for the investment in plant and equipment. The high savings in the household sector have through the financial system been invested in the industrial sectors which have at least partly been influenced by the suppliers of financial capital. However, such leading industries as automobiles, steel and electric household goods were all the time able to maintain a relative independence because they maintained links with a variety of industrial groups.

On the whole there is little doubt that the dynamic investment strategy adopted by the financial groups in the 1960s led to a channeling of funds to new growth industries. Government finance has in the past played an important role in the capital flow to various industrial sectors. The funds which originated from postal savings, life insurance and other such accounts have been controlled by the Ministry of Finance have been made available through the Japan Development Bank.

The supply of capital played an important role in investement for the capital-intensive industries in the early part of the high economic growth. The government share in the supply of new industrial investment funds exceeded 20% in the 1950s and the government finance constituted almost 40% in the four basic industries at the time - electricity, marine transportation, coal mining and steel. It was clearly understood that government finance was seen not only as a supplier of preferential credits but also as a catalyst to induce private sector to coordinate its financing of strategic industries - and has remained a catalytic instrument. Later on - in the 1960s - the Japan Development Bank started to provide loans for the development of advanced technologies which is exemplified by computers. The provision of finance from The Japan Development Bank to the strategic industries including the high tecnnology sectors can be termed as "forward looking loans". These have in recent years become relatively small while finance to sectors such as textiles, agriculture and in particular infrastructure has increased dramatically, which could be termed backward-looking loans. So, the role of finance as policy instrument to direct industrial development has declined in importance while technology initatives have increased in importance.

TECHNOLOGY POLICY INSTRUMENTS

The achievements of Japan's engineering industry, like colour TV, video tape recorders and more recently numerically controlled machine tools and robots must be traced to government initiatives taken already in the 1950s. Recognizing that the country had to develop production based on mental resources rather than natural resources two important laws were promulgated: Law concerning temporary measures for the promotion of machinery industry in 1956 and Law concerning temporary measues for the promotion of Electronics Industry in 1957. At the time the Japanese computer industry was certainly 10 years behind that of the US but the combination of government plans, the high rate of economic growth of the 1960s and the solving of a number of problems gradually raised the level of the industry's capability both in technology itself but also in production.

An interim report from the Industrial Structure Council of MITI in late 1971 called for a shift of economic management from growth pursuit to growth utilization. A "knowledge-intensive industrial structure" was seen as the proper industrial vision for the 1970s, which would attach importance to the industrial structure policies which emphasize such industries as:[1]

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1) The report was part of a larger study "The Basic Direction of Trade and Industry in the 1970's" commissioned by the Ministry of International Trade and Industry. The categories have been taken from Shinohara Miyohei; Industrial Growth, Trade and Dynamic Patterns in the Japanese Economy. Tokyo 1982, p. 31-32.

1. Research and development-intensive industries (computer, aircraft, industrial robots, atomic power-related industries, large-scale integrated circuits, fine chemicals, ocean development, etc); numerical control machine tools, pollution prevention machinery, industrial housing production, high-quality printing, automated warehousing, educational equipmen, etc);
2. High processing industries (office communication equipment,
3. Fashion industries (high-quality clothing and furniture, electronic musical instruments, etc);
4. Knowledge industries (information management services, information supplying services, education-related industries such as video, software, systems engineering, consulting, etc).

One of the Japanese economists, Shinohara, who has in an illuminating way written about the dynamic changes in Japan's economy, says:

> "Compared with the past slogans emphasizing economies of scale, large-scale investments, and building up of international competitiveness, the new policy puts emphasis on the necessity for diversification of industrial policies."

An illustration of this changed emphasis is evident in the overall planning for the electronics sector already referred to. In the 1970s the two laws mentioned above became focused on Specified Electronics and Specified Machinery Industries (Specified Industries Laws).This can be interpreted as a policy shift to emphasize the integration of industrial and technological policies. Special programs during the 1970s subsequently led Japan to become a world leader in the area of computer hardware technology including very large scale integrated circuits (VLSI) - particularly memory circuits. It is natural that in line with this historical background the Japanese government in 1978 established the Law Concerning Temporary Measures for Promotion of Specified Machinery and Information Industries (Machinery and Information Industry Promotion Law). See diagram below. Another pattern is that the future will see a concentration of resources in large joint projects - often involving joint ventures between governments and international firms.

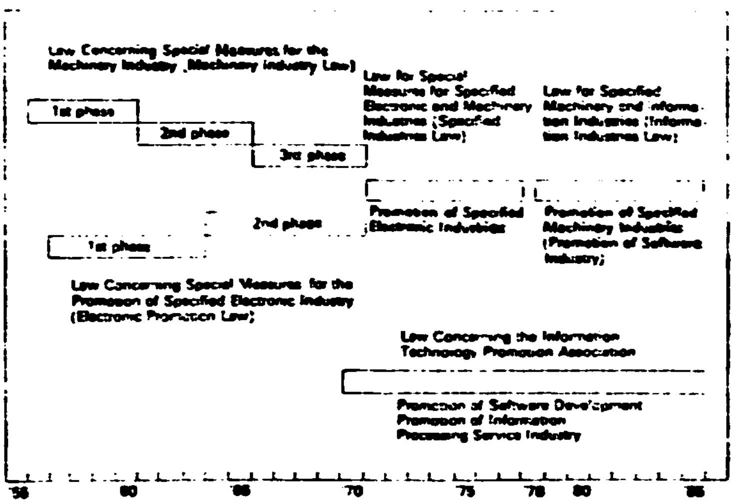
It should also be remembered that under its method of administrative guidance - rather than direct control - MITI attempted in the 1962-64 period to introduce "Designated Industries Promotion Provisional Measures". The objective was industrial organization of heavy industries based on neither free trade nor a controlled economy but a third method of "cooperation between public and private sectors" comprised of industry, financial interests, and government.

The reason for attempting to introduce these measures was the coming of capital or direct investment liberalization in Japan. So it was argued that strengthening of the international competitiveness of Japanese enterprises should be done by reorganization of industries, and encouraging centralization, amalgamation, and specialization of enterprises on a larger scale. However, the measures failed to receive the necessary support and the fact is that Japanese industries, without the help of this particular program, managed to continue to grow in strength.

However, Shinohara notes that

> "In the meantime, the leader in industrial development in the mid-1950s was without a doubt the machinery industry. In this respect, the Machinery Industry Promotion Provisional Measures enacted in June of 1956 (the MIP Law) and the Electronics Industry Promotion Provisional Measures enacted in June of 1957 (the EIP Law) could be considered epoch-making. These two laws divided the basic machinery, common parts, and export machinery industries into about 30 different kinds of machinery industries, and these industries, in accordance with promotion and rationalization programs, were supplied with special funds by the Development Bank and semi-governmental finance corporations. The automobile and related industries achieved the most outstanding development."

Figure 1: Progression of policy instruments for developing the electronics industry in Japan



Source: Computer White Paper, 1980 Edition. A Summary of Highlights Compiled from the Japanese Original, Japan Information Processing Development, p 33.

Shinohara also mentions that

> "The MIP law was revised a second and a third time, and finally in 1971 was replaced by the Special Electronics Industry and Special Machinery Industry Provisional Measures (the ME Law). As a result, in addition to he automobile industry, computers began to attract a great deal of attention as a potential growth industry. Under the ME law the hardware side of the computer industry was greatly strengthened, and the Japanese industry achieved the same level as that of the advanced nations."

The usefulness of this succession of laws for promoting the new knowledge-intensive industries or rather the electronics sector broadly defined has not come an end. There was no direct continuation when the laws expired in 1985. However, there was the establishment of a new regulatory or support framework in order to develop the country's ability in basic research. This was done for two different reasons. First Japan was criticized by all its major industrialized trading partners for giving unfair advantages to its emerging high technology industries. Second, the key policy argued that Japan had to find ways of bridging the gap in basic research whre the country sees itself as trailing far behind the industrialized West.

Categories of technology

In analyzing the new stage of Japan's technology development it becomes essential to differentiate between various types of technology. To this end I will use concepts taken from the writings of research colleagues at the Research Policy Institute.

Granberg and Stankiewicz make the following distinction:[1]

> "A technical solution can, as a rule, be analyzed in terms of (1) the function it is meant to perform (e.g. the supply of power); (2) the natural processes, or causal relations, properties or effects, exploited for this purpose (e.g. nuclear fission) - the satisfaction of any given functional need typically requires the coordinated use of many kinds of processes or effects; and (3) the design which links these processes into a functional whole (e.g. a particular reactor design)."

In order to clarify the transition stage and the new phase of development in Japan it is necessary to explain the three technology concepts in some detail. The first category, functional technology, is generally characterized by the use of existing technology in the identification and exploitation of new markets. Traditional examples are found in computer and aircraft technology. A more recent example is the video tape recorder concept where Japan has scored an enormous success in the export markets.

The third category, design technology, is characterized by developing new characteristics and "pushing" products into the market. Much of this design technology is found in Japanese consumer electronics. Finally we will turn our attention to the middle category of process of rather basic technologies which include nuclear fusion technology, enzyme engineering, laser technology, optical fibers and various aspects of semiconductor technology. This category often combines, through adaption, technologies which already exists in other applications.

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1) "The Development of 'generic technologies' - the cognitive aspects" in Technological and Industrial Policy in China and Europe. Proceedings from the First Joint TIPCE Conference by Ove Granstrand and Jon Sigurdson (eds), RPI, Lund 1981.

Naturally a given functional technology can be based on different basic technologies examplified by electronic, electrical and mechanical calculators. It is important to realize that many functional technologies require the integration of several basic technologies. On the other hand most basic technologies are generic in nature which means that they are applicable in several functional areas.

In the past Japan has extensively relied on the outside world in gaining access to basic technologies while the country has been very successful in developing and refining functional and design technologies. It has now become clear that the possibilities for outside reliance in the development of basic technologies has more or less come to an end.

The new approach is even more obvious in the new planning for "basic technologies". In 1981 AIST inaugurated the "Research and Development Project on Basic Technologies for New Industries" to promote orientation towards the future in the development of basic technologies. The aim is to combine all the abilities of industry, science and government (the national laboratories) and to conduct planned and efficient R&D on basic technologies.

AIST says that the project will deal with revolutionary basic technologies essential to the establishment of the new industries which are expected to flourish in the 1990s. The fields covered will be new materials, biotechnology and new types of electronic elements. From among these fields, twelve themes, which have been theoretically or experimentally shown to have a potential for applications in new industrial technologies, have been selected. The project will conduct research and development on these themes until they are ready for practical application in industry.

To exploit the full potential of private companies and to conduct efficient research and development, a parallel development system will be implemented. This system will involve appealing to many participants and having several companies carry out research and development using several different methods. The long-term plans (about 10 years) will be divided into periods of a few years each, with objectives set for each of these periods. The most suitable development methods as revealed through appraisals of progress and results achieved under these methods will then be selected.

ACTORS - THE POLITICAL DIMENSION

The earlier sections have presented industrial policies and the financial and technological policies. It is now time to turn the attention to the major actors on the scene - the Ministry of International Trade and Industry, the big private companies, and Liberal Democratic Party (LPD), the ruling party controlling the government. Naturally, it will only be possible to superficially deal with the interaction of the three major actor groups. However, this may still reveal the struggle which went on among them but also indicate the amount of consensus which has existed - in directing the industrial development in Japan. Finally, it will be necesary to add one more caveat. This section, although superficial, will mainly discuss the information technology industries.

Almost all observers agree that MITI has played an extraordinary role in promoting Japan's industrial development in the postwar period. The major policy instruments for this has been the indirect control of industrial financial resources and various means of regulation. The former has previously been very efficient due to the low level of capitalization of most major Japanese companies. The use of the second instrument has been more subtle because most regulations have been in the form of administrative guidance and not formally binding. However, due to the characteristics of the Japanese society these loose agreements have often had a binding character due to the consensus shaping discussing preceding the formulation of an administrative guidance.

Thus, MITI was able to guide or support the stages of industrial development since WW II. The first major shift was from light and labour-intensive production of textiles, simple machinery to capital-intensive and heavy industry with a focus on steel, shipbuilding, chemical and petrochemical industry which also included the car industry. The second shift was into knowledge-intensive industries during the 1970s which included the computer industry. The actions taken by MITI was on the basis of carefully studying the global markets, the major competitors abroad and carefullly analyzing the shifting conditions at home - labour costs, and productivity of capital and labour.

In second and third stages MITI officials, with the apparent blessing of the ruling party, LDP, seriously attempted to restructure two major industries - the car industry and the computer industry. The first case of the unsuccessful attempt to merge the car companies to build a "People's Car" has been told in many different contexts and will not be recounted here. It was strongly resisted by the companies and came to nothing. Similarly, MITI again some ten years later tried to restructure the computer industry into one major company. The precedent for this was seen in Europe when both France and Great Britain tried to establish national computer to stand up against IBM. The Japanese objective was naturally to create conditions for Japanese companies to fight against the American giant IBM. This story is less well known and will be presented with a few details, based on interviews with some of the actors at the time - in MITI, LDP and computer companies.

The Japanese policy makers in the late 1960s and early 1970s regarded IBM as the elephant and the Japanese computer manufacturers were seen as mosquitos. Altogether there were at the time six computer manufacturers - NEC, Fujitsu, Hitachi, Mitsubishi, Oki and Toshiba. The Ministry of Finance and LDP wanted a merger in order for them to be able to successfully compete with IBM. This thinking had, been strongly influenced by precedents in UK and France where the governments had created single national companies - ICL in UK and CII in France.

There was in Japan in those years a general sentiment that Japanese companies were not able to compete with IBM and the only way out was to merge the companies - along the lines in UK and France. A high-ranking MITI official objected to this idea, and the reason was the following. "Innovation is very rapid ... and accepting government funds" makes it difficult to make changes which are consonant with rapid technological change. There was a heated debate over a period of time within the ministries concerned and in LDP and eventually LDP asked MITI to take initiatives to organize the computer industry.

There were intensive contacts with members of the Japanese Parliament (Diet) and industrial leaders. This eventually led to a compromise solution which has the following thre major components of the government policy for the electronics industry (=computer industry).

First, it was decided that the computer industry should establish three industrial groups in order to jointly develop new computers. These groups were:

1. Hitachi and Fujitsu
2. NEC and Toshiba - only NEC had an interest in big computers
3. Mitsubishi and Oki - there was not such a keen interest in big computers in this group, which is particularly true for Oki.

Second, a computer rental company - JECC - was established in the 1960's in order to buy computers from the companies and rent them to the users. Japan Development Bank provided the capital for this operation. Third, government provided technology development funds for computer companies which is exemplified by the very large scale integrated circuits (VLSI) Project.

The computer industry in Japan has been succesful and this can at least partly be attributed to the healthy and strong competition which has existed between the the three industrial groups mentioned above. However, it was very difficult to work out the arrangements in the early 1970s and "many policy makers became sick", one of the interviewers said, through the long and very tedious discussions.

Many of the influential politicians had little understanding of the new technologies and the industry scene was quite difficult to comprehend so, the politicians were not certain how many computer makers there were in Japan. Some companies were making switching equipment for use in telecommunications, could also be seen as computer manufacturers. NTT at the time had a very keen interest in computers. So, the necessary connections were made between LDP, MITI and NTT - apparently in order to harmonize policy on the government side. The result was that a big national project against IBM was decided and a new law was initiated in order to support the new initiative. The instruments to be used were the Information Industry Law already referred to, low interest finance, licensing of software and providing NTT lines at low costs (for data transmission). The financial solution was improved with the money flowing to the computer companies from three different sources - bank loans, government grants and payments from the rental company.

One of the key figures at the time said in an interview that after that "everything moved". Subsidies (hojokin) was in the following years provided by MITI - after authorization by the Ministry of Finance (Mof). This support was "pushed" by LDP and MoF Budget Bureau and "there was a push every year". One of the politicians involved in the deliberation mentions that "everything moved so well" with the understanding that 50% of share of the computer market in Japan should be "reserved" for domestic makers.

There is little doubt that the computer companies were all the time opposed to and resisted the attempts of merging them into one national competitor - to fight against IBM. At the same time they were eager to get the various types of support that the government could offer as they realized that they were still the underdog - on the global arena. It is not altogether clear how strongly the Ministry of Finance and LDP pushed the idea of a merger. However LDP members argued that "in order to stand up to IBM it would be necessary to" have only one group of computer companies. It was suggested to MITI that this should be an administrative guidance to this effect . However, it was not conceived to be possible to have only one group so instead several groups were formed.

In sum it is possible to identify three circles (or groups of actors) which have been responsible for the growth of the computer industry in Japan. They are the 1. informal group, Giin Renmei, organized by LDP and supported by the government; 2. the government ministries and agencies and 3. the computer companies. There is no doubt that the actors were all striving towards the same goal - establishing a viable domestic computer industry in Japan - but had a very different understanding of requirements to achieve the objective. It appears that MITI has been holding the middle ground with LDD and MoF advocating a complete merger while the companies wanted to maintain indepedence. The calls for a merger has in all likelihood greatly contributed to a willingness of the companies to cooperate in joint development projects which has been a characteristic feature for a large number of government sponsored research projects. The compromise of having several groups instead of one is likely to have created possibilities for closer company copperation than would otherwise have been possible but still maintained a competitive sitution on the domestic scene which most observers consider to have a healthy impact on product development. Aside from the argument of competition MITI officials also argued that it would be difficult to achieve full merger because the various companies wanted to safeguard their own company- and product-specific data and would contribute them to any joint undertaking.

INSTRUMENTS

Government laboratories

The role of using the governments regulatory system has already been discussed. There has been little doubt that is has played a major role in not only promoting technology development but also in integrating technology and industrial policies. I will now turn to two major areas or sets of institutions which similarly seem to have played a major role in Japan's development of its industry and technological capability. They are the national laboratories which have had a direct supportive role and the engineering research association which have combined private and state efforts in developing technologies to suit industrial and national needs.

Japan has a vast network of national research laboratories for which the foundation was started to be laid at the end of the century.The national laboratories are often said to be "the brains of the government agencies" and have played an important role in Japan's development efforts. The same is true for the universities since the Meiji Restoration and it is often pointed out that officials cannot make good decisions without the support of universities and government laboratories.

Today Japan is improving its basic research capability although the perceived gap vis-à-vis the major industrial countries is no doubt real. It is worth noting that the attention now given to basic research has come into existence quite lately. In the early days the role of the national research laboratories was clearly geared to the needs of industry, and naturally to agriculture and other important sectors of the economy. This situation, with a few exceptions, prevailed in most the early period after WWII. This contrasts in no little way with the serious attention given to basic research institutions in countries like China and India where links to the industrial units have generally been very poor. An attempt will be made to illustrate the close and the changing relationship between a select of national laboratories and private industry.

It is in this context, as a meansof illustration it is important to include a few comments on the role of the the Electrotechnical Laboratory belonging to MITI and the four NTT laboratories. Before WW2 there was only one laboratory, (Teishin Sho), with responsibility for both power and communications technology with a very clear orientation to applied technology. Then came the changes in 1948 ordered by the General Headquarters of the Allied Occupation Forces that the basis of telecommunications and industry should be strengthened. As a consequence the laboratory sections for power industry and standardization was transferred to MITI which had the responsibility for industrial development. The remaining sections were to be controlled by the Ministry of Communications and later directly by NTT when the organization became "independent" in 1952.

The Electrotechnical Laboratory (ETL, under MITI) has had a very strong influence which comes from its research tradition and excellent researchers. There has been a very strong conflict inside ETL among electrical power people and the electronics people. It was far from the clear that the power people should yield because there was a continous and rapid increase in power consumption throughout the period since 1948. The Electrical Power Division was renamed Energy Division - 3 years before the oil shock in 1973. The conflict which was strongest during 1960-70 was in the main resolved around 1970 when the original name "Denki Shikenjo" was changed into Denshi Sogo Kenkyujo - which means Electronics Comprehensive Laboratory.

The laboratories of NTT have grown as the telecommunication network expanded and the number of subscribers grew from 1 million lines shortly after the war to around 45 million lines in 1985. Today NTT has an impressive complex of research laboratories which cover most technological and scientific fields of relevance to the telecommunications sector specifically but more generally to information technologies. In recent years the laboratories have added an increasing amount of basic research which - although clearly within expected fields of application - is exemplified by the new VLSI Research Laboratory which was opened in early 1983.

A few years back the NTT laboratories and ETL combined constituted 40% of Japan's research resources in the telecommunications sector - in terms of budget resources and research manpower. In addition there were also major other government laboratories such as those operated by NHK (the national broadcasting corporation), KDD (the company responsible for international telecommunications), National Railways Laboratory etc.. See table 1. In 1982 the estimated resources of the major private telecommunications companies - NEC, Hitachi, Fujitsu and Matsushita were considerably smaller. If looking more broadly at research on information technologies the dominance of the government sector is less pronounced - although having a very significant share of total R&D resources. The situation is now changing as the private companies are in good position to invest in their own research and also eager to do so.

Table 1: Major telecommunications laboratories in Japan - manpower and budget (1982)

Laboratory	Manpower	Budget Ymillion
Electrocommunications laboratories (NTT)	3,700	86,000
Electrotechnical Laboratory (AIST/MITI)	720	9,000
Nomen nescio	460	4,400

continued

National Railways Laboratory	700	8,900
NHK Laboratory	360	7,000
KDD Laboratory	180	6,900
Electric Power Central Lab.	767	20,000
NEC Communications Lab.	1,000	30,000
Hitachi Central Research Lab.	1,200	14,000
Fujitsu Research Laboratory	990	13,000
Matsushita Laboratory	220	3,000
TOTAL	10,297	202,200

Source: Kagaku gijutsu eno teigen, by Yoshimura Toru, in Sangyo seisaku to kokusai kangei chosa kenkyu hokokusho, Sangyo kenkyusho, Tokyo, April 1984

Before turning to the question of relationship between private company research and that in government laboratories it may be relevant to make a few additional comments on NTT laboratories because of their relative importance. The functions of all four NTT laboratories are to serve the telecommunications of Japan. It is seen as necessary to have a long lead time as it takes very long time to integrate new services and the lifetime of equipment is presently around 15-20 years. Consequently, new systems cannot be implemented until around the year 2000. The networks may actually change while the technology is developed for original systems. Thus, it is necessary for NTT to study the long term technological trends in order to be able to provide good services to the public - which gives the justification for doing basic research.

The four laboratories are separate entities but work closely together under central leadership - the engineering bureau of NTT. Now, it must be remembered that NTT does not have any production facilities and all equipment is bought from the outside. Thus NTT needs in-depth capability to evaluate the products and systems to be procured. This is the reason for the close relation between the laboratories and the service bureaus. This can be compared with the relation which, at least in the past, existed between AT&T and Western Electric on one hand and the

Bell Laboratories on the other - in the US. The situation is somewhat similar in the France with PAT and KUNET. Preparations are now underway of reorganize the laboratories as NTT became a semi-private organization on April 1, 1985.

The role of joint research has changed as the teacher-student (sensei-seito) relationship which existed in the decades immediately after the war relationship no longer applies. This can be exemplified by the development of very large scale interated circuits (VLSI) which took place in three stages. First the 16 kB was developed, then the 64 kB which has been completed. The present third stage have targets which are somewhat different as the focus is now on the development of the basic technologies - e.g. for achieving 1 micron line-width in which ultra-precision processes have become very important. So, this is an area which exemplifies the changing relationship between NTT and the private companies which is now characterized by sharing rather than transfer. In the past NTT formed joint research groups which has now been replaced by exchange of information and experience - a development which started 3-4 years ago. Furthermore, NTT is also expanding joint research to new companies which is exemplified by its relations with IBM.

The presentation above reveals that the government research resources have in the past been very important. At the same time it becomes clear that the government research resources will in relative terms be less important in the future. This means that the traditional sensei-seito relationship is rapidly being eroded for which there are two major reasons. The private companies have increasingly come to master very complex technologies through their own research and are in a comparatively better position to fund their research through allocation from expanding sales. Second, the government laboratories cannot expect that their funding will go on increasing which is alo in doubt for the important NTT laboratories. This aspect also has consequences for funding expensive equipment in emerging new areas of technologies. Thus, it is possible to see a new situation of more equal relations between the two parties and in all likelihood relations which will be limited to basic research rather than applied research which has been the case in the past.

It is natural, against this background, to find that there is only one industrial sector where the use of the engineering research associations have been both consistent and of a long term nature. This sector is what might be termed the information technology sector with a focus on computers, integrated circuits and related devices. The first ERA in the series of altogether 14 started in 1962. The most important computer development ERAs may actually have been the three associations in 1972 which achieved the grouping of the companies in three pairs. The next important one is the VLSI Project which started in 1976.

It is only recently that the major consumer electronics companies like Matsushita, Sharp and Sanyo have joined the the government-sponsored research projects. It is also of interest to note that two important projects have in recent years been organized as foundations and not as research associations. They are the Fifth Generation Computer Project and three electron device projects within the Future Generation Basic Technologies Program, already referred to.

COLLECTIVE RESEARCH (engineering research association)

An important instrument for linking industrial and technology policies are the engineering research association (ERA) which pool government and private industry resources for specific development projects. The association were initially used in the catch up phase in the early 1960s. The engineering research associations underwent a distinct change as a policy instrument when they were reintroduced in the early 1970s after a lapse of more than 5 years during which period no new ERAs were established. The new phase saw a new focus on more advanced research and much wider product technologies than during the earlier period with a smaller number of companies, on the average, participating in each ERA which have also generally become of shorter duration. In more recent years an element of basic research has become very prominent in several ERAs although others aiming at the revitalization of basic industries still have a character of the older type of collective research.

Although the ERAs is only one of many policy instruments I will use them to illustrate the integration of industrial and technology policies. The ERAs have the following two major objectives:

1. To obtain or achieve industrially relevant or significant technical and/or scientific research results.
2. To trigger and/or stimulate industrial companies to initiate or accelerate industrial research.

In the early period of using ERAs - in the late 1950s and early 1960s there is little doubt that the first motive was wholly dominant and it has remained so far certain categories of ERAs. In the second ERA period - since the early 1970s - the second motive has become increasingly important and this has also prompted a wider use of variables in promoting joint research. The variables are:

1. Form of organization.

A major requirement is that the number of participants must be kept rather low for ERAs involved in advanced research. Otherwise it is difficult to maintain a sufficiently strong leadership and direction of research. Second, the members can be selected to include also users or suppliers - the selection of which is important as it influences the possibilities of establishing efficient linkages. The research association can include various types of joint facilities such as laboratories - exemplified by the VLSI and the Optolectronics Projects - or joint design centers when careful coordination of a number of projects are necessary. The latter situation is exemplified by the jet engine and flexible manufacturing system.

2. Level of funding.

The government funds can cover more or less total costs which has been the case in all national projects sponsored by AIST - the technology development agency of MITI. In many other ERAs the government and the members of the ERA share costs which is basically the principle for the early introduction of ERAs and is followed for collective research in most countries in W. Europe.

3. Timing and direction of research

This may in fact be the most important variable in initiating research. Naturally it depends on a keen sense of understanding both the situation abroad and domestically - so "intellegence operations" are critical.

It is similarly possible to list the benefits of the engineering research associations:

1. Cost-sharing or risk-sharing for the participants is obviously of relevance. For projects fully sponsored by the government this aspect is only of mrginal relevance - unless researchers within certain disciplines are a scarce resource for the participating companies.

2. Economizing on scarce research resources by pooling resources in joint facilities. This may include both research staff and equipment.

3. Demand articulation and obtaining relevant product or equipment specifications may be a very important element in ERAs which have members both from the supplier and user side. This may in fact mean that the research orientation is negotiated in order to suit the demands of the market.

4. Obtaining guidance on the direction of technological advance may be a benefit for projects where the timing for moving into new industrial technologies is an important element.

With the mentioned variables and possibilities it may be asked under what conditions does joint research come into existence and under what conditions it is viable. First, it should be noted that joint research is found in both industrially mature sectors and in rapidly developing sectors. The prevalence of the second category has in the past been particular for Japan but is now being applied in many other industrialized countries. Second, the modern industrial enterprise accepts joint research when the benefits of coordination and subsidy clearly reduces risks and costs for subsequent product development. Third, the advantages of internatizing the research stage jointly with other companies does not arise until the risk of unforseen technological events and the magnitude of required resources pose problems which are more than offset by risks associated to carry out research jointly with competitors. Joint research in rapidly developing technologies will mainly be organized for big projects and is likely to favour large enterprises with a good foundation in R&D with the consequence that they increasingly dominate the industrial scene. Finally, it should be noted that projects which are completely financed by the government may not truly be joint research - unless members also make contribution of scarce research staff or exchange information within the membership group. Thus, it may turn out that several ERAs are not joint research but only an efficient way for the financial arrangements of subsidies.

I will now return to the linkage effects which may efficiently developed with an engineering research association with the proper focus and the right composition of members. This will in fact be illustrated by drawing on the experience of the VLSI project in which membership was limited to the five major producers of integrated circuits or formally to the assumed makers of mainframe computers who were supposedly to benefit from the Project.

The five major companies - NEC, Toshiba, Hitachi, Mitsubishi Electric and Fujitsu no doubt benefitted from the Project. However, the most important elements, was the timing and direction of the project which set the course for future long term development of integrated circuit technology in Japan. The linkage effects on other actors of the industrial system - for integrated circuits - may in fact be most important result of the VLSI Projects.

Thus, it is possible to see a number of ripple effects flowing from the VLSI Project. First, the material suppliers which were already fairly well established were further strengthened. Second, the equipment makers which were already strong in backend equipment established an almost equally strong position in front-end equipment - exmplified by IC printers. Third, the several sub-suppliers climbed into a very strong position.

Fourth, there are today several indications that the most important long term effect on the IC industrial system is the emergence of industrial groups around Toshiba and Hitachi and possibly also NEC which aim at the capability of delivering complete sets of process equipment for making very large scale integrated circuits. So, Japan may in the future have two or even three of maybe less than ten companies worldwide which will have this capability. Such an effect could hardly have been foreseen as a specific objective at the time of planning the Project, but anyhow seems to have its roots in the VLSI Project.

EXAMPLES OF PRIVATE COMPANY DEVELOPMENT

We will now present a couple of examples which show the behaviour of private companies in their cooperation with government agencies in their diversification efforts. One is a major glass manufacturer and the other is a highly specialized producer of testing equipment for integrated circuits. We will first discuss the latter, Takeda Riken, which has benefitted from close relations to NTT.

Takeda Riken - collaboration with NTT

Testing equipment has with the increasing complexity of integrated circuits become a major investment item when setting up a new manufacturing plant for integrated circuits. A major reason is that the a large number of functions have to be tested at very high speed and the days are long gone when testing could be done "manually" by looking through a microscope and simple "electric" testing. Thus, the market for testing equipment has in recent years grown rapidly. At the same time testing equipment has in itself become a high-technology item. A Japanese company, Takeda Riken has scored astounding market successes in the early 1980s and we will now trace some of the technological roots of that achievement. From all available evidence it appears that the combination of a deep technological partnership with NTT Laboratories combined with a new leadership for at the time financially ailing company are the major ingredients of this succes story.

MITI has in many technology development projects been the financial and intellectual sponsor. However, there are a very large number of cases where NTT and its technologically advanced laboratories have played the same role, and Takeda Riken exemplifies such a case. The joint research carried out between NTT and private companies is of a different nature than the MITI-sponsored projects. First, no financial grants are given. Second, there is frequent exchange of research personnel betwen NTT and company laboratories. Third, patents are generally owned jointly(?) by NTT and the companies concerned. Fourth, the companies are usually compensated through subsequent orders. Orders are forthcoming because NTT usually asks for research cooperation on the basis of market analysis, fixed plans and carefully worked out specifications. In reality joint research may occasionally mean that NTT pays the full costs for a prototype which results from a joint research project. On other occasions it may mean that NTT encourages development of new applications for which it has completely misjudged the future market - which is the case for the DIPS, distributed computer power over the general telephone network.

The development in Japan of LSI testing systems started around 1968 when MITI provided financial support to Takeda Riken to develop a 5-10 MHz tester. The result was not very encouraging as the company's technology was "not so good" and at the market was completely dominated by US manufacturers. As a consequence NTT became interested in sponsoring its own development of a tester.

NTT first negotiated with US manufacturers - in particular Fairchild - in order to arrange for joint development between NTT and the US company. Detailed plans including suggestions for architecture of the system had been worked out by NTT but long discussions with Fairchild - six months - failed to achieve any agreement. Major reasons for this was the fact that NTT placed serious restriction on joint research and Tokyo Electron Ltd - the agent of Fairchild in Japan - was not willing to make the necessary compromises.

NTT then turned to Takeda Riken to explore the possibility of joint development efforts. As a lucky coincidence it turned out that Takeda Riken was at the time in the process of formulating its own plans for the next generation test system. None of the other test system manufacturers which include Ando (NEC), Anritsu and Minato were considered because only Takeda Riken had reached a sufficiently high technological level. Takeda Riken had developed a reputation as a high technology instrument maker. Then came the consequences of the oil shock in 1974-75. The company's R&D slowed down and development efforts within the company was loosing momentum. Thus it was decided to go for the highest technology. Second, NTT had requested functional testers which would manage speeds of 100 MHz.

At this time MITI was planning its VLSI Project and Takeda Riken negotiated with the Ministry and found out that no tester project was included. The MITI-sponsored VLSI project no doubt had the ambition to evaluate the VLSI circuits but had not considered it necessary to include special sub-projects for testers. Under these circumstances it would be a big burden for Takeda Riken to develop the 100 MHz tester on its own. As a consequence the company was eager to enter into discussions with NTT to find out if conditions existed for a joint project - which proved to be the case. Thus in early 1977 the tester project started and the tester was completed in 1979.

The testers commonly used at the time were testing at a speed of less than 10 MHz and could not handle circuits with more than 110-128 pins. The test systems available were generally of a poor quality , relatively inexpensive to manufacture but were sold at high prices. Thus it was necessary to have an almost completely new approach to the next generation of testers. NTT made relevant suggestions for changing the architecture of a tester to be developed. Takeda Riken was also requested to change their fabrication system which, among other things, meant that the company had to switch to high quality LSI circuit boards already widely used by the manufacturers of mainframe computers. At this time Takeda Riken sent a new managing director and Fujitsu was instrumental in implementing the new ideas at Takeda Riken.

Fujitsu and NEC was at this time developing LSI for NTT which had placed the condition that the new circuits should be tested with the new Takeda Riken system. Detailed requirements for the new tester was collected from major VLSI manufacturers such as NEC, Fujitsu, Hitachi and Oki. However, the fundamental requirements were eventually set by NTT after several meetings to work out the joint specifications.

The tester project started in 1977 and was fully completed by 1981, although expected to have been finalized in 1980. The total costs of the tester project including an operating pilot system amounted to 1 billion yen. This amount does not cover costs undertaken at NTT laboratories related to the project nor does it include costs for related research undertaken by Takeda Riken. Thus, it can be estimated that the total projects would be approximately two or three times as much. The development of the high speed tester resulted in 15-20 patents which today are held by NTT and available to other companies if they so desire.

Using the same architecture and circuit technology Takeda Riken completed the development of a 40 MHz memory tester in 1980 which was followed by the 40 MHz logic tester in 1982. The follow-up developments were carried out very quickly which was possible because most problems had already been solved by developing the most advanced tester - much earlier. The less advanced testers are today providing the bread and butter lines for the company.

Today Takeda Riken generates about 65 % of its sales from the testers - with the strength in memory testers. The value of deliveries of testing equipment which was US$ 3 million in 1975 has grown to US& 130 million in 1983. The development of the company's strength is evident from Table 2. below which shows the market shares for the major manufacturers of LSI/VLSI test equipment. Two Japanese manufacturers Ando and Takeda Riken have increased their global market share from 7% in 1975 to 26% in 1983 - with Takeda leading over its domestic rival with two to one. When considering only memory testers Takeda Riken (TR) is clearly the leader with 30% of a global market in 1983 - worth US$ 170 million. The three major US manufacturers have in the meantime lost their dominance and together have less than 50% of the market - for all types of LSI/VLSI testing equipment.

Table 2: Worldwide market shares for LSI/VLSI testers and memory testers (percent)

Company	Year								
	1975	1976	1977	1978	1979	1980	1981	1982	1983
Fairchild	36.4	33.7	37.5	41.6	46.8	40.5	37.6	34.7	30.4
Tektronix	13.4	15.4	12.5	11.5	10.1	11.2	9.1	8.7	6
Teradyne	11.2	12.5	9.6	8.7	6.7	8.9	7.8	7.6	12.4
Ando	2.0	3.4	3.0	2.9	3.3	4.8	5.9	8.7	9.6
Takeda Riken	5.1	6.2	9.6	10.3	10.8	12.8	16.6	17.5	19.3

Takeda Riken has now almost completely closed the market gap vis-a-vis the leading US manufacturer of LSI/VLSI Tester & Memory Testers - Fairchild. Their respective market shares were 24.6 and 26% respectively in 1984. Fairchild reached its peak in 1979 with a market share of 46.8% and its dowhill movement is continuing. The global market share for Takeda Riken and Ando has increased from 18% in 1979 to 33% in 1984 while the three major US companies which also includes Teradyne and Tektronix has decreased from 65% to 45%. The other Japanese tester company Ando is also growing and is now expanding its sales outside NEC which is the controlling company. The tester markets - in terms of sales - is growing at approximately the same rate as the VLSI market which in 1984 expanded by approximately 50% although considerably lower in 1985.

The main customers of Takeda Riken are all in Japan which include the major electronics companies with the exception of NEC which is supplied with testers provided from its captive supplier and Mitsubishi which obtains deliveries from several manufacturers. The export share is presently around 20% and major customers in the US include AT&T and IBM. The export orientation can hardly be increased because of trade friction - and presently the slump in the US VLSI market makes such expansion more difficult.

Export share
1981 over 10%
1982 16%
1983 20%
1984 17%
1985 around 17%

The following four factors are all important in explaining the underlying reasons for the success of Takeda Riken:
1. Takeda Riken (TR) possessed advanced technology for electronic measurements.
2. TR also had technology for high speed counting.
3. TR established a very conscious policy to develop and produce products which were very reliable.
4. The company made a major decision to invest in tester R&D on a major scale - which was supported by NTT.

The latter factor coincided with a major expansion of the VLSI industry in Japan. Today TR considers itself to have a lead over US companies of 4-5 years. The decision to develop advanced tester had been seriously discussed but it was uncertain whether the financial resources were available so the interest of NTT to support tester development at Takeda Riken came at a very opportune time. The final decision to engage in the joint development project was taken at the end of 1976 or early 1977 after a discussion period of approximately one year. The joint project proved to be an excellent clearinghouse for information from the wafer makers as NTT was involved in joint development with several VLSI makers. However, NTT was not influencing their decision to buy testers from Takeda Riken, it was emphasized in interviews. But it is possible that the testing requirements might have been specified in such way that testers from the company would be the logical choice if Takeda Riken was succesful in its product development. The company may have been helped by its long standing relationship with NTT as the president/ founder, Mr Takeda, came from NTT in 1954.

The involvement of Fujitsu in 1976 was a very critical event for the future development at Takeda Riken as the company was experiencing serious difficulties in product engineering and was in a very difficult financial situation. As a consequence, Dai-ichi Kangyo Bank asked Fujitsu to assist in the reorganization of the company and also to become a stockowner. Furthermore, Fujitsu was also asked by MITI provide the necessary assistance to turn the company around in terms of management. Fujitsu agreed to take on a major role in the reorganization of the Takeda Riken company.

Asahi Glass - An example of diversification

Asahi Glass which is one of the three major glassmakers in Japan is today on the verge of establishing a strong foothold in electronics. The company's name is in fact misleading as its strength is not only in glass but also in chemicals and ceramics and the name may be even less revealing for the future. The pattern of diversification can be clearly traced to the company's origin in glassmaking and an attempt will be made to show how restructuring and technological rejuvenation takes place within a Japanese company.

Asahi Glass today employs slightly less than 10 000 people and employment has remained at that level for almost 20 years with a peak in 1973 with 11 400 employees. The value of total sales amounted to 541 billion yen in 1983 which means a tenfold increase since 1964. The rate of return on investment - according to analysis by Nihon Keizai Shimbun - has over the past 20 years remained between 5 and 6 percent with exceptional dips around 1973 and 1979. The figures for rate of return compares quite favourably with those of other major companies in Japan. The figures indicate a company which has expanded rapidly over the past 20 years - an expansion which has meant remaining in traditional product areas but at the same time entering new areas without any serious disruptions in employment or profitiablity.

The major development resources have been the company's central research laboratories in Yokohama which presently employs more than 600 people. One third of them do research related to chemicals, one fourth each are working on glass/building materials and electronics respectively. The remaining researchers - approximately 10% work on ceramics. The total research staff at Asahi Glass including the divisions is altogether approximately 1,100. The total R&D budget for Asahi Glass is presently around 3% of total sales which would mean slightly less than 15 billion yen in 1983. The corresponding ratio was 2.5 % in 1975 and is expected to increase slightly - to roughly 3.5% in 1990.

The use of R&D resources are being affected by two trends. First, more and more research is being carried out by the divisions. The central research laboratories in 1975 accounted for 80% of total R&D expenditure with the remainder in the divisions. Today the balance has shifted quite dramatically with 55% of R&D in central laboratories and 45% in the divisions. This has in fact meant that the central research laboratories have become more future-oriented with less and less responsibilities for immediate applications. This is illustrated by the new electronics laboratory which is being constructed in early summer 1985. The focus of the new laboratory will be in the following areas. First, to concentrate the development effort of electronic materials and devices on the new laboratory in accordance with the company strategy to strengthen the electronics orientation. Second, the new laboratory will develop displays, optoelectronics and IC related products with overall coordination of relevant divisions.

Diversification of the production lines of Asahi Glass clearly reveal a keen sense of understanding market changes and new technological opportunities. There is no doubt that technology transfer has on occasion played an important role in the past. Asahi Glass collaborated with Glaverbel in Belgium and Massglass in Holland when it started to manufacture flatglass with a new process (Fourcault). A similar cooperation was establishied with Pilkington in England when the float glass process was introduced. Corning Glass in the US also played an important role when Asahi Glass ventured in TV bulb production in the mid-1950s. Such technology transfer agreements have been important in the initial phase and lasted for some ten years. However, in almost all cases has the transferred technology been improved upon by Asahi Glass and in many cases provided a new basis for independent development within the company. It is of interest to note in this context that Asahi Glass which 30 years ago was at the receiving end of TV bulb technology has today (1985) entered into agreements with companies in China to build up their capability in this field.

Asahi Glass is today delivering sheet glass used for housing and buildings, windshields and other glass products to all major car manufacturers in Japan. The delivery of such products constitute a major share of the sales from the glass division. Another major glass product is TV bulbs where Asahi has a leading position in Japan, while also supplying export markets. It is of interest to trace the development of the TV bulb technology. Some 30 years the Japan Broadcasting Corporation decided to develop the TV-network in the country. At the time Japan was industrially in many ways still a developing country lacking the manufacturing capability for many of the components used in TV sets - included the cathode ray tube. So, in 1955 NHK - the Japan Broadcasting Company - decided to promote the CRT technology by supporting the development of key technologies. As a consequence development contracts were given for the glass bulb itself, the shadow mask and the phospor chemical used for inside coating. The latter development was done by Dainippon Tokyo, the shadow mask was developed by Dainippon Insatsu which today has a leading position in the global market for this product. Asahi Glass was given the development contract for the TV-bulb technology which led the company to enter a license agreement with Corning Glass in the US which was then a technology leader in this field. Subsequently, NHK was involved in a technology transfer to the major consumer electronics companies like Matsushita, Toshiba, Hitachi, Mitsubishi Electric and NEC.

Asahi Glass entering into the TV-bulb business was very succesful which can be attributed to the following several reasons. First, Asahi Glass was the first company in Japan entering into the manufacture of TV-bulbs, cooperating with NHK and major electronics companies. Second, the company rapidly mastered the production technologies introduced from Corning Glass Co. Third, the company had a long history of glass manufacturing. Finally, the rapid expansion of TV broadcasting in Japan provided as basis for CRT and TV-bulb technologies to make rapid progress. Furthermore, Japanese people's rigorous expectations and evaluation of the TV picture quality largely stimulated the progress of CRT and TV-bulb technology in Japan. These factors combined have brought about today's excellence of Asahi Glass in this field worldwide.

The highly developed competence in TV-bulb technology has also had an influence on the company venturing into liquid crystal displays (LCD) - in combination with a number of other factors. It was already in 1969 seen as desirable for Asahi Glass to diversify out of TV-bulbs. Keeping track of developments abroad the company received a very early report from its New York office telling out the RCA achievements of developing a flat display. The internal report was accompanied by a strong statement saying that LCD is going to become a major product. Back in Yokohama and in Tokyo the engineers and researchers at Asahi Glass tried to come to grips with what kind of technologies were really involved in a liquid crystal display. It soon became obvious to people in Asahi that the company in fact had unique qualifications to enter this new field.

A liquid crystal display consists of layers of thin electroconductive liquid, glass and crystals and the required electronic devices to drive the device. Asahi Glass already had the competence in thin electroconductive glass because the company had in 1950 developed transparent electroconductive glass which were used for heating panels. It was also quickly realized that the liquid crystals could be manufactured in the chemical division of the company. The development started in 1969 and the first prototype - for watches - was ready the following year. A pilot plant was built in 1973 and in the following year Mitsubishi Electric Corp. joined forces with Asahi Glass to expand production. The merging of interests came from the fact that Asahi Glass provided the basic technology while the other company had the competence in mass production technology relevant for this kind of product. This was the basis for establishing a joint company - OPTREX - in 1976. In the process Asahi Glass, or rather Optrex, has become a major LCD manufacturer in a group of four companies which also include Hitachi, Epson and Sharp. The further development of products is basically carried out within Asahi Glass focussed on improved, larger displays, improved parameters for response time, temperature and moisture resistance. A major line of development is presently focussing on making colour displays. A closely related development is centering on an alternative type of display - electrochrome displays (ECD) - which offer much higher contrast and are, among other things, suited for public displays where low power consumptive rewriting is not as important as in many other applications.

Asahi Glass has earlier experience of staying in close contact with potential customers when developing new technologies. Thus it should come as no surprise that the two major groups of customers for LCDs are the automobile manufacturers and the consumer electronics companies to both of which Asahi Glass has intimate relations through its deliveries of windshield glass and TV-bulbs.

Similar to the development of new glass products there is also an internal logic to the new products which have emerged within the chemical division. The starting point was the decision to manufacture soda ash within the company. The raw material is seawater salt (sodium chloride) which is subjected to electrolysis. In order to concentrate the salt it was eventually found most effective to use ion exchange membranes the development of which started in 1950. This technology was firmly established by 1963 - at the time using traditional hydrocarbon membranes (Asahi Glass brand name: Selemion).

The electrolysis of the salt concentrated from seawater has traditionally been carried out with mercury cells. However, the serious pollution problem arising from mercury prompted the government in 1973 to order the phasing out of this technology. Naturally this forced the caustic soda companies - producers of 3 million ton annually - to rethink their situation. The alternative production technology was at the time asbestos membranes but the quality of caustic soda would suffer. So, both Asahi Glass and Asahi Chemical, the latter with no relation to the former, independently decided to develop high performance ion exchange membranes even under the highly corrosive caustic soda environment.

It was not possible to use hydrocarbon membranes and fluorine-polymer membranes which could stand the tough environment had to be developed. The development was succesfully completed in 1975. The research actually required the merging of three fundamental technologies. First, it was necessary to apply the knowledge from fluorine chemistry in which Asahi Glass had been active since the mid- 1960s. Second, the new membranes also required deep insights in the electrolysis technology. Third, ion exchange technology was also essential and the company had already mastered this technology in the early 1950s. A number of problems were encountered and succesfully solved. First, newly designed perfluorinated ion-exchange membranes (Aemion[R]) were produced by combining technologies of fluoropolymer synthesis with film processing. Second, a novel electrolytic system called AZEC (Asahi Zero-Gap Electrolytic Cell) was achieved by using Aemion.

Today this new membrane technology is fully installed not only at Asahi plants but also at many other companies such as Nippon Carbide and Kashima Denkai. Furthermore the company has become a leading supplier of fluor carbon membranes and the only competing supplier is duPont in the US. Quite surprising is the effect that the membrane technology is more economical that the alternative process using mercury cells or asbestos membranes. The energy consumption has been reduced by almost 40% from the prevailing 3,300 kWh per ton of caustic soda (NaOH).

Thus the government regulation of 1973 has had three beneficial effects. First, it has reduced the energy consumption in an important industrial process. Second, it made a Japanese company become one of the leaders in a new technology. Third, it eliminated an industrial hazard although this required much longer time than originally expected. In fact, all mercury cell production will not be faced out until 1986 which should be compared with the originally suggested phase-out period of 2-3 years - announced in 1973.

The pattern of diversification as illustrated above is of course not atypical for the industrial scene in Japan. Rather it is the general pattern for many companies. When limiting our discussion to the three major sheet glass companies - Central Glass, Nippon Sheet Glass and Asahi Glass - it is possible to see certain differences. Nippon Sheet Glass has established a leading position in optical fibre technology while Asahi Glass has made a major inroad into liquid crystal displays and membrane technology. Central Glass which is a newer company is still mainly in glass business itself. Thus, Asahi Glass may be ahead of the other glass makers on the road to diversification and into the future of electronics and other high technology sectors. The reasons for this are twofold. First, a long term company strategy to diversify its business area supported by government initiatives such as those of

NKK and the decision to move out of mercury cells in soda ash manufacture. Second, the company has a variety of technologies in glass, ceramics, chemistry and over ten years experience in electronics which have been combined into new products.

CHARACTERISTICS OF TECHNOLOGY POLICIES IN JAPAN

The earlier sections have clearly shown that Japan has gone through a series of development stages in which industrial policies have succeeded each other. It has also been shown, implicitly, that there has occassionally been a close linkage between industrial and technology policies. An attempt will now be made to describe more systematically the various technology policy instruments instrument which have been used.

Similar to the discussion on industrial development it may be useful to use a categorization of stages. The first period would then be a period of two decades - 1950-69 - when technology imports played a very important role and Japan was basically concerned with catching up through adaptation of imported technologies. Then followed a second stage - 1970-79 - during which the Japan with its companies and laboratories embarked on a more independent development of industrial technoligies. This has now been followed by a third stage which started around 1980 in which a capability in basic research has become increasingly important. We will now describe the various stages.

The catch-up phase 1950-69

The defeat of Japan in 1945 left the country's industrial structure almost completely devastated. Furthermore, the Allied Powers decided that the previously very important industrial comglomerates (zaibatsu) should be dismantled and Japan was in a number of sectors - including aircraft - not allowed to re-build its industrial competence. Thus Japan was in 1950s struggling along to provide its ppopulation with bare necessities and trying to build up its export potential. The companies were at the time small, ill-equipped and the technology level was low. At the time the provision of trained manpower was an important task as was the low level technology transfer from the various government laboratories. Technology import control, at an early stage, became an important policy combined with general support - outside and inside companies - to efficiently absorb the acquired technology. The technology import throughout this period was thoroughly screened and directed to sectors which was considered essential for various national objectives. The earlier discussion on financial instruments clearly indicate that the industrial policy instrument were linked to the same national objectives. Furthermore, it should be noted that procurement for telecommunications, railways, electricity generation etc. came to play an important role towards the end of this stage. The engineering research associations were introduced in the early 1960s withe the aim of rasing the technological level among various cooperating industrial groups - often with only token financial support from the goverment. The result from all these efforts that Japan rebuilt a new industrial sector which at the beginning of the 1970s was able to stand up to international competition in several sectors, exemplified by steel, shipbuilding and petrocehmicals.

Independent technology development 1970-80

The policy instruments of the earlier stage were continued to be used but their relative importance changed drastically. The use of capital as an instrument for directing the industrial development declined in importance as the Japanese became bigger and financially stronger. In many technological fields they embarked on independent technological development, exemplified in areas such as cameras, motorcycles and consumer electronics. The NTT procurement of telecommunications still played an important role for some of the electronics companies. The changes in private finance for buying cars provided an important boost in the domestic market. The consolidation of some the major government laboratories, particularly in electronics, including the NTT laboratories provided an important basis for joint development and exchange of information. The orientation of the engineeering research associations changed as they become more specialized and more limited in company membership. A new element, which had started already in the 1960s, was the the large scale national projects supported by the Agency for Industrial Development of MITI. The projects are of long range nature and are usually completely financed by the government but involves both national laboratories and private companies.

There were several motives for the government's involvement in such project. First the large development costs were often too large compared with the resource base in most Japanese companies. This provided the justification for arranging cooperative ventures and for providing government subsidy. Second, the strength in technology and marketing of major foreign companies was on several occassions preceived as an external threat to the Japanese companies - for example in computers, which has already been discussed. Third, in several areas it was deemed desirable to build up the technological and industrial competence so that Japanese companies would become equal partners with foreign companies in globsl market arrangements - exemplified by the aircraft engine industry. The combined efforts where of course the competition among companies and their own efforts played a very important role has led to a situation where a large number of companies today have become large and independent of further governmen support.

Basic research support - 1980-

In the early 1980s Japan had fully completed the catch-up phase and embarked on independent technological development in most industrial sectors. At the same it was realized that the future success of the country's economic development would require a much stronger basis in basic research. However, the policy instruments of the earlier period were no longer relevant and for the past few years there has been an active search for new policies which can provide the necessary underpinning for developing the basic technologies to be used in future industrial development. The Future Generation Basic Technologies Program launched in 1981 should be seen in this context. Another significant new element is the program to enlist the private companies in joint basic research by using some of the capital obtained from the privatization of NTT as seed money.

The justification for a continued government involvement in technologies rests on the assumption that certain technological risks are to be great to be borne by the companies themselves. Unless the government initiates projects the companies are because of risk aversion likely to shy away from certain important future-oriented projects. Another justification for certain projects is the assumed externalities benefitting a large number of companies or users which is often the case for certain types of basic research.

The three stages with their characteristics have been simplistically entered into Table 3 below.

Table 3: Characteristics of technology policies in Japan

Period	1950-69	1970-80	1981-
Characte-ristics	catch-up and technology import	technology develop-ment	basic research support
Motives	Small markets Easy to imitate	Large costs - small resources External threat Develop equal partners	Large ex-ternalities High risks
Motivation	Catch up syndrome	Visions Analysis	
Actors	MITI, JTB Companies	MITI Compaies	Companies MITI
Results	Technology level improving	Large success-ful firms	Independent technology

CONCLUDIN(REMARKS

Several developing countries - including India, China, Brazil and Mexico - have over the past few decades built up impressive industrial structures which cover a broad range of products and technologies. However, most industries,both at the firm and sectorial level are lacking in dynamic development, compared with already industrialized countries. This is evident not only in sectors such as computers and integrated circuits but also in heavy industry and engineering exemplified by steel production and the manufacture of machine tools. This situation can be traced to the following factors. First, the industrialization process has been excessively directed and controlled by government agencies. Second, partly as a consequence the competition among companies have been stifled. Third, there has been little understanding that industrial processes and products need to be constantly upgraded in order to reduce costs and stay competitive visavi foreign products. Thus, the industrialization in many developing countries has been characteristiced by a static outlook because the industrial units have been seen as static building blocks with little need for that constant change which is so characteristic in most industrialized countries.

What can be learned from the experience of Japan which has a relevance for developing countries. Before trying to address this question it is necessary to make some kind of categorization of developing countries with regard to size, level of economic development, availability of scientific and technological infrastructure and not least important the political infrastructure. Let us first address the last one.

The success of Japan in industrial, technological and economic development can hardly be duplicated without a strong and fairly elaborate network of government institutions and the power not only to formulate but also to implement policies. It may be worth noting that many developing countries, often planned economies or those following planned economy recipes, have exercised the political power but rarely with the results of Japan. This can partly be traced to non-existence of two fundamental conditions. First, the knowledge about the domestic and international environment and the ability to analyze characteristics and changes of these environments is critical. Second, the political power to be exercised on industrial and technological structures must be closely related to actual or potential markets. Thus, it appears that the existence of key actors in layers between politicians and industrialists is an essential component in explaining the Japanese success.

We will now turn to the question of scientific and industrial structure. Many developing countries, at least those who can afford it, have built up an impressive structure of research institutions partly influenced by the existence of such structures in industrialized countries and the advice of agencies such as UNESCO. The planned economies have often dogmatically adopted ideas from the USSR. The experience of Japan teaches very different lessons. First, there is little use in technologically running way out in front of the industrial development. Second, if there are poor, or non-existant, linkages with the production units resources within the technological structure are mainly wasted. Third, it is always more important to be able to adapt and modify technologies imported from abroad than to develop your own technologies. This aspect clearly relates to the comment above stressing the capability to make correct analysis of the domestic and international environment. Finally, following from the above, it is essential to have proper timing or sequence in building up the infrastructure.

In this context it may be worth noting that Japan has in almost all its industrialization efforts started from downstream and moving upstream. This is for example illustrated by the plastics industry where Japan gained a strong position in plastic goods, and plastic moulding machinery, in plastic raw materials before entering into petrochemical industry. All the time market consideration played an important role.

The level of economic development naturally has an important bearing on choice of technology and industrial policy instruments. However, Japan has gone through successesive stages of development and in fact there may lessons to be learned or insight gained for every developing country. However, it appears that there are two countries which in particular have been studying the Japanese experience - Korea and Taiwan - for which there are several reasons. First, the geographical and cultural closeness may have facilitated this. Second, the colonization of the two countries by Japan may have left an important institutional legacy in spite of the animosity which was also created. Furthermore, the relatively high level of economic development of Korea and Province of Taiwan makes it easier to relate to the Japanese experience.

However, there can be little doubt that the size of Japan is a key factor which stands Japan apart for many types of comparisons. This situation is further compounded by the fact that Japan was able to control its domestic market to support its industrial development. Very few developing countries can expect to enjoy such a situation combined with the benefits from rapidly emerging global free market which facilitates the export-orientation of major industries.

Thus, it is clear that Japan cannot be duplicated although a few countries have the ability to use the Japanese experience as a guidance. However, there are a few lessons to be learned. First, there seems to be little justification for attempting leapfrogging the technological and industrial development and a sequence of stages have to be followed. Second, resurces are wasted if technology is far ahead of industrial policies. The domestic market may for a number of countries be the most important asset for integrating industrial and technological development which is exemplified by transportation, electricity generation and distribution, etc. This has recently become obvious in a number of developing countries which are rapidly expanding their telecommunications systems. In several countries where other conditions, mentioned above, also existed it has been possible to establish a fledgeling technological and industrial capability. This in no way guarantees the emergence of healthy electronics sector but it certainly resembles the Japanese experience in using the expansion of the TV and telephone networks, mentioned above, for its industrial and technological purposes.

The survey of the development in Japan and the examples above clearly indicate the need to understand industrialization as a very dynamic process. This process has in Japan been speeded up by by an intelligent formulation and implementation of technology policies which have often been closely integrated with industrial and economic policies - although occassionally mistaken as was exemplified by MITI's of a Japanese "People's car" and the attempt to establish one computer company to fight against IBM. The following elements are most significant in linking technological and industrial development. First, the allocation of resources for technological development must be closely related to the level of technology flowing into the country. There must be a substantial absorbtive technology capability in order to receive, modify and improve the technology imported. Japan scores very high on this particular aspect. Second, when a new direction of industrial development is required technology resources must be allocated on a substantial scale and closely related to industrial objectives rather than R&D as such - in order to have any impact. Thirdly, the timing is usually very critical as a technology policy being implemented too early or too late often fails to achieve the objective. Finally, it must be understood that the indirect catalytic effects of government technology support is often more important that the direct results from various technology projects or programs.

Again it must be stated that the efficient integration or meshing of technology policies with industrial policies requires a in-depth understanding of the both the international and the domestic situation with regard to market and industrial structures, with regard to technological trends and absorbtive capacities at home and abroad. It will also require suitable policy instruments which will have to change over time in order to remain efficient. Finally, there is little doubt that a competitive environment which constantly challenges the industrial companies is very helpful - although it is highly desirable to achieve close cooperation for technologies where great externalities and risks are involved.

Several cases have been cited above. However, it would be useful if more systematic studies could be carried which in some detail discusses the interaction of the policy instruments both at sectorial level and company level. Such studies could be carried out not only in Japan but also in Korea which in a surprisingly succesful way has been able to follow the Japanese precedent.