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National Champion Strategy in Technology Development

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National Champion Strategy in Technology Development

Abstract

To cope with the severe international competition as well as the increasingly huge resources needed for technology development, many countries have been trying to concert national efforts in strategic fields. "National champion strategy," like many recent national technology programs, seems to represent one promising strategic thrust. This paper examines cases in several critical technological fields, namely, information technology, new biotechnology, advanced materials, nuclear power and aerospace in industrialized countries, and reaches the following preliminary conclusions:

1. The protection of national market to nurture national champion(s) is often considered. This also concerns the decision about the appropriate number of champions. In practice, however, the size of the potential market is very difficult to predict at the early stages of the product life cycle. Therefore, most initial decision making is rather subjective, and should thus be adapted to new situations. The inclusion of foreign markets in the strategic thinking from the beginning appears crucial to the ultimate success of a champion strategy.

2. "Small" countries with small domestic markets relative to a presumably "minimum threshold size" would find it difficult to insulate their national champion(s), if any, from international competition. But systems technologies and applications fields which justify "internalization" provide many opportunities for small countries, and certainly large ones, to bolster their national champions through a protected domestic market.

3. "Single champion strategy" along with protracted market protection is risky due to the absence of competition pressure.

4. "Multiple champion strategy" with so severe internal competition as to result in fragmentation of critical technology

knowledge required in very large-scale, highly integrated systems is potentially deleterious.

5. In highly complex technologies, public regulatory bodies may also have to play a developmental and even partner role and share some complementary technical knowledge with the regulated organizations for the sake of technology integrity and progress. If they try to do so, they have to concurrently manage the two seemingly conflicting roles in order not to hurt their credibility in the main missions.

6. A relatively narrowly defined domain of a champion in increasingly converging technologies tends to impede its growth because of the difficulty in reaping synergy across formal organizational boundaries.

7. In newly emerging technologies where there are many types of actors with complementary capabilities in different stages of innovation, national champion strategy is difficult to apply. Instead, strategic alliances may be more appropriate.

8. In more conventional technologies where innovation is basically incremental and there exist large, established firms, government national champion strategy would be of less importance because of its relatively marginal effect.

9. In technologies whose initial progress is mainly prompted for military missions, the "military champion(s)" may not become successful "civilian champion(s)" when civilian applications arise. The main reasons include the diverging military and civilian technology requirements and different competition rules.

10. When national champion strategy in the face of seemingly insurmountable foreign competitors has little opportunity of success, "multinational champion strategy" may be advisable. This strategy, if not confined only in "pre-competitive" and public goods fields, requires participant national members to relinquish substantial managerial jurisdiction to the organization to behave like an integrated competitor. This strategy, except in the extreme case of acquisition or merger, goes beyond today's prevailing "strategic alliances."

Introduction

As the history of the past three decades shows, the strategy of national champion(s) usually applies to the fields of nationally strategic importance, or is used to cover the key "nodes" of the *filière*,[1] the network of interdependent upstream and downstream industries. Though this strategy does not entirely coincide with the recently proliferating national technology programs, it is implicitly or explicitly on the central and long-term agenda of many governments, and often has an important role in national technology development. This strategy therefore warrants special attention.

In classical economics, competition is favored over monopoly even in technology development, because the former stimulates most efficient allocation of resources whereas the latter permits under-investment in addition to production restriction and higher prices. However, too much competition may dilute and spread too thinly the limited resources available and preclude the formation of "critical mass" necessary to surpass some thresholds of bigger thrusts. It may also result in redundant and thus wasteful efforts, though redundancy may yield a larger number of solution routes and thus increase the likelihood of success.[2] Maintaining that the static inefficiencies of monopolies are more than counterbalanced by their greater innovative capabilities, Schumpeter advocates that large, monopolistic firms undertake innovation,[3] the driving force and the necessary consequence of capitalism.[4] "National champion strategy" in some sense follows Schumpeter's argument. It internalizes cooperation which may otherwise be difficult to achieve across formal organizational boundaries, and emphasizes international country competition instead of intra-national company competition. But it seems to be also unable to completely escape the rule in classic economics. Therefore the strategy of "multiple champions" is suggested as opposed to that of "single champion" under certain circumstances. For this strategic issue, the investigation of real world experience in several important technological fields may shed light on some of its critical aspects. In the following discussion, only cases with profound technological implications will be used. Therefore cases like the establishment of a large integrated steel mill, which is certainly a national champion in most countries but mainly for the domestic supply of basic materials, will thus be excluded.

Domestic Market Strategy and Number of Champions

To nurture national champion(s) in particular and indigenous industry in general, many countries also take the protection of domestic market into consideration. But between these two decisions are complex relations needing further clarification.

First take information technology (IT) for elaboration. In the major fields of "stand-alone" IT products, such as computers (mainly mainframe or large computers) and semiconductors, basically no small advanced countries have explicitly considered protection of domestic market as a way to support their own national champions. Openness of their economies derives directly from their market size even smaller than a certain threshold presumably necessary for the economies of scale and specialization.[5] Scandinavian and Benelux countries are obvious examples. Therefore their firms are normally exposed to international competition from the very beginning. Few champions have emerged because of protected market. Philips in the Netherlands is an example, in contrast with Thomson in France where government can use protection strategy due to its much larger domestic market. As a natural extension, when a national champion is in danger, government in a small country has to seek other measures, if it will and can, than the protection of domestic market. The present dilemma imposed by the shaky Norsk Data on the Norwegian government typifies the difficult situation.

When the domestic market seems to be big enough relative to the presumably necessary minimum size, the protection of it becomes a real option. But there may also be possibility to support more than one champion. The key question lies in not only the degree of internal competition but also the subsequent penetration into foreign market.

Without special mechanism to influence the industrial concentration, low entry threshold and severe competition may result in a great number of small firms which cannot survive challenge from big foreign firms. But unreserved support to a single champion in a protected market may rid it of competition pressure and make it relaxed in preparation for subsequent international competition. This gives rise to the rationale of the strategy of multiple champions with constant competition ingrained between them, if collusion can be prevented. In the real world, however, it is extremely difficult to estimate even the potential domestic market in the early stages of product life cycle. Therefore the initial decision making is in fact rather subjective, and should be followed by close monitoring of the development and necessary measures to adapt to the new situations.

In France, government has a long tradition to support or create national champions in strategic areas. But it usually relies on the strategy of single champion: betting on one or the only one. Japanese government in the early post-war era also tried to rationalize several industries, for example, automobile and computer, to enhance national competitiveness by merging smaller domestic firms. "Fortunately" Japanese companies succeeded in resisting government initiatives except temporary participation in national programs; and "unfortunately" French government succeeded in creating many single national champions in many strategic fields. In IT, and most notably in semiconductors, the outcome is that the severe internal competition among multiple champions in the initial protected domestic market has strengthened Japanese companies' capabilities for the subsequent international competition with great success. On the other hand, throughout the whole process the number of champions has been controlled by Japanese government through some mechanisms such as membership of a series of national programs and government procurement.[6] The Japanese government has also timely used export encouragement measures to help these champions penetrate foreign market.[7] By contrast, French IT champions have shown weakness in competing satisfactorily outside their home market. In the U.K. the support to the single national computer champion ICL and semiconductor champion INMOS also did not succeed. The plausible reasons are many, including, for instance, that the British government effort involved little commercial assessment, and that the French government pursue both military and commercial objectives which were not congruent to each other.[8] But it would be fair to say that the distinction between "single champion" and "multiple champions" counts.

With the benefit of hindsight, Japan's domestic IT market now proves to be larger than either France or the U.K. But it was by no means easy to predict in the 1960s and 1970s when the three governments all took actions to cultivate their own national champions, that Japan's domestic market would be larger over some time horizon given Japan's then considerable lag behind France and the U.K. in average income and industrial and technological levels. Therefore, although no conclusive statement can be made based on a brief analysis of such a small number of cases, it may be quite reasonable to propose that single champion strategy along with protracted market protection is rather risky in the long run, even if it is justified by the initial estimate of potential domestic market. In other words, competition pressure either at home or from abroad or both is necessary.

In the U.S. where there is no explicit industrial policy, the Department of Defense (DOD), the major government agency sponsoring many IT innovations, also follows similar principle. DOD picks potential winners out of the vigorous internal competition, while the military procurement market is insulated from foreign competition too. Certainly in this case it can be argued that U.S. market, military or civilian, has been clearly much larger than either French or British counterparts to accommodate multiple champions.

It is worth noting that the preceding analysis cannot apply to lower-end IT products at "paradigmatic stages." One example is present microcomputer. The relevant industrial standards have been nearly set up; key microprocessors and memory chips are available in the open markets; and companies compete more or less in accordance with the "traditional" principle of comparative advantage. To explain this, the classic theory of "international product life cycle" suffices roughly.[9] Hence there is no big surprise that personal computers from Taiwan and South Korea compete quite successfully in the world market. South Korea has several national champions purposefully backed by its government for several decades. Taiwan, on the contrary, mainly relies on small and medium enterprises. But nearly all the firms in this field are followers or "clones." They are far behind the technological forefronts where the major industrialized countries have been trying to rival vehemently. This argument, however, is not to underestimate, for example, their quite successful technology and alliance strategies to upgrade their relative position in the "international product life cycle."[10]

Internalization in Systems Technologies and Applications

In IT applications fields, there are many opportunities in favor of national companies. In banking automation in Finland, Norkia's microcomputers which could hardly compete against foreign products have a special privilege to serve their country's banking systems. Many industrial processes with embedded IT also belong to this category. The "systemic character," meaning that element or subsystem technologies or products are part of a large system and extensive efforts to adapt them to the context are required, provides some kind of shield for domestic firms. This in effect is an extension of the argument for internalization at the firm level[11] to the country level. Therefore in national IT policies and programs, even in small countries, candidate champions usually can have better chance in the applications areas.

In telecommunications, a large scale IT systems technology, most PTTs (Post, Telephone and Telegraph Authorities) follow this principle through R&D contract and procurement policy to nurture big national suppliers or national firms in the joint ventures with foreign counterparts, despite the frequent outcome of unreasonably high prices, weak international competitiveness, and outdated services or hardware systems in many countries.[12] Recently the telecommunications world is undergoing "structural change." Deregulation, liberalization and multinational collaborative programs have been introduced in the U.S., Japan and West Europe. The resultant new scenarios, such as more competition, integration of previously fragmented standards and markets, and more international alliances among major firms, will certainly add new uncertainty and challenge to the national champion strategy.[13]

Business Domain of Champions

Another important issue in national champion strategy is the coverage of business. As a historical lesson, CII, the French national champion in computers, resisted buying products from another semiconductor champion Sescosem. It bought rather from U.S. firms that were producing more advanced products. The French telecommunications industry did purchase from the U.S. for similar reasons.

In striking contrast, all Japanese major IT competitors are highly vertically integrated. Hitachi, Fujitsu, NEC, Toshiba, Mitsubishi and Matsushita, the six of the world's ten largest semiconductor companies account for 80% of Japan's semiconductor production, 60% of semiconductor consumption, 80% of computer production, 80% of telecommunications equipment production, and about half of consumer electronics in which Japan holds two thirds of OECD export market share, ahead of the second country FRG by a factor of six.[14] Besides, they have also close linkages, including equity cross-ownership, with suppliers and affiliated industrial groups, banks and insurance companies, and general trading companies. A good example is NEC, one of the two companies (the other one is IBM) concurrently among the world's top ten producers of semiconductors, computers and telecommunications equipments. Its integrated circuits are designed into its electronic products; its semiconductor design systems use its mainframes and supercomputers. These integrated companies sell in the open markets only those microchips which could not be used by other competitors to threaten themselves. They also enjoy far more intensive cooperation between users and suppliers, which is essential to innovation and would be much more difficult to achieve if formal organizational boundaries exist in between.

This special feature of Japanese IT industry is also pointed out as a big threat to the U.S. where only AT&T and IBM belong to the same category and are able to achieve dynamic economies of scale. Other U.S. "merchant semiconductor companies" may easily fall victims to Japanese conglomerates because they have to sell their most advanced products in the open market and are facing difficulty to keep pace with Japanese firms in continuous and increasingly huge investments.[15]

As a matter of fact, the converging IT, exemplified by the integration of computers and telecommunications and the incorporation of more and more systems into microchips, naturally necessitates the converging business. Firms which can master microelectronics, data processing, telecommunications, computer-integrated manufacturing, etc. will have upper hand in the global competition. This is exactly the advantage of the unique firm structure of Japan's national innovation system in the new IT techno-economic paradigm.[16] In this regard, Siemens and Philips, both covering a wide array of IT technologies, seem to have better chance than most other European champions, if they can successfully compensate for their relative deficiencies in semiconductors probably through the joint Mega Project which is also underwritten by FRG and Dutch governments.

Complementarity of Actors in Various Innovation Stages

In new biotechnology, another also strategically important field, national champion strategy has been rarely used. This phenomenon may give clues to the strategic thinking in other also newly emerging technologies with similar character.

Broadly defined, biotechnology includes any technique which uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop micro-organisms for specific uses. But following the seminal breakthroughs in genetic engineering in the mid 1970s, "new biotechnology" emerged centering around recombinant DNA (rDNA), cell fusion, novel bioprocessing, etc., as opposed to "old biotechnology" which certainly still provides a base for and complements "new biotechnology."

Due to its tremendous potential of applications in a very wide variety of fields, many countries have identified new biotechnology as a priority area for national attention and effort. However, some features specific to new biotechnology present a picture of national strategies quite different from that in IT.

First, the serious concern over safety and moral issues resulted in rather restrictive regulations in many countries, and deterred the consensus formation and investment in the development of new biotechnology. Second, like in many other newly emerging fields, most countries, except the pioneers, have been more or less slow to recognize the pivotal importance of new technology. Nevertheless, Japan MITI's declaration in 1981 of new biotechnology to be one of the next generation basic technologies triggered much attention and reactions. Many governments thus tried to "do something," including a plethora of reports and national plans. But it would still take time for some countries even to prepare human resources necessary to carry out missions of considerable challenge, as the cases of France and Sweden show.[17]

Furthermore, to date success in new biotechnology still depends largely on the progress in fundamental research mainly situated in universities and non-profit research institutes. Partly because of the rather obvious and immediate commercial applications of many research advances and partly because of the relatively low financial entry threshold, many small new biotechnology firms have been formed through "spin-offs" of "academic entrepreneurs" if "climate" and venture capital or other equity markets allow. Up to now, however, this phenomenon is still uniquely American. In Japan and Western Europe, new biotechnology is being commercialized almost exclusively by established firms, with only a few exceptions like Celltech in the U.K.

But the profit of new biotechnology firms so far has come principally from stock market trading and the sale of research leads and contracts rather than from products. In human health care arena, insulin and human growth hormone are among the still very few genetically-engineered products in the market. In contrast with many small firms in IT which were formed to market definite products, most small new biotechnology firms were started as R&D houses with the objective of determining how to make products.[18]

On the other hand, large established firms have apparently much stronger capabilities at the later stages of commercialization, i.e., production, marketing and, when necessary, getting regulatory approval for new products. Many of them nowadays have been establishing "strategic alliances" with research institutes, universities and small innovative firms. This new strategy may take such forms as research grant, R&D contract, licensing, joint venture, venture nurturing and equity investment. In the face of emerging technologies or radically new innovations with high uncertainty, alliance strategy, as compared with progressive internal R&D or internal venture which were rather commonly adopted by large firms during 1960s and 1970s respectively, may offer more organizational and resource allocation flexibility, reduce financial exposure and risk, acquire "windows" to new scientific and technical advances, and keep pioneering and entrepreneurial spirit, albeit also with its own pitfalls.[19] Therefore alliance strategy, in addition to increasing internal effort, is an explicit policy in many large firms. In fact, this strategy avoids two "extreme" governance structures--integrated hierarchy and pure market transaction. The high technological volatility makes it risky to commit too much resources to some focal areas, hence inappropriateness of integration.[20] But the uncertainty and complexity of technology also makes it vulnerable to entirely rely on market transaction should needs arise.[21] As a matter of fact, large firms' internal R&D investment suddenly increased dramatically since 1984 in the U.S. The main reason is that the potential of protein engineering became clear and the related technology seemed to enter "trajectory phase" around then.[22]

Moreover, because of the seemingly less strict regulatory environment and the more advanced research activities in the U.S., many European large firms seek alliances with U.S. firms or institutes, sometimes at the expense of their domestic counterparts. Examples include famous FRG's Hoechst, Bayer and BASF, and Swiss Ciba-Geigy, Hoffmann-La Roche and Sandoz.

Given the situations as discussed above, most industrialized countries are relying more on the approach of whole innovation process, including strengthening the two-way linkages between academic community and industry, than on programs with narrower foci. The U.S. emphasizes particularly funding research, encouraging firms, and cultivating human resources, and regards targeting policies as least important.[23] Many European countries have similar policies and try to emulate U.S. unique experience by supporting small firms through venture capital and secondary stock markets, but with little obvious success except in the U.K.[24]

Japan, recently often referred to by western world as the "biggest threat" due to its effective government guidance and industrial collaboration, seems not very smooth in organizing its national effort in this field. There are at least two reasons. First, new biotechnology concerns the jurisdiction of at least four ministries (i.e., Ministries of International Trade and Industry, Agriculture, Fisheries and Forestry, Education and Culture, and Health and Welfare). It proves very difficult to orchestrate a national response because each ministry guards jealously its own territory despite MITI's active promotion. Second, in the research consortium sponsored by MITI for pre-competitive collaboration, there are over forty members with diverse background and interest. It has become the biggest problem to reach agreement on specific topics for common projects.[25] Besides, some major companies are reluctant to join. Sensitivity to intellectual property also stands in the way to collaboration. Hence the picture of new biotechnology program is quite different from that of the well-known VLSI Project. And there is reason to believe that many countries are facing more or less similar dilemma if they try to follow Japan's strategy.

The evidence in new biotechnology therefore suggests that it is very difficult, if not impossible, to adopt national champion strategy in such a new field with diverging promising directions to pursue and with many actors of complementary capabilities. Fundamental research community needs a considerable amount of resources and rather high degree of freedom to generate novel results. The strategy of "center of excellence" may apply here, but not "big science" approach. Large established firms are existing "champions" relying mainly on themselves and autonomously organized alliances to move ahead. There is little marginal effect which can be induced by government champion strategy. Small innovative firms seek to materialize their entrepreneurship and in some sense bridge the former two groups. It is now crucial to provide them a favorable environment rather than to consolidate them into a small number of larger players. The law of "microcosm," which is claimed to characterize U.S. unique strength,[26] seems to apply very appropriately here, though it is disputable in semiconductors. On the other hand, the rapidly prevailing internationalization of strategic alliances further complicates national effort with exclusive character.

Based on the preceding rationale, it could be inferred that some small industrialized countries may enjoy special advantage over major countries, as the case of the Netherlands shows. Because the country is small and there are only a small number of major actors, it is easier than in major countries to coordinate both government policies and business strategies, though there is also concern about the dominant role of large firms in guiding government policies at the expense of small and medium enterprises. In the meantime, niche strategy rooted in the country's unique strength (e.g., agriculture) can also be more easily agreed upon by different parties than when the coverage of national effort is, and usually should be, too wide, too general and thus too divergent to handle as in major countries. Therefore even if national champion strategy is not appropriate, a more focused and concerted national endeavor may be more feasible in a small country. In fact, biotechnology is the first national program launched in the Netherlands, contrary to the experience of many other countries where IT program is normally the first one.[27] This potential advantage, nonetheless, is still of little relevance to those countries which, albeit small, have deep-rooted decentralization tradition, like Switzerland.

Military and Commercial Champions

In Japan, MITI has stated its belief that "mew materials" is one of the three basic technologies essential to the establishment of the new industries in the 1990s. The other two, predictably, are new biotechnology and new electronic devices. In the U.S., Office of

Technology Assessment of Congress has maintained that advanced materials technology will be a determining factor in the global competitiveness of U.S. manufacturing industries in the 1990s and beyond.[28]

Advanced materials can be classified into metals, ceramics, polymers and composites which generally consist of fibers of one material held together by a matrix of another material. Relevant technologies in advanced materials result from the advances in scientific understanding of the relationships between materials micro-structure and macro-properties, and in techniques by which they are processed. Advanced materials have opened up new perspectives of supplying customer specifications--a radical change from the past when materials usually created a constraint to which users had to adapt, hence the rising consumption and great potential in almost every manufacturing sector. They have also prompted a renewal of activities in more conventional materials (e.g., super alloys). This is why the term "advanced" rather than "new" materials is generally preferred.[29]

In advanced materials technology, the U.S. has achieved a strong position largely as a result of military and, to a lesser degree, space programs demanding high performance materials. In advanced structural materials, for example, DOD accounts for about 60% of Federal R&D budget, aiming especially at such goals as higher operating temperatures, higher toughness, lower radar observability, and reduced weight. If military development, testing and evaluation funds, as well as funds for classified programs were included, this fraction would be higher. This is a major reason for U.S. leadership in advanced composite technology of all types.[30]

At present, though, advanced materials developed for military applications are expensive, and fabrication processes are poorly suited for mass production. According to potential U.S. commercial end users, major use of these advanced materials will not be profitable within the next five years--the typical planning horizon of most U.S. firms. In many cases, ten to twenty years will be required to solve remaining technical problems and to develop rapid, low-cost manufacturing methods.[31] Hence there is little commercial "market pull" on advanced materials technology in the U.S. In other words, U.S. military technology leadership would not easily be translated into a strong domestic commercial industry. As a consequence, the major military contractors in advanced materials have not played a significant role in commercial area. Given the U.S. Administration's reluctance to accept a Congress suggestion to have a nationally-coordinated approach to advanced materials R&D, and its insistence on leaving commercial decisions to the private sector, it is difficult to predict how preeminent "commercial champions" will emerge in the U.S. As the early development of IT industry implies, U.S. military programs normally have at most indirect, albeit maybe very far-reaching, influence on the commercial sector, and the early "military champions" do not always become the later "commercial champions."

In Japan, where there is little indigenous military R&D and procurement relative to the U.S. nor viable aircraft industry, most effort in advanced materials is explicitly commercial. It focuses on fine ceramics, carbon fibers, engineering plastics and amorphous alloys. As in IT industry, Japanese highly horizontally and vertically integrated companies enjoy some relative advantage in advanced materials too. They create "market pull" inside their companies, and use "technology push" through long-term investment in gaining production experience. In advanced ceramics, Japanese end users exhibit far higher commitment than their U.S. counterparts to the use of these materials. Both governments spend roughly equal R&D funds in this field, but Japanese industry spends about three times more than its government, whereas U.S. industry invests only slightly higher than its government.[32] Electronic ceramics have proved Japan's superiority. The manufacturing technology of superconductive materials into thin and thick films, and wires and tapes in Japan is also expected to lead the world.[33] Kyocera, the largest and most highly integrated ceramics firm in the world, typifies the firm structure unique to Japan. In contrast with aircraft customers like Airbus Industrie, the single largest consumer of polymer matrix composites in Europe, Toyota introduced metal matrix composite diesel engine piston consisting of aluminum locally reinforced with ceramic fibers. This is an important harbinger of the use of composites in low-cost, high-volume commercial applications.

In all European countries, military R&D budget is incomparable to that in the U.S. Furthermore, the budget is normally used to incorporate new advances into military systems to catch up with the U.S., not to create real innovations.[34] The field of advanced materials is no exception. In the commercial area, most countries also lack the highly integrated firm structure as in Japan. Therefore most European countries have neither "American type strength" nor "Japanese type strength," though FRG is regarded as full of potential with its own type in between.

As to universities, public research institutes and industry research consortia, U.S. experience points to their main success in education and "window" function rather than research results or commercial outcomes. In advanced materials, relevant disciplines needed are many,[35] but they are normally scattered widely across departments and it is not easy to integrate them into a fully functional whole. In the meantime, design and manufacturing should also be closely connected. This character may also explain the relatively small role of small companies in advanced materials.

It is certainly still too early to make any strong argument about the strategies in advanced materials technology. However, it may be reasonable to hypothesize that highly integrated firms can best meet the requirements of "commercial champions," because they can best integrate demand, design and production functions. This is not to imply that they can afford overlooking the cooperation with other actors.

For more conventional materials where innovation is incremental, usually large, established firms will play the central role, and there is not much room for government champion strategy. The rationale is similar to that in "old biotechnology" as noted previously.

Competition and Cooperation in Highly Integrated Systems

Nuclear power technology is characterized by extremely high complexity and integration. This nature is in striking contrast with that of IT. In IT, information transmission is the main goal. The whole system required can usually be disintegrated in different ways under the condition that the information input and output is in some prescribed manner. Therefore there are many technological options in terms of products, processes and discrete subsystems.

In nuclear power, the transmission of huge amount of energy and materials is the focus. The requirement in flow balance necessitates a huge package of highly interdependent subsystems. The deep concern over safety and environment further urges very stringent specifications. In order to be commercially viable and competitive with conventional power, the minimum economic scale is very large. Besides, the investment is highly capital intensive and rather rigid. The very sophisticated core technology, nuclear steam supply system (NSSS, including reactor), has few options, and there are only a very small number of vendors in the world. Moreover, each nuclear power plant is more or less site-specific. Architect-engineers, which are responsible for designing the rest of a nuclear power plant, thus have to be capable of large scale and complex system engineering. In the meantime, utilities have to be involved in the procurement and construction project management too. Because of the push toward many extreme technical conditions in the real scale and the very long life cycle of a nuclear power plant--usually more than thirty years from design to retirement, there may exist many technical problems which cannot be foreseen through small scale demonstrative versions or through rather complete experience accumulated from prior plants. This constitutes a big challenge in operation and maintenance phase. As a result, all key actors in nuclear power are major players. Each plant construction is equivalent to a "national project" in most countries given its huge financial investment and technological and managerial challenge.

Due to different traditions in electricity production and distribution, utilities may be centralized or decentralized. In reactor development, France and the U.K. are more centralized than the U.S., FRG and Japan. Nonetheless, all governments finance generic research and experimental development. Some like the U.S., France and the U.K. also have military interest. To meet the high standard of capability and enhance international competitiveness, NSSS vendors in most major countries have been consolidated into, for example, the single nationalized one in France, three consortia in Japan, and privately merged one in FRG. As to architect-engineers, they may be independent professional companies. In Japan and FRG, NSSS vendors also do the job. In France and the U.S., many utilities take the responsibility. In Sweden, the only NSSS vendor cooperates with several utilities for the task.

For safety sake, all countries have regulatory agencies. They are supposed to be independent of utilities and suppliers, and strictly execute their duty in approving, monitoring and even closing, if necessary, nuclear power plants.

In reactor technology, FRG and Japan mainly guided by utilities' opinion adopted U.S. versions from the beginning, whereas France and the U.K. guided by government agencies pursued gas-cooled type using natural uranium. But the much greater number of U.S. version plant constructions drove the learning curve down much faster, therefore France and the U.K. finally gave up gas-cooled type and turned to U.S. versions. They lost not really because of the "ultimate" inferiority of their technology if experience of same number of plant constructions could be compared, but because of the economic inviability determined by comparing alternative reactor options at the same time.[36]

As noted earlier, the operation of nuclear power plant also calls for tremendous technical support. Its performance can be evaluated by percentage of availability. Under normal condition, the designed full power availability is about 88% due to refueling and maintenance of six weeks per annum. Because capacity loss will incur very high replacement cost,[37] for example, about US$10 million cost for 1% loss in a 1000MW plant, to maintain high availability is hence the main goal of all plants. In this line, the senior leader, the U.S., performs badly on the national average relative to most other industrialized countries. According to a study investigating about 150 light water reactors (LWRs) in the U.S., France, Japan, FRG, Sweden and Switzerland,[38] U.S. 77 plants' average availability during 1975-84 is only around 60%, with highest standard deviation and showing no sign of significant improvement. Some other countries like Japan and FRG also met serious technical problems in the 1970s, but both have made big progress, and their availability level in the mid-1980s is far ahead of U.S. counterparts.

To explain this situation, the different patterns of relations existing between key actors in different countries sound the most plausible. Between regulator and utilities, antagonistic relation typifies the U.S., whereas in other countries open communication about technical issues is common. In this respect, Finland's experience is exemplary.

The regulatory body in Finland also has strict rule and maintains high standard. In 1970s Finland imported its first two 440MW PWRs (pressurized water reactors) from USSR. But these reactors required western electronic control and simulators, and it was not an easy job. Therefore the regulatory body worked hard with utilities to adapt USSR technology to western code, solve technical problems and make own specifications. Later Finland imported two Swedish 710MW BWRs (boiled water reactors). This time the delivery was nearly turn-key type, so the regulator's involvement was much less.

As regards the relations between utilities and suppliers, in the U.S. the normal practice is to solicit competitive bids to keep cost down. Therefore the suppliers are highly competitive against one another. In other countries, long term relationship between utilities and suppliers is valued, hence more intensive technical information sharing. Among utilities, there is evidence that the experience exchange is also far less in the U.S. The U.S. Electric Power Research Institute (EPRI) has had done something to compensate for this weakness, but not enough. So the Institute of Nuclear Power Operations (INPO) was established in 1980 to take the responsibility. However, INPO only serves utilities and lacks support from suppliers and regulatory agencies. Its technical data base is thus only partial at most.[39]

To summarize, the history of reactor technology shows the pivotal role of government R&D investment and protected domestic market in backing national champions. In operation of nuclear power plant, some lessons are obvious. A generalized implication could be put in the following way. In a large-scale, highly integrated and complex technology like nuclear power, multiple "champions" with too severe competition which results in fragmentation of critical technology knowledge may do serious damage to the whole industry and technology progress. On the other hand, the public agencies shouldering regulatory responsibilities may also have to play a developmental role in case their expertise is crucial to the success of those being regulated. For these agencies, however, the management of the two seemingly conflicting roles in order not to hurt their credibility in the main missions is certainly not easy.

Multinational Champion Strategy

When national champion strategy is not sufficient to cope with international competition, multinational champion strategy becomes an option. Commercial aircraft (excluding light aircraft) in Europe is a good example. To compete with Boeing and McDouglas, the investment scale and technology complexity needed are beyond the capabilities of any one European country. Similar rationale applies to the space sector, where purely national options are obviously not viable in Europe. But both are a little different from nuclear power.

In addition to regulation and safeguards activities, joint nuclear power reactor research was pursued in several centers since 1958 under the framework of the European Atomic Energy Community (Euratom) to encourage the creation and growth of a civilian nuclear industry. This multinational collaboration was paralleled by national programs in many countries. When commercial applications appeared feasible, firms with potential in this industry became in strong competition against one another. Some preferred to be linked with U.S. firms. And most firms were still tied closely to national procurement, standards and regulation, hence having little incentive to pursue collective projects. On the other hand, for governments in major countries nuclear power was also too important to be dependent on foreign suppliers. Therefore, in nuclear power technology development, the interest is predominantly nationalistic even when pursued within a European framework.[40]

In the case of fast breeder reactor, collaboration under Euratom's umbrella was duplicated by research programs in France and FRG. Until recently two main projects, Superphenix and SNR, including a number of countries are still underway. But the progress has been slowed down due to technology complexity and economic constraints. The commercialization so far is not in prospect partly because the predicted scarcity of uranium supplies has failed to materialize. This has led to diminishing enthusiasm of some members. The withdrawal of the Netherlands is an example.[41]

In space R&D, early European activities were to provide public goods. This fact more or less simplified multinational collaboration in the European Launcher Development Organization (ELDO) and the European Space Research Organization (ESRO), and later the European Space Agency (ESA). However, ESRO is evaluated as more successful than ELDO due to less intervention from different national bureaucracies, more unified leadership, better goal congruence, shared vision and relationships with industry, etc.[42] As to ESA, by learning lessons from ESRO and ELDO, it helped produce a coherence of policies among member countries and even became the cornerstone of the national programs of its members. It also enabled the Europeans to establish a foothold in launchers and to develop a range of sophisticated payloads. But once the activities moved to more commercial phase, Arianespace was created separately to handle commercial launches. ESA also lacks the influence to promote the collective interests of the European space industry in competition against U.S. suppliers for international contracts. One possible reason is that the far superior position of U.S. space technology and industry makes this attempt not very appealing. Therefore the European space collaboration basically remains in the "pre-competitive" phase and the fields of public goods nature.[43]

In contrast with space sector where U.S. and many European governments are direct participants, commercial aircraft industry in the U.S. has little government direct support, though it has benefited greatly from the spill-over effects of government huge space and military technology programs. In Europe, not any single country can match the U.S. in military and space programs, available resources and domestic market size. The high development cost, which usually requires the sales of up to 70 planes to recoup, and the break-even point between 300 to 600 planes, depending on whether it is a new type or an offspring of another program, make the protection policy extremely difficult. Financial needs which starts from development and culminates at the sales equivalent of 100 planes is also larger than any single firm can stand.[44] Besides, the market of airlines needs a family of products, not only a single type. This forces European governments, if they want to enter commercial aircraft market, to directly underwrite aircraft industry, and to look to international collaboration to pool resources and, hopefully, also market access (e.g., national flag airlines) as the only viable alternative. As a matter of fact, even military aircraft which by nature is less based on economic criteria shares some similarities with commercial aircraft, and is subject to severe international competition pressure too.

In Western Europe, the collaborative projects, regardless of commercial or military aircraft, include Franco-German Transall and Atlantic, the first case in the 1950s, Anglo-French Concorde, Anglo-French helicopter and Jaguar, Tornado, and the recent Airbus. Tornado was the first three-partner project, undertaken by the U.K., Germany and Italy. In view of its potentially much more complex issues inherent in the trilateral relations than in the previous projects of bilateral cooperation, Tornado could be regarded as a big step further in management of multinational aircraft joint efforts. In commercial aircraft, however, Concorde and Airbus provide the most relevant lessons.

According to many reports, Concorde is a big failure in all aspects except technological achievement. Instead of being operated by an integrated management as originally designed, Concorde was in fact supervised rather directly by a cumbersome dual structure of French and British government bureaucracies with different, fluctuating and conflicting decisions, and even non-economic criteria.[45] But it did induce a sharpened awareness of the management of multinational collaboration, hence benefiting subsequent projects.

In Airbus program, a big difference is the establishment of Airbus Industrie. It has no capital, makes no profit and is fiscally transparent. But it coordinates and institutionalizes cooperation without merging firms involved, and is responsible for marketing and service to customers. More importantly, Airbus Industrie "transcends" parent companies and works for common interest. It has also managed to keep governments at arm's length. Therefore Airbus is a rather integrated consortium with institution in its own right but endorsed by member country governments. Though not financially successful yet, Airbus has become the only real foreign challenger to U.S. commercial aircraft industry.[46]

Recently, many international technology collaborative programs have been promoted in Europe. But very few cases belong to multinational champion strategy. Even Mega-project is only strategic alliance between Philips and Siemens. No common body has been set up to push forward some thrust of common interest.

Based on the above analysis, it is rather understandable that an effective multinational champion strategy is very difficult to achieve. For a multinational champion in which participant countries are reluctant to relinquish their own assets and control and even request the enforcement of "juste retour" principle,[47] how to compete against other formidable rivals with fully integrated management is a big question. The answer seems quite simple: a multinational champion should also be an integrated competitor while receiving support from multiple countries.

Concluding Remarks

National champion strategy emerged in 1960s in Europe when many governments thought that size was the main reason explaining Europe's lagging behind the U.S. in productivity. "Big was beautiful" and it was the origin of American challenge.[48] For Europe to compete with the likes of IBM and GM, the only way was to grow firms of equivalent size. Through government rationalization and endorsement, in 1970s many national champions were in being. However, the two oil crises and new technologies shaked the previous belief. Many champions had fiasco, exemplified by semiconductor industry. In some fields, mass production paradigm seems to be replaced by a new one and "small may be more beautiful;" in others, national champions by fragmenting markets precludes more appropriate larger scale operations, like in telecommunications. Therefore the old strategy is under scrutiny and many new strategic schemes arise. This paper examines champion strategy mainly from a comparative technology perspective. Experience from many countries shows that competition, market size, business domain, governance structure, and technology characteristics all have profound impact on the performance of champions. In the meantime, champion strategy is not so simple as it may appear. It has to adapt to many conditions and sometimes it is not viable. Despite some argument for the inappropriateness of national champion strategy in today's global arena,[49] it still is a useful concept to guide strategic thinking at the national level. And national rivalry does not seem to diminish in the foreseeable future.

Notes

1 For a brief discussion of the concept of the *filière*, see, for example, Nguyen and Arnold (1985).

2 That a better selection comes from a wider variety is one of the main arguments in the theory of evolutionary technological change. See Nelson and Winter (1982).

3 Schumpeter (1942).

4 Schumpeter (1911).

5 Arnold (1987).

6 Levy and Samuels (1989), pp. 60-73.

7 For further details about Japan's strategy in computer industry, see, for example, Anchordoguy (1989).

8 For a brief discussion, see Nelson (1984), pp. 45-47.

9 For a revised theory of international product life cycle, see Vernon (1979).

10 This is called "second follower strategy." See Chiang (1989).

11 For the conditions in favor of internalization at the firm level, see Teece (1986).

12 Turner (1988).

[13] For a brief discussion about recent structural change in telecommunications, see, for example, Nguyen (1985).

[14] For recent development of consumer electronics, see Vickery (1989).

[15] This is one of the main arguments explaining the rapid decline of U.S. semiconductor industry relative to Japanese companies. See Ferguson (1988).

[16] For more details, see Freeman (1987), pp. 79-90.

[17] U.S. OTA (1984), pp. 518-522.

[18] Borrus and Millstein (1983).

[19] For a comparison of strategic alliances with progressive R&D and internal ventures, see Olleros and Macdonald (1988).

[20] Similar argument is made in the study of vertical integration strategy in face of industrial volatility. See Harrigan (1983).

[21] The uncertainty and complexity, all others being equal, will draw the balance in favor of integration is one main point made by Williamson (1975).

[22] U.S. OTA (1988c).

[23] U.S. OTA (1984).

[24] For European biotechnology strategies, see, for example, Gyllenberg (1985), Creasey (1986) and Sharp (1987).

[25] For more details, see Lewis (1984).

[26] For the principle of microcosm, see Gilder (1988).

[27] The Dutch experience in organizing biotechnology program is based on several interviews with concerned government officials in Amsterdam and Hague in December 1989.

[28] U.S. OTA (1988a).

[29] Dubarle (1989).

[30] U.S. OTA (1988a).

[31] U.S. OTA (1988a).

[32] For more details about ten countries, see Strategic Analysis, Inc. (1987).

[33] U.S. OTA (1988b).

[34] U.S. OTA (1989).

[35] For a typical case in design, see Mecholsky (1985).

[36] For a brief review of the development of nuclear power technology, see, for example, Thomas (1988).

[37] Replacement cost means the additional cost incurred using conventional power to "replace" the loss of availability in nuclear power.

38 Hansen et al. (1989).

39 The discussion of experience in Finland is based on an interview with the director of the national reactor laboratory in Helsinki in May 1989. The analysis of relations among key actors in nuclear power is from Hansen et al. (1989).

40 The experience of Euratom has been well documented. For a brief summary see, for example, Sharp and Shearman (1987), pp. 28-30.

41 For further details about the European fast breeder reactor, see Shearman (1986).

42 For a comparison of ELDO and ESLO, see Koenig and Thietart (1988).

43 For a brief summary of European space collaboration, see Sharp and Shearman (1987), pp. 36-38.

44 For a general description of aircraft industry, see Newhouse (1982).

45 Experience in Concorde has been well discussed. See, for example, Clarke and Gibson (1976), Knight (1976) and Feldman (1985).

46 For further details see Hayward (1986).

47 "Juste retour" principle means that each country's contribution must be spent within that country.

48 For the concept of "American challenge" in 1960s see Schreiber (1965).

49 Sharp (1989).

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