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Empirical studies of country patterns in R&D have been dominated by the analysis of aggregate system-level variables. One common approach has been comparative analysis of national data on such variables as research expenditures, patent applications, and the numbers and distribution of researchers (e.g. Okimoto and Saxonhouse, 1987; Slaughter and Utterback, 1989). Another approach has been to study the state's role in the R&D system (Brooks, 1986; Ergas, 1987). However, the growing interest in the effect of institutionalized patterns in manufacturing organization on technological change and country competitiveness[1] raises the question of whether country patterns in R&D organization -- patterns that cut across industries and individual firms -- also influence country patterns in the pace and direction of technological change.

The question is difficult to answer, given the paucity of data on country patterns in the organization of industrial R&D. Nevertheless, the growing interest in the similarities and differences in U.S. and Japanese firm-level R&D organization has produced at least some comparative studies to complement and in some cases contradict the widely shared "common knowledge" about the dominant patterns in the two countries. This paper examines current comparative analyses of Japanese and U.S. industrial R&D and looks at their implications for theories of the relationships between country differences in technology and those in organizational patterns.

1. Differences in the Technological Behaviour of U.S. and Japanese Firms

In the second half of the 1980s, Japanese competitive strengths in technology development have attracted increasing attention in the popular and academic business literature. A widespread consensus has emerged on some of the key characteristics of the technological behaviour of Japanese firms, compared to those of the United States:

1. Shorter development times (Mansfield, 1988b; 1988c; Stalker and Hout, 1990);
2. More effective identification and acquisition of external technology, on a global scale (Rosenberg and Steinmueller, 1988; Mansfield, 1988b);
3. Higher propensity to patent (Hall & Azumi, 1989);
4. More effective design for manufacturability (Aoki, 1988; Rosenberg and Steinmueller, 1988);
5. More resources to incremental product and process improvement (Rosenberg and Steinmueller, 1988; Aoki, 1988: 237-247);
6. Stronger propensity to competitive matching of products and processes (Abegglen and Stalk, 1986);
7. Innovation dominated by large rather than small firms (Scherer, 1980);

8. Growing strength in innovation through combining technologies (The Economist, 1989);

9. Weaker in science-based industries (e.g. pharmaceuticals, chemicals, biotechnology).

While these traits have been observed across several industries, not all have been subjected to rigorous measurement of the extent of the differences between Japan and the United States. However, there have been several recent efforts to test the accuracy of these widespread popular perceptions, particularly of the first (shorter development times). The analysis of development times for Japanese, European, and U.S. firms in the auto industry (Clark et al., 1987) confirmed the fact that, despite considerable dispersion around the mean within each country, the Japanese had a clear advantage over both their European and U.S. counterparts.

Edwin Mansfield's multi-industry study, using managers' assessments of the average development times and costs for Japanese and U.S. firms in their industry, showed the same pattern over the average for the six industries he studied. However, the difference was not statistically significant for the chemical and metals industries (1988c: 1158). Mansfield compared the time and cost for innovations based on internal and external technology between 1975 and 1985 in 30 matched pairs of firms in Japan and the United States, and found that the U.S. suffered from an "apparent inability to match Japan as a quick and effective user of external technology" (1988c: 1167). Indeed, Mansfield asserts that the innovation time and cost advantage of the Japanese firms resides solely in their greater efficiency in using external technology, although he does not present the data that undergird his contention that "the average cost and time for innovations based on internal technology does not differ significantly between the two countries"(1988c: 1160, ft. 9).

Mansfield went on to examine the elasticity of innovation cost with respect to time, and found that the Japanese figure was twice the American: that is, "Japanese firms seem willing to devote a much greater amount of resources than American firms to reduce the time taken to develop and introduce an innovation" (1988c:1162). Mansfield's data thus provide empirical confirmation for the first two of the nine dimensions of comparison outlined above.

The third pattern on the list, the higher Japanese propensity to patent, has been inferred from the aggregate data on patent applications: between 1982 and 1987, the ratio of domestic patents received per 100 reserchers was 99.6 in Japan and 28.2 in the United States (Hull and Azumi, 1989). The aggressive patenting by Japanese firms in the United States is a further indicator: since the mid-1980s, more Japanese firms than American have ranked in the top 10 firms in number of patents received in the United States.

While the remaining six factors on the list have only relatively unsystematic empirical underpinnings, there is a logical coherence in their overall pattern, given Japan's position as a technology follower. As Rosenberg and Steinmuller (1988) have pointed out, U.S. firms and researchers have become accustomed to their country's technological preeminence, and are only now adjusting to a world where the leading centres of science and technology are not necessarily found within their own borders. Japanese firms, in contrast, have spent decades developing organizational systems to identify and acquire foreign technology (Herbert, 1989).

Given their reliance on a global pool of technology under conditions where no single firm could hope to gain exclusive access, competition among Japanese industrial firms focused on the speed and quality with which that technology could be embodied in products, on incremental improvements in the acquired technology, and on rapid competitive matching of products and processes. The continuous incremental improvements were far from trivial: many U.S. firms in the 1980s found themselves licensing back from a Japanese firms products based on technology that they had themselves licensed to the Japanese in the 1950s or 1960s. Technology followership also gave an advantage to large firms over small: the larger firms had greater resources to devote to global technology scanning and acquisition and to invest in rapid incremental improvement of that technology.

Clearly there were systemic factors conducive to these developments. Postwar Japanese government technology policy fostered technology dissemination: a disclosure-oriented patent system, an insistence in the 1950s and 1960s on multiple licensees for major technology imports, and state sponsorship of interfirm cooperation R&D. Japanese industrial policy consistently eschewed fostering a single "national champion" in any industry, perhaps because government bureaucrats felt that maintaining a small population of oligopolistically competing firms was more likely to maintain their own position of authority than the creation of a single, perhaps countervailing, behemoth. These policies in turn reinforced companies' focus on seeking competitive advantage in the application of technology and rapid incremental innovation. The universities contributed through their emphasis on foreign language training (focused on reading capability) and on keeping abreast of the Western technical literature.

The relative weakness of Japan's science-based industries compared to the United States is also explicable in terms of institutional factors above the level of the firm. U.S. universities have provided a much more favourable environment for scientific research and have produced far more advanced degree-holders in the sciences than Japan. Japanese universities, in contrast, have long given priority to the "applied" fields of engineering and medicine (Bartholemew, 1989). Moreover, R&D in the Japanese pharmaceutical industry has faced major constraints imposed by the price regulations imposed by the health care delivery system (Reich, 1990).

But of the nine factors in the comparison between the technological behaviour of U.S. and Japanese firms listed above, only the last (the comparative weakness of science-based industries in Japan) operates primarily beyond the level of the firm. The other eight factors are overwhelmingly shaped by the organization of research and development within firms and by the R&D networks among firms.

2. Institutionalized Differences in R&D Organization

The organizational patterns in industrial R&D that are institutionalized across industries can be divided into three major categories. One type is isomorphic with patterns institutionalized in other functions of the industrial firm; these are often integrally connected with and reinforced by external labour markets. A second category is isomorphic with patterns institutionalized in the professional research community as a whole; these are frequently a consequence of and reinforced by the organizational patterns that prevail in the leading research institutions, which in many countries are the major universities. And a third consists of the distinctive patterns that characterize industrial R&D within a society, and that are a product of the institutionalization processes within that function.

ISOMORPHISM WITH GENERAL PATTERNS IN INDUSTRIAL ORGANIZATIONS

Patterns institutionalized across industries in large industrial firms have received far more attention in studies of Japan than in the United States. Western researchers have been more inclined to view the Japanese firm and "Japanese management" holistically and to be struck by the commonalities across industries -- witness the number of books with titles like <u>The Japanese Factory</u> (Abegglen, 1958); <u>The Japanese Company</u> (Clark, 1979); <u>The Economic Analysis of the Japanese Firm</u> (Aoki, ed, 1984); and <u>Kaisha: The Japanese Corporation</u> (Abegglen and Stalk, 1986). But in the United States as well as Japan, certain patterns are common across industrial firms, and these have exerted strong isomorphic pulls on the organization of industrial R&D. In the case of Japan, as we shall see below, the pulls have been towards standardization across functions within the industrial firm; in the United States, they have favoured differentiation. In consequence, in the United States the second type of isomorphic pulls -- towards patterns instituionalized in the professional research community -- have been stronger than in Japan.

(a) Recruitment and Career Structure

By now it is virtually a truism that recruitment and career structures in large Japanese firms are directed toward the development of generalists, both in management and in blue collar positions, whereas in the United States they are directed towards bringing in and developing specialists (aoki, 1988: 49-52). It is hardly surprising that the same patterns characterize the R&D organization of large firms.

One of the clearest indicators of the difference is the strong resistance of Japanese companies to hiring university-trained Ph.Ds into their research organizations. Whereas the R&D groups of large U.S. firms have formed a major market for the more than 12,000 Ph.Ds produced in science and engineering each year, the reluctance of Japan's industrial firms to hire researchers directly from the Ph.D. programmes of the universities is the major factor explaining the very small scale of these programmes in Japan. In engineering in 1986, for example, Japan produced 73,316 Bachelor's graduates in engineering, compared to the United States' 77,061; however, it produced only 588 doctoral graduates of university courses, compared to the 3,376 in the United States (National Science Foundation, 1988).

Many of the Ph.Ds in science and engineering in Japan are indeed held by industrial researchers, but they are obtained in a programme (adapted from the German model) whereby researchers employed in companies can submit papers to their alma mater and receive a Ph.D. in recognition of their contributions to the field. These degrees are granted without any of the specialized coursework and university-based socialization of the American Ph.D. In 1986, 57% of the doctorates granted in Japan in natural science and engineering were of this type (Kagaku Gijutsu Cho, 1987).

The generalist structure of Japanese technical careers means that relatively few of those who are recruited into the R&D function spend their careers there. The "standard" career in most industries leads from R&D into divisional technical roles and then into line or staff positions in the operating divisions (Westney and Sakakibara, 1985; Nihon Noritsu Kyokai, 1987).

Underpinning this career structure is a marked difference from the technical career structure that prevails in most U.S. firms. In the R&D organization of large Japanese firms, as in other functions, the primary locus of responsibility for planning the employee's career rests with the company, rather than with the individual, as is the case in most U.S. firms. This difference was reflected in many of the indicators in the comparative study of computer engineers cited above (Westney & Sakakibara, 1985). In assignment to projects, the most important factor for the U.S. engineers was their own expressed desire to participate; for the Japanese engineers, it was the supervisor of their last project. In training after entry into the company, Japanese engineers were far more likely than their U.S. counterparts to have been assigned to courses by their company, rather than undertaking them at their own initiative. Significantly more of the Japanese engineers agreed with the statement that "the recruitment of engineers is based on long-range personnel planning rather than immediate needs." This is reflected in the fact that when Japanese engineers join a company upon graduation, not only do they not know what project they will join; they do not know to what part of the company they will be assigned after the entry-level training pogramme. And over half the Japanese engineers agreed that their performance was evaluated over a period of five to ten years, compared to just 10% of their U.S. counterparts.

(b) Reward Structures

Another aspect of R&D organization that is strongly shaped by the general patterns of the industrial corporation is the reward structure. In Japanese firms, criteria for base pay and annual increments for blue collar workers and the nonsupervisory levels of management are set in annual spring negotiations with the company union (to which management and technical personnel below until they reach the level of section head -- usually in their mid-thirties). In consequence, wages, salaries, and bonuses are standardized across functions, and there are strong barriers in the way of using monetary incentives to reward outstanding researchers or to differentiate across functions (Westney and Sakakibara, 1985). In interviews in sixteen technology-intensive firms in Japan, Sully Taylor found that:

> Resistance to using salary as a motivator may be quite strong. One R&D manager stated that if a high performing researcher were being headhunted by another firm, his company would rather let him go than entice him to stay through a salary increase. This manager felt that increasing his salary would severely undermine the lifetime employment system by destroying the cherished sense of internal equity that the system provides...This sentiment was echoed in various ways by the R&D managers at other firms, as well as the researchers themselves...In short, the heavy emphasis on seniority in allocating rewards is felt to be the cornerstone of the present employment relationship between the firms and employees...Changes in this part of the HRM system were felt to have potentially severe repercussions throughout the company and could not be instituted as easily as other changes. Several R&D managers also mentioned the question of union resistance to changes in any part of their firm's salary structure. (Taylor, 1989: 139)

In U.S. firms, in contrast, reward structures are highly differentiated within each firm across functions and between blue collar and managerial employees, but strongly isomorphic across firms in terms of function and level.

(c) Summary

The strong isomorphism across the functions and levels within the industrial firms in Japan has been a critically important element of their strengths in reducing development times, designing for manufacturability, and incremental product and process innovation, all of which are undergirded by the transfer of engineers across functions and the ability of the firm to assign them to tasks (such as incremental product improvement) that may lack intrinsic interest but which have high value to the firm. The stronger propensity of Japanese firms to patent also has its roots in intra-firm isomorphic processes: it is an outcome of the efforts of firms to develop concrete measures of productivity within their R&D function that are analogous to those that have been so useful in benchmarking their manufacturing processes.

ISOMORPHISM WITH PROFESSIONAL PATTERNS

Given the fact that isomorphism with company-wide organizational patterns is so strong in Japan, U.S. analysts have tended to assume that the pulls of professionalism and professional identity are extremely weak (see for example Saxonhouse, 1986: 127-129). The context in which this difference has attracted most attention has been in the area of patterns of technical communication. U.S. researchers, even those in industry, are portrayed as being oriented primarily to their professional identity, and therefore as willing to publish research results and communicate freely with researchers outside their company. Japanese researchers, on the other hand, are seen as being loyal "company men," and as therefore being reluctant to share information with "outsiders."

However, this perception of the Japanese researcher is based primarily on an economically rational model of professionalization rather than on empirical research: it assumed that researchers communicate within their profession primarily in order to enhance their individual market value (Saxonhouse, 1986: 128). In the abence of high levels of cross-company mobility, as in Japan, one would expect incentives for professional communication to be low. There is some empirical evidence that this perception is wrong. In the comparative study of R&D in the computer industry, Japanese company engineers were found to be significantly more likely than their U.S. counterparts to participate in professional societies, to attend professional meetings, and to believe that their company encourages them to publish the results of their work. They are also, surprisingly enough, more likely to value the approval and respect of their professional colleagues outside their own company than are the U.S. engineers (Westney and Sakakibara, 1985). The longstanding Western assumption that "loyalty to the company" and "professional identity" are at opposite poles of a single continuum needs reassessment: the two dimensions amy well be orthogonal. Companies can create an environment that fosters the "organizational professional" for whom enhancing personal reputation in the profession is also a way of enhancing the prestige of the company.

In the United States, the role of the professional researcher is epitomized and reinforced by the faculty of the major research universities. The norm of autonomy, the commitment to public disclosure and dissemination, the strong concern with external reputation, the high value on original and creative research, a higher value on the scope of opportunity to pursue self-defined research agendas than on institutional loyalty (which has made for such a high level of mobility of faculty across universities) -- all these epitomize the professional model. The influence of the model is reinforced by the key role of research universities in the national technology system and the consequent interaction between industrial and academic researchers -- and perhaps by the fact that industry often competes with universities to hire promising Ph.D. graduates. The model's effects are also perpetuated by the strong socialization of those industrial researchers who have pursued Ph.Ds at a research university.

In Japan, the universities play a far less significant role in providing a strong model of the professional researcher. In part this is due to the less salient role of the university in the national research system (National Research Council, 1989). In part it is attributable to the far lower proportion of university-trained Ph.Ds in industry. But it is also due to the fact that the university does not provide a strongly institutionalized alternative role model. University faculty members in Japan are not subject to the strong pressures to generate new knowledge embodied in the "publish or perish" tenure tournament of the North American research universities. The major Japanese universities recruit their faculty members overwhelmingly from the ranks of their own graduate students, and most faculty members obtain Chairs in the same university in which they did their postgraduate and even their undergraduate work, and they enjoy the equivalent of tenure from the time of their initial appointment. Their most important role in the national research system is to function not as creators of new knowledge but as sources of information: information about new technologies (domestic and foreign), about the directions of government policy (in which they play an important advisory role), and about the students who provide the future cohorts of industrial researchers. This role, insofar as it affects the definition of the role of the research professional in industry, reinforces the importance of external information gathering and dissemination.

Universities make at least one more important contribution to that model in the course of the education of scientists and engineers. In contrast to the emphasis of the research universities of North America, with their emphasis on fostering the ability to define and solve problems, the technical education at Japanese universities has historically emphasized the mastery of a body of knowledge, much of it from abroad (Westney & Sakakibara, 1985). Technical graduates enter the industrial research setting with a strong orientation to keeping abreast of external technology developments that is often missing from North American technical education at the elite institutions, where originality is more highly valued than a "mindless" mastery of the technical literature.

There is perhaps another way in which the universities in Japan have contributed to the role of the "organizational professional" whose company identity and professional identity are not at odds, although it is difficult to measure: the longstanding bias of Japanese universities to the development of "useful" knowledge. This trait has been discussed in some detail in James Bartholemew's history of the early decades of the development of Japan's research system (Bartholemew, 1989), where he documents the early dominance of engineering and medicine in the evolution of the national universities. He leaves open the question of whether this trait is grounded in Japan's status as a follower nation or whether its roots are older, in the longstanding neo-Confucian emphasis on the obligation of the scholar to serve society. But among the highly advanced industrial nations, Japan remains the only country in which there are more engineering doctorates granted as a proportion of the population than natural science doctorates (NSF, 1988: 51).

In summary, the model of the professional researcher in Japan is less strongly institutionalized than in the United States. Moreover, such features as are institutionalized are more compatible with at least some of the goals of industrial research, particularly the orientation to effective use of externally generated technology and to product-oriented research rather than basic or advanced research.

ISOMORPHISM ACROSS FIRMS WITHIN INDUSTRIAL RESEARCH

This type of country-based patterns in R&D organization, which refers to patterns attributable to isomorphic pulls across industrial firms within the R&D function, has been the least systematically explored. There are two arenas where somewhat unsystematic observation suggests important country-level effects: one concerns the formal structure of R&D, the other the propensity for interfirm cooperation in technology development.

Historical descriptions of the evolution of R&D facilities in Japan suggests that there are strongly marked development phases that stretch across industries (Nihon Noritsu Kyokai, 1987).

Relatively few Japanese firms established R&D facilities before World War II; most relied for technology development on technology departments attached to major factories, whose role was primarily the identification, acquisition, and adaptation of foreign technology. The early 1950s saw an "R&D centre" boom, in which many of the larger firms set up "kenkyujo" (research centres). The early and mid-1960s produced a "Chuo Kenkyujo Bu-mu" (Central R&D Laboratory boom), in which companies either consolidated their existing research centres into a single central lab or added a central lab to do advanced product development. The 1970s was a decade in which divisonal laboratories proliferated; one firm has identified it as a period when the dominant thrust was towards fostering the ties between the growing technology development organization and the jigyobu (business divisions). Finally, the mid-1980s witnessed the establishment of basic research labs in Japan's leading companies, a development promptly dubbed the "kiso kenkyu bu-mu" (basic research boom) by the business press.

Given this apparently widely shared development trajectory, institutionalization theory would lead one to expect strong isomorphic pulls across the R&D organizations. One reason is what W. Richard Scott calls "imprinting" -- structural features shared across organizations by virtue of the environmental conditions at the time of their establishment (Scott, 1987). Another is that one would expect what DiMaggio and Powell call "mimetic isomorphism" -- strong mutual awareness and emulation of patterns defined as "state of the art." However, at this point the research on the development of R&D in Japan has only begun. The isomorphic pulls within industrial R&D over the five decades of its development in Japan remain a fertile ground for future institutional research.

The propensity of Japanese firms to cooperate on technology development has been the object of more sustained, though hardly more systematic, interest. Western observers have focused primarily on the large-scale horizontal cooperative projects involving direct competitors, such as the VLSI project, that are sponsored by the government. But more numerous and probably more important are the various vertical technology development collaborations with suppliers and with customers.

Most large Japanese firms carry out considerable numbers of these each year (see the data provided in Westney, 1989). These vary from arrangements that are virtually contract research, in which one firm carries out the project after its parameters have been decided), to genuinely joint research involving the exchange of researchers and sustained interfirm communications.

This large number of collaborative research arrangements means that Japanese firms have evolved an array of organizational patterns to support such projects, especially for keeping in touch with and reabsorbing researchers sent out to other companies (shukko) and for montioring and evaluating collaborative projects (Westney, 1987).

Such cooperative arrangements have not only an output agenda but also a developmental one. They have become an important way for Japanese firms to enhance their technological capabilities. A recent MITI survey of Japanese manufacturing firms found that nearly three-quarters of the responding companies viewed technical cooperation with a Japanese firm as their most commonly used mode of strengthening their own R&D capabilities; over half also identified technical cooperation with companies in other industries and cooperation with foreign firms as useful avenues (the data are presented in Appendix 1).

Some at least of this high propensity to cooperate in technology development can be better attributed to the first category of factors producing country effects in R&D: isomorphism with patterns institutionalized elsewhere within the industrial firm. As several scholars have pointed out (Aoki, 1988; Fruin, forthcoming), Japanese firms have marked tendency to cooperate with other firms in several contexts. But the particular patterns institutionalized in R&D to support extensive technology collaboration, while perhaps attributable to the same underlying firm-level and environmental factors, are distinctively suited to the more intense (and potentially more intrusive) interactions required by the joint development of technology.

CONCLUSION

As Japanese and Western researchers alike become increasingly interested in the similarities and differences between their respective countries' R&D organizations, the amount of information on which we can ground our assessments of country effect on organizational structure and the behaviour of organizations will inevitably grow. But one interesting complication will continue to be the isomorphic pulls across societies. For example, currently Japanese firms are looking to the United States for organizational models on which to develop their basic research institutes. U.S. firms have developed growing interest in "learning" from how the Japanese link R&D to other functions within the firm and to customers and suppliers across the boundaries of the firm. And the growing internationalization of R&D will inevitably exert some unanticipated pressures on current patterns of R&D organization in the United States, Europe, and Japan alike. The careful documentation and analysis of evolving R&D organization is one of the most promising avenues for understanding the nature and extent of country effects on organizations, and on the forces which work to change and to reduce those effects.

APPENDIX 1:

8. CURRENT MODES TO STRENGTHEN R&D

a. Technical cooperation with a leading Japanese company	73.4%
b. Technical cooperation with Japanese universities.	72.3
c. Building a new R&D centre within the company.	60.1
d. Technical cooperation with companies in other industries	58.8
e. Hiring mid-career researchers	57.1
f. Cooperation with foreign companies	51.5
g. Utilizing subsidiaries	34.1
h. Technical cooperation with foreign universities	17.0
i. Acquisition of another company	10.9
j. Setting up research facitilites overseas.	6.2

(Note: These data are from a MITI survey of manufacturing companies listed on the Tokyo Stock exchange. The questionnaire was sent to the 1,090 manufacturing companies, of whom 466 responded (42.8%).

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1. See for example R. Jaikumar, "Postindustrial Manufacturing" Harvard Business Review 1986 on the influence of production worker organization on the use of flexible manufacturing systems in Japan and the United States, and the more general approach in Michael L. Dertouzos et al, Made in America: Regaining the Productive Edge (Cambridge, MA: MIT Press, 1989).