The Relationship of Industry Evolution to Patterns of Technological Linkages, Joint Ventures, and Direct Investment Between the U.S. and Japan

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The patterns of technological linkages, joint ventures, and direct investment between U.S. and Japan were predicted for emerging, growing, maturing, and declining industries based on an analysis of the key characteristics of each stage of industry evolution and the costs and benefits of each form of resource investment. A first model predicting peak activity for technological linkages in emerging industries, joint ventures in growing industries, and direct investment in maturing industries was supported as was a second model which customized prediction for all forms at each stage of evolution. Implications and suggestions for future research are discussed.

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Economic activity between the U.S. and Japan has skyrocketed in the 1980's, triggering the need for research on the interconnections that bind these two major players of the world economy. Case studies and business press coverage of some of the highly visible joint ventures between U.S. and Japanese companies such as Nummi (Toyota/General Motors) or Diamondstar (Chrysler/Mitsubishi) have illuminated the dynamics of these relationships (Business Week, July 14, 1986, August, 14, 1989; Phillips, 1989; Roehl & Truitt, 1987; Weiss, 1987). Aggregate statistics have provided information on the volume of activity (Hergert & Morris, 1988; Rappaport, 1989; U.S. News and World Report, 1988). And work such as that by Hull, Slowinski, & Wharton (1988) on technological linkages of 21 large companies in U.S. and Japan or Tybejee's (1988) study on the formation and configuration of 21 manufacturing joint ventures between U.S and Japan have moved our understanding of the patterns of activity in certain industrial subsectors forward.

Relatively unexplored however, is large sample, systematic interindustry research that analyzes multiple forms of resource investment between U.S. and Japan. This type of research could uncover the texture and variation underlying the overall trends, allow comparative within and between industry analyses, and enrich our understanding of the context the micro process-oriented research is embedded in. As Contractor and Lorange recently note (1988:xxvii), "How to translate these firm level observations into empirical studies that compare industries remains a problem".

This study responds to that need by exploring the patterns of three different forms of resource investment between U.S. and Japan in industries at four stages of evolution. More specifically, it analyzes and compares the formation rates of technological linkages, joint ventures, and direct investment in emerging, growing, maturing, and declining industries.

Although previous research has not directly addressed this topic, there is theoretical and empirical work that is relevant and offers guidance on different dimensions of this study. Strategic perspectives are useful for their categorization of the stages of industry evolution, and for their discussion of the strategic needs of organizations trying to compete in those environments (Harrigan, 1980, 1988; Porter, 1980). Work in the 1960's and 1970's grounded in exchange theory, resource dependence, and ecology on domestic interorganizational relationships is helpful for analyzing different forms of interorganizational linkages and their costs and benefits (Aldrich, 1979; Aldrich & Whetten, 1981; Levine & White, 1961; Litwak & Hilton, 1966; Pfeffer & Salancik, 1978). An extension of these theories by Contractor and Lorange (1988) is useful for classifying forms according to their degree of interdependence.

Transaction cost views provide yet another perspective on the pros and cons of different forms emphasizing internal governance. Theoretical discussion has clarified some of the trade-offs of joint ventures versus direct investment (Mowery, 1988:8-12; Williamson, 1985). In addition, several recent empirical studies, although not focusing explicitly on U.S./Japan interconnections, provide comparative information on specific industries (Pisano, Russo, & Teece, 1988; Pisano, Shan, and Teece, 1988; Thomas, 1988).

This study draws on these literatures but also extends them. Previous work in strategy has focused largely on joint ventures, emphasizing the competitive benefits of alliances in improving the firm's strategic posture in its industry and issues in managing the parent-child-parent relationship (Harrigan, 1986; Lorange and Probst, 1987; Lyles, 1987). Recent research is more diverse, often analyzing multiple forms of linkages, but rarely is direct investment included for comparisons or U.S./Japan connections isolated (Contractor & Lorange, 1988; Doz, 1988; Hladlik, 1988). Similarly, although previous exchange, resource dependence and ecological work on interorganizational forms has focused on a range of different types, analyses have tended to be restricted to domestic linkages (Aldrich, 1979; Pfeffer and Salancik, 1978). This study analyzes multiple forms of resource investment, focuses exclusively on U.S. and Japan, and develops a theoretical basis for predicting the relationship between these various forms and stage of industry evolution. In addition, it extends the industry-specific transaction cost research by allowing interindustry comparisons while controlling for the time span of the data, the types of forms analyzed, and the countries included (U.S. and Japan).

THEORETICAL BACKGROUND AND DEVELOPMENT

Stages of Industry Evolution

An assumption underlying much of the management literature is that industries evolve. Although issues such as: the duration of each stage of evolution; whether industries skip stages; and the exact form and nature of evolution continue to be debated and researched, there is consensus that conceptualizing industries by stage of evolution makes sense (Porter, 1980: 275-298; Tushman & Anderson, 1986; Chaganti, 1987). Indeed, research is often framed according to stage of industry evolution. For example, in the last decade a growing research base has been developed on mature and declining industries (Hambrick, 1983a, 1983b; Harrigan, 1980; Harrigan, 1988; Vasconcellos & Hambrick, 1989).

Four basic stages of evolution are commonly distinguished. Industries in the first stage, and labelled the emerging stage, operate in environments characterized by tremendous uncertainty. There are "no rules of the game". Indeed " the absence of rules" is the game and "both a risk and opportunity" (Porter, 1980:215-216). Technology is in constant flux, causing dramatic shifts in markets and products. Short production runs and custom tailored products are the norm. Extreme shortages in trained personnel compound uncertainties. Proprietary technology and difficulties in acquiring access to raw materials and distribution channels create barriers to entry that must be overcome (Olleros, 1986). As a result of these conditions, relatively few companies survive and those that do tend to have high prices and low profits. Consequently, they constantly search for ways to reduce risk without overcommitting resources. They need information, skills, and technology but must acquire those resources without sacificing the flexibility required to adapt to the technological rollercoaster they face.

As technological innovation begins to converge around a dominant design and user needs become clearer, the industry shifts from emerging to growth (Abernathy & Utterback, 1978; Moore & Tushman, 1982).

In this second stage, products and markets begin to take hold. Demand has been created and companies are battling to attract customers based on their technologies, the performance of their products and their marketing acumen. Production has shifted from batch to more standardized mass production. Process improvements take on new importance. Prices are high. Profits are good for those who survive, but mergers and deaths are common (Porter, 1980).

As those competing gain more confidence and see their profits accumulate, they look for new opportunities. In addition, to improving current products, they begin to explore new products, product line extensions, and related diversification. Often, the necessary skills and resources are not available in-house, so they search for partners with similiar interests and complementary resouces to share costs and lower risks. At the same time, for those companies that have accumulated capital, new market segments, often overseas, become enticing as a means of rapidly increasing customer bases and compensating for intensifying domestic competition.

As the industry experiences the shift from growth to maturity, products often become more commodity-like and competition for market share becomes more fierce. In response, companies typically pursue several strategies. They try to cut costs and improve service through incremental improvements in products and processes (Moore and Tushman, 1982). They may renew interest in technological advancements and invest more money in R&D as they attempt to revitalize aging products and manufacturing processes. Research and development activity may also be triggered by the need to develop second generation technologies to carry them into the future. As price competition escalates, the search for new customer bases to cultivate also gains added fervor. Increased regulatory scrutiny and trade restrictions create additional strain (Porter, 1980).

Although companies in mature industries have some slack, they must invest it wisely to maintain and sustain their position. They need to find new markets to sell their established products. They need to improve and extend both products and processes to sustain profits in the future. They may engage in related diversification to reduce costs and capitalize on strengths (Porter, 1980).

Industry shifts from maturity to decline are often prompted by major shifts in the external environment. International competition that was not anticipated, regulatory and legislative changes, social and demographic changes, or technological jumps making current products and processes obsolete are some common causal factors (Harrigan, 1988; Porter, 1980). Depending on the underlying causes of decline and the organizations current resources, strengths and weaknesses, these firms may decide to pursue strategies of rapid divestment, milking or creating or defending a particular niche or segment (Porter, 1980).

Thus, emerging industries are searching for ways to reduce costs and risks while maintaining flexibility. Growing industries are searching for partners with complementary skills to help them expand markets and broaden their customer base. Mature industries face intense competition, need new markets and need to discover ways to continue innovation in both products and processes. Declining industries struggle to squeeze what they can out of their margins and hope to find an area where they can still survive.

Interorganizational Linkages

Interorganizational linkages offer a set of possible tools that may help organizations cope with the different problems faced at each stage of evolution (Roberts & Berry, 1985). Interorganizational linkages are relations between two or more organizations formed to transfer, exchange, develop or produce technology, raw materials, products, or information. Although terms such as "strategic alliance, collaborative agreement, and industrial cooperation" have been used in previous research, neutral terms such as interorganizational linkage or relation are used here. These terms do not assume that the partners are working together towards mutually shared goals. They allow for the possibility of conflict, exploitation and changing interests over time (Auster, 1987).

Interorganizational form is the term used to distinguish different types of interorganizational linkages. Although precise definitions and research applications of the concept form have varied among ecologists, the term form typically is used as a synonym for organizational type (Aldrich, 1979; Hannan & Freeman, 1977; McKelvey, 1982). Many different interorganizational forms have been created by organizations and the bounds on the number of forms is only limited by the creativity of the managers developing them.

Theoretically, however, these interorganizational forms can be categorized along a continuum according to the degree of resource investment they require. High resource investment linkages (hereafter called HRIL's) are those linkages requiring a substantial commitment of money, technology, people and trust. Joint ventures, defined as "a new operating or legal entity created through a combination of resources by two legally distinct, sponsoring firms that share ownership or responsibility for the venture" (Brahm and Astley, 1988) would be HRIL's. Joint ventures require long-term commitment and trust, a major financial investment, the construction or acquisition of physical space to house the joint venture, equipment and technology to produce the output, and managment time and energy to oversee and run the venture. Given this resource investment, switching costs and barriers to exit would be high. In transaction cost terms, HRIL's are attractive when asset specificity is a competitive advantage.

The benefits of HRIL's are that they allow large scale and relatively quick penetration of a new and unfamiliar market, access to new skills, technology, and resources, and the risks and costs are shared. However, with these benefits come costs. Joint ventures have the highest degree of interdependence of all types of interorganizational forms (Contractor & Lorange, 1988:6). The consequence of this interdependence is that HRIL's are difficult to form, difficult to manage -- a great deal of time is spent on coordination and governance and difficult to terminate. Goals and interests may conflict. Strategic flexibility may be thwarted. Administrative costs may run high and cross-cultural gaps may create difficulties mixing American and Japanese production methods and work styles (Phillips, 1989). In addition, partners may fear that information, resources and technology shared now may enhance their competitor in the future or that they may be forced to buy from designated sources or sell through particular distribution channels (Contractor & Lorange, 1988:8,23).

Low resource investment linkages (LRIL's) would fall at the other end of the continuum and include linkages such as joint research and development arrangements, technological exchanges and transfers, and licensing agreements. These forms offer shared costs and risks with access to technology and technological know-how, without tremendous sacrifices in autonomy (Hladlik, 1988: p.189-192). The financial investment required for these forms is relatively low. LRIL's are set up in one of the parent companies, and typically use employees already on staff and resources already available. Thus, unlike HRIL's, LRIL's have much more flexibilility and the linkage can be severed more easily.

The drawback of LRIL's is that the scope of the relationship is much more narrow. Goals, interests and the future of the relationship are often uncertain and more tenuous. As a result, proprietary information or technology may be applied to unauthorized areas and resolving issues such as the boundaries of the contract or disaggreement on design specifications may be extremely time consuming. In addition, economies of scale may be difficult to achieve because of small scale (Hladlik, 1988: 192-195).

Direct Investment

Although not an interorganizational linkage, direct investment is a third form of resource investment. It is a form of interconnection that handles the flow of economic activity between two countries, although not managed through an agreement of organizations based in each country. Direct investment would be above HRIL's on a continuum of resource investment from high to low because the financial, managerial, technological and raw materials of a joint venture are required, yet they are not shared.

Direct investment is a concept that has been used loosely in the management literature to mean investment overseas ranging from 10 to 100% (Kujawa and Bob, 1988). Following Arpan, Flowers & Ricks (1981), direct investment is defined here as a 100% ownership of a company on foreign soil. Direct investment is included in these analyses for theoretical reasons and because of insights gained from qualititative interviews with managers overseeing overseas investments in the U.S. and Japan (Personal interviews, March, 1989).

Theoretical justification is grounded in discussions such as that of Mowery (1988:8-12) or Contractor & Lorange (1988: xxvi) where entering a joint venture is viewed as an alternative judged in terms of its relative costs and benefits compared to direct investment. For example, Contractor & Lorange propose that "many of the joint ventures, consortia, and technology sharing agreements in the eighties were undertaken by preference over a fully owned subsidiary option" (Lorange & Contractor, 1988:xxvi).

Further support for including direct investment in this study emerged in qualitative interviews conducted with top managers in Japan and the U.S. who clearly indicated that they view direct investment as one of a set of several strategic alternatives they consider when deciding on an international overseas hook-up (Personal interviews, January through March, 1989).

Direct investment is ideal when an organization has resources, skills and technology in-house, knows the foreign market or can hire good people who do, and when the environment is relatively stable. The advantage of direct investment versus a joint venture is that all the hassles and compromises emerging from joint ownership are avoided. That freedom, however, is traded off for sole responsibility for the entire risk and cost of the investment. Consequently, a company establishing an overseas direct investment must have substantial slack, resources, and confidence in the future viability of that market and product and in their ability to manage foreign suppliers, distributors, personnel, customs, managerial expectations, and unions (Root, 1982).

A Contingent Approach to Form and Industry Evolution

The relationship between form of resource investment and industry evolution can be predicted based on the characteristics of each stage of evolution and the costs and benefits of the three different forms highlighted in the last several sections.

LRIL's and Stages of Industry Evolution. Organizations in emerging industries are frantically struggling to find a viable technology around which they can build a customer base and sustainable range of products. Faced with tight budgets and turbulent environments, they search for ways to reduce risks and costs without surrendering the long-term adaptability they need to adjust to technological and market shifts. Low resource investment forms such as technological transfers and exchanges, and joint R&D, would be extremely attractive under these conditions. They offer a mechanism for organizations with little slack to acquire information, expertise and technology while sharing cost and risk, and without a tremendous sacrifice in flexibility. Moreover, given the need to monitor information in rapidly changing environments, these forms often act as tentacles for capturing information at a fairly low cost.

In growing industries, the proportion of LRIL's compared to other forms is expected to decline as companies shift their interest and emphasis away from technology towards mass production. Having discovered the marketable technology and products that propelled them into growth, they will invest less in LRIL's and look for forms of interconnection that will help them to build their customers bases and product line.

Maturing industries however, having experienced the negative effects of overlooking technology in the growing stages are expected to renew their interest in LRIL's as they search for new technology to regain their stamina and for technological process improvements to help them cut costs and improve quality.

Declining industries, in their struggle for survival, are expected to have very low levels of any form of activity, but technological linkages may be attractive because they are affordable and may help sustain momentum in the few niches still viable.

Thus, it is predicted that the formation rates of LRIL's will peak in emerging industries, decline to medium levels in growing industries, regain stamina in maturing industries and drop off substantially in declining industries.

HRIL's and Stages of Industry Evolution. The formation of HRIL's is expected to be low in emerging industries because of lack of the necessary resources and capital and the fear that environmental shifts will make the joint venture obsolete or non-optimal. High commitment forms would be unattractive in these uncertain environments.

Peak activity for HRIL's is expected in growing industries. Companies in growing industries typically have discovered a profitable but narrow realm of expertise. As competition heats up, cost effective ways to diversify their customer base and product line without jeopardizing the capital they worked so hard to build will be particularly attractive. Joint ventures with companies with complementary areas of expertise allow the pursuit of long run interests while sharing costs and risks, reducing exposure and vulnerability.

In mature industries, some HRIL activity is likely to continue as a strategy for gaining skills, resources, and avoiding trade barriers, or as a prelude to direct investment. Given that these companies have the capital and the majority of markets are relatively stable, HRIL's remain attractive in areas where in-house expertise is lacking. However, the levels of HRIL activity is expected to have decreased in mature industries relative to the activity in growing industries.

In declining industries, very little activity is expected because companies would lack the financial resources and slack required to set up a joint venture.

Thus, it is predicted that the formation rates of HRIL's in emerging industries will be low but some activity is expected. It is predicted that HRIL's will peak in growing industries. In maturing industries, the HRIL rates will be higher than HRIL activity in emerging industries because of available resources, but somewhat lower than in growing industries because of the attractiveness of direct investment at that stage. HRIL's, are not expected in declining industries.

Direct Investment and Stage of Industry Evolution. It would be expected that direct investments would not be established in emerging industries due to the tremendous resource requirements and the constraints of environmental uncertainties.

Some direct investments may be created in growing industries in pockets of the market that seem more stable but limited capital and expertise will constrain most growing companies even in those markets that are beginning to settle.

Peak activity for direct investment is expected in mature industries. Environments are relatively predictable and long-range planning is possible. Established companies with substantial slack, diversified skills and resources will opt for sole ownership and control in those areas where in-house or acquirable expertise is available. Given the intensified domestic competition for market share, direct investment will offer a method for generating demand in new markets where competition may be less severe.

Declining industries would be expected to be unable to afford direct investment and thus activity levels would be extremely low.

Thus, direct investments are not expected to be formed in emerging industries. In growing industries, levels are expected to increase. In maturing industries, direct investment is expected to climb to peak levels, and like HRIL's, direct investment will drop off completely in declining industries.

Based on the discussion above, exact formulations of expected rates of formation of each form are not possible. However, by categorizing the expected patterns of LRIL's, HRIL's and direct investment into crude levels of activity, the relationship between form and evolution can be depicted graphically. Five levels were chosen: none, low, medium, high and peak. Figure 1 shows a graphic representation of the expected relationships between form and industry evolution based on the predictions delineated in the three previous sections.

Insert Figure 1 about here

METHODS

Industry Selection

A content analysis of Industry Outlooks from Business Week for 1983-1985, and industry summaries in Asian Business for 1983 to 1985 was conducted to identify industries at each stage of evolution. Industry Outlooks offers a robust view of each industry. In addition to a discussion of sales and profits, it provides an overview of the major competitive, economic, and political factors in each industry and their expected consequences. This information is summarized from interviews with a broad range of sources including corporate leaders, business analysts, and government specialists (Industry Outlooks, 1983; 1984; 1985). In addition, comparable industry summaries in Asian Business were analyzed.

1984 and 1985 were content analyzed because they were the years for which data was available. 1983 was also content analyzed under the assumption that business conditions in the preceeding year would have affected business decisions in 1984 and 1985. The industries selected to study were those that could be clearly classified for the years 1984 and 1985. Table 1 provides a distillation of the results. Biotechnology, Robotics and New Materials were classified as emerging industries during 1984 and 1985. Computer and Communications were growing industries. Chemical, Auto, Electrical and Machinery were mature industries and Textiles, Iron and steel were declining industries during those years. Classification of industries was further validated by a panel of experts from academia and industry.

Insert Table 1 about here

Based on the classification in table 1, an ordinal variable for stage of industry evolution was created where 1 = emerging, 2 = growing, 3 = maturing, and 4 = declining.

Form

The three organizational forms analyzed were low resource investment linkages (LRIL's), high resource investment linkages (HRIL'S) and direct investment. They were operationalized as a trichotomous ordinal variable where 1 = low resource investment form, 2 = high resource investment form, and 3 = direct investment. More specifically, cases were assigned to each category as follows: 1 = technological transfers, exchanges and cooperation, joint research and development, and management exchanges; 2 = joint ventures with one or more firms and joint manufacturing, and 3 = direct investment. The logic behind the scale is that linkages in the low category are easier to establish and terminate and requires less commitment of money, and other resources, than the high categories. Direct investment was categorized as 3 because as noted previously the resources for establishing a new organization are required but the burden is not shared as with a joint venture.

Data

The data for this study are based on case information compiled by the Japanese External Trade Organization on interorganizational relationships and direct investment that were formed in 1984 and 1985 between the U.S. and Japan. Although they draw on numerous sources, the bulk of the information they collect is based on announcements appearing in six newspapers including Nihon Keizai Shimbun, Nikkei Sangyo Shimbun, Nikkan Kogyo Shimbun, Nihon Kogyo Shimbun, Jiji Fax News, and Kyoda Sogo Sekai Keizai Tsushin. Their mission according the Ministry of Trade and Industry is to both track and document the economic activity between the U.S. and Japan.

The eleven industries chosen based on the industry analysis described above yielded 179 cases for 1984 and 300 cases in 1985. For each case, the line of business of the agreement, the nature of the agreement, the companies involved, and the date the venture or direct investment was established was documented. Qualitative interviews with top managers in selected companies in both the U.S. and Japan were conducted to supplement the case information.

Analysis and Results

Basic descriptive information about the data is shown in Table 2. As the top part of the table indicates, direct investments were the most common form in both years (1984: 42%; 1985: 41%), followed by LRIL's and then HRIL's. The distribution of the data was remarkably stable between 1984 and 1985 particularly given that the absolute numbers grew substantially, from 179 in 1984 to 300 in 1985. The bottom part of the table displays proportion of resource investments by stage of industry evolution. For both years the greatest activity occurred in maturing industries, followed by growing industries, followed by emerging industries and lastly declining industries. This suggests that the amount of resource investment was directly related to the degree of slack found in industries at each stage of evolution. Again, the pattern was remarkably stable between 1984 and 1985, given the gains in absolute numbers.

Insert Table 2 about here

The Del procedure developed by Hildebrand, Laing, and Rosenthal (1974 a; 1974b; 1977) was used to test the predicted relationships between the three forms of resource investment and the four stages of industry evolution. Del is a statistical technique that gauges the strength and significance of the relationship between two categorical variables based on specific a priori predictions. The del procedure is ideal for these analyses because it allows for both unweighted and weighted predictions to be tested for each cell in a cross classification matrix. In addition, the Del technique calculates a summary statistic of association that can be interpreted simililarly to the coefficient of determination in regression (R^2). It represents the "proportionate reduction in error of knowing the specific prediction rule over not knowing the prediction rule" (Drazin and Kazanjin 1989:14; Hildebrand, Laing, and Rosenthal, 1974a:171). Tests of significance can also be calculated with Del. Other categorical data techniques such as Chi square, Cross-Product ratio, Lambda, and Tau have much more limited prediction and testing abilities. Some lack measures of the strength of association, others are only useful for dichotomous variables. None allow tailored predictions for each cell to be tested

(Blalock, 1979; Kazanjian and Drazin, 1989; Hildebrand, Laing, and Rosenthal, 1974).

The assumptions of del, like many other categorical data analytical techniques, are that observations fall into only one category and that the outcomes for observations are independent.

In a Del test based on an unweighted prediction rule, either a 1 or 0 is assigned to each cell of a A*B matrix where A represents the first variable and B represents the second variable. 0 is assigned to "predicted" cells where a relationship between A and B is expected and 1 is assigned to the non-predicted "error" cells.

Table 3 displays the cell assignment for an unweighted prediction rule based on the expected relationship between the four stages of industry evolution and the three forms. Peak activity cells were assigned a predicted 0 and all other cells were assigned a 1 and calculated as error cells. Since peak activity was predicted for LRIL's in emerging industries, for HRIL's in growing industries, and for direct investments in maturing industries, those cells were assigned a 0. The remaining cells were assigned a 1 in this first test.

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Insert Table 3 about here

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Del and its associated statistics were calculated using BASIC. Formulas for the calculation of Del are provided in Appendix A. The results of the Del calulation for both 1984 and 1985 indicate support for the predictions of peak activity at each stage of industry growth. In 1984, del=.10 ($p < .0001$). For 1985, Del was somewhat more powerful with del= .20 ($p < .001$). Thus, the unweighted prediction rule reduced the error 10% in

1984 and 20% in 1985. Note that as mentioned earlier, since Del is the categorical equivalent of R^2, these Dels are analogous to correlation coefficients of of .32 ($\sqrt{.10}$) and .45 ($\sqrt{.20}$) respectively (Hildebrand, Laing and Rosenthal, 1974).

More sophisticated predictions can also be tested with Del using a customized (weighted) prediction matrix. Rather than assigning 0's to predicted cells and 1's to error cells, weights (between 0 and 1) can be assigned to cells according to the theory underlying the predictions. As the weighting moves from 0 towards 1, the penalties for errors increase. Social science theory is rarely refined enough to assign precise weights as Hildebrand, Laing and Rosenthal (1974) note, but crude prediction rules of expected weighted relationships can be assigned. If the variance explained increases, the weighted prediction rule is more powerful than the unweighted prediction rule.

Based on the propositions outlined previously and displayed in Figure 1, the following weighted prediction rule was developed (see Table 4). 0 (no penalty) was assigned to peak cells for each form as above. .25 (1/4 penalty for errors) was assigned to the cells expected to be at high levels of activity. This included the LRIL's in mature industries and HRIL's in mature industries. .5 (1/2 penalty for errors) was assigned to the LRIL cell in growth industries and direct investment in growing industries where medium levels of activity were expected. .75 (3/4) penalty was assigned to those cells where low activity levels were expected including LRIL's in declining industries and HRIL's in emerging industries. A 1 (full error penalty) was assigned to those cells where no activity was expected. Those cells were the declining industry cells for each form and the direct investment/emerging industries cell. Note that essentially the scale in the graph in Figure 1 has been reversed to fit the required form for Del analysis. So, for example, a cell that was graphed as peak (1.00) in Figure 1 is now assigned a 0 for the Del analysis.

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Insert Table 4 about here

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The results of the Del procedure based on customized predictions for each cell indicated that the weighted matrix was a somewhat more powerful predictor of the relationship between industry evolution and form for both 1984 and 1985. For 1984, the Del increased to .14 ($p < .000$) and was significant. For 1985, Del increased to .24 ($p < .001$) and was significant. Again, it is important to note that these results equate to correlation coefficients of .37 ($\sqrt{.14}$) and .49 ($\sqrt{.24}$) respectively. For both 1984 and 1985, additional variation in formation rates by stage of industry evolution was explained by the weighted prediction matrix. For both 1984 and 1985, the increase in Del was significant.

DISCUSSION

Economic interconnections between U.S. and Japan are likely to continue to proliferate in the coming decades. This study contributes both theoretically and empirically to a growing body of knowledge attempting to better understand those linkages. The theoretical strength of this study was that it integrated ideas from several theoretical perspectives including strategy, resource dependence and ecological theory to develop and test a series of propositions about the relationship of industry evolution to inteorganizational forms and direct investment. Much of the previous research on this topic has worked primarily within one theoretical perspective. The empirical strength of this study was that it tested the patterns of several different forms of interconnections between U.S. and Japan across industries at different stages of evolution. Some previous research has examined interorganizational linkages in one industry, or small samples of joint ventures in multiple industries, but studies examining direct investment, joint ventures, and technological linkages in industries at four different stages of growth between the U.S. and Japan allow comparative insights that are not possible when the range of forms or the industries examined are more narrow.

The results indicate that overall formation rates were highest in mature industries. However, this aggregate birth rate obscured distinct patterns by form and by stage of evolution. The first model tested the predictions of peak rates of each form by each stage of industry evolution using the Del technique and an unweighted prediction matrix. Technological linkages were predicted to be highest in emerging industries, joint ventures in growing industries, and direct investment in mature industries. Prediction cells were assigned a 0, all others were assigned a 1. The predictions were supported and significant for both years with a 10% reduction in error for 1984 and 20% reduction in error for 1985.

In the second model, a more refined version of the predicted patterns was tested by assigning weights to the off-diagonal cells according to the patterns predicted for non-peak but active cells. In the second test, Del was more powerful in both 1984 and 1985 and still significant and the weighted prediction matrix improved the reduction in error to 14% for 1984 and to 24% for 1985 equivalent to correlation coefficients of .37 and .49 respectively.

These results are fairly powerful given that only the relationship between three forms and four stages of evolution were tested. In addition, these findings are consistent with several industry specific studies conducted on interorganizational linkages, although these other studies did not exclusively focus on U.S./Japan linkages. For example, Klepper (1988) analyzed global linkages among the initial six producers of robots, electronic control and software specialists, application specialists, and factory of the future companies. Out of 117 linkages examined, less than 10% were HRIL's, thus reinforcing the pattern of LRIL's in emerging industries. (Direct investment was not studied.) In addition, those joint ventures that were created occurred mostly among application specialists (Klepper, 1988:236-252). Similarly, Pisano, Shan & Teece's (1988) study of 280 new biotechnology firms, established between 1976 and 1986, found that out of 200 randomly selected arrangments only "in a relatively small number of cases" were "relationships formed around equity partnerships or joint ventures" (1988: 195). The bulk were LRIL's including research and development arrangements, supply relationships and technological transfers again showing LRIL patterns in an emerging industry.

Pisano, Russo and Teece (1988) study of the telecommunications industry found 50% of the linkages were HRIL's (equity, joint ventures or consortiums) in data collected by researchers at Futoro Organizzazione Risorse in Rome between 1982-1985 validating the prediction for growing industries.

This study was exploratory, however, and its limitations suggest a number of directions for future research. To begin with, this study focused on formation rates. Much more information is needed about factors that affect the success, survival, decline, transformation and termination of different forms of linkages between U.S. and Japan. Studies on the life cycles of joint ventures (Harrigan, 1988: 205-226; Kogut, 1988: 169-186) should be replicated with data focusing solely on U.S. and Japan. Comparisons of life cycles of different interorganizational forms and direct investment across multiple industries would also be useful. They would shed light on whether similar patterns persist across different industries and whether different forms evolve in similar or different ways.

Second, more complex environmental measures including trade policies, regulatory changes, and the political climate between the two countries and how those factors affect the life cycles of forms would enrich our understanding substantially. A third avenue would include a deeper examination of the history of relationships between firms that form interorganizational relationships and how that affects their success and likelihood of subsequent hook-ups.

Fourth, the results found in this study also raise a number of policy questions about the aggregate consequences of the patterns of technological linkages, joint ventures and direct investment between U.S. and Japan. Those concerned with the U.S. protecting its technological strengths would want to explore the direction and flow of technology underlying the patterns of technological linkages predominating in high tech emerging industries. Further research would also be useful on how the joint ventures in growing industries change the competitive dynamics of those industries and whether those changes fortify or weaken the U.S. economy. The patterns in mature industries also deserve greater attention. Studies need to investigate whether the massive direct investment in mature industries by the Japanese in the U.S. cannibalizes those customer bases or makes U.S. companies and their suppliers tighter and leaner. These types of issues are stimulated by inter-industry studies and reinforce the need for future work at this level of analysis.

Finally, this study used dyadic analyses. Another extremely fruitful avenue for future research is the application of network methodology to this topic so that the webs of relationships that these dyads are embedded in are brought to the surface. Previous work on interconnections within Japan has demonstrated the role that networks play in domestic Japanese transactions (Gerlach, 1987). Research on interconnections between U.S. and Japan is likely to benefit from adopting the same wide angle approach. Network analyses would be expected to contribute significantly to our understanding of how partners are chosen, what kinds of portfolios of linkages are optimal, and the political dynamics created by interdependencies and different combinations of networks between U.S. and Japanese companies.

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APPENDIX A

Calculating Del

Values of del, and tests of the significance of del were calculated according to the following formulas:

$$\nabla = 1 - \frac{\Sigma_i \Sigma_j (w_{ij} P_{ij})}{\Sigma_i \Sigma_j (w_{ij} P_{i\cdot} P_{\cdot j})} ,$$

where w_{ij} = 1 or less for specified error cells and 0 for predicted cells,

and, P_{ij} = cell probabilities,

and, $P_{i\cdot}$ and $P_{\cdot j}$ = marginal probabilities.

The hypothesis $\nabla > 0$ is tested against normal tables using the statistic

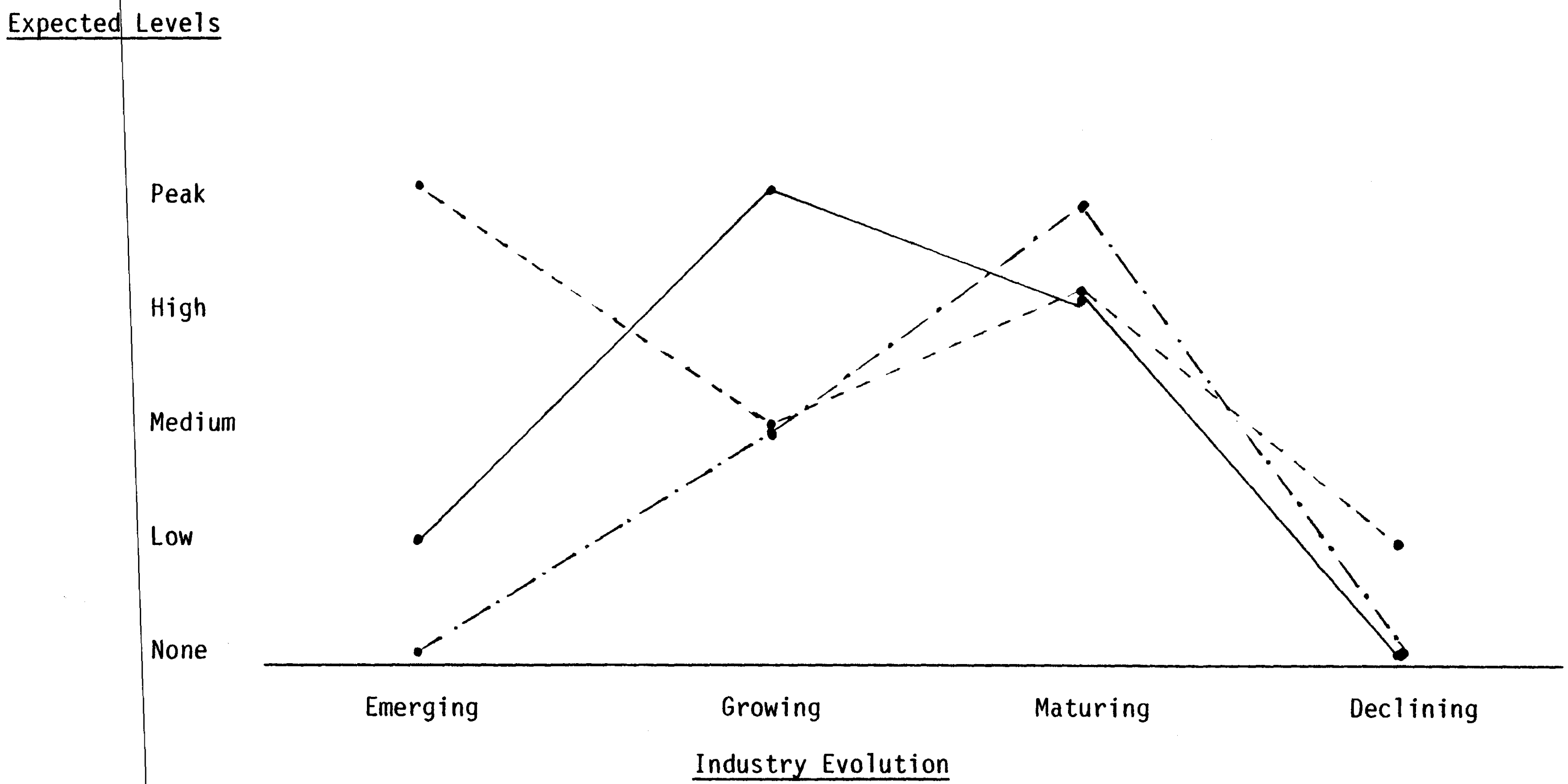
$$Z = \frac{\nabla}{(V)^{\frac{1}{2}}}$$

where V = variance of del, and

$$V = \frac{\Sigma_i \Sigma_j (w_{ij}{}^2 P_{ij}) - (\Sigma_j \Sigma_j w_{ij} P_{ij})^2)}{n(\Sigma_i \Sigma_j (w_{ij} P_{i\cdot} P_{\cdot j}))^2} .$$

FIGURE 1

A Graphic Depiction of the Predicted Relationship between Form and Stage of Industry Evolution*



* Key: Form

LRIL's: - - - - - -

HRIL's: ————

Direct Investment: —— · —— · ——

TABLE 1

Key Environmental Factors by Industry: 1983, 1984, 1985[1]

Emerging	
Industrial Robotics	- rapid technological change - growth and production increasing with giant strides - shake-out may begin
Biotechnology	- rapid technological change - changing FDA and EPA regulations - rapid growth
New Materials	- vigorous area that's expected to soar - substitutions are stronger, more lightweight with better heat and corrosion resistance - tremendous innovations in both new materials and improved versions of old materials
Growing	
Computers and Related Products	- rapid technological change - shift from PC's to work stations - strong threats from Japanese competitors - heavy domestic competition - solid growth for those who survive
Communications	- demand continues to climb - high growth in telephone and computer data hook-ups - business information services are booming - competition is stiffening - facsimile booming in Japan, expected in U.S.
Maturing	
Chemicals/Drugs	- long range outlook blurry - stiff competition in some areas of drug development such as painkillers - strong growth in a few areas of drug development such as cardiovascular drugs - tightening of environmental regulations - increasing legal liability
Automobiles and Parts	- demand is strong, $8-10 billion profits expected - import restrictions on Japanese autos have enhanced domestic growth - Japanese competition and popularity of imports continues
Machinery	- machine tools up again - demand from auto and defense expected to hold strong - spare machinery, replacement equipment and forklifts

on the rise
- intense competition continues
- imports chip away at all corners of the capital equipment market

Electrical
- cost cutting measures and quality improvement critical in established areas
- increased pressure from Japan and other foreign competition
- growth strong in some niches
- domestic producers need to prove they can defend markets against imports

Declining

Steel and Iron
- declining consumption and losses continue
- an anemic market plagued by rising machinery imports
- plants operating at 65% capacity, at best
- price pressures and intense competition
- the picture for flat-rolled steel might improve a bit

Textiles
- demand is weakening
- declining industry
- apparel imports doubled from 1982 to 1985 stealing market share from U.S. manufacturers
- "Made in U.S.A." law in effect 12/24/87

[1] Sources: Business Week, Industry Outlooks, January 17, 1983: 57-93; Business Week, Industry Outlooks, January 9, 1984; 51-83; Business Week, Industry Outlooks, January 14, 1985: 66-114; Asian Business, Industrial Japan, January 1983: 30-37; June 1983: 82-85; July 1983: 34-47; October, 1983: 84-85; December 1983;:58-64; April 1984: 38-56; August 1985: 64-67; November 1985: 34-50; November 1985: 57-82.

TABLE 2

Proportions of Resource Investment by Form by Stage of Evolution

	1984*	1985**
Form		
LRIL's	36%	35%
HRIL's	22%	24%
Direct investment	42%	41%
Industry Evolution		
Emerging	18%	18%
Growing	24%	24%
Maturing	47%	57%
Declining	11%	7%

* N = 179

** N = 300

TABLE 3

Unweighted Prediction Matrix Between

Form and Industry Evolution*

Form	Emerging	Growing	Maturing	Declining
LRIL	0	1	1	1
HRIL	1	0	1	1
Direct Investment	1	1	0	1

Stage of Industry Evolution

*Key:
Predicted cell = 0
Error cell = 1

TABLE 4

Customized Prediction Matrix Between

Form and Industry Evolution*

Form	Emerging	Growing	Maturing	Declining
LRIL	0	.5	.25	.75
HRIL	.75	0	.25	1
Direct Investment	1	.5	0	1

Stage of Industry Evolution

*Key to weighting scheme:

Peak activity	=	0
High	=	.25
Medium	=	.50
Low	=	.75
No activity	=	1.00