Competitive Dynamics of Technological Strategy

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Introduction

Using the typology developed by Porter (1985) for competitive analysis, this paper seeks to investigate the role of generic technological strategy in wealth-creation capability of the firms. It asks whether a firm could generate returns above the market over a period of time using appropriate generic strategies for technological innovation. According to Porter (1985: 17), "cost leadership" and "differentiation" are two mutually exclusive generic strategies, because each of these involve "a fundamentally different approach to creating and sustaining a competitive advantage." The firms pursuing a cost leadership strategy seek overall cost control for generating above-average returns, despite low prices. The differentiation strategy, in contrast, must typically be supported by substantial investments in research, product design and marketing. In addition, the firms may specialize in servicing particular customer groups, or in offering specific product expertise, and thereby follow a focus or niche strategy. This paper suggests that a focused technological strategy founded on the home base knowledge advantages can help firms sustain a rapid growth in their wealth creation capability over a period of time. On the other hand, a leadership-oriented technological strategy, founded on the knowledge base already existing in the market, tends to destroy wealth in absence of any new competitive advantages for the firm. Differentiation strategy, which is oriented towards creation of complementary research, administrative and marketing assets, can help firms offset the commodity orientation threatened by a cost-based leadership strategy. Previously, differentiation strategy has been noted as more effective than the cost leadership strategy under uncertain and unpredictable environments, such as those characterizing technology intensive industries (Hambrick, 1983; Kim and Lim, 1988). This paper highlights the limitations of simply relying on the current wealth creation implications of various generic technological strategies, especially under dynamic conditions where the global rivals are seeking to imitate wealth creation initiatives. It further inquires how the firms demonstrating a successful track record of sustained wealth creation advantage manage the competitive learning processes, in particular through strategic exploitation and development of the local entrepreneurial efforts into revolutionary, yet complementary, domains.

Specifically, three kinds of strategic challenges of the network-level learning processes are studied. The first challenge pertains to the risks of various domestic firms trying to gain a competitive edge through learning that revolutionizes the way in which currently unproductive innovations can be used. The second challenge involves the risks of global rivals seeking to contest the advantage through incremental learning of the high value-adding innovations. The final challenge is how the firms might develop technological leadership, especially under conditions that threaten loss of wealth creation edge.

The wealth creation edge of a firm is grounded in focused firm-specific know-how, whose development and learning is critically contingent on the localized home-base competencies. Previous research (Abo, 1994; Teece, 1998) has shown that the firms face considerable difficulties in the diffusion of their firm-specific know-how from their home base to other locations, domestic or overseas. The attempts by rival firms to learn from this local geography-specific know-how are further impeded by the limitations of identifying and replicating the complementary organizational assets underpinning the success of a firm. Yet the entrepreneurial initiatives to develop revolutionary breakthroughs can render a firm's technological investments worthless, unless the firm is able to develop cross-geography learning or a cost-effective substitute for that. Thus, it might be worthwhile to encourage continuous linkages between a firm's technological base and the innovative efforts of other local and international networks. As such, the firm can maintain an option on the outcomes of the learning initiatives of the potentially competing networks, and can focus its efforts on generic integration and upgrading of the diverse innovative efforts of local as well as global networks.

Using a sample of all five electronics firms founded between the World War II and 1974 Oil Crises period, that were part of the Fortune 500 US rankings in early as well as late 1990s, this paper highlights the significance of inter-firm dynamics in leadership-oriented innovations and learning. The analysis includes all patents issued to these firms over a six-year period, 1986-91, and all citations to these patents until the end of 1998. The data were collected using the publicly accessible online database maintained by the United States Patent Office, and include all US patents as well as citations to foreign patents by the patents issued in the United States. Using the online subscription of the University of Pennsylvania Library, additional data on the differentiation strategy of the firms during 1986-91 were obtained from COMPUSTAT database, and on the wealth creation outcomes during the same period were obtained from CRISP database. The model was tested in two steps. The first step investigated the relationship between three types of generic strategies (focus, leadership, and differentiation) and two types of wealth creation outcomes (rents and value), at an annual firm level of analysis. The second step analyzed the relationship between the two types of wealth creation outcomes and three types of network-level learning processes. Evolutionary learning of rival network was measured using the spillovers of focused know-how to the Japanese firms. Revolutionary learning of local network was measured using the spillovers of leadership-oriented know-how to the American firms. Productivity of generic leadership learning was measured as a high productivity performance weighted by the emphasis of leadership-oriented innovations on generic scientific know-how. Both the sub-models were tested using the latent measurement and structural equation modeling approach, with the help of EQS software of Bentler (1995). Wald test for the non-significance of specified paths, and Langrange's test for the significance of non-specified paths, were used to assess the overall validity of the hypothesized relationships. Generic technological strategies were found to have a significant impact on wealth created in form of the independent measures of rent as well as value-added. When the model controlled for the generic technological strategy, the residual correlation between rent and value-added by a firm was not significant. Finally, the correlated measures of rent as well as value-added had significant impact on the rival, local as well as leadership learning behavior. Though these results need further validation using alternate samples, the findings appear quite robust given that the number of total observations was just 30 and still all the indices for the model fit were excellent.

Literature Review

Even though industrial R&D investments in the United States leveled off after mid-1980s, the number of patents issued in the United States surged dramatically. Kortum and Lerner (1999) found that the increased patenting phenomenon could not be attributed to a favorable regulatory environment motivating the leading firms to increase their patenting levels. There was no evidence for an increased patenting by the US relative to overseas firms, or even for a super-normal fertility of newer technologies such as biotechnology or software. Instead, a "broad increase in research productivity" appeared to have taken place across industries involving a "reallocation of efforts to more applied activities and a consequent increase in patentable discoveries." (Kortum and Lerner, 1999: 5) Cohen et al. (1997: 17) surveyed R&D lab managers in US manufacturing firms, and found that the patenting was used to block other firms, prevent suits and facilitate negotiations, rather than to simply protect the returns to a specific innovation.

Traditionally, patents are known to be quite ineffective mechanisms for appropriating innovation rents in the electronics industry (Levin et al., 1987). The electronics industry is characterized by product life cycles of typically one-year duration, even though it takes an average of 18 months for a patent to be issued from the date of application. Until 1994 the United States patents were valid for a period of 17 years from the date of issue, and since then have been made valid for a period of 20 years from the date of application. Therefore if own or others' initiatives can help extend the utility of a firm's innovation, then the patenting may be worthwhile. Such considerations are particularly relevant for modern technologies, which are quite systemic and dependent on other related technologies. For instance, Grindley and Teece (1997) note that after adopting an aggressive policy on the use of its patents in 1985, Texas Instruments generated nearly $2 billion from licensing rights to its semiconductor patents during 1986-93.

Patents contain codified knowledge that can be articulated in written form, though much of the value-added by a technological innovation tends to be tacit and uncodifiable. Under the United States law, patent applications are required to cite the invention's prior art, including bibliographic references as well as previously issued domestic and overseas patents on which the invention builds. Just citation of a prior patent does not imply that the current patent is using the intellectual property of the prior patent, and that the assignee of the current patent, if different, is liable to compensate the assignee of the prior patent. Rather, one may cite an earlier patent if that patent had similar technical or functional utility, even though the tacit know-how and scientific process contained in the two inventions are quite different. Insofar as the subsequent assignee develops a revolutionary entrepreneurial application of its invention, the assignee of the prior patent can also gain learning about new uses of its own innovation.

The above considerations raise some interesting research challenges. To begin with, each patent typically cites very few prior patents – in the sample used in this study the average patent citations per patent were just over 2. Further, even if a firm keeps track of all new patent applications that cite its own prior patents, it might need additional knowledge for exploiting the opportunity identified by the new patent applicant. Commercial innovations in the electronics industry generally are based on knowledge contained in multiple patents, and furthermore require appropriate working experience with these diverse knowledge bases. Thus, it is unlikely that a firm would be able to generate incremental value using other patents in the same technological class. Yet, success of related competing innovations signal the super-normal value of an option to develop more differentiated innovations using one's own tacit know-how. Accordingly, a firm may reorient its technological strategy based on the patenting activities of other firms, and thereby seek super-normal rents. In a globally competitive landscape, the firms generating sustained growth in wealth tend to motivate rival initiatives targeted at substituting their core competencies. While it may not be easy, if not impossible, to imitate the tacit know-how of the leading innovative firms, the rivals can yet pursue incremental learning of various prominent knowledge bases of these leading innovative firms. Through a creative assembly of different, high value adding, knowledge bases, the rivals may be able to win over more dynamic customer groups who seek differentiated inputs for their own downstream competitive advantages. If the leading firms are able to tap the entrepreneurial initiatives that build upon their own patents, then it would be quite difficult for the rivals to keep up with the revolutionary breakthroughs and to offer a credible differentiated advantage to the dynamic customer groups. Under these conditions, the leading firms would prefer to patent their technological innovations rather than keep them secret, so that they can enjoy greatest benefits from the developmental initiatives of the entrepreneurs, and thereby more effectively preclude competitive penetration from the rival firms. Wealth creation thus is more contingent on creative applications of generic scientific know-how, and discovery of domains to do so, than simply on technical innovation.

Hypotheses Formulation

Two sets of conditions are relevant for formulating hypotheses pertaining to the forces guiding a firm's technological strategy. The first condition relates to the factors impacting effectiveness of a technological strategy, and the second condition relates to the learning and adaptation of a firm's innovation path as a function of the feedback received from the market outcomes.

Analysis of Factors Impacting Effectiveness of a Technological Strategy

Since the rivals are likely to emulate any generic technological strategy that yields sustained super-normal returns, the firms must build on their own core competencies for gaining a wealth-creation advantage. A simple deployment of core competencies is unlikely to generate a growth in wealth creation advantage. It is essential for a firm to focus on learning from the initiatives of other domestic as well as overseas firms, and from the scientific breakthroughs, in order to upgrade its core competencies and to create additional wealth. Therefore it is proposed that:

H 1.1: Focused Strategy and Wealth Creation

The more focused a firm's technological strategy, the greater the wealth creation.

A firm may try to create a reputation for technical excellence through innovations that improve upon a similar technology already available in the market. Such an innovation strategy requires the firm to make considerable commitments for facing competitive retaliation, and in addition engenders risk of knowledge spillovers to the owners of original technology. The retaliation risks for the firm are likely to particularly great when it adopts an aggressive leadership-oriented strategy, and seeks to make major improvements over other similar technology through creative links with other currently unrelated knowledge bases. In fact under such conditions, the firm must also guard against other possible entrants who might be attracted by the high value adding potential of the innovation. Therefore it is proposed that:

H 1.2: Leadership-oriented Strategy and Wealth Creation

The more leadership-oriented a firm's technological strategy, the lower the wealth creation.

To add value from its learning through the knowledge-building initiatives of the market, and its effective protection against spillovers to the competitors, a firm must productively exploit its innovative technological know-how. Considerable additional research may be needed for a firm to actually commercialize the results of a patented know-how. Appropriate complementary assets must be developed for a cost-effective, and high quality, formulation, organization and delivery of the products satisfying the customer requirements. The customer must be convinced that the services offered by the firm's new products are well differentiated from other available options, and that the customer would benefit from spending for the product as an intermediate input or a final consumption unit. While purposeless expenditures into research, administration and marketing can signal wasteful management, yet when deployed judiciously product development and customer servicing initiatives are expected to set a firm ahead of its competitors. Therefore it is proposed that:

H 1.3: Differentiated Strategy and Wealth Creation

The more differentiated a firm's technological strategy, the greater the wealth creation.

Analysis of Factors Impacting Learning from the Market Outcomes

As the leading firms build on their core competence for generating wealth from their technological know-how, the rival firms perceive great pressure to catch-up using follow-up research. Some aspects of the technological know-how may be replicated using approaches such as poaching of the innovator's employees, hiring of technical experts knowledgeable about the targeted innovation, and purchase of complementary lab items and machinery from the original equipment manufacturers. These approaches can help rivals reproduce part of the innovation services through various evolutionary steps, and also save them considerable costs of research and development of customer interest. Yet owing to the high costs of differentiation and risks of oligopolistic competition, the rival firms are likely to be interested in a firm's innovation only if that firm demonstrates wealth-adding capability. As such it is proposed that:

H 2.1: Wealth Creation and Incremental Learning

The greater the wealth created by an innovative firm, the stronger the evolutionary learning initiatives of the rival network of firms.

When firms operate in an oligopolistic environment, and compete for innovations in technological fields also targeted by competing firms, the incremental wealth created by the initiatives of any single firm is likely to be quite limited. Despite the lower value added, other firms in the oligopolistic network would have strong incentives to follow up on the innovation of a leading firm, or else face the risks of being selected out from the competitive market place. Their follow up initiatives would generally have to pursue a revolutionary approach, so that the firms can justify sustained technological investments notwithstanding intensity of current competition. Under conditions where a firm is able to generate substantial additional wealth, and leapfrog on the local oligopolistic rivals, it might face stronger competition from the global rivals that have distinctive competencies. However, so long as the firm's innovations seek to gain technical leadership by building upon other previous innovations in same technological class, the prospects for super-normal wealth creation are likely to be low, and the strength of local rivalry is likely to be quite strong. Therefore it is proposed that:

H 2.2: Wealth Creation and Revolutionary Learning

The lower the wealth created by an innovative firm, the stronger the revolutionary learning initiatives of the local network of firms.

Under pressures of strong local rivalry for incremental innovations, and intense global rivalry for revolutionary innovations, the leading firms must seek to develop a next generation of unrivaled core competence if they wish to sustain their wealth creation capability. Towards this end, they can tap the generic know-how contained in scientific and research publications for adding substantive, commercially unique, knowledge within any technological class. If a firm tries to develop applications and market for its unique learning on its own, it may be able to generate only limited rents and the risks of competitive substitution could escalate. Therefore, the weak wealth creation signals pose strong incentives on the firm to try boosting the productivity of leadership-oriented generic learning, such as through immediate decisions for a more open sharing of information and knowledge with the external network of firms for further application development. Though considerable inertial forces often tend to impede rapid decision making, for a sample of firms, which sustained their market leadership position, it is proposed that:

H 2.3: Wealth Creation and Generic Learning

The lower the wealth created by a firm, the stronger the productivity of generic leadership learning.

As a firm seeks to sustain the productivity of its generic leadership-oriented learning, the external firms enjoy sustained opportunities for revolutionary design and application using this learning. The face-to-face interaction needed to communicate the emergent generic know-how might preclude firms from distant landscapes from participating in these opportunities. The local firms on the same landscape may be in a better position to exploit the revolutionary options generated by the productivity-augmenting initiatives of the firms seeking generic technological leadership. Therefore it is proposed that:

H 3.0: Generic Initiatives and Revolutionary Learning

The stronger the productivity of generic leadership learning, the stronger the local revolutionary learning.

Test of the Hypotheses

The following discussion presents the sample selection, construct measurement, and model specification, for testing the proposed hypotheses.

Sample Selection

A list of all 24 electronics firms founded after World War II and present in Fortune 500 listing for 1998 was identified. The principal line of business for these electronic firms was 334 (Computer and Electronic Product Manufacturing) of 1997 North American Standard Industrial Classification. To ensure that the selected firms have sufficiently long history for supporting quick competitive responses to their strategy and performance, the sample was pruned to 6 firms founded before 1975. The final sample comprised of 5 firms that were still operating independently as of end 1998. These were Applied Materials, Intel, Litton, Thermo Electron, and Western Digital. Before 1986 most of these firms did not receive approved patents on a regular annual basis. To minimize the biases resulting from the uneven sampling of different years and firms, the analysis used patents issued from 1986 to 1991. It was necessary to limit the selection of original patents to period until 1991, in order to allow for the lead times in research and approval of patent application for firms learning from these patents. The number of observations in the sample, though small at thirty comprising of six annual observations of five firms, is sufficient to offer an acceptable test of significance.

Construct Measurement

The hypotheses use three types of constructs: technological strategy (focused, leadership-oriented, or differentiated), wealth creation (rents or value-added), and learning initiatives (evolutionary, revolutionary or generic) of different network groups.

Technological Strategy:

Focused strategy - The focus strategy targets a specific narrow market segment, classified by customer group, product line, or geographical region (Porter, 1985). This focus allows for the firm to develop specialized capability in servicing the targeted segment, and thus gain a competitive advantage over the general-service providers. The firm's capability derives from differentiation through better service, and/or low costs through more efficient linkages with the targeted segment. Prior research suggests the significance of core competence in the ability of a firm to upgrade advantage in servicing a targeted segment (Prahalad and Hamel, 1990). Core competence of a firm resides in the network of relationships, and face to face interactions among various members of the group. Core competence facilitates an effective monitoring and absorption of the market know-how relevant to the firm's target group. Therefore implementation of a focused strategy by a firm is evaluated in terms of the proportion of patents that involved inventors residing at the headquarter state of the firm, after weighting these home inventor patents with the number of citations to domestic or foreign patents. Focused Strategy construct comprises of two variables:

DOMFOC = (Average # of citations to US patents by those patents issued to a firm during a year as involved an inventor from the firm's headquarter state)/ (Average # of citations to US patents by all patents issued to a firm during a year)

FORFOC = (Average # of citations to foreign patents by those patents issued to a firm during a year as involved an inventor from the firm's headquarter state)/ (Average # of citations to foreign patents by all patents issued to a firm during a year)

Leadership-oriented strategy - The cost leadership strategy sets out to become the lowest-cost operator in one's industry. Cost leadership is attained through economies of scale or scope that offer value for money products to a broad-based customer group. Prior research suggests that in knowledge-intensive industries, economies of learning or experience are the pre-dominant factor supporting persistent cost reduction (Ghemawat, 1985). While large market size is essential to spread out the fixed costs of a single innovation, organizational learning is prerequisite for an efficient control of developmental overheads. More efficient innovators enjoy greater flexibility in substituting or upgrading existing know-how, and thereby gain a cost-based competitive edge. Therefore implementation of a leadership-oriented strategy by a firm is evaluated in terms of the proportion of patents that cited a patent in the same technological class, after weighting those same class patents with the number of citations to domestic or overseas patents. Leadership-oriented strategy construct comprises of two variables:

DOMLEAD = (Average # of citations to US patents by those patents issued to a firm during a year as cite another patent in same technological class)/ (Average # of citations to US patents by all patents issued to a firm during a year)

FORLEAD = (Average # of citations to foreign patents by those patents issued to a firm during a year as cite another patent in same technological class)/ (Average # of citations to foreign patents by all patents issued to a firm during a year)

Differentiated strategy - A differentiation strategy is intended to help firm be unique in its industry along some dimensions widely valued by buyers. Differentiation typically involves additional unit cost outlays, which the customers are expected to compensate by paying higher prices for the unique conveniences and services offered to them. Prior research suggests that the firms communicate their distinctive competence to the customers through not only hardware aspects of their products, but also software-intensive complementary assets (Teece, 1986). These assets include research, organizational and marketing infrastructure. Therefore implementation of a differentiated strategy by a firm is evaluated in terms of the proportion of sales value that is invested into R&D and Selling, General and Administrative functions. Since the accounting data had varying fiscal years, data were transformed to a calendar year basis using time-weighted averages. Differentiated strategy construct comprises of two variables:

RNDDFN = (Research and Development Expenses)/(Sales) for a firm during a year

SGADFN = (Selling, General and Administrative Expenses)/(Sales) for a firm during a year

Wealth Creation:

Rent – Corporate strategies are fundamentally guided by the objective of searching for and generation of rents. The firms derive rents by discovering under-served needs of the customers, and then offering products that yield returns beyond what are available normally otherwise. To compute super-normal returns, one needs information on total investment, normal rate of return, and actual rate of return. Due to the differences in the age of various assets, it is difficult to compute total investment outlay of any firm on a basis that is comparable across other firms and over time. Further, assets reported by the firms usually include only the value of tangible resources. In practice, intangible resources such as intellectual property rights, brand equity, and human capital, constitute dominant proportion of knowledge-intensive firms. Therefore the total investment is evaluated as the value of a firm's common stock, which reflects the equilibrium going-concern value attached by the owners and non-owners of the firm in the market. Normal rate of return is evaluated as the average returns available to the investors from broad-based investments in the market, as signaled by S&P index and value-weighted stock index. Actual rate of return is evaluated as the percentage rise in the firm's market value. The following measurement was used to measure rents in terms of two variables:

SNPRENT = [(Product of (1 + (monthly return on a firm's stock)) over 12 months)/(Product of (1 + (monthly return on S&P index) over 12 months)] – 1

VWTRENT = [(Product of (1 + (monthly return on a firm's stock)) over 12 months)/(Product of (1 + (monthly return on Value weighted CRISP index) over 12 months)] – 1

Value-added – Knowledge-intensive operations typically entail substantial up-front allocations, the returns from which may accrue only over a period of time. Further, there tends to be considerable uncertainty in the ability of firms to actually realize the expected returns, or to outperform these expectations. Therefore even if corporate initiatives yield current returns less than the market average, the investors may not wish to liquidate the firm. The incentives of the investors to sustain their investments into a firm may be evaluated in terms of the growth in the market value of firm's stock. This growth reflects rise in the market's evaluation of the firm's potential, given other investment options.

VADDED = [(Year end # common stock outstanding) * (Year end common stock price) – (Last Year end # common stock outstanding) * (Last Year end common stock price)]/ [Last year end # common stock outstanding) * (Last Year end common stock price)]

Learning Initiatives:

Rival Evolutionary Learning – It is quite difficult for rival firms to imitate or substitute the wealth creation advantage of any firm. First, the genesis of advantage is not easy to identify since underlying resources are largely invisible, sticky and bundled. Secondly, firms staunchly protect their intellectual properties, and bar rivals from emulating their successful product or process innovations. Therefore it is only through sustained incremental process, involving trial-and-error learning-by-doing, that the rivals can expect to meet the competitive challenges imposed by the successful firms. This is especially so when the rivals operate in a distant geographical landscape. The evolutionary learning is particularly necessary for competitive retaliation to innovations involving core home-base strengths of successful firms. The rival evolutionary learning, accordingly, is evaluated in terms of two variables:

FOCJAPA = Proportion of Japanese citations to all patents of a firm during a year that involved an inventor from the firm’s headquarter state

FOCJAPB = (Proportion of Japanese citations to all patents of a firm during a year that involved an inventor from the firm’s headquarter state)/(Proportion of Japanese citations to all patents of a firm during a year)

Local Revolutionary Learning – If a firm’s initiatives under-perform, then no firm has any incentive to build upon them unless substantive improvements could be realized. The need for path-breaking development becomes quite prominent when the option of using other related technological know-how has already been explored. The local revolutionary learning is thus evaluated in terms of two variables:

LEADUSA = Proportion of American citations to all patents of a firm during a year that cited a patent from the same technological class

LEADUSB = (Proportion of American citations to all patents of a firm during a year that cited a patent from the same technological class)/(Proportion of American citations to all patents of a firm during a year)

Productivity of Generic Leadership Learning – For creating a fundamentally new learning, a firm needs basic research into generic scientific knowledge. Generic research tends to entail high risks, especially when the firm has limited complementary capabilities in the new area. If the firms bridge the gaps in their core competencies, such as through networking of the skills of other firms in the market, then they can realize high productivity in the generic development of leadership-oriented innovations. The productivity-effect of the generic leadership learning is therefore evaluated as:

LPVTYBIB = LN (Productivity) * (Average # of bibliographic citations by all patents of a firm during a year that cited another patent from the same technological class/ Average # of bibliographic citations by all patents of a firm during a year)

Model Specification

The model specification involved validation of the construct measurement and of the relationships between the independent and dependent parameters. The objective was to identify whether the hypothesized set of relationships yield a parsimonious and valid characterization of the observed data. The following theoretical considerations were relevant in relation to other possible relationships.

Relationships among different types of technological strategies: Porter (1985) asserted that the successful firms can not pursue more than one generic strategy independently at one time, but allowed for two types of integration – focused and differentiation or focused and cost leadership. Nevertheless, there is some evidence that the firms integrating two or more generic strategies might have higher performance than those with a single generic strategy do (Miller, 1992). Thus, each of the generic strategies can have an independent effect on performance, and/or an interactive effect. The need for considering the complex interactive effects among technological strategies, and across their independent manifest variables, is evaluated using Langrange's test of the significance of path between various technology strategy factors and of path between the measures of any two technological strategy factors.

Relationship between the two measures of each technological strategy: Previous research suggests that the diffusion of know-how tends to the geography-bound, and cross-border knowledge transfers are considerably more difficult than the within border spillovers. The firms may seek to exploit only domestic know-how through increasing marketing outlays, and avoid the costlier cross-border knowledge integration. Alternatively, increasing R&D outlays for absorbing overseas knowledge could yield unique, differentiated, advantage to the firms, and also enable them to be at par with their global competitors.

Accordingly, a technological strategy can be manifested in simultaneously increasing absorption of both domestic as well as overseas know-how, as well as in independent changes of absorption rate that are negatively correlated. The need for considering the complex higher order relationships between the two measures of each technological strategy is evaluated using the Langrange's test of the significance of inter-residual and residual-variable path values.

Relationship between the two types of wealth creation: Wealth created by a top firm through rent usually goes along the wealth created through value-added. However, if the emergence of new industries causes the top firms to lose their rapid growth, then it may be possible that they generate sub-normal rents and yet have a value-adding advantage owing to their large initial size. The need for considering the complex opposite behaviors of the two types of wealth creation factors is evaluated using the Langrange's test for the significance of paths between the residuals of wealth creation factors and different technological strategies as well as different learning processes.

Relationship between the two measures of rent: Usually the two manifest indicators of rent -- supra- S&P index returns and supra- value-weighted stock index returns – go together. But if the large firms included in S&P index experience diseconomies of size, then the smaller firms included in the value-weighted index may enjoy outsourcing and other kind of growth opportunities. The need for considering the non-symmetric behavior of the two measures of rent is evaluated using the Langrange's test for the significance of paths involving the residuals of the two measures of rent.

Relationships among the different types of learning processes: Quite apart from the first order relationships, as the rival firms pursue evolutionary learning, there may be intensifying pressures on the local firms for revolutionary learning and on individual firms to seek generic learning. The need for considering incremental competitive effects of the networking learning processes is evaluated using the Langrange's test of the significance of paths involving the residuals of three learning structural equations, after correcting for the effects of initial wealth creation.

Relationship between the two measures of each learning process: The two measures of a learning process, though generally positively correlated, may have second order negative correlation. For instance, the local network of firms may react on a short-term basis to the wealth destroying outcomes of the leadership-oriented innovations of the top firms. Thence, the proportion of American citations to patents citing the same technological class patents may fall, even though the same proportion normalized by the proportion of American citations to all patents is rising. The need for considering such complex relations is evaluated using the Langrange's test of the significance of paths involving the residuals of factor measurement model of each learning process.

Direct relationship between the technological strategies and learning processes: Inertia in the technological strategies of individual firms creates opportunities for new entrepreneurs, especially when the signals are based on the performance of the leading Fortune 500 firms. As such the learning processes in relation to the Fortune 500 firms should be quite competitive in nature, and be guided directly by the wealth creation outcomes. Therefore for the sake of simplicity, model specification tests the causal relationships between technological strategy and learning processes, only to the extent that they are mediated by wealth creation outcomes.

Scale of Measurement: The efficiency and accuracy with which a parametric function can be optimized depends on the condition number of the input matrix, which in turn is strongly affected by differences in scale of the input variables (Bentler, 1995: 20). Therefore, all the variables were standardized using mean = 0 and variance = 1.

Computational Algorithm: The estimates for the specified model function were obtained using the Generalized Least Squares to get initial coefficients, and then optimizing using the Maximum Likelihood algorithm. Since standardized variables were used for measuring data, the model was run using the correlation matrix for the input data.

Statistical Program: The integrated confirmatory factor measurement and structurale equation modeling program available in EQS software of Bentler (1995) was used to run the specified model, and to test the robustness of the model to unspecified paths. Since EQS does not give a test of the significance of the residuals of manifest variables in the measurement model, the model was also run using the structural equation path package included in the STATISTICA software program.

Findings

Table 1 gives the inter-item correlation matrix. Table 2 gives the estimates for the model investigating the relationship between technological strategies and wealth creation. Table 3 gives the estimates for the model investigating the network learning processes.

Measurement Model for Technological Strategies: The factor analytic model for all the three types of technological strategies generated statistically significant loading above 0.70. Thus, individual manifest variables account for at least half of the variance in respective technological strategies. Langrange's test indicated that the correlation between various technological strategy variables and constructs was not significant. Thus, the technological strategy factors had good convergent as well as discriminant validity. However, STATISTICA program indicated that the residual loading estimates were significant under domestic citations, both for focused innovations and leadership-oriented innovations. This implies that the focused and leadership-oriented strategy constructs reflect the know-how absorbed more from distant sources, than from localized sources. In other words, they capture firm's strategic efforts to build competencies rising above the domestic constraints.

Measurement Model for Endogenous Wealth Creation: For the purpose of model identification, the value-added variable was fixed at 1, and its residual impact on the value-added factor was fixed at 0. Similarly, the supra-value weighted stock index returns variable was fixed at 1, and its residual impact on the rent factor was fixed at 0. The supra-S&P index returns had a statistically significant factor loading of 0.998, and its residual loading of 0.004 was also statistically significant. Langrange's test indicated that both the rent variables had a significant unaccounted correlation of 0.041 (p=0.004) with focused strategy factor, and of 0.032 (p=0.040) with leadership-oriented strategy factor, but the relation was positive for supra-

S&P index returns and negative for the other. This might partially reflect a general under-performance of S&P index compared to value-weighted index for the sample period.

Structural Model for Technological Strategy – Wealth Creation Relationship: H1.1 and H 1.3 assert that focused and differentiated strategies generate wealth, and H1.2 predicts that the leadership-oriented strategy destroys wealth. All the path coefficients are in the expected direction. However, the relationships were statistically significant only for the positive impact of focused and differentiated strategies on value-added, and for the negative impact of leadership-oriented strategies on rent. This suggests that (i) all firms in the market tended to pursue focused and differentiation strategies for adding value. (ii) Leadership-oriented strategy of the electronic firms tended to diffuse rents to the market, but the decline in value-added was partially insured possibly on account of the expansion in demand and in the input supplies from those other firms in the market.

In the path model, the residual of rent had a standardized value of 0.775, and of value-added had a standardized value of 0.769. Thus, idiosyncratic firm-level technological strategies accounted for 60% of the variation in abnormal rents (net of sample average) within the sample and for 59.1% of the variation in abnormal value-added. The fit of the factor measurement and structural equations model, based on four different criteria, was very good. Maximum likelihood chi-square was 30.500, with 23 degrees of freedom, yielding a non-significant p-level of 0.136. Bentler Comparative Fit Index was estimated at 0.968. Bentler-Bonett Non-Normed Fit Index had a value of 0.950. Average off-diagonal absolute standardized residuals had a value of 0.1384.

Measurement Model for Independent Wealth Creation: For the purpose of model identification, the value-added variable was fixed at 1, and its residual impact on the value-added factor was fixed at 0. Similarly, the supra-value weighted stock index returns variable was fixed at 1, and its residual impact on the rent factor was fixed at 0. The supra-S&P index returns had a statistically significant factor loading of 0.998, and its residual loading of 0.004 was also statistically significant. The correlation between rent factor and value-added factor was estimated at 0.453 (t=3.370).

Measurement Model for Network Learning Processes: For the purpose of model identification, three of the five measures of network learning processes were specified to carry a factor loading of 1, and the corresponding residual was fixed at 0. LEADUSB had a factor loading of 0.875, and FOCJAPA had a factor loading of 0.500, both of which were statistically significant. STATISTICA package indicated that the corresponding residuals also had statistically significant factor loading. This implies that the local revolutionary learning construct is not strongly limited to patents that cite same class patents, but includes other patents related to such same class patents. Further, the rival evolutionary learning construct is strongly limited to patents that involved inventor from the headquarter state, and emphasizes pre-dominance of such patents in rival learning.

Structural Model for Wealth creation – Learning process Relationship: H 2.1 predicts positive impact of wealth on rival evolutionary learning. H 2.2 and H 2.3 assert negative impact of wealth on local revolutionary learning and on the productivity of generic leadership learning. Rent factor is found to have negative impact on local revolutionary learning and on generic leadership productivity, though the effect was statistically significant only for generic leadership productivity. Value-added factor is found to have positive, statistically significant, impact on rival evolutionary learning. The impact on other two learning processes is also positive, though not significant statistically. These results suggest that: (1) Poor rents motivate top firms to try enhancing the productivity of generic leadership learning. (2) Strong value-added motivates evolutionary learning on part of the global rivals. On the whole, wealth creation accounts for 29% in rival evolutionary learning, and 22% in the productivity of generic leadership learning. The direct effect on local revolutionary learning is just 7.8%.

Structural Model for Relationship among Learning Processes: As predicted by H 3.0, productivity of generic leadership learning is found to have statistically significant positive impact on local revolutionary learning. Further, Langrange's test indicated a significant negative correlation of 0.331 (p = 0.040) between local revolutionary learning and FOCJAPA. This implies that the attempts of the rival Japanese firms, to refer to a broader base of knowledge than that just based on the headquarter regions of top US electronic firms, tend in fact to be facilitated by the revolutionary initiatives of various US firms.

The fit of the factor measurement and structural equation path model, involving learning processes, was quite good. Maximum Likelihood chi-square had a value of 17.757, with 19 degrees of freedom (p=0.539). Bentler's Comparative Fit Index had a value of 1.000, and Bentler-Bonett Non-Normed Fit Index had a value of 1.008. Average off-diagonal absolute standardized residuals were 0.0724.

Conclusions

The test of the model clearly shows that a firm's wealth generation captured by the stock market signals is predicted by its generic technological strategies, and in turn predicts the learning process within a firm, and over the domestic and international competitive landscape of the firm. These tests support the thesis that growth in a firm's knowledge base using local and differentiated resources is wealth creating, and that without such resource base, the attempts to absorb external know-how tend to be wealth destroying. The top American knowledge-intensive firms are found to be able to sustain their competitive advantage over the 1990s, notwithstanding persistent efforts on part of the local as well as global firms to benefit from their patented technological breakthroughs. These top firms responded to the threats to their rent-generating ability rapidly through greater emphasis on the diffusion of generic leadership know-how, and more focused absorption of domestic and overseas know-how using core home-base assets.

Limitations of the findings

The findings of the study may be subject to several potential threats to validity. Since the measures for independent and dependent constructs in each sub-model were collected using different sources (i.e. firm reported COMPUSTAT/Patent data and market signals in CRISP data), there is no source bias common to both. The threat of common source bias cannot be ruled out with respect to relationships between productivity of generic leadership learning and local learning, however, since they were based on the same patent database. The significance of this bias needs to be balanced against the fact that the study used a carefully selected sample of firms over a common period. On account of the small size of the sample, with a total of 30 observations, the relationships are unlikely to be significant just because they are based on data from a common source. That the productivity of generic leadership learning and rival evolutionary learning did not have any significant relationship supports this position. If there was a non-trivial common source bias associated with the findings, then this bias was expected to generate significant relationships between other parameters also.

The assessment of wealth creation using stock market signals could be criticized on the basis of the proposition that normal behavior of the firms would not generate change in their fundamentals, and therefore has no valid impact on stock market signals. Further it might not be possible for the firms to identify the sources of a firm's wealth creation, and to learn from that firm. Stock market performance is guided by unexpected events, and just pursuit of certain generic technological strategies can not ensure super-normal stock market outcomes. These challenges need to be considered in light of the position that the hypothesized model asserts that a firm pursues specific generic technological strategy, or for that matter a learning process, conditional on expected opportunity and profitability. The information about the capability of a firm, for instance to integrate all innovations with its core home-base competencies using headquarter state inventors, is only imperfectly available to the market. Each successful patenting by a firm adds to the information, resolves uncertainty and unpredictability, and to that extent is predicted to generate a positive wealth creation signal. This signal then catalyzes learning initiatives of various networks, by providing concrete and verifiable criteria on the basis of which the benefits and costs of different alternative courses can be compared.

Another criticism of the model could be based on empirical grounds: do Japanese firms, for instance, really look at the stock market signals of the American firms while pursuing their incremental learning? The intellectual property rights protection may even preclude in-depth analysis of US patents cited by the Japanese innovations. Note that the hypothesized model does not require that the firms would actually evaluate the benefits and costs of developing technologies related to the patents, specifically of high or low wealth creating firms. Rather it asserts that in competitive market conditions, the top firms in the market would have a non-trivial influence on the decisions and behavior of various local and global firms. Their super-normal and sub-normal performances would create a specific pattern of constraints and opportunities in associated technological domains, and therefore would manifest in predicted learning behaviors of various firms.

As an additional threat to the validity, several free manifest variables left statistically significant residuals in the factor construct measurement models. Domestic citations in focused and leadership-oriented strategies had significant residual loading. Similarly, supra-S&P returns in rent had significant residual loading. Also, LEADUSA and FOCJAPB had significant residual loading. One must, however, recognize that the significant residual loading in each case actually refined the measurement of the corresponding factor construct. Thus, focused and leadership-oriented strategy constructs captured development of pre-dominantly overseas innovations by a firm indigenously. Rent construct benchmarked a broader base of market, going beyond the under-performing S&P index. Finally, local revolutionary learning captured patents based on a different class know-how, when such learning was simultaneous with that using patents based on the same class know-how. Rival evolutionary learning excluded patents based on the inventors from a firm's headquarter state, when such learning was simultaneous with that using patents not based on these inventors, and therefore did not reflect an incremental evolutionary imperative. Furthermore, the variable loading was significant in each case, and the model fit deteriorated substantively if the loading was set to zero.

It might be argued that the stock market signals were falsely related with the measured technological strategies, and that these signals were actually related to the current inventive activities on which patents would be received in subsequent years. Also, measured learning processes were falsely related with the initial stock market signals, and were actually under constant reorientation as a function of contemporaneous signals every year. If these leads and lags do have a non-trivial effect, it would decrease the likelihood of confirming hypothesis, and thus produce a conservative test of the model.

A related issue pertains to the validity of causal inference. The events leading to the receipt of patent preceded the wealth creation outcomes. Further, firms tend to have a broad target for R&D and marketing allocations, and as such the events leading up to the differentiation strategy also preceded the wealth creation outcomes. In addition, the data on rival evolutionary and local evolutionary learning were collected using citations from patents issued at subsequent times, and thus followed the wealth creation outcomes. Finally the evidence that the productivity of generic leadership learning has a positive impact, not predicted by the wealth creation, on the local evolutionary learning, validates the sequential precedence of wealth creation signal over the productivity of generic leadership learning.

Implications for Further Research

Previous research indicates that tacit, local and non-tradable know-how is a critical factor in the sustenance of firm-specific advantages. However, there have been no systematic studies, other than those building upon the Marshall's (1921) economies of agglomeration and the consequential increasing returns, that investigate how the localized know-how actually gets developed. The agglomeration model offers little strategic explanation for the initial conditions that create supportive environment on a particular local landscape, and instead invokes the logic of luck or chance in initial creation of a technological network that then gains strength through the complementary network linkages. The present study suggests that the leading firms seek generic scientific learning for assembling a broad-based network of domestic and international technological knowledge. As such, the leading firms can upgrade their home-base advantages, and then generate increasing wealth by creatively differentiating their accumulated know-how. However, if the leading firm is unable to change the technological area of the knowledge absorbed, then it risks cut throat competition or commodification of its technological initiatives and therefore wealth destruction.

The major revision of the competitive dynamics model suggested by the empirical findings concern the learning processes of external networks. It appears that the domestic network responds primarily to the high productivity outcomes of generic research on part of the leaders, rather than to the wealth creation signals preceding these outcomes. On the other hand, the international rivals respond by intensifying their evolutionary learning in response to the leader's wealth creation signals, and by reducing their evolutionary learning in response to the revolutionary responses of the domestic network. Thus, while the domestic network may find itself at a disadvantage compared to the international rivals in imitating the leader know-how, it could expand the leader-know in revolutionary ways that substantially augment the wealth generation potential.

Implications for Managerial Practice

Japanese firms are more responsive to the wealth creating technological strategies, than are the American firms. The positive wealth creation signals appear to enhance the confidence of the Japanese firms for sustaining their incremental learning, based on the know-how embodied in core regions that host leading technology-intensive firms. However, as other firms pursue revolutionary learning, using alternative know-how, Japanese firms seem to seek benefits of such learning also. But in the process Japanese firms are found to have difficulties in sustaining their learning from the market leaders. The increasing differentiation of technologies, and the resulting complexity of knowledge benchmarking, can impede the overall learning process of the Japanese firms based on the external initiatives.

American firms instead appear to rely more on differentiating the applications, while being open to the use of a common base of market know-how – both generic as well as distinctive know-how developed by other firms. Thus, the external initiatives can be leveraged as complementary resources, using which incremental wealth creation innovations can be developed within a firm.

The successful American electronic firms seem to also engage in practices such as open-systems collaboration for mobilizing the revolutionary developmental initiatives of the external firms. This enhanced the productivity of generic leadership learning in various domains, by exploiting knowledge-base assets beyond those available within their home-base core competency.

Concluding Remarks

While the findings collectively form a coherent pattern and are consistent with prior theory and evidence, one may note that the causal inferences are based on the conditions most likely to generate the specific relationships. While these causal inferences are consistent with the generally known behavior of the Japanese and American firms, qualitative case studies that permit sequential investigation of the causative factors are clearly called for before firm causal conclusions can be drawn.

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Table 1

Correlation Table

	RNDDIF	SGADIF	SNPRENT	VWTRENT	DOMLEAD	FORLEAD	DOMFOC	FORFOC	LEADUSA	LEADUSB	FOCJAPA	FOCJAPB	VADDED
RNDDIF	1.000												
SGADIF	0.856	1.000											
SNPRENT	0.142	0.267	1.000										
VWTRENT	0.146	0.269	0.998	1.000									
DOMLEAD	0.039	-0.004	-0.229	-0.245	1.000								
FORLEAD	-0.041	-0.053	-0.353	-0.376	0.643	1.000							
DOMFOC	-0.289	-0.247	0.107	0.091	0.243	0.077	1.000						
FORFOC	-0.297	-0.276	-0.062	-0.099	0.353	0.327	0.594	1.000					
LEADUSA	-0.231	-0.270	-0.434	-0.439	0.299	0.148	0.010	0.117	1.000				
LEADUSB	-0.238	-0.113	-0.273	-0.275	0.138	-0.007	-0.160	0.048	0.875	1.000			
FOCJAPA	0.271	0.252	0.278	0.269	0.170	0.053	0.246	0.182	-0.247	-0.317	1.000		
FOCJAPB	0.701	0.508	0.343	0.352	-0.170	-0.290	-0.252	-0.247	-0.452	-0.408	0.500	1.000	
VADDED	0.252	0.247	0.462	0.453	-0.112	-0.165	0.095	0.162	-0.144	-0.123	0.483	0.372	1.000
LPVTYBIB	0.256	0.167	-0.371	-0.378	-0.042	0.093	-0.073	0.121	0.477	0.404	-0.025	0.014	-0.030

Note: N = 30; $p<0.05$ for $r > 0.365$; $p < 0.01$ for $r > 0.465$

Table 2

Technological Strategy and Wealth Creation Model

Standardized Solution Structural Equation Parameter Estimates

RNDDFN = .890*F1 + .456 E1

SGADFN = .961*F1 + .277 E2

DOMLEAD = .748*F2 + .664 E3

FORLEAD = .842*F2 + .539 E4

DOMFOC = .706*F3 + .709 E5

FORFOC = .823*F3 + .568 E6

SNPRENT = .998*F4 + .061 E7

VWTRENT = 1.000 F4 + .000 E8

VADDED = 1.000 F5 + .000 E9

F4 = .306*F1 +-.483*F2 + .269*F3 + .775 D1

F5 = .357*F1 +-.323*F2 + .419*F3 + .769 D2

GOODNESS OF FIT SUMMARY

CHI-SQUARE = 30.500 BASED ON 23 DEGREES OF FREEDOM

PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS 0.13558

BENTLER-BONETT NORMED FIT INDEX= 0.887

BENTLER-BONETT NONNORMED FIT INDEX= 0.950

COMPARATIVE FIT INDEX (CFI) = 0.968

Table 3

Wealth Creation and Network Learning Model

Standardized Solution Structural Equation Parameter Estimates

```
SNPRENT          =   .998*F4    + .064 E1

VWTRENT          =  1.000 F4    + .000 E2

VADDED           =  1.000 F5    + .000 E3

LEADUSA          =  1.000 F1    + .000 E4

LEADUSB          =   .875*F1    + .484 E5

FOCJAPA          =   .500*F2    + .866 E6

FOCJAPB          =  1.000 F2    + .000 E7

LPVTYBIB         =  1.000 F3    + .000 E8

F1               = -.470*F4     + .069*F5    + .896 D1

F2               =  .064*F4     + .454*F5    + .874 D2

F3               = -.459*F4     + .178*F5    + .912 D3
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GOODNESS OF FIT SUMMARY

```
CHI-SQUARE =       22.001 BASED ON    20 DEGREES OF FREEDOM

PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS     0.34044

BENTLER-BONETT NORMED    FIT INDEX       =       0.915

BENTLER-BONETT NONNORMED FIT INDEX  =       0.988

COMPARATIVE FIT INDEX (CFI)                 =       0.991
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