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Firm organization, industrial structure, and technological innovation[1]

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Abstract

The formal and informal structures of firms and their external linkages have an important bearing on the rate and direction of innovation. This paper explores the properties of different types of firms with respect to the generation of new technology. Various archetypes are recognized and an effort is made to match organization structure to the type of innovation. The framework is relevant to technology and competition policy as it broadens the framework economists use to identify environments that assist innovation.

Keywords: Organizational structure; Innovation; Market structure-innovation relationships; Proprietary technology; Vertical Integration; Flexible hierarchy

1. Introduction

It is increasingly recognized that the dynamism of a competitive private enterprise system flows from the development and application of new technology and the adoption of new organizational forms. As a result, attention is being focused on trying to develop a better understanding of the institutional environment in which these activities take place. In market economies, the business firm is clearly the leading player in the development and commercialization of new products and processes.[2] However, much of the literature

[1]I am grateful for helpful comments and conversations with Glenn Carroll, Hank Chesbrough, Niel Kay, Ralph Landau, Richard Nelson, Nathan Rosenberg, Oliver Williamson, and two anonymous referees.

[2]In fact, there are governments, universities, and also professional societies in the system, and certain activities that firms cannot be expected to do on their own because the returns are so low, are picked up by other institutions, or receive public monies, or both.

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in economics proceeds as if the identity of the firm in which innovation is taking place is of little moment. Moreover, the links between firm structure and strategy and the innovation process are poorly understood.[3]

In this paper, it is suggested that the formal and informal structures of the firm, as well as the network of external linkages that they possess, has an important bearing on the strength as well as the kind of innovative activity conducted by private enterprise economies.[4] Frameworks are presented to indicate how firm structure and the nature of innovation are linked. The approach adopted eschews optimality and embraces comparative analysis, in the spirit of Williamson[5] (1975, 1985), whereby alternatives are compared to each other rather than to hypothetical ideals.The institutional context is also considered. In particular, the role of capital markets is at least addressed, and the legal infrastructure is not assumed away completely. Indeed, various aspects of the legal system, and in particular intellectual property law, are explicitly considered.

The general approach adopted involves (1) identifying the fundamental characteristics of technological development, (2) determining the factors that affect innovation at the level of the firm, (3) identifying distinctive archetypes or governance modes for firms, and (4) choosing from available alternatives the organizational forms better suited to deal with various types of innovation. It is hoped that analyzing innovation in this manner will help broaden the agenda for industrial organization economists and organization theorists as they begin to grapple with understanding one of the most distinctive features of modern capitalism.

2. Fundamental characteristics of technological development

It is impossible to identify the organizational requirements of the innovation process without first specifying underlying properties of technological innovation. Fortunately, there appears to be on emerging consensus among scholars who study the innovation process with respect to the stylized facts. In the main, these appear to characterize innovation independently of the organizational context in which it takes place.

2.1. Uncertainty

Innovation is a quest into the unknown. It involves searching and the probing and reprobing of technological as well as market opportunities. With hindsight, much effort is spent traveling down blind alleys. Serendipity and luck play an important role. There are various types of uncertainty. Tjalling Koopmans (1957) has made a useful distinction between primary and secondary uncertainty. Both are critical in the context of innovation.

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[3]For a review, see Dosi et al. (1988).

[4]The following statement by Little (1985, p.14) is representative of accepted views: "Our work among innovative companies indicates that the management decision on how to organize for innovation is critical."

[5]The approach rejects assumptions of temporal equilibrium. The framework does not assume that the selection process immediately weeds out all organizations that do not match the business environment at a particular point in time. While the organizational system is seen as gravitating toward an end point or equilibrium, it takes so long to reach it that the environment is likely to change again in the interim, leading to a state of perpetual disequilibrium.

Secondary uncertainty arises "from lack of communication, that is, from one decision-maker having no way of finding out the concurrent decisions and plans made by others." Primary uncertainty arises from "random acts of nature and unpredictable changes in concurrent preferences" (1957, pp.162,163). Williamson recognizes a third kind of uncertainty, which he calls behavioral uncertainty, which is attributable to opportunism. Such uncertainty can lead to ex post surprises.[6] It is important to note that secondary uncertainty can be affected by changing the boundaries of the organization. As Richardson (1990) and Williamson (1975) have explained, vertical integration can facilitate the coordination of complementary investments through the sharing of investment plans. Secondary uncertainty is thus a function of organizational form.

2.2. *Path dependency*

Technology often evolves in certain path dependent ways, contoured and channeled by what might be thought of as technological paradigms (Dosi, 1982, 1982). A technological paradigm is a pattern of solutions to selected technical problems which derives from certain engineering relationships. A paradigm identifies the problems that have to be solved and the way to inquire about them; within a paradigm, research efforts become channeled along certain trajectories.[7] Relatedly, new product and process developments for a particular organization are likely to lie in the technological neighborhood of previous successes.

2.3. *Cumulative nature*

Technology development, particularly inside a particular paradigm, proceeds cumulatively along the path defined by the paradigm. The fact that technological progress builds on what went before, and that much of it is tacit and proprietary, means that it usually has significant organization-specific dimensions. Moreover, an organization's technical capabilities are likely to be "close in" to previous technological accomplishments.[8]

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[6]Uncertainty also makes information a valuable commodity. Information about which outcomes will occur, or are more likely to occur, will obviously have great value. Information, of course, itself has very special characteristics. It is not only an indivisible commodity, in which case the classic problems of allocation in the presence of indivisibilities will be present, but it is also highly tacit, as discussed below. Often it cannot be readily articulated and codified in language. Combined with the absence of legal protection, these features make it difficult to trade.

[7]Examples of technological paradigms include the internal combustion engine, biotechnology, and tungsten filament lighting. Technological discontinuities occur when new paradigms emerge. Thus new technologies are more threatening to existing skills and capabilities if they embody a new paradigm. The emergence of microelectronics, which carried with it a new paradigm, was far more threatening to the skills of incumbents than the emergence of the facsimile, which fused the technology of the telephone and the copier.

[8]Specific technological skills in one field (e.g. pharmaceuticals) may be applicable in closely-related fields (e.g. pesticides) but they are unlikely to be of use in distant fields (e.g. aircraft). See Teece (1988), Teece et al. (1994).

2.4. Irreversibilities

Technological progress exhibits strong irreversibilities. This follows not just because innovation typically requires specialized investments, but because the evolution of technologies along certain trajectories eliminates the possibility of competition from older technologies, even if relative prices change significantly. Thus mechanical calculators are unlikely to ever replace electronic ones, even if the relative prices of silicon and steel were to switch by a factor of 1 000[9] in favor of steel.

2.5. Technological interrelatedness

Innovation is characterized by technological interrelatedness between various subsystems. Linkages to other technologies, to complementary assets, and to users must be maintained if innovation is to be successful. If recognizable organizational subunits such as R&D, manufacturing, and marketing exist, they must be in close and continuous communication and engage in mutual adaptation if innovation in commercially relevant products and processes is to have a chance of succeeding. Moreover, successful commercial innovation usually requires quick decision making and close coupling and coordination among research, development, manufacturing, sales and service. Put differently, organizational capacities must exist to enable these activities to be closely coordinated, and to occur with dispatch.

2.6. Tacitness

The knowledge developed by organizations is often highly tacit. That is, it is difficult if not impossible to articulate and codify (Polanyi, 1962, Winter, 1987). A corollary is that technology transfer is often difficult without the transfer of key individuals. This simultaneously explains why imitation is often costly, and why the diffusion of new technology often depends on the mobility of engineers and scientists (Teece, 1977, Nelson and Winter, 1977). Relatedly, an organization's technology ought not to be thought of as residing in some hypothetical book of blueprints, or with some hypothetical chief engineer, but in an organization's system and habits of coordinating and managing tasks. These systems and habits have been referred to as organizational routines (Nelson and Winter, 1982). It is the performance of these routines that is at the essence of an organization's technological capacity.

2.7. Inappropriability

Under many legal systems, the ownership rights associated with technical know-how are often ambiguous, do not always permit rewards that match contribution,[10] vary in the degree of exclusion they permit (often according to the innate patentability or

[9] If sailing ships ever replace propeller-driven ships, it will be with such a different sailing technology as to be almost unrecognizable from nineteenth century counterparts. And if the prop-fan recaptures markets from the fan-jet, it will also be with a markedly different prop and engine.

[10] For instance, it is possible to receive a patent which is arguably too narrow or too broad in relation to the patent holder's contribution to economic welfare. Moreover, in many cases legal protection for technical contributions may simply not be available, or if available may be difficult to enforce.

copyrightability of the object or subject matter) and are temporary. Or as Arrow (1996) put it, technical information is a "fugitive resource, with limited property rights." Accordingly, investment in innovative activity may not necessarily yield property which can be reserved for the exclusive use of the innovator. But the activity may nevertheless still be valuable enough to attract some investment, depending in part on other institutional arrangements to be examined later. The degree to which new products and processes are protectable under intellectual property law will henceforth be referred to as the intellectual property regime. For expositional simplicity, regimes will be classified as strong if patents and copyrights are effective, and weak otherwise. Clearly, the industrial world does not readily bifurcate, and there exists a continuum of appropriability regimes, as data assembled by Levin et al. (1987) make apparent.

The market for know-how is further confounded because in order to provide full information to the buyer, the seller of know-how may have to disclose the object of the exchange, but in so doing the basis for the exchange evaporates, or at least erodes, as the potential buyer might now have in its possession that which he was seeking to acquire. Hence, transactions in the market for know-how must proceed under conditions of ignorance. Accordingly, at least until reputations become established, exchange is likely to be exposed to hazards. Optimal resource allocation is unlikely to result.

3. Organizational and market determinants of the rate and direction of innovation

While our understanding of innovation has been enriched in recent years, the basic framework employed in policy debates about innovation, technology policy, and competition policy are often remarkably naive and highly incomplete. Even elementary considerations such as those identified in Section 2 are frequently neglected. In economics, for instance, it is not uncommon to find debate about innovation policy collapsing to a rather outmoded discussion of the relative virtues of competition and monopoly, as if they were the key determinants of innovation. Clearly there is much more at work. In this section, various classes of variables – some economic, some organizational – are identified that impact the rate and direction of innovation. Subsequent sections will identify distinct types of organizations based on various organizational attributes. A final section will then endeavor to match these organizations to different types and levels of innovation.

3.1. Monopoly power

One reason why our understanding of innovation has not proceeded faster in the last half century is that many researchers, particularly industrial organization economists, have overly focused on just one variable: the degree of market power that a firm or firms may have. The evidence is unequivocal that competition and rivalry are important for innovation; but few believe that the world of perfect competition in which firms compete in highly fragmented markets using identical nonproprietary technologies is an organizational arrangement that any advanced economy would aspire to achieve.

Nevertheless, many policy debates proceed on the assumption that fragmented markets assist innovation.[11]

Schumpeter was among the first to declare that perfect competition was incompatible with innovation. He noted, "The introduction of new methods of production and new commodities is hardly conceivable with perfect – and perfectly prompt – competition from the start. And this means that the bulk of what we call economic progress is incompatible with it."[12] However, the Schumpeterian notion that small entrepreneurial firms lack financial resources seems archaic, at least in countries with a vigorous venture capital market. In any case, the Schumpeterian debate seems a little beside the point, as there is an enormous number of variables that can potentially intervene between the generation of monopolistic rents and the allocation of resources to the development of new products and processes. Consider, first, single product firms. The notion that innovation requires the cash flow generated by the exercise of monopoly power assumes both that (1) capital markets are inefficient, and (2) that monopolistic levels of internal cash flows are adequate to fund the requisite R&D programs. If capital markets are operating according to what Fama (1970) has called *strong form efficiency*, then cash flow is unimportant because firms with high yield projects will be able to signal their profit opportunities to the capital market and the requisite financing will come forth on competitive terms. Thus if there is strong form efficiency and zero transaction costs (its corollary), cash will get matched to projects whether or not the cash is internally generated.

In fact, the world is not properly characterized by zero transaction costs, but that does not mean that the availability of internal cash flows from monopoly (as compared to competitive) product market positions is what makes the difference between being able to fund a project and not being able to fund it. Significant innovative efforts involve expenditures in a particular year which may be many times the available cash flows. So the availability of marginally higher cash flows occasioned by monopoly power are unlikely to grossly change the financial picture, except in unusual circumstances.

Furthermore, even in the absence of adequate internal cash flow, firms need not go to the capital market to find the requisite financing. The "Schumpeterian" view of the innovation processes appears to be one that involves full integration, from research, development, manufacturing and marketing. But the financial requirements associated with developing and commercializing new products and processes can be accomplished with a myriad organizational arrangements including research joint ventures, co-production, and co-marketing arrangements. With such arrangements, there is the possibility that the capital requirements associated with a new project could be drastically reduced for the innovator. Economies of scale and scope can often be captured through interfirm arrangements. In some instances they cannot.[13]

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[11] Clearly rivalry and competition are important to innovation, but belief in the virtues of perfectly competitive systems is lore, reflecting casual empiricism and prejudice and not careful theorizing and empirical study. The same is true for monopoly.

[12] Schumpeter (1934, p.105).

[13] For a managerially oriented analysis of the limits of outsourcing in the context of innovation, see Chesbrough and Teece (1996).

The link between market power and innovation in specific markets is further undone if the multidivisional multiproduct firm is admitted into the scene.[14] The basic function and purpose of the multiproduct structure is to allocate cash generated everywhere to high-yield purposes anywhere. If a multidivisional multiproduct firm does operate this way, and there is plenty of evidence to suggest that they can and do, then the link between market power in a particular market and the funding of innovation in that market is undone. In a multiproduct firm selling products in markets A through Z, the cash generated by virtue of power in market A can indeed fund innovation relevant to market A, but it can equally well fund innovative activity in market Z. The capital market inside the multiproduct firm thus unlocks the relationship between market structure and innovation proposed by Schumpeter.

When firms do go into the capital market they generally have multiple sources of funding available. Generically, these can be split into debt and equity. The various types of debt and equity can on the one hand be thought of as financial instruments or, as Williamson suggests, as different "governance structures" (Williamson, 1988, 1996). Williamson explains that the decision by firms to use debt or equity to support individual investment projects is likely to be linked to the redeployability of the underlying investment. Since new product development programs commonly involve investment in assets that are substantially irreversible (like R&D) and/or non-redeployable (like specialized equipment), debt is only of limited value in financing innovation, unless a firm has collateral and is under-leveraged to begin with. Accordingly, the fund sources generally available to support new product development are internal cash flow and new equity. In instances when a firm does not already have substantial cash flows, then equity is the major source of new funds. The role of equity is made distinct if it is considered in the context of "start-up" firms which do not already have free cash flows. Investors have obvious problems in evaluating the prospects for new products and processes, and the best investees have problems, though less serious, in identifying the best investors.[15]

Now consider internally generated cash flow. Even in the United States where there is a vibrant venture capital market, internal "free" cash flow is the major source of private financing for innovation. A firm's cash flow is not just a function of price-cost margins in the product markets (sometimes suggested as a proxy for monopoly power) but its existing asset structures and the need for new investment in existing businesses. A business can clearly be a "cash cow" even if it is earning only competitive returns. This would be true if the firm was gradually divesting itself, or simply harvesting its position

[14]See Kay et al. (1990), undated working paper.

[15]The investors' problems are rather obvious. The investor has the difficult challenge of calibrating investment prospects in an environment where there is usually high market uncertainty, high technical uncertainty, and bountiful opportunism and optimism. Several kinds of opportunism are possible. One is simply that the technology can be misrepresented. This tendency, however, can be checked if the investor hires technical consultants to validate the entrepreneurs' claims. Another is that the tenacity and veracity of the entrepreneur are difficult to calibrate, with consequences much more unfortunate for the investor than for the entrepreneur. Ascertaining whether the entrepreneurs' optimism is honest yet misplaced is perhaps even more difficult. There is "much evidence that in the context of planning and action most people are prone to extreme optimism in their forecasts of outcomes, and often fail to appreciate the chances of an unfavorable outcome" (Kahneman and Lovallo, 1995, p.2). Decision makers often take risks because they deny their existence or underestimate their extent (March and Shapira, 1987).

in a particular market. Internally generated cash can be readily allocated by management and is not typically constrained by covenants.

Over the last half decade, a controversial body of literature has emerged which, in essence, argues that free cash flows must be distributed to shareholders, rather than being invested internally in discretionary projects, if firms are to operate efficiently (Jensen, 1989). The basic idea is that the discipline of debt is needed to cause capital to be channeled to high-yield uses in the economy, as well as in the firm. There are severe problems with this thesis, not least of which is that debt holders are loss averse and not at all business-opportunity driven. While it may indeed be the case that free cash flows do sometimes get misallocated by managers, to delimit them in the manner proposed by advocates of the free cash flow hypothesis is to force the firm into equity markets to finance innovation. For reasons explained earlier, this is not always desirable because the new issues markets, both public and private, have disabilities with respect to recognizing and funding new opportunities.

To summarize, innovation clearly requires access to capital. The necessary capital can come from cash flows or from equity. At least with respect to early stage activity, debt financing is unlikely to be viable, unless the firm has other assets to pledge. However, certain downstream investments needed to commercialize innovation can be debt financed if they are redeployable. Alternatively, alliances can be entered which reduce the need for new investment in complementary assets. The point, however, is that there are many factors besides firm size, and the presence or absence of market power, that affect an innovator's capacity to access capital.[16]

3.2. Hierarchy

Hierarchy arose to help in the administration of military, religious, and governmental activities.[17] While hierarchies are old, deep hierarchies are relatively new. Anthropologists point out that most tribes, clans and agricultural enterprises have rather flat hierarchies. The Roman Catholic Church, for instance, has only four levels. Centralizing and decentralizing are not genuine alternatives for organization; the key issue is to decide the mix. Hierarchies can accomplish complex organizational tasks, but they are often associated with organizational properties inimical to innovation, such as slow (bureaucratic) decision making and weak incentives.

3.2.1. Bureaucratic decision making.

Decision making processes in hierarchical organizations almost always involve bureaucratic features. In particular, a formal expenditure process involving submissions and approvals is characteristic. Decision making is likely to have a committee structure, with top management requiring reports and written justifications for significant decisions. Moreover, approvals may need to be sought from outside the organizational unit in which

[16]For an expanded discussion, see Day et al. (1993), part I.

[17]Hierarchical subdivision is not a characteristic that is peculiar to human organization. It is common to virtually all complex systems of which we have knowledge (Simon, 1973, p.202). The advantages of hierarchy are well understood. In particular, among systems of a given size and complexity, hierarchical systems require much less information transmission among their parts than do other types of systems.

the expenditure is to take place. While this may ensure a matching up of expenditures to opportunities across a wider range of economic activity, it unquestionably slows decision making and tends to reinforce the status quo.

The latter characteristic follows from committee decision making structures, which almost always tend toward balancing and compromise. But innovation is often ill served by such structures, as the new and the radical will almost always appear threatening to some constituents. Put differently, representative structures, bureaucratic or political, often tend to endorse the status quo. Strong leaders can often overcome such tendencies, but such leaders are not always present and their capacities are often thwarted by the organization.[18]

One consequence is what Williamson (1975) has referred to as a "program persistence bias," and its corollary the "anti-innovation bias." Program persistence refers to the funding of programs beyond what can be sustained on merits, and follows from the presence or influence of program advocates in the resource allocation process. This proclivity almost automatically has the countervailing effect of reducing funds available to new programs, which are unlikely to be well represented in the decision making process. As Anthony Downs points out, "the increasing size of the bureau leads to a gradual ossification of operations – since each proposed action must receive multiple approvals, the probability of its being rejected is quite high – its cumbersome machinery cannot produce results fast enough, and its anti-novelty bias may block the necessary innovation" (p.160).

The sharpening of global competition, and diversification (organizationally and geographically) in the sources of new knowledge compels firms to make decisions faster, and to reduce time to market in order to capture value from technological innovation. It seems clear that to accomplish such responsiveness, organizations need new structures and different decision-making protocols to facilitate entrepreneurial and innovative behavior. Burgelman (1984) identifies a menu of such arrangements which include: special business units, new ventures department, new venture divisions, and independent business units. Clearly, all of these designs imply smaller, flatter and more specialized structures within which to conduct activities where speed and responsiveness are critical. In the limit, the spinoff or spinout of a new division signifies that the enterprise's (or at least the individuals associated with it) chances of success are greater outside rather than inside an established hierarchy. In addition to the creation of semi-autonomous units, firms can attempt to "delayer" by stripping out layers of middle management. But flattening organizations need not fundamentally redefine the relationships between people and functions in the organizations. Functions may still work sequentially, with decisions being made from fragmented perspectives.

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[18]Crozier (1964, p.225) puts it this way: "People on top theoretically have a great deal of power and often much more power than they would have in other, more authoritarian societies. But these powers are not very useful, since people on top can act only in an impersonal way and can in no way interfere with the subordinate strata. They cannot, therefore, provide real leadership on a daily basis. If they want to introduce change, they must go through the long and difficult ordeal of a crisis. Thus, although they are all-powerful because they are at the apex of the whole centralized system, they are made so weak by the pattern of resistance of the different isolated strata that they can use their power only in truly exceptional circumstances."

In essence, the organizational challenge appears to be that activities are not as decomposable as they used to be, and that cross-functional interaction must take place concurrently, rather than sequentially, if firms are to cut time-to-market for new products and processes. Cross-functional and cross-departmental networks must be strengthened without causing information overload. Computer networks can assist cross-functional interaction by project teams, concurrent engineering teams, network teams, task forces and the like. If such activity becomes completely unstructured, it augments rather than displaces bureaucracy. Instead of random ad hoc approaches, what is needed are well-defined cross-functional teams, which can be redefined as needed. With organizational subunits cross-linked in this way, authority occurs as much from knowledge as position in the organizational hierarchy. The challenge is to develop a culture which supports the establishment of cross-functional teams which draw on the requisite knowledge, wherever it may be located.

3.2.2. *Low-powered incentives.*

As they grow, organizations often become characterized by what Williamson (1985, p.153) calls "low powered incentives." Low-powered incentives can be defined as those where the co-variance of employee compensation with business unit performance is low. One reason is that compensation structures inside large organizations need to be sensitive to relative as well as absolute levels of compensation. If the compensation structure itself has value through the relativities it establishes, then the enterprise will be reluctant to disturb the structure to support innovation. Another reason is that stock options cannot be granted to reflect divisional performance since it is generally the case that the division's shares are nontradeable in public markets. The absence of a public equity market for subunit shares thus deprives the firm of the opportunity to provide an objective capital market-based augmentation to compensation.[19] If the employee is rewarded instead through stock in the total enterprise, the impact of divisional, departmental, and individual performance is likely to be severely diluted.[20]

3.2.3. *Principal-agent distortions.*

Business firms of great size are rarely owner managed. Inasmuch as managers (agents) trade-off enterprise performance for their own welfare, innovation is likely to be impaired. This is because the interests of managers are sometimes at odds with what innovation requires, because the tenure of top management is usually much shorter than the gestation period for major innovations. Moreover, principals must invest in costly information collection and monitoring activities in order to check up on the performance of agents. These costs can be considerable. Moreover, principals may insist on certain expenditure controls which themselves slow decision making and thwart innovation.

[19]Surrogate valuation indexes can sometimes be created based on the use of "yardstick" companies, but they typically do not convey liquidity.

[20]For further discussion on measurement problems, see Holmström (1993, pp.144–146).

3.2.4. Myopia.

Organizations can become closed to changes in the market and business environment and to new sources of technology. Individuals in organizations, including chief executive officers, can fall into the trap of adopting a citadel mentality. The availability of free cash flows can help sustain that mentality and behavior for considerable periods of time. Closed systems may be able to hone existing routines, but they will lose the capacity to engage in new routines. Organizations can become closed through administrative arrangements (as when the firm's boundaries are delimited by its organization chart), through legalistic (rather than relational) contracting with suppliers and customers, and through social and cultural norms which stress the importance of inside rather than outside considerations.

3.3. Scope

The scope of product market activities may impact the innovative performance of firms in at least three ways. One has just been discussed in the context of finance: the multi-divisional multiproduct firm is in a position to re-allocate cash from businesses that have positive cash flow to new businesses with negative cash flow. A second hypothesis, put forward at various times by Joseph Schumpeter, Richard Nelson and others, is that the product market portfolios of multiproduct firms will increase the payoff to uncertain R&D by increasing the probability that new products and processes resulting from corporate R&D can be commercialized inside the firm. Neither of these will be the main focus here.

Instead, it is suggested that multiproduct firms can more readily develop and commercialize "fusion" technologies which involve the melding of technological capacities relevant to disparate lines of business. This fusion – as with mechanics and electronics (what Kodama, 1986 calls "mechatronics") – by no means occurs automatically, and requires internal structures which are flexible and permeable.[21] Indeed, there appears to be less diversity in firms' products than in their technologies (Pavitt et al. 1989). Nevertheless, the multiproduct firm does afford opportunities for economies of scope based on transferring technologies across product lines and melding them to create new products (Teece, 1980, 1982). Despite the path dependent-nature of technological change, the diversity of application areas for a given technology are often quite large, and it is often feasible and sometimes efficient to apply the firm's capabilities to different market opportunities.

Suppose application areas outside of the core business do in fact open up. The question arises as to whether potential scope economies deriving from the application of proprietary know-how in new markets add more to the innovating firm's value if they are served through licensing and related contractual arrangements to unaffiliated firms who then serve the new product markets in question, or by direct investment, either de novo or by merger/acquisition. This is an important question, the answer to which ought to help shape a positive theory of the scope of the firm's activities.

Whether the firm integrates or not is likely to depend critically on four sets of factors: (1) whether the technology can be transferred to an unaffiliated entity at higher or lower

[21] This is discussed in Section 4.3.

cost than it can be transferred to an affiliated entity; (2) the degree of intellectual property protection afforded to the technology in question by the relevant statutes and laws; (3) whether a contract can be crafted which will regulate the sale of technology with greater or less efficiency and effectiveness or whether department-to-department or division-to-division sales can be regulated by internal administrative procedures; and (4) whether the set of complementary competences possessed by the potential licensee can be assessed by the licensor at a cost lower than alternatives. If they are lower, the available returns from the market will be higher, and the opportunity for a satisfactory royalty or profit-sharing arrangement accordingly greater.

These matters are explored in more detail elsewhere (Teece, 1980, 1984, 1986, Chesbrough and Teece, 1996). Suffice to say that contractual mechanisms are often less satisfactory than the alternative. Proprietary considerations are more often than not assisted by integration, and technology transfer is difficult both to unaffiliated and affiliated partners, with the consequence that integration (or multiproduct diversification) is the more attractive alternative, except where incumbents are already competitively established in downstream activities, and are in a position to render de novo entry by the technology-based firms unattractive because of the excess capacity it would generate. Hence, multiproduct firms can be expected to appear as efficient responses to contractual, proprietary and technology transfer problems in an important set of circumstances. Mixed modes, such as joint ventures and complex forms of profit-sharing collaboration, will also be common according to how the set of transactions in question stacks up against the criteria identified above.

3.4. Vertical integration

The characteristics of technological development identified earlier also have important implications for the vertical structure of the firm, and vice versa. Economic historians have long suggested that there may be links between vertical structures and the rate and direction of innovation. For instance, Frankel (1955) has argued that the slow rate of diffusion of innovations in the British textile and iron and steel industries around the turn of the century was due to the absence of vertically integrated firms. Kindleberger (1964) has gone so far as to suggest that the reason why West Germany and Japan have overtaken Britain may be due to "the organization of [British] industry into separate firms dealing with each other at arm's length." This "may have impeded technological change because of the possibility that part of the benefits of that change would have been external to the separate firms" (pp.146,147). Kindleberger also studied the reasons for the failure of the British railroads to abandon the 10-ton coal wagon in favor of the more efficient 20-ton wagon, and concludes (1964) that the reason for the slow rate of diffusion was institutional and not technical. In short, it stemmed from the absence of vertical integration.[22] General Motors' early dominance in the diesel electric locomotive industry

[22]Technical aspects of interrelatedness do not seem to have held up the movement to more efficient size, either through making such a change uneconomic because of the enormity of the investment required or by adding amounts too great for any one firm to borrow. The sums involved were not large, and railway finance was rarely a limiting factor in the period up to 1914. Private ownership of the coal cars by the collieries, on the other hand, posed a type of interrelatedness that was institutional rather than technical.

has also been attributed to the fact that it was integrated into electrical supply while its competitors were not (Marx, 1976). A systematic exploration of the relationship between technological innovation and enterprise boundaries is needed.

For present purposes, it is useful to distinguish between two types of innovation: autonomous (or "stand-alone") and systemic. An autonomous innovation is one which can be introduced without modifying other components or items of equipment. The component or device in that sense "stands alone." A systemic innovation, on the other hand, requires significant readjustment to other parts of the system. The major distinction relates to the amount of design coordination which development and commercialization are likely to require. An example of a systemic innovation would be electronic funds transfer, instant photography (it required redesign of the camera and the film), front-wheel drive, and the jet airliner (it required new stress-resistant airframes).

With systemic innovation, internal organization (integration) can often assist the workings of the market. Integration facilitates systemic innovations by facilitating information flows, and the coordination of investments plans. It also removes institutional barriers to innovation where the innovation in question requires allocating costs and benefits, or placing specialized investments into several parts of an industry.

Comprehensive evidence with respect to these propositions has yet to be assembled. Vignettes can be found in Chesbrough and Teece (1996). The only statistical test performed to date relates to the petroleum industry (Armour and Teece, 1978). These findings indicated that firm and R&D expenditures for basic and applied research in the U.S. petroleum industry between 1951–1975, were statistically related to the level of vertical integration which the enterprise possessed.[23]

3.5. *Organizational culture and values*

Market power is an element of industrial structure; scale, scope, integration and hierarchy can be thought of as elements of the formal structure of an organization. Of equal if not greater importance is the informal structure of an organization. Organizational culture is the essence of an organization's informal structure. It is "the pattern of beliefs and expectations shared by the organization's members. These beliefs and expectations produce norms that powerfully shape the behavior of individuals and groups" (Schwartz and Davis, 1981, p. 33).

Organizational culture can be thought of as the "central norms that may characterize an organization" (O'Reilly, 1989, p. 305). A strong culture is a system of informal rules that spells out how people are to behave most of the time. By knowing what is expected of them, employees will waste little time deciding how to act in a given situation (Deal and Kennedy, 1982). There need not be consensus within an organization with respect to these beliefs, as the guiding beliefs or vision held by top management and by individuals

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[23]Despite the fact that the ultimate objective of R&D programs is to produce innovations, not simply to dissipate resources on R&D activities, expenditure data can be viewed as a useful proxy for innovative performance in that they reveal the intensity of innovative activity. Furthermore, if the discount rate facing non-integrated firms is similar to that facing integrated firms and if similar risk preferences exist across the management of these firms, the higher productivity per dollar of research expenditure posited in vertically integrated firms implies that, ceteris paribus, such firms will devote more resources to R&D.

lower down in the organization may not be congruent. It is the latter, however, which define an organization's culture (O'Reilly, 1989, p.305).

There seems to be an emerging consensus (Deal and Kennedy, 1982, Peters and Waterman, 1982, O'Reilly, 1989) that the following set of norms assists the development and commercialization of new products and processes. With respect to development, these include: the autonomy to try and fail; the right of employees to challenge the status quo; open communication to customers, to external sources of technology, and within the firm itself. With respect to commercialization or implementation, teamwork, flexibility, trust and hard work are considered to be critically important. The right culture is not just an important asset to assist in technological development; it may be a requirement.

With a few notable exceptions (North, 1990), economists have given almost no attention, and little sympathy, to the topic of organizational culture.[24] Occasionally, economists may speak to the importance of trust and consciousness. Thus Arrow (1974, p.28) notes that "social demands may be expressed through formal rules and authorities, or they may be expressed through internalized demands of conscience. Looked at collectively, these demands may be compromises which are needed to increase the efficacy of all."[25] If Arrow is right in his claim that values can increase efficiency, it is unfortunate that the topic has been left to organizational sociologists and psychologists, and that economic science ignores what appears to be an important set of variables in the understanding of organizational performance.

One way for economists to begin grappling with organizational culture is to see it as control on the cheap; reduction in shirking is just one element.[26] If individuals can be motivated and directed without pecuniary incentives (and disincentives) and the exercise of authority, tremendous resource savings can ensue, and innovation processes can avoid the burdens of bureaucracy. Conversely, if a firm's culture and strategy do not align, it is likely to be unable to implement its strategy, especially strategies which involve innovation. For instance, a declaration by top management of a firm that the firm is now going to be more open to external sources of technological ideas will not ensure that the strategy will be successful if there is a well entrenched "not invented here" culture inside the organization. The failure to develop new norms supportive of a particular strategy "means that changes will persist only where they are closely monitored and directly rewarded" (O'Reilly, 1989, p.310).

[24]North's discussion (chapter 5) is almost exclusively limited to societal culture rather than organizational culture. He does however note that informal constraints flowing from the broader societal culture are pervasive. Veblen (1972, p.174) notes that "at least since mankind reached the human plane, the economic unit has been not a solitary hunter, but a community of some kind."

[25]Moreover, there is a tendency to squeeze such concepts into "externalities," where it is not clear they belong. Thus Arrow (1974, p.23) notes that: "Trust and similar values, loyalty or truth-telling, are examples of what the economist would call 'externalities'. They are good, they are commodities; they have real, practical economic value; they increase the efficiency of the system, enable you to produce more goods or more whatever values you hold in high esteem. But they are not commodities for which trade on the open market is technically possible or even meaningful."

[26]Alchien and Demsetz (1972).

3.6. External linkages

Economists, as well as many organization theorists, have traditionally thought of firms as islands of hierarchical control embedded in a market structure and interacting with each other through the price mechanism. Indeed, Coase (1937) has referred to firms as "islands of conscious power." Coase's metaphor needs to be transformed from islands to archipelagos to capture important elements of business organization. This is because firms commonly need to form strategic alliances, vertically (both upstream and downstream), laterally, and sometimes horizontally in order to develop and commercialize new technologies.[27] Compared to arm's-length market contracts, such arrangements have more structure, involve constant interaction among the parts, more open information channels, greater trust, rely on voice rather than exit, and put less emphasis on price. Compared to hierarchies, such alliances or networks among firms call for negotiation rather than authority and put great emphasis on boundary-spanning roles. Although firms connected through alliances have a high degree of autonomy, the relationship may well be anchored by a minority equity position. These arrangements can be used to provide some of the benefits of integration while avoiding some of the costs. This undoubtedly helps explain the proliferation of alliances in recent decades.

The variety of such arrangements to link organizations is almost unlimited, and the resultant forms quite diverse. A constellation of licensing, manufacturing and marketing agreements will typically characterize many interorganizational arrangements. R&D joint ventures, manufacturing joint ventures, co-marketing arrangements and consortia are just a few of the resultant forms. Some of these arrangements constitute extremely complex open systems, and some may be unstable. The managerial functions in these interorganizational networks are quite different from the authority relationship which commonly exists in hierarchies. Managers have to perform boundary-spanning roles, and learn to manage in circumstances that involve mutual dependency.

3.7. Assessment

The above discussion of the variables which impact firm-level innovation suggests that economic and organizational research needs a richer framework if the innovation process is to be better understood. Economic research needs to pay greater attention to organizational structure, both formal and informal, and organizational research needs to understand the importance of market structure, internal structure, and the business environment. Fig. 1 is a diagrammatic presentation of the various classes of variables that have been identified, as well as considerations deemed to be important but assumed away in this analysis. For instance, the firm's human resources/capital and the mechanism by which firms attract, train, and hold first-rate people has not been deeply analyzed. Nor has the role of government in the support of the scientific and technological infrastructure been analyzed. Another major omission has been the strategy by which firms identify

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[27] Imai (1988, p.2) notes that "corporate networks in a broad sense are the vital economic institution which has led the Japanese economic development. The long history of cooperation between firms may be a crucial factor to explain the special adaptability of the Japanese economy." Imai uses the term, as it is used in this paper, to indicate interfirm relationships in general, including zaibatsu and business groups.

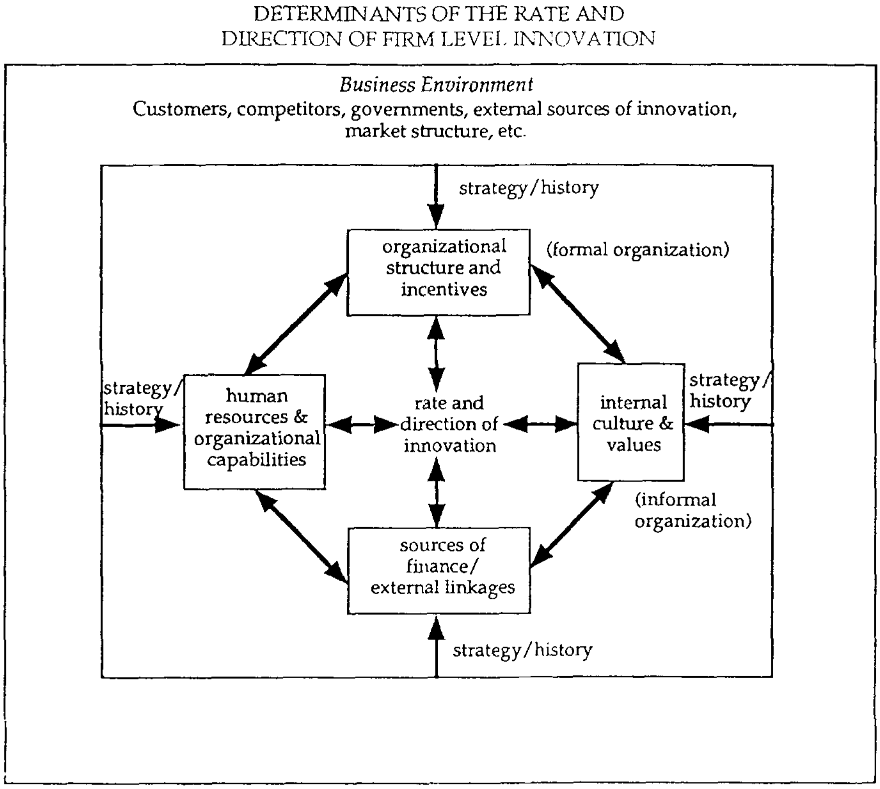

Fig. 1. A determinants of the rate and direction of firm level innovation.

what projects to engage and what assets to build or buy in order to commercialize technology.

In Sections 4 and 5 consideration is given to identifying particular organizational forms that have distinct implications for certain types of innovation. The treatment is illustrative and not comprehensive. It suggests that there are a variety of organizational modes that can support innovation, but that there are important differences amongst organizations in the types of innovation they can support.

4. Distinctive governance modes (Archetypes)

In the previous section, various organizational characteristics were identified. Distinctive governance modes arise when these characteristics are represented to greater or lesser degrees. The specification of the governance mode requires attention to at least four classes of variables: firm boundaries, internal formal structure, internal informal structure, and external linkages. What immediately becomes clear is that for purposes of considering the innovative potential of various organizational forms, one can no longer simply specify the type by reference to one or two aspects of structure. For example, it is no longer meaningful to discuss the innovative potential of conglomerates, vertically

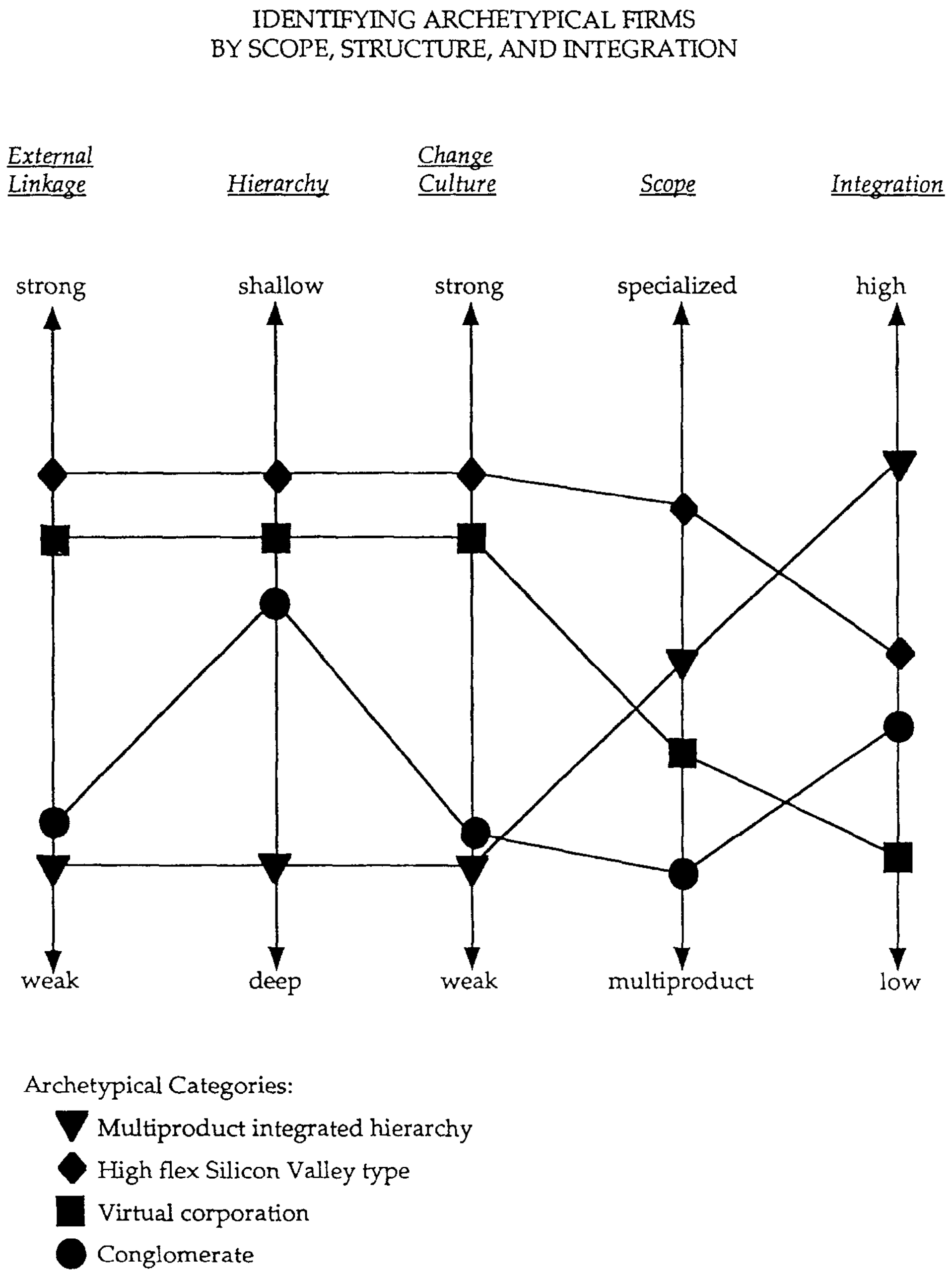

Fig. 2. Identifying archetypical firms by scope, structure, and integration.

integrated firms, etc. without specifying much more. Rather than specify all possible permutations and combinations of these variables in this paper, the focus will be on the following archetypes: (1) stolid, multiproduct, integrated hierarchies; (2) high flex "Silicon Valley"-type firms; (3) hollow corporations of various types; and (4) conglomerates of various types. There will also be a brief discussion of the individual inventor (not really an organizational form). Fig. 2 graphs these structures on ordinal scales measuring various structure variables plus scope and external linkages.

4.1. The individual inventor and the stand-alone laboratory

Many still cling to the notion that the individual inventor, standing outside of an organization, is responsible for the lion's share of innovation in today's economy. This myth springs in part from the first industrial revolution when invention was the province of the individual or pairs. But since the last quarter of the 19th century and the emergence of R&D labs, and more recently venture capital, innovation has become more the domain of organizations, not individuals.[28]

The problems that the inventor-entrepreneurs have in extracting value from new technology are considerable. However, when an inventor (or an enterprise) can rely on the instruments of intellectual property protection to protect invention from imitation, theory suggests that the inventor can appropriate a substantial fraction of the invention's market value. When property rights are weak (the normal case), the inventors' ability to capture value are dramatically circumscribed (Teece, 1986). In the case where the individual inventor has a patent but little else, then the patent holder's options include: (i) licensing the technology to incumbent firms who already have the necessary complementary assets in place; (ii) using the patent as collateral to raise debt funds to help develop an organization to exploit the technology; (iii) exchanging the patent for equity in a start-up, equity-funded firm; (iv) exchanging the patent for equity in an established firm.

None of these options avoid the problem of valuing the patent and the concomitant leakage problems which this process exposes. Valuation is likely to require disclosure and the triggering of what Arrow (1971, p.152) has referred to as the *fundamental paradox* of information: Its value for the purchaser is not known until one has the information, but then one has in effect acquired it without cost. While this problem is somewhat softened when there is good patent protection, most non-industrial providers of funds are going to need technical experts to evaluate the technology, in which case the risk of leakage remains. A wealthy inventor can of course overcome some of these problems by signaling value to financiers and joint venture partners through providing collateral, performance guarantees, or by co-investing.

If imitation is easy, the problems are more difficult. In those instances the granting of low royalty, non-exclusive output-based licenses (i.e. royalties rather than up-front fees) are likely to yield higher rents to the inventor. In this way, the inventor does not provide much incentive for firms to invent around (in the case of a weak patent) or otherwise invest resources in imitation; these costs can be extracted in part by the licensor.

[28] That is not to say that individual inventors are not sometimes very important and very successful. My argument is that when they are successful commercially, it is generally in an organizational setting.

Even when the valuation problem is overcome the parties must meet another challenge – transferring the technology to the buyers. As discussed earlier, the tacit nature of knowledge (which helps make imitation difficult) also makes transfer difficult (Teece, 1980, 1982). Hence the circumstances where imitation is difficult are also the circumstances where transfer is often difficult. The only clear circumstance where the inventor can succeed alone is when (1) the technology is well protected by intellectual property law, (2) the technology can be transferred from the inventor to an organization, and (3) the inventor already has great wealth. The circumstances where these factors occur together is likely to be relatively rare.

The stand-alone research laboratory faces many of the same challenges as the individual inventor. The main difference is that the laboratory can bring multiple organizational skills to bear on the R& D process, and the probabilities of fusing multiple technologies is likely to be enhanced from the bringing together of multiple research disciplines. Moreover, if scale economies exist in R&D, the laboratory is better able to capture these than the individual. But the framework would suggest that stand-alone laboratories cannot be viable, unless they happen to work in areas where strong intellectual property protection is assured.[29]

4.2. *Multiproduct, integrated, hierarchical firms*

It is not uncommon to find such enterprises on the industrial scene. N.V. Phillips and General Motors in the 1980s were good examples. Hierarchical is meant to signal the presence of bureaucratic decisions, and absence of a powerful change culture and high-powered incentives. Such enterprises are also likely to be internally focused. As a consequence, external changes in the market as well as in the science and technology establishment are unlikely to get recognized in a timely fashion. Decision making is slow and ponderous.

However, if such organizations are able to achieve what Downs (1967, p.160) calls "breakout" – where a new organization, possibly a new venture division, is set up for a special task – it may be able to overcome the anti-innovation bias, at least temporarily. Burgelman (1984) has argued that "autonomous strategic behavior" can take place inside large firms, if management sets up the appropriate internal structures. The range of enabling structures is quite large and includes venture teams' "skunk-works," new venture divisions and the like. The suitability of these various structures depends on a variety of technological, market and organizational factors which will not be explored here.

Nevertheless, integrated firms overcome some basic problems associated with relying on an economy of Lilliputian firms. Integrated firms can readily support systemic innovation as discussed earlier. They can also adapt to uncertainty (Williamson, 1975) in a sequential fashion as events unfold. (Managerial hierarchies are often better at adjudicating disputes inside the firm than courts are at adjudicating

[29]Even setting aside protection issues, stand-alone R&D laboratories have problems in developing information channels to their sponsors to understand their sponsors' needs, and in transferring technology back to the sponsor if in fact useful technology is developed. Moreover, because of leakage problems, competitors are likely to be reluctant to use a common R&D laboratory.

disputes between and among firms.) Large multiproduct, multidivisional integrated firms can take on large projects and can help set standards important to the continued evolution of a technology. In the early years of the PC industry, IBM drove floppy-disk drive capacity. The 5.25 in. floppy diskettes initially held 180 KB each when IBM introduced its PC in 1981. By 1983, capacity had doubled to 360 KB, and a year later had increased to 1.44MB. But they stayed stuck at 1.44 MB for over a decade. The explanation does not lie in inherent limits to the technology, but in IBM's declining ability to coordinate choices of follow-along standards. A new standard requires PC manufacturers to agree to accommodate it in their machines, that diskette manufacturers tool up for it, and that software publishers agree to supply programs in the new format. IBM's leadership is no longer sufficient to convert the industry over.[30]

There are also appropriability benefits. If it is a process technology which is at issue, the vertically integrated firm is capable of using the technology in-house and taking profits not by selling the technology directly, but by selling products that embody or use the process. Thus inasmuch as this type of firm does not have to utilize the market for know-how to capture value from the technology, the appropriability problem is softened. Inasmuch as contracting is internal, specialized assets are protected and recontracting hazards are attenuated. The technology transfer process is likely to be internal, so the tacitness problem is eased considerably, as the redeployment of personnel internally raises far fewer default issues than does external redeployment.

Such firms are likely to need alliance structures in order to tap into external sources of new knowledge. If large integrated firms are able to successfully team up with other firms[31] that have the entrepreneurial structures in place to promote creativity, then such firms are likely to be able to access a pipeline of new product and process concepts. The benefits here are a corollary to the benefits associated with strategic alliances.[32] However, the absence of a change culture and an outward orientation mean that such relationships may not be sought.

4.3. High flex "Silicon Valley"-type firms

The distinguishing features of such firms are that they will possess a change culture upon which there is great consensus.[33] They will have shallow hierarchies and significant

[30] I wish to thank Henry Chesbrough for helping develop the facts on this point.

[31] Such as the one described in VI.3.

[32] It is important to recognize, based on historical experience in the United States in the period up to 1980, that the acquisition of a multiproduct, integrated, hierarchical company by high-flex "Silicon Valley"-type company is often extremely difficult to achieve without destroying the creative and entrepreneurial capacity of the small companies. This is because the organizational controls of the large organization tend to destroy the innovative capacities of small firms, as discussed earlier.

[33] Indicative of this spirit is a statement by Andy Grove, CEO of Intel, "You need to try to do the impossible, to anticipate the unexpected. And when the unexpected happens, you should double your efforts to make order from the disorder it creates in your life. The motto I am advocating is, *Let chaos reign, then rein in chaos*. Does that mean that you shouldn't plan? Not at all. You need to plan the way a fire department plans. It cannot anticipate fires, so it has to shape a flexible organization that is capable of responding to unpredictable events."

local autonomy. Such firms will resist the hierarchical accouterments of seniority and rank found in Category 2 above, and they will resist functional specialization which restricts the flow of ideas and destroys the sense of commonality of purpose. Examples of firms that started this way and still reflect much of this style are Intel, Hewlett Packard, Sun Microsystems, Motorola, Raychem, Genentech, and 3M.

Decision making in these firms is usually simple and informal. Communication and coordination among functions is relatively quick and open. Early on in their development, one or two key individuals, typically the founders, make the key decisions. In the early stages, these firms, however, typically do not have a steady stream of internally generated cash with which to fund new opportunities. Hence, connections to the venture capital community or to other firms with cash available are important. These firms are likely to be highly innovative. But they are also likely to be cash-constrained. Those that are not, are likely to do very well.

The highly specialized nature of such firms and the absence of good intellectual property protection create strategic risks. The ability to capture the rents from innovation is by no means assured. But if such firms are able to develop and manage their external relationships without losing their distinct culture and responsive structures, then many of the problems stemming from uncertainty,[34] indivisibilities,[35] inappropriability,[36] asset specificity,[37] and tacitness[38] can be overcome, while organizational failure issues are held at a distance because much is outsourced and alliances are used frequently. By providing considerable autonomy and strong

[34]Primary uncertainty can never be reduced, but organizations can adapt to it. Secondary uncertainty, due to ignorance of complementary investment plans, can obviously be much reduced through bilateral agreements which involve mutual commitments and the maintenance of reciprocity through the exchange of hostages (Williamson, 1985).

[35]It is perhaps in the realm of indivisibilities that bilateral exchange comes closest to the perfect solution of a market failure problem. As discussed elsewhere (Teece, 1980, 1982), interfirm agreements are a relatively straightforward way to access complementary assets, particularly if they are already in place, are in excess capacity, and do not involve a high degree of asset specificity. Even when asset specificity is involved, the incentives for opportunistic recontracting can be attenuated by reputation effects, repeat contracting, or exchange of hostages.

[36]Inasmuch as firms can use bilateral contracts to access existing industry capacities so that new capacity does not have to be put in place de novo, product commercialization time can be reduced and lead time lengthened. Thus a major strategic advantage, lead time, can often be enhanced through the use of bilateral contracts. While the innovator may have to share part of the rent stream with the provider of complementary assets, investment risk for the innovator is typically reduced and imitators can be outpaced.

[37]Bilateral contracts enable specialized assets to be protected. While the degree of protection may not be as great as is provided under vertical integration, it is likely to be significantly higher than under unilateral contracts. A "hostage," or its economic equivalent, including specific investments which are mutually dependent, can be used to help support exchange. Thus if a manufacturer installs dedicated equipment to serve the developer, and the developer makes specialized investments which dovetail with the manufacturer, both can be assured that transactions will have a better chance of continuing in the face of adversity or superior opportunities.

[38]Tacitness is less a problem if a bilateral relationship exists, particularly if it is supported by equity. If repeated transactions are contemplated, spillovers and costs associated with seconding technical staff are less severe as adjustments can be made in subsequent transactions, as long as spillovers and costs are perceived similarly by both parties.

incentives, this organizational form is likely to be able to support many different types of innovation.

4.4. Virtual corporations

The term *virtual corporation* has been used in business parlence in the 1980s and 1990s to refer to business enterprises that subcontract anything and everything. A key question is whether the innovative capacities of such companies are impaired by the absence of in-house manufacturing and other capabilities. Virtual corporations are of course smaller than they might otherwise be (by virtue of the absence of vertical integration) and thus generally have shallow hierarchies. They might well have innovative cultures and external linkages to competent manufacturers.

Defined this way, virtuals have the capacity to be very creative and to excel at early-stage innovation activities. If they do indeed establish a strong alliance with a competent manufacturer, they may also have the capacity to be first to market, despite the absence of the requisite internal capabilities.

The hazards associated with *virtual* structures are not unlike the hazards facing the individual inventor. The problem is that unless the firm is operating in a regime of tight appropriability, the innovator may not be able to capture value from the innovation, and the manufacturer, by integrating into research and distribution, is likely to become the firm's competitor (Teece, 1986). Accordingly, the virtual corporation is not seen to be a viable long-run organizational form, except in limited circumstances.

The RCA color television experience demonstrates the downside of the *virtual* approach to innovation.[39] When RCA developed the color television, it made no attempt to keep the innovation to itself.[40] Rather, it licensed its color TV technology aggressively, and outsourced the manufacturing of key components of the television itself. It utilized a network of retailers to market the sets. Its licensees, however (particularly the Japanese licensees), made major investments in the integration of the television components, and then integrated forward and made the entire television set. In the 1970s, RCA had to abandon the manufacturing and development of color television sets, leaving the Japanese as world leaders in consumer electronics.

The RCA experience is not an anomaly. There are real risks in contracting everything out to the market and functioning as the hub or nexus of contracts. Research and development markets, in particular, are fraught with contractual hazards that undercut the ability of firms to coordinate arms-length purchases of R&D through markets (Teece, 1988). Consider the problem of using fixed price contracts to develop new products and processes. With fixed price contracts, one hazard is the inability to adequately specify in advance the desired output of the contract. Another hazard is that, if the R&D supplier shares too much knowledge ex ante, the buying firm can appropriate the knowledge without any payment. A third concern is the specific nature of most R&D activity. The R&D supplier and buyer confront hold-up hazards from each other, and there are strong lock-in

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[39]See Yamamura and Vandenberg (1986). I am not suggesting that RCA was or is a virtual organization; but merely that at various times it has embraced key elements of the virtual approach to innovation.

[40]Peters (1990), for example, advises firms to *License your most advanced technology* as well as *Subcontract anything and everything*.

effects once a relationship is begun. These hazards are softened with cost-plus contracts, but these contracts create other problems. The supplying R&D firm has no incentive to control costs, which creates the possibility of a blank check agreement for the buyer.

For these reasons, R&D is usually linked with manufacturing inside the firm.[41] For a similar set of reasons, the marketing function is also joined with these two functions. The desired output of an R&D process depends critically on the perceived user requirements for the product. This is highly impacted information, which cannot be contracted for in advance. And usually there is iteration between the emerging design and user reactions to the design, requiring an ongoing flow of information between the marketing and R&D functions. As a result, firms find it necessary to combine these complementary functions, not through the high-powered incentives of the market, but through the low-powered incentives of the firm.

Another dimension of this is that while markets are very efficient at coordinating adjustments where the technological coordination is low in terms of the interdependence of one technology on another, as the technologies become more interdependent, the hazards of coordinating through the market rise quickly. Internal organization often incurs greater costs than markets when technological interdependence is low. While coordination costs do rise as interdependence grows, those costs rise much more slowly than the market's costs. Accordingly, as interdependence rises, more integrated structures displace virtuals. Clearly, virtual is not always virtuous (Chesbrough and Teece, 1996).

4.5. Conglomerates

In the framework developed here, the conglomerate is not an especially distinctive organizational form. It is likely to be decentralized, and this favors the innovation process. It can also use the internal capital market to fund the development of new technologies. However, the importance of this is likely to be reduced the more (i) access to capital, including venture capital, is available for new stand-alone businesses, and (ii) headquarters management acts much like external capital market agents. Accordingly, on grounds of access to capital and diversity of activities, one would not expect the conglomerate to look too different from a portfolio of stand-alone firms with respect to its innovative capacity.[42]

However, there are two ways in which one might expect the conglomerate to underperform a portfolio of stand-alone firms with respect to innovation. One is that it is difficult for conglomerates to develop distinctive company-wide corporate cultures.

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[41] Mowery (1982) also finds that the contract research laboratories in the first half of the 20th century confined their work to simple testing and materials analysis, while internal R&D laboratories conducted the more sophisticated and firm-specific research.

[42] There has been very little discussion of the relationship between the conglomerate and technological innovation. The arguments advanced by Williamson (1975) that conglomerate firms possess miniature capital markets would suggest that the conglomerate is an ideal form for identifying new investment opportunities, including process and product innovations, and funding them until they become cash-flow positive. In the absence of market-for-venture capital, this argument would seem to imply that the conglomerate form ought to be associated with a stream of new product and process launches. The best evidence (Kline, 1995) indicates that relative to appropriately defined yardsticks, conglomerates did not underinvest in R&D, and indeed before 1970 they may well have overinvested.

Accordingly, it may be quite difficult to build a strong internal change culture at the corporate level. Certainly, as compared to a stand-alone firm, getting across to employees the notion that the unit must ultimately "stand on its own bottom" will be quite a challenge. As a consequence, free riding may well be accentuated. Likewise, the design of high-powered incentives for top management and employees will be hindered by the absence of an equity instrument geared to divisional performance. In short, the conglomerate does not appear to offer distinctive advantages in environments characterized by rapid technological change.

4.6. Alliance enterprise

We define an alliance enterprise as a *virtual corporation* that has developed strong commitments to other enterprises, usually through equity-based links to affiliated enterprises lying upstream, downstream, horizontal, and lateral from its core business. Such structures include consortia (e.g. Airbus, Sematech) as well as semipermanent teaming arrangements that transcend particular projects. Many new biotech firms in the United States are heavily alliance-dependent to fund their R&D and move drugs to the market.

The viability and desirability of alliances and other external linkage arrangements depend, not just on the efficacy of this form of contract, but also on the resources/ capabilities which can be accessed in this fashion. Alliances were essential in the 1980s and 1990s to the pharmaceutical industry as a mechanism to tap into the drug development capabilities of new biotech firms. Since the biotechnology revolution has occurred outside the organizational gambit of the established pharmaceutical industry, alliances have been embued with virtues they might not otherwise possess. Put differently, the value of a contract can easily be confused with what it enables one to access. The comparative institutional approach used here imputes to the alliance only that which it can uniquely access as compared to other arrangements.

5. Matching innovation and organizational archetypes[43]

The diversity of organizational forms observed is semipermanent and not a transitional feature of modern industrial economies. The diversity of observed forms in and of itself suggests that different organizational arrangements are suited to different types of competitive environments and differing types of innovation.

One cannot possibly expect to be comprehensive in developing a taxonomy of innovations and organizational archetypes. However, illustrations are developed below which involve matching organizational form to the locus of existing capabilities, and to the type of innovation (autonomous or systemic).

As the interdependence between technologies increases, pure market forms are less effective at achieving the requisite coordination. The more systemic the innovation, the greater the interdependence. Exposure to recontracting hazards is likely to be frequent.

[43]This section draws in part on Chesbrough and Teece (1996).

The discussion in Section 4.4 noted the distinction between autonomous and systemic innovation. Autonomous innovations (Teece, 1984) create improved products and processes that fit comfortably into existing systems. These innovations not only fit well within current industry standards, but they reinforce those standards. An example would be the introduction of a faster microprocessor using the same architecture, such as the Intel 80×86/Pentium family. Systemic innovations, however, change technological requirements and offer new opportunities so that the resulting configuration of both the innovation and its related technologies (which comprise a system of technology) are different; for example, audio CD plays require the abandonment of vinyl records and the manufacture of CD discs. Innovations of this type require that the design of the subsystems be coordinated in order for the gains from the innovation to be realized. Since these innovations span current technology boundaries, a complex coordination problem arises.

The other key dimension in organization form is the extent to which the capabilities needed to exploit the innovation exist within the firm already, and if not, whether those capabilities are available outside the firm. It has been argued elsewhere (Teece et al. 1994) that the firm is best regarded as a bundle of distinctive capabilities that enables it to perform functions more efficiently than its historical competitors. The presence or absence of critical complementary assets affects the prospects for appropriating the gains from innovation when the appropriability regime is not tight (Teece, 1986). These two dimensions motivate the simple framework presented in Fig. 3.

5.1. Autonomous innovation

Alliances and virtual structures will work well when the technology can be sourced externally, and the high-flex Silicon Valley-type will work well if it must be developed internally. When the technology can be sourced externally, the required coordination takes place with known technologies, so that no special hazards in contracting arise and adjustments to related technologies to realize the benefits of innovation are minimal. Indeed, when firms use bureaucratic centralized structures inappropriately to manage autonomous innovations, small firms and more decentralized large firms are likely to outperform them.

As noted, there are important nuances with respect to the particulars of how to organize for autonomous innovation. (1) The first circumstance is when the technology exploits capabilities already present within the firm. In these circumstances, internal development by high-flex Silicon Valley-type firms will work well. (An example here would be the introduction of a faster microprocessor using the same architecture, such as the Intel 80×86/Pentium family.) (2) The second is when innovation remains autonomous, but exploitation requires the firm to access capabilities outside its boundaries. Innovating firms must craft relational structures such as alliances to obtain access, thereby sharing the gains from innovation. Such firms must also overcome hold-up problems between the innovator and the owner of relevant outside capabilities. This is where virtual structures are often virtuous. Sun Microsystems pursued this strategy quite successfully with its SPARC microprocessor architecture. Sun defined the basic architecture, and then licensed out the design to other firms. This strategy induced enough entry by SPARC licensees to

Type of Innovation

	autonomous	systemic
Capabilities Exist Inhouse	**S**	**M**
Capabilities Exist Outside	**V**	**A**
Capabilities Must be Created	**A,S**	**S**

Key:

S= Silicon Valley type

M= Multiproduct integrated

A= Alliances (virtual with equity)

V= Virtual (outsource everything & anything)

Fig. 3. A proposed matrix of innovation, capabilities and preferred organization forms.

develop a standard, and attracted outside software developers to support the architecture. Sun later split its organization so that its hardware was separated from its software and its microprocessor design.[44]

(3) A third circumstance is when innovation remains autonomous, but requires new capabilities to be created to exploit its potential. Virtual structures are not quite enough. Consider biotechnology. New products can continue to pass through the same regulatory procedures and sell to physicians through the same marketing and distribution channels as yesterday's ethical drugs. But the underlying technology draws from a different science base. Here, internal development or alliances with equity are required to manage contractual problems between the young biotechnology companies developing new products and the older pharmaceutical companies seeking to add new products to their

[44]Note that Sun's strategy of defining a standard microprocessor architecture, and then licensing it, created a well-defined technical interface and resulted in transforming what would have been a systemic innovation to an autonomous innovation. Sun's approach facilitated decentralized innovation around its standard. The downside to this approach was experienced by IBM in the PC market.

lineup. These additional structures provide a credible ex ante basis for dividing the gains from innovation between the two types of firms.[45]

5.2. *Systemic innovations*

By their nature, systemic innovations require coordinated adjustment throughout the system to realize the gains from innovation. The potential from systemic innovations cannot be fully realized until adjustments are made throughout the system. Unaffiliated enterprises with weak internal integration will not suffice. The problem is that tight coordination is needed. Without the close integration of personnel, necessary coordination may be forsaken. Property rights issues may also arise if multiple enterprises are involved. Information sharing can be reduced or biased, as each seeks to get the most at the expense of the other. The party that commits first can be held-up by the other parties, while the party that waits until the others have committed themselves can extract more rents from the other partners. Even if such opportunism is contained, the rate of advance of complementary technologies may not be properly matched, so that product release dates slip and co-investment schedules of the parties are mismatched.

Lockheed's failure in the wide-bodied civilian airliner market can be attributed in part to the debacle it had with Rolls Royce. Rolls Royce committed to develop the RB-211 engine to power the L-1011, but technical problems that took time to be revealed to Lockheed caused major delays in commercialization, and took both Lockheed and Rolls Royce into bankruptcy. Similarly, GM's success with the diesel electric locomotive, and the failure of the GE/Alco co-development efforts can properly be tied to the inability of GE and Alcoa to properly coordinate and integrate their development efforts (Marx, 1976).

What is needed to successfully develop and commercialize systemic innovations are institutions with low-powered incentives, where information can be freely shared without worry of expropriation, where entities can commit themselves and not be exploited by that commitment, and where disputes can be monitored and resolved in a timely way. This is precisely what multi-product integrated firms achieve.

While systemic innovation favors integrated structures from a coordination perspective, it may nevertheless be the case that the relevant technological capabilities are resident in unaffiliated enterprises.[46] Alliances are then the best arrangement. Virtuals and even small Silicon Valley-type firms will not survive. NeXT and MIPS, for example, were dependent of the autonomous decisions of other firms in order to be able to realize the benefit of their technology. When these other firms delayed their supporting investments, each company was forced to narrow its focus and retrench.[47] This is where larger firms may have an advantage, by being able to secure minority investment positions in smaller firms with necessary capabilities, or by using their scale to create

[45]Pisano (1988) detailed the practice of using joint equity agreements to facilitate these relations in the biotechnology industry.

[46]For a discussion of capabilities, see Teece and Pisano (1994), Teece et al. (1997).

[47]NeXT has completely withdrawn from the hardware side of its workstation business, focusing entirely on its NeXTStep operating system. MIPS was acquired by Silicon Graphics, and is no longer a significant player as a workstation microprocessor architecture developer.

sufficient momentum so that complementary innovations are developed.[48] Japanese *keiretsu* commonly leverage strong relationships to access needed capabilities outside the firm, and they fit this model. For example, Toyota's successful introduction of the *kanban* production system (a truly systemic innovation) required tremendous coordination with its network of suppliers. Since Toyota was much larger than its suppliers, and because until recently it was the largest customer of virtually all of its suppliers, it had sufficient leverage to compel its suppliers to make radical changes to their business practices without exposing itself to hold-up.[49]

Another circumstance considered is where the systemic innovation requires entirely new capabilities in order for the innovation's potential to be realized. This is precisely the situation Chandler (1990) describes in *Scale and Scope* for the leading industries of the late 19th and early 20th centuries. The leading industries of that era – chemicals, steel, and railroads – were all transformed by systemic innovation (Teece, 1993). The winners were the companies that made major investments to shape the markets, and simply did not rely upon them. Today one sees leading companies like Intel and Microsoft making extensive investments to enhance their current capabilities and spur the creation of new ones.[50] Network arrangements among unaffiliated enterprises are exactly the wrong organizational strategy when firms are trying to commercialize and appropriate the gains of systemic innovation. An excellent illustration of this is an example often held to support the benefits of decentralization – the IBM PC. While the PC's early years highlighted the benefits of the *virtual* approach, the passage of more time has revealed the downside of that approach. This example is examined elsewhere (Chesbrough and Teece, 1996).

The process of matching organizational form to underlying technological and market conditions is of course a dynamic one. This aspect is somewhat expressed in Fig. 4. An illustration of some of the dynamics is provided by Motorola which continues to innovate in hand-held communication devices, including cellular phones. Future improvements on cellphone designs, and in particular, weight reduction and extended operation, requires lighter and more long-lived batteries. Motorola is in a position to advance these technologies through its own internal R&D programs, which have historically been very productive. As the older more established battery technologies like Nickel Cadmium have

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[48]The contrast between MIPS and DEC's Alpha chip is one example. By committing to supply Alpha on its own workstations, DEC is gathering greater commitment from third-party developers than did MIPS. Apple and IBM's PowerPC chip are garnering even more support, as Apple and IBM together claim to have shipped over one million systems with the PowerPC chip. Scale and integration are the key differences here.

[49]According to Gerlach (1992), Japanese manufacturers also place managers on the boards of its supplier firms and usually share their main bank with them. This allows a manufacturer such as Toyota to wield control over the supplier's strategic decisions and control the supplier's access to capital without requiring Toyota to have complete ownership of its suppliers. It is this which creates functional control. These structures provide a blend of market incentives (high-powered incentives, external measures of prices, profits and value added) with internal coordination capability.

[50]Intel, for example, has just committed itself to building the largest fab in the world in New Mexico to improve its manufacturing prowess. Microsoft is competing in virtually every segment of the PC software business with internally-developed products, rather than licensing or buying outside products. It recently announced plans to spend over $900 million in its current fiscal year, a 50% increase over last year's spending (*San Francisco Chronicle*, September 10, 1994, p.D2).

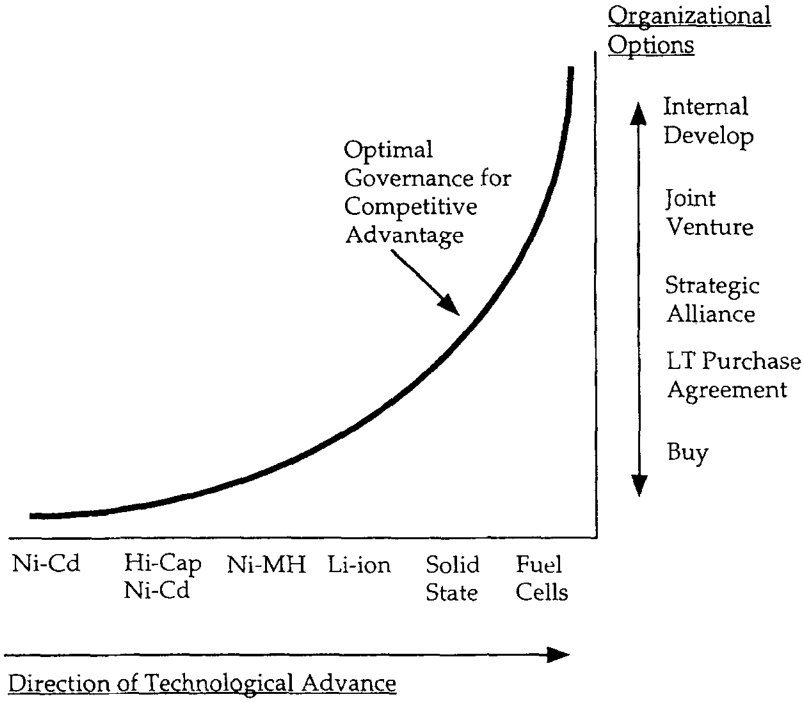

Fig. 4. Available technologies and organizational options for Motorola in battery cell technology.

been widely diffused, Motorola can reasonably rely on outsourcing from numerous existing suppliers to access its requirements in the Ni–Cd domain. However, solid state and fuel cells are still in their infancy as technologies to support personal communication devices. Moreover, Motorola is as well placed as others to advance the development of such technologies. With reliance on unaffiliated parties leading to obvious contractual hazards (Teece, 1988), internal development, or at the minimum joint venture development, is suggested for such technologies. In Fig. 4, this suggests that desirable governance arrangements will migrate toward *internal development* as the technology becomes more *state-of-the-art* and the population of outsider vendors diminishes.[51] It is likely to do so as one confronts more advanced technological options.

6. Conclusions

If this analysis is correct, it has rather strong implications for theory building, for management, and for public policy. With respect to theory building, it suggests the inadequacy of standard economic approaches that have market structure as the key if not the only determinant of the rate and direction of innovation. Clearly, such approaches are

[51] LT purchase agreement in Fig. 4 is an abbreviation for long-term purchase agreement.

poor guides to policy. At the minimum, firm boundaries (the level of integration), the structure of financial markets, and formal and informal organizational structure must be recognized as major determinants. This paper indicates that firm organization (not just product market structure) is an important determinant of innovation, a point made by Williamson (1975) that has largely gone unheeded by industrial organization economists.

The framework developed here is designed to shift the market structure–innovation debate in industrial organization beyond the domain where Schumpeter (1942), Galbraith (1952), Mansfield (1968), Scherer (1980) and others have put it, and into a new domain where internal structure, interfirm agreements, and capital market structures attain new significance. This also has obvious policy significance. The opening up of financial markets and the emergence of a vibrant venture capital industry have "provided new forms of finance for innovative activity again on a scale never seen before, effectively reducing barriers to innovative, competitive entry, across the industrialized world" (Rybczynski, 1993). Put differently, product market structure is not the main and possibly not the key factor in determining the rate and direction of innovation.

The framework also has strong implications for business history. It suggests the possible viability of new hybrid organizational arrangements – such as complex forms of interfirm agreements linking firms with complementary capabilities and capacities – over both the integrated alternatives and the small firm alternatives. These organizational forms may well represent a new and dramatic organizational innovation in business history. Firms are continuing to learn how and when to use them, and scholars are trying to understand them. In retrospect, the emergence and growth of these new forms, dating from about 1970, may turn out to be as significant an organizational innovation as the moving assembly line and the multidivisional firm.

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