This work is distributed as a Discussion Paper by the

STANFORD INSTITUTE FOR ECONOMIC POLICY RESEARCH

SIEPR Discussion Paper No. 00-03

INNOVATION IN THE GOVERNANCE OF PRODUCT-SYSTEM INNOVATION: THE SILICON VALLEY MODEL

by

Masahiko Aoki
Stanford University

October 2000

Stanford Institute for Economic Policy Research
Stanford University
Stanford, CA 94305
(650) 725-1874

INNOVATION IN THE GOVERNANCE OF PRODUCT-SYSTEM INNOVATION: THE SILICON VALLEY MODEL*

Masahiko Aoki

Summary

The subject of this paper is the Silicon Valley model as a new coordination-cum-governance mechanism of technological product-system innovation. The thrust of the arguments is: in order to understand the truly innovative nature of the Silicon Valley phenomena and its implications beyond Silicon Valley, it is necessary to grasp it as a coherent system composed of a cluster of entrepreneurial firms on the one hand, and various intermediaries, such as venture capitalists, leading firms in relevant niche markets, and other professional service providers, on the other. In the first section the information systemic aspect of the Silicon Valley model is discussed in a comparative systemic perspective. The second section then characterizes the mechanism of venture capital governance as a tournament game played among entrepreneurial firms. We will see, among other factors, that the entrepreneur's confidence in the venture capitalist's ability to judge the outcome of tournament precisely and fairly plays an essential role in eliciting their innovation efforts. The third section discusses the importance of the role of venture capitalists' reputations and norms in capital markets in eliciting their monitoring and governance efforts. The appendix provides stylized factual backgrounds for modeling. Those readers who are relatively unfamiliar with venture capital contracting and

related facts are advised to read it first.

The subject of this paper is the Silicon Valley model as a new coordination-cum-governance mechanism of technological product system innovation. The thrust of the arguments is: in order to understand the truly innovative nature of the Silicon Valley phenomena and its implications beyond Silicon Valley, it is not enough to formulate it as either a principal-agency relationship between a single individual entrepreneur and a venture capitalist, or as a de-integrated property rights arrangement.[1] It is necessary to grasp the phenomena as an emergent system composed of a cluster of entrepreneurial firms on the one hand, and various intermediaries, such as venture capitalists, leading firms in relevant niche markets, and other professional service providers, on the other. In other words, it is necessary to have a broader perspective that deals with the overall Silicon Valley phenomena as a unit of analysis and capture them as a coherent system. Only by doing so, we can understand them as an institutional innovation in the domain of technological product system innovation.

As described in the appendix to this paper, the venture capitalist usually retains a control block of shares in entrepreneurial firms and exercises a broad range of governance roles with them. It is certainly not the case that residual rights of control over physical assets are firmly integrated within the hands of entrepreneurs if they are cash-constrained at the outset. However, this does not imply that the entrepreneurs of product-development firms play a less autonomous role in information processing. Indeed, they are more autonomous in the production of knowledge in some technology areas than the traditional research and development laboratories of established firms. On the other hand, as Saxenian (1994) documented, there is also a substantial degree of information sharing across those entrepreneurial firms mediated by venture capitalists and others. How can these ostensibly contradictory characteristics co-exist? How can we understand their unique contributions to the process of technological product system innovation? What incentive impact does the apparently strong governance role of the venture capitalist have? Is there anything that the Silicon Valley model can do which cannot be duplicated in either a single firm or in arm's-length market relationships? Is the Silicon Valley model applicable elsewhere and in industries other than the high-technology industry? Are there any specific social costs and wastes, together with social benefits, associated with this model?

In order to consider these issues, this paper tries to build a coherent, theoretical construct that is referred to as the Silicon Valley model. Its construction is motivated by observations of the stylized Silicon-Valley phenomena as summarized in the appendix to this paper. But, stylized facts are changing fast so that any model may not capture every aspect of their dynamic trajectories all at once. Further, while some changes may possibly reflect the endogenous evolution of a new institution, some others may be merely generated by business cyclic factors. Therefore, in building the model we will limit our focus to some generic, systemic features of the Silicon Valley phenomena that we regard as essential for considering the above-mentioned issues.

The plan of the paper is as follows. The first section deals with the information-systemic architecture of the Silicon Valley model. The entrepreneurial firms in Silicon Valley compete in innovation in selective niche markets and thus their activities are fundamentally substitutes. Therefore, their information processing activities need to be encapsulated from each other in order to surpass competitors. However different from older established integrated firms, such as IBM which conceived *ex ante* of a concept for a possible new technological product system in a centralized manner, these firms are engaged in innovation efforts in particular niche markets in a decentralized way. A new technological product system therefore is evolutionarily formed by selecting and combining *ex post* mutually-compatible module products by successful firms. The first section examines technological and organizational conditions under which this type of information-systemic architecture can generate technological product system innovation more effectively than traditional corporate R&D organizations, albeit with associated social costs of duplicated innovation efforts and financing. This focus on *ex post* flexibility in the design of a new technological product system differs in emphasis from the conventional one in the technology literature on increasing returns (Arthur 1989, Romer 1986), and accordingly will have different public policy implications.

The second section then proceeds to the analysis of the governance role of the venture-capitalist complementary to this type of information-systemic architecture. We characterized the mechanism of venture capital governance as a tournament game played among initially funded firms for the subsequent staged financing necessary for the completion of projects. We will examine the conditions under which the associated threat of termination of financial support by the venture capitalist is seen to provide greater incentives for the entrepreneurs than under arm's-length financing. We will see, among other factors, that the entrepreneur's confidence in the venture capitalist's ability to judge the outcome of tournament precisely and fairly plays an essential role in eliciting their innovation efforts. This suggests that the provision of incentives for the venture capitalists is also an essential ingredient of the Silicon Valley model. The third section turns to this aspect of the Silicon Valley model and discusses the importance of the role of venture capitalists' reputations and norms in capital markets in eliciting their monitoring and governance efforts. Also this last section discusses some broader institutional ramifications of the Silicon Valley model, such as the endogenous formation of the entrepreneurial risk-taking tendency, complementary between mobile engineers' markets and venture capitalist governance. The appendix provides stylized factual backgrounds for modeling. Those readers who are relatively unfamiliar with venture capital contracting and related facts are advised to read it first.

1. The Information-Systemic Architecture of the Silicon Valley Model

(A) Comparative R&D Architectures

To begin an inquiry into the overall Silicon Valley phenomena as a system, we first focus on its information-systemic architecture. In doing so we apply and extend the comparative organizational framework developed in Aoki (1995: 2000 chapter 4.1) to the product-system innovation domain and see under what technological and organizational conditions the Silicon Valley clustering mediated by venture capitalists may, or may not, be superior to the traditional, corporate in-house R&D organizations.

Imagine that an innovative technological product system can be generated by a new combination of modular component products (element technologies). For example, a laptop computer as a technological product system consists of component elements as a LC monitor, MPU, image-processing LSI, hard disk drive, OS, audio and communication devices, etc. In order to develop such a product system, modular component products must be designed in such a way that they fit with each other to form a coherent, high-performing, market-competitive, technological system. Suppose for simplicity's sake that a generic R&D organization is constituted simply of the development management, denoted as *M*, and two task units, denoted as *Ti (i=a, b)*. The management may be engaged in the planning and systemic design of a technological product system innovation, involving such choices as system attributes, component composition, and the allocation of R&D funds between task units. The task units are engaged in the design of modular products, each of which is to constitute a component of an integral technological system.

The organizational environments are segmented like the first row of Figure 1. Namely, there is a systemic segment, *E-s*, that simultaneously affects the organizational returns to an entire technological product system, such as emergent industrial standards, availability of R&D funds, etc. We assume that information regarding this segment is primarily processed by the management. Next, there are the segments of the environment that affect the organizational returns to the designs of new modular products by the *Ti*'s, say engineering environments, which can be further divided into three subsets: *E-e*, common to both task units, and *E-a* and *E-b*, idiosyncratic to respective units. The processing of information regarding the common segment is necessary for resolving engineering problems underlying the designs of both modular products (e.g., the reduction of problems that may occur at the interfaces of modular products; the reduction of poor performance characteristics that may arise as synergy effects of operating the modular products). The information regarding an idiosyncratic segment of the engineering environment is relevant only to the design of a respective modular product. Thus the environments of the development of a product system innovation constitute a hierarchical order. However, although the processing of the idiosyncratic environment at the lowest level needs to be performed at the relevant task unit, the common segment of the engineering environment (and to some extent the industrial systemic environment as well) may be processed, and associated decisions may be made, by *M* and/or the *Ti*'s in various ways to be specified momentarily. We refer to the processing of information regarding engineering environments as "development", and the actions taken based on development as "design."

Let us identify the following three types of information-systemic architecture in the technological product-system-innovation domain.

Figure 1 about here

(i) The waterfall model and the "star model." This model corresponds to the functional hierarchy (the nested hierarchical-decomposition mode) introduced in Aoki (1995, 2000). As one example, *M* is the research director of an integrated firm and the *Ti*'s are its internal design-task units. Between them the intermediate agent *IM*, say the product development manager, may be inserted. *M* analyzes the systemic environment, *E-s*, conceives of a conceptual design for a potential technological product system innovation, and then communicates its decisions to *IM*. *IM* performs an analytical design that determines the division of design-tasks among the subordinate units within the budget and other systemic constraints imposed by *M* by analyzing the systemic-engineering environment, *E-e*. Then he hands over his decisions to *Ta* and *Tb*. The design-task units then resolve detail design problems that arise in their respective task-specific engineering

environments, *E-i (i=a, b)*. This organization reflects the essential aspects of the R&D organization of traditional, large, hierarchical firms, sometimes referred to as the “waterfall” model (Klein and Rosenberg (1986)).

Another analogue of this model can be found in what Hannan *et al* (1996) called the “star model”: a class of internal coordination mechanisms that they find among some entrepreneurial firms in Silicon Valley, in which wide-ranging systemic design (“the larger strategic directions shaping the work”) is entrusted to a star. He is instrumental in analyzing the highly uncertain systemic segments of the environment and after the completion of the analytical design, detailed designs may be reduced to relatively routine tasks. This model is adopted when there is a large amount of systemic uncertainty involved in developing a technological product system which requires distinguished competence to resolve (Aoki 1995; 2000). This is often a characteristic of academic research groups in fields such as biotech.

(ii) Interactive R&D organization. This model corresponds to the horizontal hierarchy (nested information-assimilation mode) introduced in (Aoki 1995; 2000, chapter 4.2(iv)). In this type of organization, *M* is the project manager and the *Ti*’s are design-task units. There is information sharing among them all regarding

the systemic environment, *E-s*. The two design-task units collaborate on development affected by the systemic engineering environment, *E-e*, while coping individually with technical and engineering problems arising in their own segments of the engineering environment, *E-i (i=a, b).* Each design-task unit thus has wide-ranging information about environments, partially shared and partially individuated, on which their respective decision choice (modular product design) is based. This system corresponds to what S. Klein conceptualized as the "chain-linked model"(Klein and Rosenberg(1986); Aoki and Rosenberg(1989)). In this model information assimilation is realized through the feedback of information from the lower level to the higher level, as well as through information sharing and joint development efforts across design-task units on the same level, just like multiple linkages of chains. This model is innovation-productive (informationally efficient) when there are high technological and attribute complementarities between modular component products while resolving design problems at each design-task unit requires specific expertises (Aoki 1995; 2000, Proposition 4.2 and 4.4).

This model is akin to the coordination aspect of what Hannan *et al* called the "peer and cultural control model, where the employees have extensive control over the means by which work gets done but little control over strategic directions, projects to be pursued, etc."(1996: 512-3) They found that some of the emergent Silicon Valley entrepreneurial firms internalize such a model. We also find that a mode of development teams in the automobile industry shares features with this architectural type. Clark and Fujimoto identified the most competitive type of development team in this industry as the one led by the "heavy weight product development manager – a combination of a strong project coordinator and a strong concept leader"(Clark and Fujimoto, 1991; Fujimoto 1999, chapter 6). In this model the product development manager leads a development team encompassing work groups drawn from various functional units in development, as well as manufacturing and marketing representatives. He exercises strong leadership in the entire process of developing a new product, starting from the conceptual design, based on the perception of potential future markets, to various downstream stages, such as analytical design, detailed design, manufacturing process design, as well as feedback for design improvement from manufacturing and marketing experiences to upstream design stages. Needless to say, modular components of an automobile as a technological product system are characterized by high attribute complementarities. For example, making a vehicle compact, less noisy, energy-efficient, resistant to wide-ranging temperature variation, etc., requires mutual fitness and finely coordinated designs of modular parts, as well as specific engineering expertise in resolving problems within each design task.

(iii) Silicon Valley model. In this system, there is a modicum of information assimilation regarding the systemic environment between *M* and the *Ti*'s, somewhat like in an interactive R&D organization. However, suppose that there are two additional characteristics to this system: One, design tasks are independent from each other in that there is less statistical correlation between their engineering environments - that is, engineering problems facing both design tasks can be resolved independently as each of them is constituted of an integrative design problem rather than mutually inter-related ones; two, each design task is simultaneously performed by multiple units and the final technological product system is formed by selecting the best combination of one development outcome from each of the design tasks *ex post* (after the completion of development effort). The first characteristic renders encapsulated information processing of the engineering environment by individual design tasks informationally more efficient (Aoki 2000, Proposition 4.5). The second characteristic entails that information processing of the engineering environment is encapsulated by individual design units *within* the same design task because they compete in development outcomes (Proposition 4.1). However, in spite of

these two characteristics there must be a modicum of information assimilation among all design units to make their modular products be potentially compatible to form an integrative technological product system. The role of M in this system is to mediate such information assimilation as well as to construct a new technological product system by selecting the best combination of modular products from both design tasks *ad interim* (after development efforts by design-task units started, but before they are completed) and/or *ex post* (after they are completed).

We submit that this model captures in an embryonic form the information-systemic architecture of the Silicon Valley model. In this interpretation, multiple units at the *Ti*' level are independent entrepreneurial firms. Instead of creating mutually competitive, stand-alone products of their own, they tend to be specialized in the development of innovative product designs that may constitute useful modules in the evolving technological product system. In this way they may be able to carve out niche markets or gain a better bargaining position vis-a-vis larger firms trying to acquire new technologies. The standardization of interfaces across modular products and protocols of communications among them may be partly a product of architecture defined by dominant firms (e.g., Intel, Cisco Systems, and Microsoft in the current era) as well as of industry standard-setting organizations (such as the Semiconductor Equipment and Materials International [SEMI], and the Internet Engineering Task Force [IETF]). Similarly, firms like Sun with Jini and Java, as well as cooperative ventures like Linux, may compete to define new standards for emerging markets. Thus, standards are evolutionarily formed and modified through the interactions of firms, large and small as well as established and new. The venture capitalists also play an important role in mediating information necessary for the evolutionary formation of industrial standards across these agents.

The selection from competing products in each niche market can be done in a step-wise fashion. At the time of startup the venture capitalist commits only a fraction of the capital needed for the ultimate development of a project, with the expectation that additional financing will be made step-wise, contingent upon the smooth proceeding of the project which may not be contractible – a process which Salman (1990) called “staged” capital commitment. There are thus many business failures among entrepreneurial start-up firms. If the project is successful, relational financing terminates, either with an initial public offering (IPO) or buy-out (acquisitions) by other firms. These firms themselves often used to be entrepreneurial firms that have been successful in assuming leadership in setting standards in their niche markets. They want to acquire successful start-up firms, either to kill off potential sources of challenge to their set standards, or to further strengthen their market positions by bundling complementary products to form a more comprehensive technological product system. In comparison to the R&D organizations of previous types, they can shorten the period of technological product system innovation by substituting the so-called A&D (acquisition and development) for in-house R&D. For further discussions of stylized facts about the Silicon Valley phenomena that substantiate the present modeling, see the appendix.

Thus, the dual roles of M in this model, the information mediating role for standard-setting and the ad *interim* and *ex post* selection of modular products for the formation of a new innovative technological product system, are actually born by various agents, including venture capitalists but not limited to them, such as standard-setting industrial associations, informal professional communities, leading firms in niche markets, etc. However, in the model below we refer to the aggregate of these agents generically as the VC.

We may summarize the above classification of R&D organizations in the technological product-system-innovation domain and their relative performance characteristics in Figure 1. In sum, the waterfall model or the star model would be the most productive arrangement when the conceptual design of the product system itself is highly uncertain and/or there is a significant disparity of development competence among organizational participants. On the other hand, if relatively independent, integrative design problems needs to be resolved at the level of modular product design, the Silicon Valley model can be expected to be more productive in innovation. Interactive R&D organization is expected to perform better in the industry where attribute complementary between modular products are high, and when both systemic and idiosyncratic segments of the engineering environment need to be analyzed with equal weight. Thus, no model can perform absolutely best in all industries regardless of industrial and engineering conditions involved. In the following sub-section we amplify further some organizational and institutional conditions that would make the Silicon Valley model innovative.

(B) Information Encapsulation and Evolutionary Constitution of Technological Product Systems

(i) Implications of Standard Setting. We have indicated that there are two distinct properties characterizing the Silicon Valley model: the relative independence of processing of engineering environments across design tasks and the competition

among multiple units in designing any single modular component product. Let us take up the first characteristic and examine its implications, leaving consideration of the second one for the next subsection. In other words, we assume for a while that there is only one unit (entrepreneurial firm) for each design task in the Silicon Valley model – call this the quasi-Silicon Valley model. In this model (thus in the Silicon Valley model as well), information processing leading to the development and design of a modular component product is encapsulated. But, even if the engineering environments to be processed by design units (firms) in respective product design are mutually independent information-wise (e.g., the development of software and hardware requires different development efforts), the advantage of this model may be reduced, or even the feasibility of this model may become problematical, if there is large attribute complementarity between their modular component products in constituting a consistent system. That is, even if the design contents of component products are modularized, their interfaces or communications protocols need to be standardized.[2]

Interface standards can be set centrally and *ex ante* (in the sense “before research and development”) by a dominating firm, or in some cases even by the government. But such a centralized and *ex ante* approach may not yield a good outcome when there is a high degree of *ex ante* uncertainty involved in product-system design as well as module-product design. In this case, emergent information in the process of development effort needs to be better utilized. One possible informational advantage of an interactive R&D organization vis-a-vis the waterfall model may be its flexibility in fine-tuning interfaces in response to information emergent in the process of development. However, in the interactive R&D organization *ad interim* adaptation to emergent information is not in general limited to interface designs but often involves simultaneous changes in the contents of product designs by both design-task units. Thus, the information load in these types of organizations can become high, and accordingly desirable *ad interim* adjustment may take time and involve extra efforts.

In contrast, in the quasi-Silicon Valley model, the information assimilation role of the VC is precisely to mediate the systemic-engineering information among the *Ti*'s (entrepreneurial firms) *ad interim* regarding evolving interface standards, whether it is endogenously generated through their development processes or set by standard-setting organizations or established firms. Then individual task units (entrepreneurial firms) can adapt to emergent standards, even sometimes becoming involved in the formation of *de facto* standardization by themselves, without their design of product contents being affected. Thus the type of engineering environments that are advantageous to the Silicon Valley model may be endogenously generated.

Lemma 1. Accordingly as the designs of modular products by individual entrepreneurial firms are made self-contained and less complementary, the innovative capacity of the Silicon Valley model is enhanced. VC's information mediation can create such situation endogenously by mediating interface-standard setting and thus becomes complementary to independent development efforts by individual entrepreneurial firms.

(ii) The Evolutionary Nature of the Innovation Process under the Silicon Valley Model.

The comparison of informational efficiency among alternative organizations above is based on the assumption that the stochastic distribution of parameters characterizing technological and other environments are *ex ante* known and unchanged during the period of product development and design. However, such an assumption may not be tenable as the complexity of technological environments becomes ever greater. The arrival of new discoveries and innovation may unexpectedly change the horizon of the landscapes of technological environments. The inevitable bounded rationality of agents may compel their perception of the distribution of stochastic events to be revised now and then beyond Bayesian learning, because they can never have a complete description of possible states of nature *ex ante.* Does the Silicon Valley model have unique characteristic in coping with such uncertain, increasingly complex, technological environments?

Consider an innovation process of a large-scale, complex, technological product system. Suppose that it can be hierarchically decomposed into several distinct steps, such as basic conceptualization, system analysis, product design, process design, pilot manufacturing, testing, etc. Some steps may be further decomposed into sub-task units. In such a hierarchical decomposition, once a system concept is centrally conceived and a system design is drawn accordingly, even if some revision to the system is perceived as necessary afterwards because of the occurrence of unanticipated events at a later stage, it may be too costly to redo the whole process from the beginning. Then the design may have to be only partially revised on an *ad hoc* basis at a later stage, sometimes losing the internal coherence and consistency initially intended. If a new generation of the technological product system is to be designed, the whole process may have to be repeated all over again, which takes time and resources.

The interactive R&D organization can possibly cope better with emergent unexpected events by using frequent feedback mechanisms between different stages of product development, as well as collaboration in problem solving between task units engaged in interrelated design tasks at the same level. In this type of organization the technological product system can be continually improved, or accumulated learning from unexpected events at all development stages can be utilized for the design of a new generation of the system. However, once communications channels are set up between different developmental stages and task units, it becomes difficult to change the basic organizational architecture of development in a radical way, such as replacing a group of tasks. Accordingly, innovation in the technological product system tends to be incremental.

Even in functional and horizontal hierarchies, the detailed design of components of a large, complex, technological product system can be modularized. However, in the former the modular structure is designed centrally and fixed once and for all. In the latter information needs to be exchanged among task units in order to keep their product compatibility fine-tuned in response to emergent events so that the information-connected among task units need to be tight and their modular component products cannot easily be coupled with products of other organizations.

However, if there are competing design units in each design-task unit as in the Silicon Valley model, the development of a large, complex, technological product system can be evolutionary. It can evolve without a centralized design or a fixed structure. In order to understand this, it is very important to recognize that in the Silicon Valley model not only does each entrepreneurial firm develop modular component products, but *its information-processing activity (analysis, development and design) is also modular (i.e., encapsulated) across tasks units.* As a result of this dual modularization in information processing and product, the complexity of the internal workings and informational content of modular products can be hidden from each other, and a relatively weak information linkage (the standardization of interfaces) needs to be provided to the rest of possible systems. This has two inter-related implications.

First, information encapsulation insulates each entrepreneurial design from outside interventions, by protecting its design effort from relying on the details of how the content of other modular products might change over time. Thus, autonomous and continual improvement of modular products by each entrepreneurial project becomes possible without hurting the integrity of existing systems. Further, because of the presence of multiple competing units (entrepreneurial firms) in the design of same modular component products, an innovative technological product system may evolve without *a priori* centralized design but by continual reconfiguration of modular products. The system design cam be free from the forces suppressing a radical departure from existing patterns of bundling modules. It may rapidly evolve from a relatively simple prototype system into an ever-more-complex system by flexibly re-bundling improved modular products from different entrepreneurial firms. An often invoked analogy to this *ex post* flexibility is Lego building blocks with their interlocking-cylinder faces. The number of objects that can be built with Legos is limited only by one's imagination (Pine 1993). There are, of course, transaction costs involved in the process of evolutionary selection under the Silicon Valley model. In particular, there is the cost involved in attaining *ex post* flexibility in the form of the duplication of development efforts and the resource expenditures supporting them. In the next section we analyze how the governance aspect of the Silicon Valley model tries to strike a balance between benefits and costs in a unique way.[3]

(iii) The Parallel Paradigm Development in Software Technology.

The observation in the preceding paragraphs has an interesting parallel in the paradigmatic development in computer software technology. Initially, large-scale software development followed the so-called "waterfall" paradigm in which a solution to computing tasks is first analyzed and then tasks of design, coding, testing, and maintenance are hierarchically organized in discrete steps. Only the completion of one task leads to the next step, just as water falls from a higher level to a lower level. Needless to say, this paradigm is isomorphic to the model of hierarchical R&D organization.[4]

However, as computer hardware technology developed with enormous enhancement of computing capability and accessibility, requirements for software development became more demanding and complex. The iterative programming paradigm characterized by feedback mechanisms from downstream stages to upstream stages was a natural response to improving the development process and making it faster. For example, the accumulated stock of subroutine programs helped shorten the time needed for the design of an improved program version. Or, problems frequently encountered in the maintenance stage might suggest a new approach in the design stage, etc. This iterative paradigm can be regarded as somewhat analogous to the model of the interactive R&D organization in that information sharing across different tasks plays an essential role. However, the basic subdivision structure of the development cycle remained intact and, once the actual programming has begun beyond the stage of analysis, this structure does not allow any radical modifications. As computing tasks got even more complex and rapidly-changing because of the fast development of the business, scientific, and hardware environments, the interactive method began to feel burdensome. As iterative improvements on old programming accumulated, it became increasingly difficult to predict the impacts that further local improvement would have on the workings of the whole program. It also takes time to reach an agreement about a basic system design of new programming that will not exhibit serious problems afterward.

In order to cope with the need for rapid programming development, a less centralized way of developing programming evolved, first among practitioners, and then gradually becoming established as a new paradigm known as "object-oriented" programming. In this paradigm, the design of programming for a complex computing task utilizes classes of reusable software "packets" referred to as objects. Objects encapsulate a collection of related data elements and a set of procedures (methods) operating on those elements. Objects from different classes communicate with each other only through simple messages to request that the receiving object carry out the indicated method and return the result of that action. Thus they can be mutually protected from corruption by others, while protecting others from being affected by details that might change within a class. Prototype programs for specific computing needs may be constructed by combining objects from different classes to simulate the real world process that submits the computation problem. This paradigm then successively modifies and refines a mode of combining objects from classes by trial and error, while enriching classes of objects by adding newly redesigned elements. Since objects hide implementation details behind a common message interface, the object-oriented technology allows new kinds of objects to be added to enhance the complexity of a system without rewriting existing procedures as was necessary in old conventional paradigms.

This evolutionary construction of a new program thus has a close analogue in the innovative process operating under information-encapsulation *cum* product-modularization. However there is one important difference between the two. Classes of objects in object-oriented programming are collections of software packets that are superior to the human mind in processing digitalized data faster and precisely but is mindless itself (it does not modify programming by itself because it is tired or excited). In the innovative process under information encapsulation, we have units of human agents (entrepreneurial firms), rather than objects, who have their own motivations. How are the entrepreneurs motivated to contribute to the library of objects, even if there is a large chance that their products may not be used? How is the VC (program designer) motivated to bear the costs of enhancing a stock of objects in the library? This is the question of the institutionalization of the Silicon Valley model, the discussion of which will be the subject of the next section.

2. The VC Governance of Innovation by Tournament

In the previous section, we dealt with the information-systemic architecture of the Silicon Valley model. It has the two distinct features: an entrepreneur's information processing regarding developmental environments is encapsulated from that of others under a modicum of information mediation by the VC; and a technological product system innovation is achieved *ex post/ad interim* by a combination of entrepreneurial modular products selected from competitive ones. We indicated that this *ex post/ad interim* flexibility is a key for an understanding of the innovativeness of the Silicon Valley model. However, we have not yet explicitly dealt with the issue of how this information-systemic architecture can be supported incentive-wise. The present section tries to explore in a game-theoretic framework what kind of governance mechanism can complement this architecture by generating the particular expectations among the VC and the entrepreneurs that are conducive to the resolution of the potential incentive problems inherent in it.

(A) The Structure of the VC Tournament Game

As background for the model below, imagine that time consists of an infinite sequence of stage games, each of which is played over three dates between venture capitalists and entrepreneurial firms. The venture capitalists live permanently, competing with each other to nurture valuable firms, and entrepreneurial firms start up at the beginning of date 1 of a stage game and exit by the end of date 3, either by going public, being acquired by other firms, or being terminated. When terminated, entrepreneurs can come back to the next stage game as new start-up firms. In this section, we do not explore the impacts that the repeated nature of the game may have on venture capitalists' reputations, or the endogenous impacts on the risk-taking traits of would-be entrepreneurs. We concentrate instead on the analysis of the single-stage game between one venture capitalist and multiple start-up firms embedded in the repeated game. We call the stage game the *VC-tournament game*. We take up the possible impacts of the repeated nature of the game and competition among venture capitalists in the next section.

We assume that before date 1 starts (and thus outside the model), a venture capitalist, denoted by VC, has screened many developmental projects proposed by cash-constrained, would-be entrepreneurs and selected some of them for start-up funding (*ex ante* monitoring). For simplicity's sake, there are only two types of projects (design tasks, in the terms of the previous section) and the VC has selected two proposals for each. The start-up firms are indexed by subscript *ij*, where $i=a,b$ denotes a project type, and $j=1,2$ distinguishes entrepreneurs. Hereafter we use a "start-up firm" and its "entrepreneur" as interchangeable terms. The entrepreneurs are *ex ante* symmetric in their parametric characteristics except for project type in which they are engaged. There are three dates within each VC-tournament game. In the beginning of the first date, contracts are drawn between selected entrepreneurs and the VC. The first date corresponds to the phase of individual information processing – research and development – by entrepreneurs; the second to that of communications between entrepreneurs and the VC, and associated design specification by the entrepreneurs; and the third to that of refinancing selection by the VC and project completion by selected entrepreneurs. At the end of date 3, the values of the entrepreneurial firms are realized and distributed among them and the VC according to contracts drawn at the beginning of date 1. The time line of this VC-tournament Game is summarized by Figure 2.

Figure 2. The Time Line of the VC-Tournament Game

	beginning of the game	date 1: development	date 2: design specification	date 3: refinancing selection	end of the game
entrepreneur s	contract agreement: start-up financing	development effort	design specification	exit or project implementati on	value realization and distribution
venture capital			information mediation	selective final-stage financing	

Let us specify the model further. At date 1, each start-up firm, *ij*, funded by the VC is engaged in development efforts, which amount to observing a parameter in the respective engineering environment, *E-i*, with some noise. The choice of entrepreneurial effort level (investment in knowledge) at start-up firm *ij* is denoted by e_{ij} and its cost by $c(e_{ij})$, with the usual increasing marginal cost property, $c'(e_{ij})>0$ and $c''(e_{ij}) >0$. The actual levels of effort implemented by the start-up firms are not observable so that they are not contractible. The engineering environment *E-i* is representable by a one-dimensional parameter and the development effort by entrepreneur, *ij*, generates noisy one-dimensional observation, ξ_{ij} – research results – with precision $\Pi_{\text{ij}}(e_{ij})$. The higher his effort level, the higher the precision of his posterior estimates regarding the engineering environment which he faces. Each entrepreneur also generates a tentative conjecture regarding the systemic environment *E-s* as a by-product of his own development effort without additional effort cost. The fixed amount of funding provided to each entrepreneur by the VC only covers the cost of information processing (including wages) at this date and is not enough for further product development of start-up firms.

At the beginning of date 2 when uncertainties regarding the environment still persist, on the basis of research results obtained at date 1, the entrepreneurs tentatively specify product-design attributes, y_{ij}, from a one-dimensional set, $\mathscr{Y}$ $(i=a,b)$, with observable interface properties and performance characteristics; let us call this observable portion of the design the external design specification. Besides information obtained at date 1, each entrepreneur needs to take into consideration in his own design of how industrial standards are evolving. In order to obtain information regarding others' choices, entrepreneurs engage in communication through the intermediary of the VC, using the external design specifications of products as messages with the internal workings of the products hidden. Implicit in external design specifications are the tentative conjectures of entrepreneurs regarding the systemic environment.

The VC aggregates the entrepreneurial messages and combines them with his own assessment of the emerging industrial framework to generate a one-dimensional parametric message drawn from the space of the systemic environment *E-s*. In other words, the VC generates an estimate of the systemic environmental parameter with some noise. The entrepreneurs successively revise their design attributes, internal and external, in response to the VC's message. Communications and design revisions continue until the aggregate estimate of the systemic environmental parameter converges to an equilibrium value of the systemic, $\xi_{E\text{-}s}$ (we assume it does so within date 2). Suppose, for simplicity's sake, that the precision of the aggregated information is a function, $\Pi_{vc}(.)$ of the VC's mediating effort, e_{vc}. The cost of the VC's mediating and monitoring efforts are represented by $\kappa(e_{vc})$ with the usual increasing cost property. Suppose that the precision of the VC's information is observable to the entrepreneurs (but not court-verifiable). At an equilibrium, entrepreneur, *ij*, specifies his product design attribute, y_{ij}, as a combination of the VC-mediated assimilated information, $\xi_{E\text{-}s}$, and his own research results, ξ_{ij}, with respective weights equal to $\Pi_{vc}(e_{vc})$ and $\Pi_{ij}(e_{ij})$.

At the beginning of date 3, the VC estimates which combination of product designs from each type is expected to generate a higher value, if the respective firms are offered to the public or acquired by an existing firm at the end of the date. According to this judgement, the VC selects one proposal from each type of project for implementation and allocates one unit of available funds to each of them for the completion of the project. The VC's decision is represented by $x = (x_{a1}, x_{a2}, x_{b1}, x_{b2})$, where $x_{ij} = 1$ if the *ij* product is selected for financing and $x_{ij} = 0$ if it is not. If $x_{ij} = 1$ then $x_{ik} = 0$ for $k \neq j$. The firms that are not selected by the VC exit.

At the end of date 3, the selected projects are completed and the VC offers the ownership of these firms to the public through a share market or sells to an acquiring firm. At that time, all environmental uncertainty is resolved and the total market value, $V(x_{a1}y_{a1}, x_{a2}y_{a2}, x_{b1}y_{b1}, x_{b2}y_{b2}: E)$, is realizable, contingent on the state of the environment, $E = (E\text{-}s, E\text{-}a, E\text{-}b)$, prevailing at that time. The realized value is distributed among the VC and the entrepreneurs. Let us denote the distributive share of the value to firm-*ij* by α_{ij} and that of VC by $\alpha_{vc} = 1 - \Sigma_{ij}\alpha_{ij}$. The payoff of each firm is then $\alpha_{ij}V - c(e_{ij})$ ($i=a,b;\ j=1,2$) and that of the VC is $\alpha_{vc}V - \kappa(e_{vc})$, assuming there is no discounting over dates within a SV-tournament game. Before the beginning of the SV-tournament game, the VC and the entrepreneurs have to agree on the way in which realized values are to be distributed at the end of date 3 (we will specify this momentarily). The incentive of each agent is to maximize his or her own expected pay-off according to that agreement. .

(B) Institutional Benefits and Costs of the Silicon Valley Model

Suppose for a moment that development expenditures have been made by the agents and that information regarding the engineering environment has become available to them with some imprecision. At that moment, both the entrepreneurs and the VC are interested in utilizing their respective information for making decisions so as to maximize the total value, V, expected at the end of the V-tournament game, because the larger the total value, the larger their incomes with respect to *ex ante* agreed on shares. We assume that the expected total value is a separable function of efforts by players:

$$E[V] = H\Pi_{vc}(e_{vc}) + x_{a1}Z(\Pi_{a1}(e_{a1})) + x_{a2}\,Z(\Pi_{a2}(e_{a2})) + x_{b1}\,Z(\Pi_{b1}(e_{b1})) + x_{b2}\,Z(\Pi_{b2}(e_{b2}))$$

where H is a positive constant and Z(.) is a monotone-increasing, positive-valued function. Information encapsulation among entrepreneurs warrants the assumption of separability.

It was assumed that the contributions to the expected value by individual entrepreneurs would become estimable with some noise to the VC at date 3 after observing the external attribute specifications of the proposed design. Suppose that the entrepreneurs believe that the VC chooses winning entrepreneurs with an error specified as follows: the VC's measurement of entrepreneur *i1*'s potential contribution equals $Z(\Pi_{i1}(e_{i1})) - \zeta/2$, and that of *i2*'s equals $Z(\Pi_{i2}(e_{i2})) + \zeta/2$ with $i=a,b$, where ζ is a random variable representing the observation error that is symmetrically distributed around zero with density function $f(.)$ and a cumulative distribution function $F(.)$. If $f(.)$ is tightly distributed around zero with less spread, that means the judgment of the VC is more precise and accordingly more sensitive to the entrepreneurs' actual effort levels Suppose the VC chooses entrepreneur j vis-a-vis k for refinancing and project implementation if and only if $Z(\Pi_{ij}(e_{ij}))- \zeta/2 > Z(\Pi_{ik}(e_{ik}))+ \zeta/2$ ($i=a,b;\ k\neq j =1,2$). That is, the VC selects only those entrepreneurs who are expected to yield higher values according to her judgement for the refinancing necessary for the completion of their proposed designs at date 3. From the way F and f are constructed, the value of $f(.)$ viewed as a function of e_{ij} for a given level of e_{ik} is regarded as the marginal winning probability due to j's extra effort.

Suppose that an initial contract is such that at the time when winners are selected, a share $\alpha_{ij}= \alpha_i > 0$ is vested with the winning entrepreneur $(i=1,2)$ and the unfunded entrepreneur forfeits any share. We refer to this scheme as *VC governance by tournament*. Expecting such selection criteria, entrepreneur *ij*'s objective function at date 1 is to choose e_{ij}, so as to

$$\text{Max}_{e}\ [\alpha_i F((Z(\Pi_{ij}(e_{ij}))- Z(\Pi_{ik}(e_{ik})))(Z(\Pi_{ij}(e_{ij})) - c(e_{ij})], \quad i = a,b,\ j=1,2,\ k\neq j.$$

Since two entrepreneurial firms in the same project are assumed to be exactly alike in their characteristics and the probability density function of ζ is symmetric around zero, they are expected to choose the same effort level *ceteris paribus* and have equal chances of being selected *ex ante* so that the entrepreneur's choice must satisfy the following first-order condition:

$$\alpha_i\,[F(0)Z'(\Pi_{ij}(e_{ij}))\Pi_{ij}'(e_{ij}) + F'(0)Z(\Pi_{ij}(e_{ij}))]=$$

$$\alpha_i\,[½Z'(\Pi_{ij}(e_{ij}))\Pi_{ij}'(e_{ij}) + f(0)Z(\Pi_{ij}(e_{ij}))]= c'(e_{ij})$$

where $i= a,b,\ j=1,2,\ k \neq j$. Here we assume that efforts are not mutually observable (encapsulated) among entrepreneurs so that strategic interactions in effort choices among them are absent. Each entrepreneur equates his marginal expected private benefit of additional effort with its marginal cost. The marginal expected private benefit (the left-hand side of the above equality) is composed of two parts: its share times the probability of being selected for refinancing times its marginal expected value contribution *plus* its share times the marginal increase in the probability of being selected for refinancing times its expected value contribution. Let us refer to the second term as the "tournament effect."

Let us examine this choice vis-a-vis the following alternative taken as a comparative benchmark. Suppose that the financier selects *ex ante* (i.e., before date 1 begins) only *one* proposal from each project and promises each of them will be entitled to the same share α_i in the value V as the one that the winning entrepreneur in the V-tournament game is entitled to. Otherwise, the financier neither mediates information assimilation across entrepreneurs nor selects/rejects projects *ad interim*. He might as well sell his own share *ad interim* to any buyer in the market. Let us call this scheme the *arm's-length financing contract*. Since their effort levels are not observable, the entrepreneurial effort choice in project *i* would be described by $\alpha_i Z'(\Pi_i(e_i))\Pi_i'(e_i) = c'(e_i)$. Therefore, if

$$\tfrac{1}{2} Z'(\Pi_{ij}(e_{ij}))\Pi_{ij}'(e_{ij}) < f(0)Z(\Pi_{ij}(e_{ij})),$$

that is, if the entrepreneurs believe that the VC's refinancing selection is without much error so that the marginal winning probability due to extra effort is high (which is implied by a higher value of *f(0)*), and if the total value that the winning entrepreneur can produce is expected to be very large relative to the marginal effort value, then the governance by tournament may elicit a higher development effort than under the arm's-length financing.

Let us take the balance obtained so far from the viewpoint of the VC. The VC's benefit from running a tournament is her share in the additional gains from the tournament effect. Her costs are :(1) duplicated start-up funding at date 1, and (2) intermediating and monitoring effort costs at dates 2 and 3, which will have impacts on entrepreneurial confidence in the VC's ability to choose value-enhancing winners. Thus we submit:

Proposition 1. If the total value created by entrepreneurial development efforts is expected to be high relative to the marginal values, and if the venture capitalist's selection of winning entrepreneurs is believed to be relatively precise by the entrepreneurs, then it is possible that, even for the same share allocation between entrepreneurs and financiers, the VC governance by tournament can elicit higher development efforts from entrepreneurs than under arm's-length financing, and that its effect on the final total value can *compensate venture capitalist's duplicated start-up financing and interim monitoring costs. Conversely, if the entrepreneur's confidence in the venture capitalist's competence in selecting value-enhancing projects for refinancing is low, the venture capitalist cannot adequately elicit the entrepreneurs' developmental efforts.*

There are unique social costs and benefits arising from venture capitalist governance by tournament that institutionalizes the *ad interim* selection of modular product designs. One cost is that of the duplication of research and development efforts by entrepreneurs that are sunk at date 1. The effort costs of entrepreneurs who do not win the tournament become deadweight losses. As just mentioned above, there is also the sunk cost of the initial funding to them by the VC. The social net balance between the deadweight losses and the benefits from increased effort by the entrepreneurs is not clear without a further parametric specification of the model. It might be negative. Nevertheless, even in such a case venture capital financing may be institutionalized by the VC as the preceding proposition indicates. If entrepreneurs are risk-lovers who place a high utility on an uncertain high value obtainable as the prize of the tournament, then venture capital contracting may be preferred to arm's-length contracting by entrepreneurs as well, in spite of the possibility of *ex post* bearing of the deadweight loss. I will discuss in the next section how such risk-taking traits may be endogenously formed when governance by tournament is institutionalized.

As already argued, however, there is a unique social benefit from venture capitalist governance because of the possibility of the *ad interim* selection of projects, particularly when engineering environments involved in modular product developments are highly uncertain and statistically less correlated among entrepreneurial firms and attribute complementarity between modular products are made low.

Proposition 2. The VC governance by tournament generates deadweight losses of the loser's development efforts and duplicated financial costs. On the other hand, it can configure ad interim a system of product design in response to the emergent state of highly uncertain systemic and engineering environments, and this possibility may create unique system benefits in the absence of strong attribute complementarity and/or strong correlation in developmental uncertainties among entrepreneurial projects.

3. Norms and Values in the Silicon Valley Model

(A) The Market Reputations and Club Norms of Venture Capitalists

We now turn to the venture capitalist's incentives. In the model of the previous section, the venture capitalist's net pay-off within a stage game – a VC-tournament game – is $\alpha_{vc} E[V] - \kappa(e_{vc})$. If the VC maximizes the pay-offs only within the horizon of the current V-tournament game, the static Nash-equilibrium condition would be: $\alpha_{vc} E[dV/de_{vc}] = \kappa'(e_{vc})$. However, the optimal level of effort by the VC requires that the following condition holds: $E[dV/d\, e_{vc}] = \kappa'(e_{vc})$. Thus, an under-supply of effort by the VC would occur, if she is myopic, since her private marginal benefit from her effort equals only her share in her marginal contribution to the total value.

At this point, it becomes necessary to make the repeated nature of venture capital financing explicit, albeit vis-a-vis a different set of entrepreneurs in each stage game, and to make explicit the role of reputation and competition among multiple venture capitalists. Venture capitalists are financial intermediaries who manage venture capital funds contributed by other investors such as wealth individuals, banks, portfolio funds, foundations, etc., who lack knowledge and expertise in administering the system of governance by tournament. Venture capitalists compete with each other in securing those funds for the formation of successive venture capital funds over time. At the same time, they often co-invest in entrepreneurial start-up firms, while reciprocating the role of leading financier (see the Appendix). In such situations, reputation mechanisms that operate in markets for the supply of funds, as well as among venture capitalists, can play an important role. If a venture capitalist fails to deliver a high value to her own investors at the contractual end of a fund, she will have difficulty in raising future funds. If she fails to do the same for the other venture capitalists who have delegated monitoring to her, she may be ostracized from future joint financing through a "club norm" regulating reciprocal delegation of monitoring (see chapter 3.1.(B) of Aoki 2000 for a club norm).[5] The benefits for the venture capitalist from pursuing the value maximization of current funds are not limited to a one-time share in the current venture capital funds that she manages, but include the avoidance of losing her reputation in the market and the club. Suppose then that the venture capitalist chooses her effort level in each period to maximize her own continuation value in the face of this possibility of punishment for under-performance. However, note that the effect of the venture capitalist's effort is hidden behind the state of the environment so that investors and other venture capitalists can observe only the realized value at the end of each period, but not her effort level.

To see more formally the impacts of market competition and a club norm on venture capitalists' incentives, let the cumulative probability function of value V created at the end of date 3 when her effort level is e_{vc} be written as $F(V{:}e_{vc})$. Suppose that if the value of a venture capital fund at the end of date 3 falls short of a threshold value $\underline{V}$, then the capacity of its manager (VC) to raise further funding, as well as to join profitable co-financing led by other venture capitalists, is weakened from the next stage game on so that her future earning ability is lowered by J in flow terms. In a repeated game context with stationary environments, the VC chooses the same effort level if she can raise the same quantity of funds. Then, her problem of choosing *e* ought to be:

$$\upsilon = Max_{e}\ (1-\delta)(\alpha_{vc}\ E[V]-\kappa(e_{vc}))+\delta[(1-F(\underline{V},e_{vc}))\upsilon+F(\underline{V},e_{vc})(\upsilon\text{-J})],$$

where υ is the present value of her future income in equivalent flow terms, and δ is the time discount factor. The corresponding value in stock can be found by dividing υ through by $1-\delta$. In the current stage game, the VC receives the contracted share in realizable value and incurs effort cost, $\kappa(e_{vc})$. If the VC can raise funds in the next period with probability $1-F(\underline{V},e_{vc})$, she receives flow value υ at the end of the period. If she fails to raise adequate funds for the next stage game on, because the value falls below $\underline{V}$ with probability $F(\underline{V},e_{vc})$, she expects to receive only υ-J in each future period. The weights in the equation on the present and future payoffs are 1-δ and δ, respectively. The weighting expresses the present value of incomes in equivalent flow terms v. The corresponding stock value can be found by dividing it by 1- δ.

The Nash equilibrium effort level of the VC is then given by

$$\alpha_{VC}\ E[\frac{dV}{de_{vc}}]\ -\ \frac{\delta}{1-\delta}\, x\, \frac{J\ \ dF(\underline{V},\ e_{vc})}{de_{VC}} = \kappa\_(e_{vc}).$$

Evidently, the fear of a loss of reputation on future earnings provides greater incentives for the VC than in the case of myopic maximization because of the second term of the left-hand side of the equation: the reduction of continuation value due to a loss of reputation. Suppose that the investors can locate a threshold value $\underline{V}$ just below the expected optimal value, for which the probability of failure $1\text{-}F(\underline{V},e_{vc})$ can be dramatically reduced by an increasing effort. Then a Nash equilibrium strategy of the venture capitalist under the reputation mechanism can approximate the first-best solution.[6]

Proposition 3. The decision of suppliers of funds regarding whether or not to renew partnership contracts with a venture capitalist on the basis of his/her *previous records of capital gains realization, as well as a club norm regulating venture capitalists reciprocal delegation of monitoring, can elicit higher monitoring and governance efforts from the venture capitalists. This reputation effect becomes stronger if the probability distribution of funds' outcomes is not wide-spread when the venture capitalist's effort is near the first-best.*

(B) Other Institutional Ramifications of the Silicon Valley Model

(i) An Element of Gambling and the Social Cost of the VC Tournament Game

If venture capitalists remain active over multiple stage games, they will be able to accumulate knowledge and expertise in administering governance by tournament, such as mediating information exchanges among entrepreneurs, and judging the potential values of modular product designs in a systemic context, hence helping a complex system to configure in an evolutionary way. As a by-product of this process, the venture capitalists accumulate knowledge about development environments as well as the engineering competence and the entrepreneurship of founders of start-up firms, partially independent from the success or failure of their particular product-design projects in a particular tournament game. The failure of an entrepreneur to win a design tournament in one round of a stage game may not necessarily be due to his/her inherent incompetence, but might have been caused by sheer bad luck, lack of a fit of his/her inherently good design with an evolving system, a slight lag in design completion, etc. Therefore, he/she may be judged to be qualified to enter another tournament. Making such judgments (*ex ante* monitoring) is another important function of venture capitalists. The tacit knowledge about entrepreneurs obtained on site from past stage games may be helpful for selecting new competitors for subsequent stage tournaments. Thus, venture capitalist's *ad interim* monitoring is complementary to her *ex ante* monitoring in the next round of financing. The view often prevails abroad that the Silicon Valley model is successful in generating innovation because of the ease with which a one-time failure is provided a second chance. But this view is not entirely precise as it is, without the qualification that the endogenously-created VC's competence to judge a failure's real potential is essential in the process.

On the other hand, if potentially capable entrepreneurs can have reasonable expectations of being allowed to participate in subsequent tournament rounds in spite of past failures, their risk-taking attitudes can be endogenously enhanced in spite of possible losses of effort costs. Namely, even if there is a chance of losing in a tournament, one can be tempted to repeatedly mount a challenge in new tournaments in the hope of getting a large prize someday.

However, possible asset-value inflation in the market for initial public offering in the formative stage of an innovative technological product system may enhance the expectation of a winner's prize beyond its potential social value. Then, social losses from the multiplication of development efforts and financing may become aggravated.

> *Conjecture 1. The repeated play of the VC governance by tournament may endogenously shape the risk-taking trait of entrepreneurs, entailing an element of gambling in the VC tournament.*

(ii) Complementarity between VC Governance and the Engineer's Labor Markets

We have assumed that the venture capitalist has the ability to select a modular product from each project that fits to constitute a new technological product system. But, the VC's expertise and knowledge in judging the technological potential of entrepreneurial firms may actually be limited. However, such shortcomings are compensated for by the mobility of engineers across entrepreneurial firms. Ambitious and competent engineers may be constantly looking for a "cool" technology. If the research and development of a new entrepreneurial firm at date 1 is not generating a satisfactory outcome, and/or it turns out to be incompatible with emergent technological standards at date 2, it may be the engineers in that firm who can recognize it first. If other entrepreneurial firms are continually being organized to search for "cool" technology with the aid of VC financing, those engineers may then exit the likely-to-be-unsuccessful firm and move to a new firm. The heavy reliance on stock options as a form of compensation may in general slow the mobility of engineers, but it cannot serve as a blockage of outflow from the likely-to-be-unsuccessful firms. This outflow of engineers provides negative momentum to the process of research and development of the slowed-down firm and signals its losing status in the tournament to the VC.[7] Thus we submit:

Conjecture 2 . The limited technological ability of venture capitalists to judge winners of a VC tournament may be compensated by the signal given by engineers who exit ad interim from likely-to-be-unsuccessful entrepreneurial firms. On the other hand, the mobility of engineers is aided by the repeated play of the VC tournament game. Thus, the VC governance and the highly mobile engineer markets are institutionally complementary.

–

In this paper we have argued that in order to understand the unique governance role of the venture capitalists in the Silicon Valley model, it is not enough to take a look only at relationships between an individual entrepreneurial firm and an individual venture capitalist. Neither is it appropriate for regarding the role of the venture capitalist as simply the supplier of risk capital. Since the truly revolutionary nature of the Silicon Valley model lies in its ability to generate innovative technological product systems through the evolutionary selection of modular products generated by entrepreneurial firms, it is crucial to take a look at the multifaceted relationships between the venture capitalists, on the one hand, and the cluster of entrepreneurial firms, on the other. In this paper, we have focused on the information-systemic and governance-structural relationships between the two in an integrative way, and tried to identify the social benefits and costs of the Silicon Valley model.

One important insight of the analysis is that venture capital governance by tournament can elicit higher efforts from entrepreneurs only if the amount of the total prize for winners is very high. Therefore, the application of the Silicon Valley model may be limited to domains in which successful developmental projects are expected to yield extremely high values in markets, somewhat reminiscent of the lottery. At the same time, however, the identification of conditions for the information efficiency of information encapsulation may have broader implications for corporate organizations in general. Because of the development of communications and transportation technology, even mature products (e.g., desktop computers, automobiles) are increasingly decomposed into modules, whose production and procurement become less integrated in comparison to traditional hierarchical firms (as represented by traditional American firms of a decade ago) or relational contracting (as represented by Japanese *keiretsu)*. This tendency renders compact modular organizations (either in the form of independent firms or subsidiaries) increasingly efficient and viable. Various innovations in corporate governance appear to be evolving even within traditional firms in ways somewhat reminiscent of the Silicon Valley model. For example, some aspects of the organizational-based contingent governance is considered such an example. In this structure, operational business units are modularized as relatively autonomous subsidiaries and the information processing necessary for their operation tends to be encapsulated. Parent organizations (holding companies or management partners) are less intervening in their operation, but organizational modularization helps them to pursue strategic reconfiguration of business units in response to rapidly changing market and technological environments.

Appendix. The Stylized Factual Background for Modeling [8]

From the purely financial point of view, venture capital funds are intermediaries, channeling large sums of investment funds from other financial intermediaries, such as pension funds (45% in 1996), insurance companies and banks (6%), together with those from foundations and universities (20%), wealthy individuals and families (7%), corporations (18%), foreign investors (4%), etc., to mostly start-up entrepreneurial firms.[9] As an intermediary, the venture capital process is unique in its legal structure. It is a system of partnerships in the venture capital funds in which there are two classes of partners: general and limited. The general partners act as organizers of the fund, accepting full personal responsibility and legal liability for fund management. Limited partners supply most of the capital but are not involved in the management and investment decisions of venture capital funds, which allows them to enjoy limited liability status as well as the advantage of avoiding double taxation.[10] General partners receive an annual fee of a few percent (2-3%) of the total capital committed and receive 15% to 25% of the realized capital gains for their much smaller contribution to the funds. Funds are set up for a fixed period of time, say ten years, but in many cases management companies are formed and run by general partners to provide management continuity. Thus there can be the usual principal-agent problems between limited and general partners, which we discuss at the end of this paper. This paper does not explicitly differentiate between venture capital funds and venture capital companies and simply refers to them as venture capitalists.

Venture capitalists seek promising investment projects, while potential entrepreneurs with planned projects but insufficient funds seek venture capital financing. There are more than two hundred venture capital companies in Silicon Valley alone, but experienced venture capitalists are said to receive several hundred applications a year. Screening and searching are not easy for either side, but suppose that a promising match is found. Unless the reputation of an entrepreneur is already known to a venture capitalist and a proposed project is judged to be certainly sound and promising, the venture capitalist initially provides only seed money to see if an entrepreneur is capable of initiating the project and possibly extending aid to help his/her start-up (the so-called seed stage). When a venture capitalist decides to finance a start-up, elaborate financing and employment agreements are drawn up between the her and the entrepreneur (start-up stage).[11] These agreements specify the terms of financing and employment of the entrepreneur as a senior manager (Testa 1997; Hellman 1998).

Start-up financing may involve co-financing by several venture capitalists with one of them acting as a leading financier and manager, although this practice has recently become less common.[12] Among experienced and mutually known venture capitalists, the position of leading manager is rotated over different projects. This arrangement serves not so much as a mechanism of risk-diversification than one of reciprocal delegation of monitoring among a group of venture capitalists. The reciprocal delegation not only avoids the duplication of intense monitoring but also functions as a device to control possible shirking of monitoring by venture capitalists (Lerner 1994; Fenn, Liang and Prowse 1995). If a leading venture capitalist shirks ex ante monitoring (due diligence) or is incompetent, and more than a normal number of entrepreneurial projects monitored by him/her fail, his/her reputation will be tarnished. Then (s)he will lose opportunities for raising additional funds and participating in potentially profitable future projects organized by others. This aspect of venture capital financing is analyzed in the last section of this paper. Otherwise, we abstract from this reciprocal relationship among venture capitalists, and regard the relationship of an entrepreneur with venture capital funds as if it were with a single venture capitalist.

At the time of startup the venture capitalist commits only a fraction of the capital needed for the ultimate development of a project, with the expectation that additional financing will be made step-wise, contingent upon the smooth proceeding of the project which may not be contractible – a process which Salman (1990) called "staged" capital commitment. Recently, there is an increasing tendency for the financing of different stages to be specialized by different classes of venture capitalists.[13] However, in modeling we ignore this and assume as if staged financing were performed by a single venture capitalist. Venture capital financing normally takes the form of convertible preferred stocks, subordinated debt with conversion privileges, or combinations of multiple classes of common stock and straight preferred stock (Fenn, Liang, and Prowse 1995; Gompers and Lerner 1996, Gompers 1998, Kapalan and Stromberg 2000). In any case, venture capitalists are protected from downside risk because they are paid before holders of common stock in the event of project failure. Also, they retain an exit option exercisable by refusing additional financing at a critical moment when a start-up firm needs the infusion of new funds to survive or to proceed to the next stage of development. On the other hand, a typical shareholding agreement allows an entrepreneur to increase his ownership share (normally in common stock) at the expense of initial investors if certain performance objectives are met. Fired entrepreneurs forfeit their claims on stock that has not been vested.

The venture capitalists, leading as well as non-leading, are well represented on the boards of directors of start-up firms. For example, Lerner (1994a) reports that venture capitalists hold more than one-third of the seats on the boards of venture-backed biotechnology firms – more than the number held by management or other outside directors. Kapalan and Stromberg (2000) also report a similar finding (the venture capitalist has the majority of the board seats in normal states in 26% of their 190 samples), noting that venture capitalist control tends to increase with a number of financing rounds. In addition to attending board meetings, leading venture capitalists often visit entrepreneurs-cum-senior-managers at the site of venture-funded firms ("stay close"). They provide advice and consulting services with the senior management, ranging from helping to raise additional funds, reviewing and assisting with strategic planning, recruitment of financial and human resource management, introduction of potential customers and suppliers, public relations and legal specialists, etc. They also actively exercise conventional roles in the governance of the start-up firms, often firing the founder-managers when needed. According to the *Stanford Project on Emerging Companies (SPEC)* which collected panel data on 100 high technology start-up firms in Silicon Valley, the likelihood that a non-founder will be appointed as CEO in the first twenty months of a company's life is around 10%; this likelihood increases to about 40% after forty months and to over 80% after eighty months, to say nothing of companies going out of business that are not included in the sample (Baron, Burton, and Hannan, 1996; Hannan, Burton and Baron, 1996).

There are many business failures among entrepreneurial start-up firms.[14] Many failures crop up early, usually in the first one or two years. Frequent failures may be caused not only by over-zealous competition among ambitious entrepreneurs, but also because the venture capitalist himself may contribute to it. For example, Salman and Stevenson observed the following phenomena in an emerging segment of the computer data storage industry in the mid-1980s. “In all, forty-three start-ups were funded in an industry segment that could be expected in the long run to support perhaps four.” Thus, “‘failure’ is at the very least endemic to the venture capital process, an expected commonplace event; in some cases, the process itself may even promote failure.”(Gorman and Sahlman, 1989:238) In casual conversations in Silicon Valley, venture capitalists normally regard three successes out of ten initial fundings as successful and two successes as acceptable.

If the project is successful, the relational financing terminates, either with an initial public offering (IPO) or buy-out (acquisitions) by other firms. It used to take five to seven years for the start-up firms to be able to go to the IPO market.

Recently there has been a tendency for this period to be shortened (even two years). However, the shortening of the period may have been partially induced by the stock market boom, as were the cases in the past. Another reason could be that early-marketed firms of recent vintage aim at business applications of more-or-less known technology so that the development time can be shortened.[15] Venture capitalists decide when to go to the IPO market with marketing expertise. When an IPO exceeds a pre-specified performance criteria (such as designated stock price), the securities held by the venture capitalists, such as convertible stock and debt, automatically convert into common stock. Capital gains are distributed among the venture funds and the entrepreneur according to their shares at that time. Experienced venture capitalists can time the IPO to occur when the market valuation of portfolio firms is particularly high, while less experienced and less reputable venture capitalists are found to be eager to bring a portfolio firm to market prematurely (Lerner, 1994; Gompers, 1995)

Some authors argue that the presence of active IPO markets is an essential element of the success of venture capital financing and the resulting product innovation, and that their absence may be responsible for the fact that other economies have a difficult time emulating the Silicon Valley phenomena (e.g., Bankman and Gilson, 1996). Although there may well be an element of truth in this claim, it is also important to note that recently successful start-up firms have increasingly become the targets of acquisition by leading firms in the same market rather than going to IPO markets (e.g., Stanford GSB case materials S-SM-27). These firms are often themselves grown-up entrepreneurial firms that have been successful in assuming leadership in setting standards in their niche markets. They aim to acquire successful start-up firms, either to kill off potential sources of challenges to their set standards, or to further strengthen their market positions by shortening the period of in-house R&D by the so-called A&D (acquisition and development). These leading firms are said to have an influence on venture capitalists in guiding their activities.

From the viewpoint of start-up entrepreneurs, they are said to prefer buy-outs to IPOs, particularly when they have only a single innovative product line (Hellmann, 1998a), but competition among them for a buy-out is keen.[16] By bundling complementary technology the acquiring firms may be able to establish monopolistic positions in respective markets. However, since this bundling occurs *ex post* (after the development of products), their monopolistic positions cannot be taken as the inevitable outcome of technological increasing returns but as those of a marketing strategy. As discussed in the main text, the innovative nature of the SV model lies in its *ex post* flexibility in the reconfiguration of innovative technological product systems. Its important public-policy implication can then be that any bundling of modular products by a leading firm that is not technologically imperative but serves primarily as a deterrent to innovative re-bundling (e.g., the bundling of the OS and the internet browser by Microsoft) ought to be regulated.

The venture capitalists perform the functions of *ex ante* monitoring (screening of proposed projects to cope with the possible adverse selection problem), *ad interim* monitoring (preventing shirking and wasteful, private use of resources that do not yield economically valuable technology), and *ex post* monitoring (the verification of project results and the controlling decision as to which exit strategy is to be exercised) *vis-a-vis* venture-funded firms, although these functions tend to be specialized by different classes of venture capitalis. *Ex ante* monitoring, and *ad interim* monitoring to some extent, of an entrepreneurial project requires professional engineering competence in specialized fields, while *ex post* monitoring requires financial expertise. The venture capitalists meet such needs and tend to focus on companies in specific industries. Although the venture capitalists play a dominant governance role in venture-backed firms, their property rights arrangements have complex elements of joint-ownership with the provision of bilateral option rights: the venture capitalists' rights to exercise an exit option against the entrepreneur's interest in bad times (liquidation rights), and the entrepreneur’s right to the issued options to be vested contingent on subsequent performance. Control rights are voluntarily relinquished *ex ante* by the entrepreneur, particularly if he is liquidity-constrained at the outset (Hellmann 1998). But as the project moves ahead successfully, he can regain control rights and the venture capitalist will relinquish liquidation rights.

References

Aoki, M. [1995/2000], *Keizai Sisutemu no Shinka to Tagensei*. Tokyo: Toyokeizai Shinposya. Translated into English by S, Gehrig as *Information, Corporate Governance and Institutional Diversity: Competitiveness in Japan, US and Transition Economies*. Oxford, U.K. and N.Y.: Oxford University Press.

Aoki, M. [2000], *Toward a Comparative Institutional Analysis*, book manuscript, forthcoming from MIT Press in Spring 2001.

Aoki, M. and N.Rosenberg [1989], "The Japanese Firm as an Innovating Institution," in T. Shiraishi and Shigeto Tsuru, (eds.), *Economic Institutions in a Dynamic Society*, Macmillan, pp. 137-154.

Arthur, W. B. (1989), ‘Competing Technologies, Increasing Returns, and Lock-in by Historical Events, *The Economic Journal* **99**: 116-131.

Baldwin, C.Y. and K. B. Clark (2000), *Design Rules: Vol.1. The Power of Modularity*. Cambridge, Mass: MIT Press.

Bankman,J. And R.J.Gilson [1996], “Venture Capital and the Structure of Capital Markets: Banks Versus Stock Markets?” *Journal of Financial Economics*, 51, pp.289-303

Baron, J.N., M.D.Burton and M.T.Hannan [1966], “The Road Taken: Origins and Evolution of Employment Systems in Emerging Companies,” *Industrial and Corporate Change*, 5, pp.239-75.

Bygrve,W.D. and J.A. Timmons [1992], *Venture Capital at the Crossroads*, Harvard Business School.

Clark, K.B. and T. Fujimoto (1991), *Product Development Performance: Stratyegy, Organization, and Management in the World Auto Industry*. Boston: Harvard Business School.

Fenn, G.W. and N.Liang [1995], “The Economics of the Private Equity Market,” *Staff Study*, n.168, Board of Governors of the Federal Reserve System.

Florida,R. And M.Kenney [1998], *Financiers of Innovation: Venture Capital, Technological Change, and Industrial Development*, Princeton University Press, forthcoming.

Fujimoto, T. (1999), *The Evolution of a Manufacturing System at Toyota*. Oxford and N.Y.: Oxford University Press..

Gilson, R.[1997], “The Future of Corporate Governance in the United States,” *University of Richmond Law Review*, 31, pp.1459-72.

Gompers, P. [1995], “Optimal Investment, Monitoring, and the Staging of Venture Capital,” *Journal of Finance*, 50, pp.231-248.

Gompers, P. and J.Lerner [1996], “The Use of Covenants: An Empirical Analysis of Venture Partnership Agreements, *Journal of Law and Economics*.

Gorman, M. And W.A.Sahlman [1989], “What Do Venture Capitalists Do?” *Journal of Business Venturing*, 4, pp.231-48.

Hannan, M.T., M.D. Burton, and J.N. Baron [1996], “Inertia and Change in the Early Years: Employment Relations in Young, High-Technology Firms,” *Industrial and Corporate Change*, 5, pp. 503-536.

Hellmann, T. [1998], “The Allocation of Control Rights in Venture Capital Contracts”, *Rand Journal of Economics*,29, pp.57-76. .

Hellmann,T. [1998a], “Teaching Note for Symantec Corporation (S-SM-27), Stanford Business School.

Ikeda, N. (1997), *Jy_h_ Ts_shin Kakumei to Nihon Kigy_ (The Digital Revolution and Japanese Firms*). Tokyo: NTT Publishers.

Joint Venture, (1999), *I988 Index of Silicon Valley*, Palo Alto.

Kaplan, S. N. and P. Strömberg (2000), ‘Financial Contracting Theory Meets the Real World: An Empirical Analysis of Venture Capital Contracts,’ mimeo, University of Chicago.

Klein,S. And N. Rosenberg [1986], “An Overview of Innovation,” in R.Landau and N.Rosenberg (eds.), *The Positive Sum Strategy*, National Academy Press.

Lerner, J. [1994], “The Syndication of Venture Capital Invetments,” *Financial Management*, 23, pp.16-27.

Lerner,J. [1994a], ‘Venture Capitalists and the Oversight of Private Firms,” Working Papers, Harvard University.

Pine, B. J. [1993], *Mass Customization: The New Frontier in Business Competition*, Harvard Business School Press, Boston.

Romer, P. M. (1986), ‘Increasing Returns and Long Run Growth,’ *Journal of Political Economy*, **94:** 1002-1037.

Sahlman, W.A. [1990], “The Structure and Governance of Venture Capitalist Organizations”, *Journal of Financial Economics*, 27, pp. 473-521.

Saxenian, A. [1994], *Regional Advantage: Culture and Competition in Silicon*

Valley and Route 128 , Harvard University Press.

Testa,R. [1997], "The Legal process of Venture Capital Investments." In *Pratt's Guide to Venture Capital Sources*, Venture Economics, Wellesly Hills, Mass.

__Figure 1. Comparative Information-Systemic Architecture of R&D Organizations__

Environment / Organization: model	characteristic	(E-s) Systemic-industrial environment	(E-e) Systemic-engineering environment	(E-i) Task-specific engineering environment	Fitting engineering environment
Waterfall model (functional hierarchy)	Hierarchical *ex ante* design of product system	development director's conceptual design	middle manager's analytic design	detailed design by functional units	high systemic uncertainty, disparity in information processing competence
Star model		development director's integrative design		Supplementary design by subordinates	
Interactive R&D organization (horizontal hierarchy)	Interactive design improvement	information assimilation led by "heavy weight" development manager	information-sharing among task units	modular product design by task units	high attribute and technological complementarities
SV model	Evolutionary product system constitution	VC's mediation of information assimilation, *ex post* selection of module products	information encapsulation by entrepreneurs across and within niche markets		weak complemen-tarity, relative independence of modular design problems

Endnotes

* In writing this paper I benefitted from useful comments from Professors AnnaLee Saxenian and Thomas Hellmann.

---

1. In fact, even a most authoritative account of the influential property rights approach argues that both the increasing importance (technically speaking, indispensability) of human assets and the increasing flexibility of technologies (the reduction of complementarity) make it an optimal arrangement for property rights to physical assets to be held by an individual entrepreneur – that is “de-integration”(Hart 1998:53-54).

2. This standard-setting may be considered as corresponding to “design rules” in a conceptual framework developed by Baldwin and Clark (2000). An early draft of this paper was written in the fall of 1997 and has been circulated through the website of the Stanford economics department since early 1999. However, I was not aware of their exciting work until their publication in 2000. Their work and this paper are highly complementary and partially overlapping. They provide a rich analysis of the evolutionary process starting from the design of IBM 360 in

the 1960s to the emergence of the Silicon Valley model in the late 1970s – "modular clusters" in their word. However, as the immediate object of their study is the computer industry, their analysis does not explicitly involve a kind of comparative assessment of alternative R&D organizations ("design rules") as I do in this paper and chapter 4. They argue that the Silicon Valley model ("modular clusters") is intrinsically superior to the centralized design rule setting as observed in the era of IBM 360, to which I agree regarding the computer industry. I clarify later some conditions under which the Silicon Valley may be Pareto-superior, which may not necessarily be satisfied in other industries, for example, arguably in the auto industry. The evolutionary nature of the technological product system innovation in the Silicon Valley model (point (ii) below) is the focus of analysis in both their and our works. The complementary nature of analytical contents between the two works is mentioned in endnote 3 below.

3. Baldwain and Calrk (2000: Part III) show that, assuming the normal distribution (with the mean normalized to zero) of the value outcome of each development and design effort ("experiment" in their word), the option-value benefit of having k firms in the design of a singe modular product is proportional to the standard deviation of the value outcome of a development effort (i.e., the

degree of uncertainty in design outcome) times the expectation of the best of k trails drawn from a standard normal distribution. Thus, the higher the uncertainty, the better to have more entrepreneurial firms. Experiments are costly, however. They treat these costs parametrically. In the next section we focus on the deadweight effort costs involved in development and design. We particularly analyze a situation in which actual effort expenditures by individual firms become endogenous to the mechanism of governance and examine its welfare implications.

4. Also it is interesting to note that this software development paradigm corresponded to a similar hierarchical paradigm in hardware design: the IBM 360 was run by a centralized OS and researchers were able to access computer resources only through "dumb" terminals which merely received data inputs and gave computed outputs. See Ikeda (1997).

5. Established venture capitalists in Silicon Valley cluster in a rather small office complex located on Sand Hill Road between Stanford University and Route 280. They know each other well and form a type of professional club.

6. Let e* be the first-best effort, and for fixed $\underline{V}$ choose J so that the Nash equilibrium condition in the text is satisfied at $e_{vc}=e^*$. Let $\Delta = (\delta/1-\delta)J[dF(\underline{V},e^*)/de]$. Then, the expected penalty in flow terms is given by $\Delta \frac{F(\underline{V},e^*)}{[\partial F(\underline{V},e^*)/\partial e_{vc}]}$. If the V-distribution at $e_{vc}=e^*$ is tight in the sense there is a $\underline{V}$-value for which $-[\partial F(\underline{V},e^*)/\partial e_{vc}]$ is large while $\frac{F(\underline{V},e^*)}{[\partial F(\underline{V},e^*)/\partial e_{vc}]}$ is small, then the expected penalty becomes very small, which implies that the first-best condition is approximated by a Nash equilibrium strategy of the venture capitalist. This roughly corresponds to the situation where investors can find a threshold value $\underline{V}$ near $\int V dF(V,e^*)$ for which the probability of failure can be dramatically reduced by an increasing effort. The proof follows Holmstrom (1979).

7. I owe this point to Thomas Hellmann. Based on the SPEC data analysis, Baron, Hannan and Burton (2000) also find that changes in the employment models or blueprints embraced by organizational leaders increase turnover of the most senior employees, which in turn adversely affects subsequent organizational performance.

8. For relationships between venture capitalists and entrepreneurial firms in

general, see Salman(1990), Bygrave and Timmons(1992), Gompers and Lerner (1996), Florida and Kenney (1998) and Kaplan and Stromberg (2000).

9. Figures in 1978 give a much different picture. In that year individuals and families are the largest contributors to venture capital funds (32%), while the share of pension funds was 15%. During the last twenty years the so-called institutionalization of venture capital funds has proceeded.

10. It is known that the flow of funds into this organizational arrangement was given impetus by various tax measures which were enacted between the late 1970s and early 80s (such as the relaxation of the so-called “prudential rules” on pension fund management, the reduction of the capital gains tax in 1978 and 81, deregulation of initial public offerings in 1978 and 79, etc.).

11. In 1997, more than 3,500 companies were newly registered in Santa Clara County, even if not all of them were venture capital financed firms.

12. The decline of the practice of co-financing may partially reflect the stock market boom that has made more funds available to competing venture capitalists and partially the reduction of technological uncertainty involved in venture capital financing. Thus, it is not yet clear whether joint financing will totally disappear even if the venture capital boom subsides and/or investment is directed to very uncertain projects.

13. According to the definition by the National Venture Capital Association, there are following developmental stages of venture capital financing:

- seed stage (before the establishment of a corporation) mostly financed by the so-called angels who are experienced in venture business
- start up (development stage)
- early stage (preparation of product development, production, and marketing)
- later stage (after product shipment)
- mezzanine stage (6 months to one year before Initial Public Offering)

14. Between 1990 and 1997, about 21,000 new businesses were registered in Santa Clara County. About 7,000 entrepreneurial firms are said to currently exist (Joint Venture, 1998).

15. For example, many firms that recently went to IPO after a short period introduce new business models in the internet industry, but the technology involved is not considered strikingly innovative. For example, basic analytical algorithms of internet auction sites and other e-commerce businesses have been long-known in experimental economics. On the other hand, in the biotechnology industry where R&D uncertainty is still relatively high, the shortening of the period needed for the recovery of venture-capital investment returns is not as dramatic.

16. For example, Cisco Systems, a start-up firm itself a decade ago but now close to the top-ranking corporation in terms of stock value, has grown by acquisition. They acquired some fifty companies in the last seven years. They are said to select from about fifteen companies for acquiring one technology (Senior Vice President Volpi).