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VENTURE CAPITAL-FINANCED INNOVATION AND TECHNOLOGICAL CHANGE IN THE US

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ABSTRACT

Venture capital has transformed the innovation process in the US. Venture capitalists provide funds and assist in the formation of new high technology businesses. They actively cultivate networks comprised of financial institutions, universities, large corporations, entrepreneurial companies and other organizations. These networks and the information flow at their disposal enable them to reduce many of the risks associated with new enterprise formation and thus to overcome many of the barriers that hold back innovation. Venture capital-financed innovation is a "new model" of innovation which goes beyond both classical entrepreneurship and corporate-based innovation. Venture capitalists forge important linkages among a variety of organizations which are important to the innovation process and act as "technological gatekeepers" accelerating the process of technological change. The venture capital industry is organized in a series of relatively self-contained complexes -- technology-oriented, financial-oriented and hybrid -- which play distinct roles in the process of venture capital-financed innovation. While venture capital catalyzes technological change, it also generates costs, most notably the disruption of established research organizations and the establishment of strong incentives for "breakthroughs" as opposed to other types of innovation.

Introduction

The importance of venture capital-financed innovation to the US economy is reflected in the fast growing, high technology areas where venture backed firms have risen to prominence [1]. These include semiconductors, personal computers, biotechnology, CAD-CAM, software and artificial intelligence. Successes such as Fairchild, Intel, Digital Equipment Corporation (DEC), Apple, Microsoft, Sun Microsystems, and Genentech have virtually defined the emergence of critical new technologies and industrial branches [2]. Recent years have witnessed an explosion in venture capital financings of high technology businesses; indeed more than 85 percent of all venture capital has flowed to technology intensive areas [3].

Venture capitalists play a critical role in the innovation process in the US by providing funds and helping to organize embryonic technology-oriented companies. They sit at the center of multifaceted networks -- which they actively help develop -- comprised of financial institutions, large corporations, universities and entrepreneurs, and in doing so, forge important linkages between large and small institutions. Venture capital serves in large measure to formalize the roles historically played by the entrepreneur and independent financier and lend structure to the innovation process and attendant "gales of creative destruction" which are so vital to the wave like expansions of capitalist societies [4].

The major thesis of this paper is that venture capital has transformed the process of innovation in the US. We contend that venture capital has given rise to a "new model" of innovation which transcends the entrepreneurial

versus corporate dichotomy posed by neo-Schumpeterian theory. Venture capital-financed innovation overcomes financial, technological and organizational barriers which characterize both entrepreneurial and corporate-based innovation. We further contend that venture capital-financed innovation accelerates the process of technological change and argue that venture capitalists performing a critical, technological gatekeeping function. Lastly, we suggest that the way venture capital influences innovation differs substantially by place and that fully blown venture capital-financed innovation generally takes place only in those areas which possess well developed technological infrastructures or what we refer to as "social structures of innovation" anchored by venture capital.

This paper proceeds as follows. The first section presents a brief overview of the venture capital industry. The second section provides a concise description of the functions that venture capitalists perform over the course of the technology life cycle. The third section then outlines our model of venture capital-financed innovation. The fourth section elaborates on this model through examples taken from the semiconductor, personal computer, and biotechnology industries. The fourth section outlines some of the salient differences among the major centers of venture capital activity -- California, Boston, New York and Chicago, while the fifth explores the limits of venture capital-financed innovation. We conclude with a summary of major points and a general discussion of venture capital's impact on innovation and economic growth.

VENTURE CAPITAL: AN OVERVIEW

Venturing is a relatively unique form of investment. Venture capitalists invest in new, unproven enterprises which traditional financial institutions ignore [5]. Instead of lending money, they exchange capital for an equity or ownership stake in the companies they finance. Venture capitalists are active investors and are integrally involved in the creation of young companies. In addition, most venture capital investment takes place in syndicates involving two or more venture capital firms [6]. This process referred to as coinvesting enables venture capitalists to pool expertise, diversify their investment portfolios and share risk.

Venture capitalists reduce investment uncertainty through careful screening of business proposals and by taking an active role in the management of portfolio companies [7]. The use of equity investment rather than debt eliminates the problem of scheduled repayment. It allows young companies to reinvest their earnings and provides an asset base which can be used to attract outside capital and enhance a company's credibility with vendors and financial institutions [8]. Equity financing enables venture capitalists to assume substantial investment risks since one enormously successful investment can more than offset a series of break-even investments or outright losses. A study of the performance of 10 leading venture capital funds indicates that of 525 venture investments made during the period 1972-1983, just 56 "winners" (or 10.7 percent) generated more than half ($450 million) of the total value held in portfolio ($823 million), while roughly half (266) either broke even or lost money [9].

Venture capital is provided through a number of different types of organizations. Of particular significance are venture capital limited partnerships which account for more than half of all venture capital firms and control approximately three-quarters of industry resources (Exhibit 1). These are comprised of both general and limited partners. The general partners are the professional venture capitalists who secure capital commitments for the fund and make and manage its investments, while the limited partners are the fund's investors. Limited partnerships have a fixed life of seven to ten years. The first few years are ones of active investment, while the remaining period is used to build companies to the point of public stock offerings, merger or another form of exit. Because of their limited life expectancies, partnerships seek to rapidly build companies and liquidate investments in order to realize capital gains [10].

Recent years have seen a shift in the source of funds for limited partnerships (Exhibit 2). Between 1978 and 1984, capital supplied by families and individuals declined in importance relative to capital from financial institutions and corporations. By 1984, pension funds had become the single, most important source of funds to venture capital partnerships, supplying $1.1 billion or 35 percent of total capital. There were four primary reasons underlying the shift to institutional sources of capital. First, reductions in the tax rate on capital gains made venture capital partnerships an attractive investment vehicle for large investors. Second, changes of federal restrictions on public pension fund investments made partnership investments especially attractive for pension funds. Third, the "profit squeeze" faced by

EXHIBIT 1

Types of Venture Capital Firms

	Number of Firms	Share of Total	Capital Base (Billions)	Share of Total	Average Capital Base (Millions)
Limited Partnerships	271	53.2%	$12.2	74.7%	$44.9
Financial Subsidiaries	51	10.0	2.0	12.1	38.8
Industrial Subsidiaries	44	8.6	1.4	8.7	32.3
Venture Capital Oriented SBICs*	143	28.0	0.7	4.4	5.1
TOTAL	509	100.0	$16.3	100.0	$32.0

NOTE: * Includes only small business investment companies (SBICs) which are venture capital oriented.

Source: Venture Economics, Venture Capital Yearbook [3]

EXHIBIT 2

Capital Sources for Venture Capital
Limited Partnerships, 1978-1984
(Millions of Dollars)

	1978	1980	1984	Absolute Change	Ratio of Change
Pension Funds	$ 32 (14.8)	$ 197 (29.8)	$1,085 (34.1)	$1,053 (35.5)	32.91 -
Industrial Corporations	$ 22 (10.2)	$ 127 (19.2)	$ 463 (14.5)	$ 441 (14.9)	20.15 -
Insurance Companies	$ 35 (16.2)	$ 88 (13.3)	$ 419 (13.1)	$ 384 (12.9)	10.97 -
Foundations	$ 19 (8.8)	$ 92 (13.9)	$ 178 (5.6)	$ 159 (5.4)	8.37 -
Foreign Sources	$ 38 (17.6)	$ 55 (8.3)	$ 573 (18.0)	$ 535 (18.0)	14.08 -
Individuals/ Families	$ 70 (32.4)	$ 102 (15.4)	$ 467 (14.7)	$ 397 (13.4)	5.67 -
TOTAL	$ 216	$ 661	$3,185	$2,969	13.75

NOTE: Numbers in parantheses equal percentage share of total.

Source: Venture Economics, Venture Capital Yearbook [3]

many corporations and financial institutions over the past five years or so accelerated the flow of capital into new areas such as venture capital. Fourth, active sponsorship of companies by investment banks in the public securities market increased investor confidence in the long term viability of venture capital as an investment outlet [11].

In addition, there are approximately 50 venture capital subsidiaries of financial institutions which control approximately $2 billion in resources (Exhibit 1) [12]. Another 44 funds are subsidiaries of industrial corporations such as Xerox, General Electric and Lubrizol, which control approximately $1.4 billion in venture capital. The substantial majority of these firms invest strategically to diversify product lines, to secure a "window on technology" or as a potential first step in aquiring or developing a strategic partnership with a successful small company [13]. Generally speaking, venture capital subsidiaries are organizationally distinct entities and are not subject to the investment biases of their corporate parents.

Finally, there are 143 venture capital oriented small business investment companies (SBICs) which are able to access to federal leveraging funds under provisions of the 1958 SBIC Act [14]. Even though there are a relatively large number of SBICs, they comprise only a marginal part of the venture capital industry. SBICs are generally smaller than other types of venture capital funds having an average capitalization of just $5.1 million. For the most part, SBICs have not been important in financing cutting edge, high technology enterprises [15].

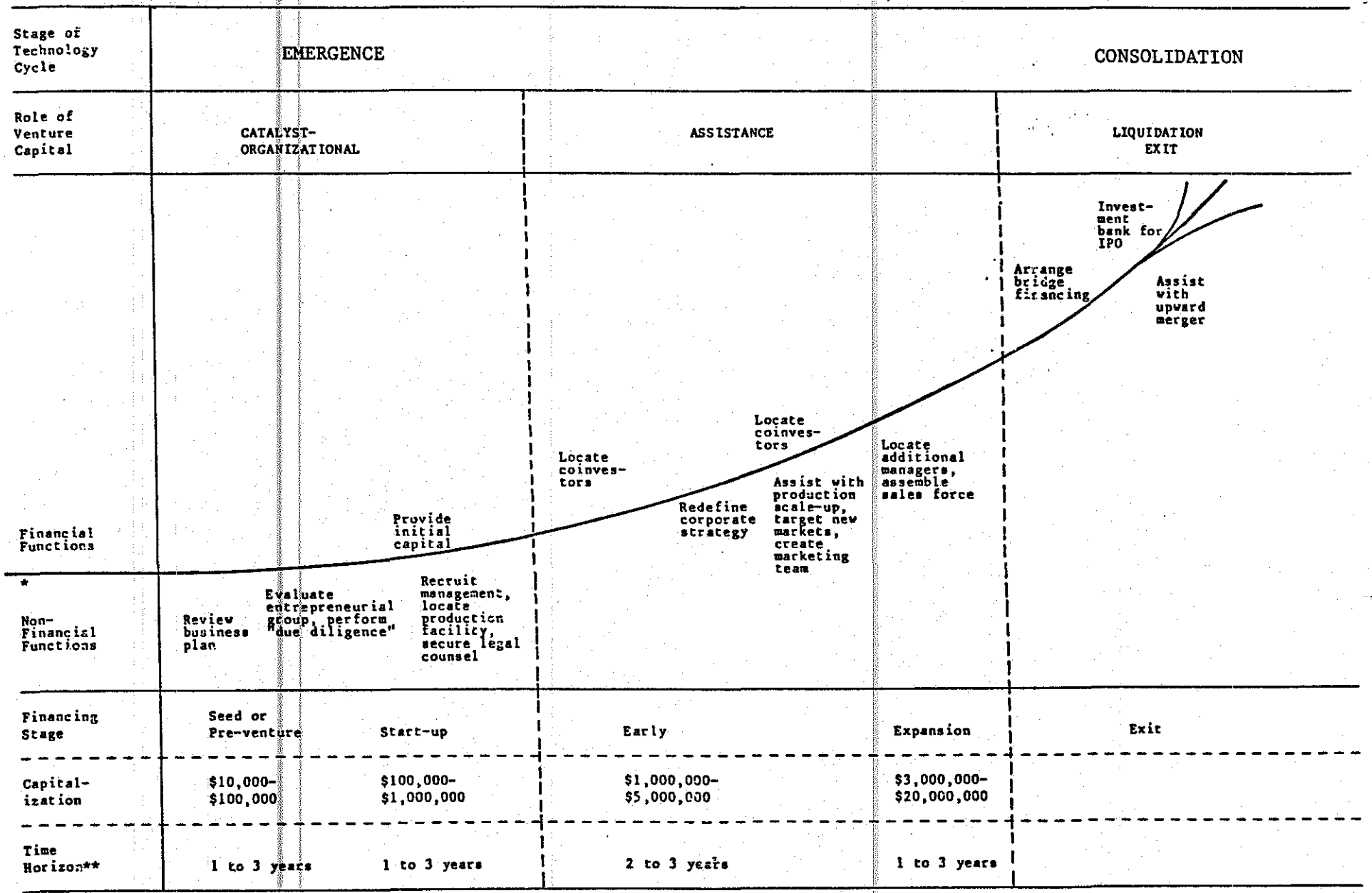
The emergence of limited partnerships as the dominant form of venture

investing was the result of a the result of a lengthy period of experimentation and evolution which distilled this mechanism from a variety of organizational forms for providing venture capital. Basically, the limited partnership eclipsed other models because it both provided an effective way to mobilize large amounts of funds from outside investors and enabled venture capitalists to realize significant financial gains. Today, partnerships are often piggy-backed one on top of another, giving rise to the phenomenon of "megafunds" valued in excess of $500 million [16]. To effectively manage their assets, megafunds have adopted increasingly formal organization.

VENTURE CAPITAL, NEW BUSINESS FORMATION AND TECHNOLOGICAL CHANGE

Venture capitalists are involved in a wide variety of tasks that are necessary to launch new, innovative businesses. In the following section, we explore the various functions performed by venture capitalists by tracing the changing nature fo their involvement over the course of the technology life cycle. The technology cycle has been described as taking the shape of an S-curve, proceeding through three stages: emergence (initiation and rapid growth), consolidation (increasing economies of scale and steady expansion) and maturity (oligopoly and decline) [17]. As Figure 1 shows, venture capital is most important during the emergence stage which begins with a major breakthrough or innovation. This phase is marked by experimentation with new technology, uncertainty regarding future progress, wide open markets, low entry barriers and diseconomies of scale.

During this stage, venture capitalists evaluate the technological



*Growth curve of a new technology intensive business.
**Average of 7 years.

Figure 1: Venture Capital in the Technology Cycle

Source: Compiled by authors

potentials, financial requirements and organizational capabilities of new businesses and the products upon which they are based [18]. It is only after carefully screening the business proposal or "business plan" that venture capitalists decide to invest. In this sense, venture capitalists affect the trajectory of technological development before actually investing.

Personal contacts are crucial to the search for good venture capital investments. Survey research indicates that nearly two-thirds of all proposals are referrals from other venture capitalists, personal acquaintances, banks or investment brokers, while only 25 percent are unsolicited "cold calls" [19]. Our interviews indicate that the large majority of proposals which are seriously evaluated by venture capitalists come from close personal contacts such as executives of successful portfolio companies, established entrepreneurs or other venture capitalists [20]. While reputable venture capitalists receive between 300 and 500 business proposals a year, just 25 to 30 are selected for careful screening and only one to five actually receive funding.

Venture capitalists evaluate business plans in light of a variety of criteria including: the originality of the proposed product or technology, its potential competitors, market size, business strategy and projected sales, the availability of patent protection or other proprietary characteristics, the quality and business accumen of the entrepreneurial group, and the prospective manner of exiting from the investment and realizing a substantial capital gain [21]. Venture capitalists also engage in extensive conferrals with the management of potential startups. This is supplemented by a

relatively formal process of "due diligence" which involves a detailed search of references and the solicitation of outside information from potential customers, suppliers and competitors about the quality of the technology and the entrepreneurial group.

Once the business plan is accepted, capital is provided to the new enterprise. In return, venture capitalists receive a significant ownership stake in the new company along with representation on the corporate board of directors. Increasingly, venture capital startup investments are taking place via syndicates. Our interviews with venture capitalists suggest that the most highly regarded investments are "self-organizing" -- that is, two or more venture capital firms will simultaneously evaluate a potential investment and mutually agree to invest and form a syndicate [22].

Venture capitalists provide significant non-financial assistance to small, technology intensive businesses. They have substantial experience and contacts which help new companies secure legal counsel, patent attorneys, accounting services, outside technical experts, public relations consultants and a wide variety of ancillary business services as well as locate office or production facilities. The provision of financing from a reputable venture firm in established technology regions like Silicon Valley or Route 128 functions as a "seal of approval" for new companies which need to establish working relationships with suppliers, financial institutions and related businesses. Venture capitalists firms may also organize strategic partnerships between portfolio companies and larger corporations through technology exchanges, OEM or other customer agreements and minority equity

investments.

Venture capitalists often recruit managers for business startups. To assist with such efforts, most venture firms have executive search firms on retainer. A recent survey of 77 important venture capital firms indicates that the venture capital community views management recruitment as the single most important form of assistance provided to young companies [23]. Indeed, the top flight Mayfield Fund has recently added a "recruiting partner" who specializes in filling management positions at portfolio companies [24]. Venture capitalists provide important assistance in luring top-level personnel from secure academic or corporate posts by offering equity stakes in fledgling businesses and the concomitant possibility of realizing large capital gains.

The role of venture capital changes as new businesses and technologies proceed through the cycle (Figure 1). Over time, technological and entrepreneurial skills diminish in importance relative to managerial and marketing capabilities, and the young company establishes a more formal organizational structure. At this stage, the role of venture capital shifts from active intervention to one of advice and assistance. The venture capitalist's expertise in particular industries and prior experience with business expansions provides a reservoir of knowledge which can be critical for the survival of a growing company. Venture capital firms also encourage collective problem solving by managers of portfolio companies, creating an intensive information exchange among entrepreneurs which eliminates or diminishes the severity of many problems associated with new business development.

The relationship between venture capitalists and the companies they finance is not always devoid of conflict. Although venture capitalists and entrepreneurs typically work together to build new companies, the reasons that they do so are often quite different. Of primary importance to venture capitalists are the profits or capital gains made on investments. While entrepreneurs are also interested in financial gain, they are also likely to be driven by some combination of profit, longterm economic security, sense of mission, and attachment to their enterprise. These differences may underscore more obvious disagreements which can at times lead to bitter confrontations over corporate policy. In such cases, venture capitalists can use their control of board positions or leverage over further rounds of financing to coerce management to make changes or to remove the founder or entrepreneurial group. If disagreements are serious enough, venture capitalists will endeavor to replace managers and in certain situations may assume direct operating positions themselves, though our interviews with venture capitalists lead us to conclude that they will do so only in the most dire situations. Venture capitalists may also remove top executives in response to organized movements of upper-level managers.

Venture capital firms use investment syndicates to secure additional rounds of financing for new companies. The original, lead investor may arrange two or three investment syndications involving as many as 15 other investors. Lead investors typically use personal networks to secure coinvestors, trading opportunities to participate in each others investments. While investment syndications are primarily accomplished to provide capital,

venture capitalists typically seek coinvestors with complementary skills and supplementary contacts.

Venture capitalists' role in the innovation process culminates when they "exit" from their investments (Figure 1). This is typically accomplished through a public stock offering or upward merger which transforms investments into liquid capital. Between 1978 and 1984, nearly 300 venture backed companies were brought into the market for initial public offerings or IPOs [25]. The push to go public is embedded in the very structure of the venture capital industry. The more quickly investment portfolios are liquidated (at high multiples of the original investment) and the limited partners receive their return, the sooner the venture capitalist can launch another fund [26].

A NEW MODEL OF INNOVATION

The rise of venture capital has dramatically transformed the way that innovation takes place in the US, giving rise to a "new model" of innovation which integrates components of entrepreneurial-driven versus corporate-led dichotomy posed by neo-Schumpetarian theory [27]. Under entrepreneurial innovation (model 1), individual entrepreneurs or entrepreneurial groups drive the innovation process. These actors either utilize ideas drawn from science or employ technical know-how to launch new products and forge new product markets. The technological and organizational changes brought about by these innovations generate strong bandwagon effects which leads to the creation of new industries, the revitalization of some older ones and the disappearance of still others.

Under corporate or managed innovation (model 2), large corporations organize the R&D process and internalize much innovative activity. These corporations use internal R&D to remain at the forefront of new technology and generate successive waves of innovation. According to Freeman et al, this creates "a strong positive feedback loop from successful innovation to increased R&D activity setting up a virtuous self-reinforcing circle" [28]. The internalization of innovation within large corporations makes technological change a less sporadic, more continuous process.

Recently, a number of analysts have posed the idea of a complementarity existing between large and small institutions [29]. According to this view, large corporations and universities establish the scientific and technological context necessary for innovation, functioning as "incubator organizations" for technological change [30]. These technological opportunities are then exploited and commercialized by small entrepreneurial companies. Such interplay is facilitated by direct circulation of personnel and attendant transfers of technological and managerial capabilities as well as through indirect channels such as informal exchanges of information, research literature and professional relations among manufacturers, suppliers and vendors [31]. Large organizations and small firms thus act in a dynamic and complementary way as part of the innovation process [32].

Figure 2 illustrates the role of venture capital in the institutional context for innovation. Venture capitalists are situated at the center of extended networks and actively forge connections which reach into large corporations, universities, financial institutions, and a variety of other

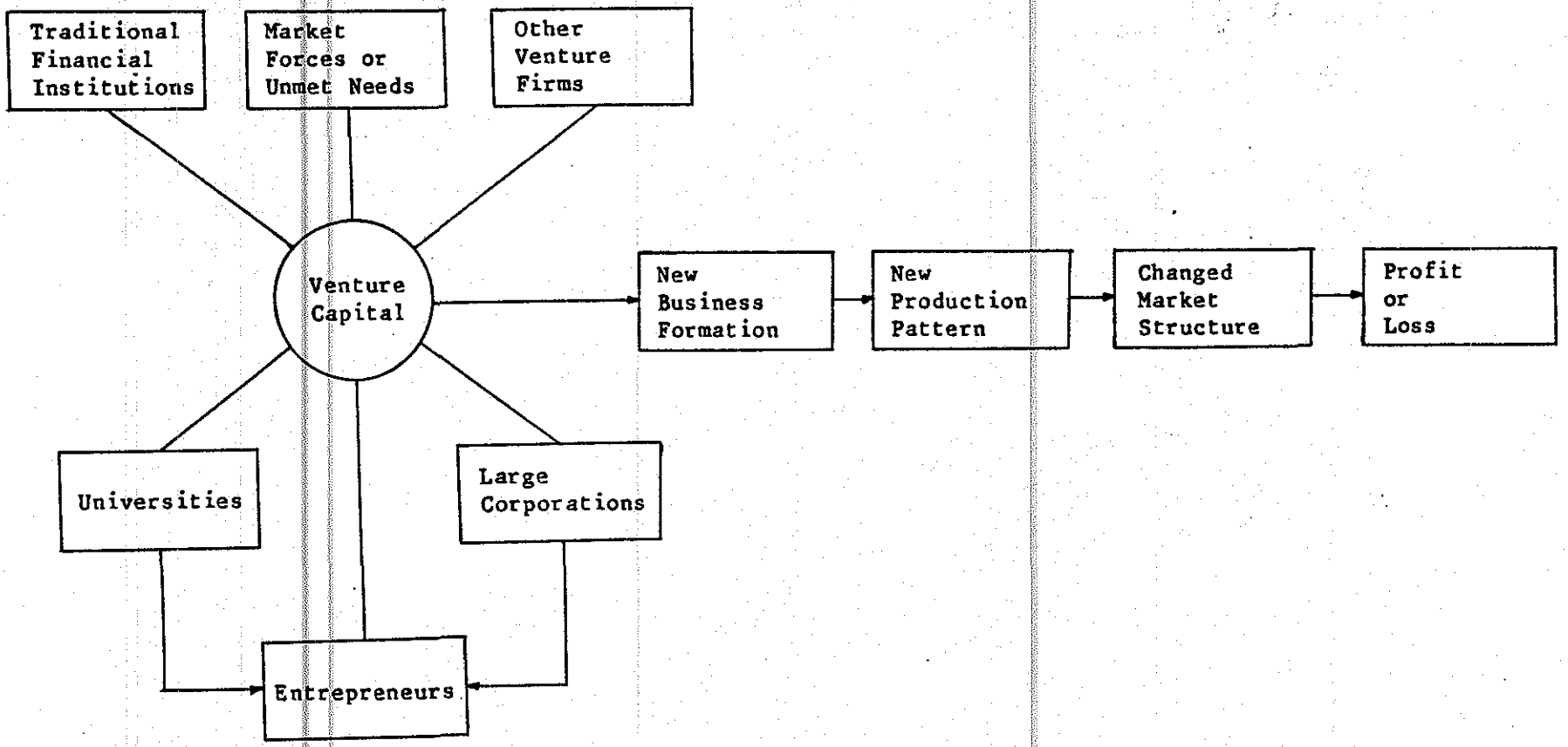


Figure 2: Venture Capital in the Institutional Framework for Innovation

Source: Compiled by authors

organizations which play important roles in the innovation process. From this central vantage point, venture capitalists are uniquely equipped to match personnel and resources drawn from various organizations in the formation of new enterprises.

Venture capital's position within the innovation process can be best thought of in terms of four overlapping networks [33]. The first of these is used to mobilize capital. It consists of investors in the venture capital fund (i.e., institutional investors and wealthy individuals) and other venture capital firms that take part in investment syndicates. A second network is used to locate and review potential investments and revolves around previously successful entrepreneurs, other venture capitalists, lawyers, and accountants as well as contacts in large corporations and universities. The role of former entrepreneurs in this network is epecially important since they have supplementary contacts which typically extend to the most promising potential startups. A third network cultivated by venture capitalists includes professional service firms such as law and accounting firms as well as market research and consulting firms which serve as sources for industry relevant information. A final network is comprised of sources of labor and other important inputs into the production process. It consists of contacts which are used to recruit management and other personnel for startups as well as sources for inputs into the production process and possible outlets for finished goods.

The rise of venture capital-financed innovation overcomes many of the obstacles asssociated with innovation under Models 1 and 2. Under Model 1,

innovation occurs in a relatively ad hoc and unorganized way. The individual entrepreneur is forced to organize the process of entreprise formation -- locate financing, purchase supplies, obtain facilities, etc. -- virtually singlehandedly. As we have seen, venture capitalists bring resources and contacts to this process which help reduce the information and opportunity costs associated with new business formation. And, by reducing the uncertainty involved in enterprise creation as well as providing the needed financial resources, they create a "spot market" of sorts for business formation and development.

Under Model 2, innovation is often impaired by organizational rigidity of large corporations -- what Kanter refers to as "segmentalism" [34]. Venture capital-financed innovation replaces the functional specialization and compartmentalized information flow characteristic of large corporations with a relatively fluid and flexible organizational environment characterized by frequent adjustment, decentralized decision making and intense flows of information. This occurs both within and to a lesser extent between venture capital backed companies -- creating significant incentives for innovation. In fact, the emergence of venture capital-financed innovation represents a partial response to the breakdown of Model 2 in large US corporations. This breakdown is evident in the inability of large corporations to provide either the organizational flexibility or incentives necessary to stimulate internal innovation, and is perhaps most visibly reflected in the rise of self-contained "innovation complexes" such as California's Silicon Valley and Boston-Route 128 far afield from traditional centers of heavy industry.

In organizing many of the elements necessary for innovation to take place, venture capitalists function to a large extent as "technological gatekeepers" -- setting the direction of technological change [35]. The idea of "natural" or "technological" trajectories suggests that the given path of technological development both both channels and constrains future technological progress [36]. The organizational and institutional context of society acts as an additional constraint on technological change [37]. Since innovation and technological change take place largely within these relatively fixed constraints, only critical technological or organizational breakthroughs can disrupt existing sociotechnical pathways and open up new technological frontiers. Ayres makes this point quite succinctly:

> Major new technological opportunities seem to occur, in general, when a critical barrier or constraint is breached. ... Specifically, opportunities are greatest just after a "breakthrough" and smallest as a new barrier is approached. ... The territory beyond such a barrier is ltle known, at first, because either the means or the motives for exploring it were lacking. But once the barrier is surmounted all is changed, a "new" territory is suddenly open for exploration and dominion [38].

Venture capitalists are a crucial part of the context within which such breakthroughs occur. Due to the intensive flows of information at their disposal, venture capitalists are well positioned to spot the opportunities that arise as critical barriers are breached. It is at these junctures that they perform a "gatekeeping" function, intervening to help create new companies and actualize important breakthroughs, while capturing the "economic rents" that come form being first across such boundaries. Although only a small subset of all venture investments ultimately pay off, the most important choices or "technological bets" made by venture capitalists in fields such as

semiconductors, personal computers and biotechnology have disrupted existing sociotechnical trajectories and opened up whole new frontiers for technological progress, setting the stage for clusters of imitative activity and swarms of improvement innovations [39].

In short, venture capital-financed innovation is more than just a mid-point between Models 1 and 2. It organizes the dynamic complementarities which exist among a variety of organizations, and as such represents a new, integrative model of innovation. In addition to this, venture capital-financed innovation plays an important technological gatekeeping function -- moving the US across new technological frontiers and setting in motion the "gales of creative destruction" which establish the context for economic restructuring.

EXAMPLES OF VENTURE CAPITAL-FINANCED INNOVATION

The operation of this new, integrative model is perhaps best illustrated through some case examples. The linkage between large corporations and venture backed companies is clearly evidenced in the evolution of the semiconductor industry. The basic technology used in semiconductors was developed at Bell Laboratories during the 1950s by William Shockley, Gordon Teal and their collaborators. In 1951, Teal left Bell Labs to join Texas Instruments, and in 1954, Shockley left to launch his own firm. The establishment of Fairchild Semiconductor in 1957 by Eugene Kleiner, Robert Noyce and six other of Schockley's former employees catalyzed the nascent semiconductor industry. Fairchild was one of the first important venture

capital backed startups -- its financing was arranged by the proto-venture capitalist, Arthur Rock, who was then an investment banker with a prominent New York City firm [40].

Fairchild laid crucial groundwork for the genesis of the Silicon Valley innovation complex, becoming an important incubator organization both for entrepreneurial spinoffs and venture capitalists [41]. By 1971, 21 of 23 semiconductor manufacturers located in the Silicon Valley area were offshoots from Fairchild, and by the early 1970s, 41 high tech startups had been established by Fairchild alumni [42]. Just as importantly, the rapid success of Fairchild provided the impetus for establishment of the first formal venture capital operations in the San Francisco/Silicon Valley area. By the early 1970s, a number of Fairchild alumni had gone on to form prominent venture capital partnerships. Kleiner was a cofounder of one of the preeminent venture capital firms, Kleiner, Perkins, Caufield and Byers, while somewhat later both Noyce and Donald Valentine established important venture capital funds.

Venture capital was of vital importance to the personal computer industry. Personal computers were virtually ignored by large companies as late as the mid-1970s, when only a handful of small, entrepreneurial companies were in this nascent market. At this point, the founders of Apple Computer, Stephen Wozniak and Steven Jobs, were building machines in a garage for sale to a small market comprised mostly of acquaintances. In 1977, the venture capitalist, Donald Valentine, provided seed capital for the new company and used his connections to link the two entrepreneurs to "Mike" Markkula a

seasoned technology manager who had worked at both Fairchild and Intel [43]. Valentine then convinced the prominent venture firm, Venrock, to invest in Apple and more investors were added at later stages. By linking entrepreneurs to financing sources and qualified managers, venture capital played an important role in opening the new market for personal computers.

The biotechnology industry provides an example of the proactive role played by venture capital. Although a series of scientific breakthroughs which occurred during the early 1970s created the possibility for commercial biotechnology, few actors realized the economic potential of this new technology. In 1976, the venture capitalist, Robert Swanson, left his position at Kleiner Perkins to become a co-founder of Genentech with Dr. Herbert Boyer, a prominent molecular biologist from the University of California. Swanson had been involved with the biotechnology field as manager of Kleiner's investment in Cetus Corporation and in this capacity had learned about important scientific breakthroughs in biotechnology. Swanson and Boyer then received an initial $100,000 from Kleiner Perkins to fund what could still be considered basic research and and launch their new company [44].

The rapid success of Genentech and other small biotechnology companies provided the impetus for large chemical and pharamaceutical companies to enter the biotechnology field. Due to the small companies' lead and because most large companies were unable to recruit topnotch scientific talent, large companies were forced to establish "strategic partnerships" with small startups. Also, large companies utilized venture capital subsidiaries to locate potential strategic partners. For example, Lubrizol made significant

venture investments in both Genentech and Agrigenetics, Monsanto utilized its joint venture capital concern with Emerson Electric -- Innoven Corporation -- to invest in Biogen, Inc., while Martin Marietta invested directly in Molecular Genetics and Chiron.

The rapid commercialization of biotechnology was due in large measure to the capacities of venture capitalists to recognize and capitalize on the economic potential of "breakthrough" innovations. In contrast to the semiconductor and personal computer industries where venture capital was essentially provided to embryonic enterprises "after-the-fact", venture capital played more of a formative role in the biotechnology industry -- seizing the commercial opportunities opened up by developments in biological science. This is in fact illustrative of a more general trend in the evolution of venture capital-financed innovation from a reactive to proactive role in the process of technological change.

VENTURE CAPITAL COMPLEXES

Although venture capital-financed innovation can in principal take place anywhere, it is highly concentrated in a few, distinct geographic areas. We identify three distinct types of venture capital complexes -- technology-oriented, financial-oriented, and hybrid -- each of which plays a distinct role in the innovation process (Exhibit 3) [45]. Technology-oriented venture capital complexes, like Northern California, most closely mirror our characterization of venture capital-financed innovation. Such complexes are located around existing concentrations of high technology businesses, invest

EXHIBIT 3

Distribution of Resources and Firms
for Venture Capital Complexes

	Capital Base (Millions)	Share of Total	No. of Firms*	Share of Total
TECHNOLOGY-ORIENTED COMPLEXES				
Northern California (Silicon Valley/ San Francisco)	$ 5,296	32.5%	173	27.3%
FINANCIAL-ORIENTED COMPLEXES				
New York	3,262	20.0	95	15.0
Chicago	863	5.3	23	3.6
HYBRID COMPLEXES				
Boston	2,054	12.6	60	9.5
Total	11,475	70.4	351	55.4
US TOTAL	$16,308	100.0	634	100.0

NOTES: * Includes all SBICs.

Source: Adapted from Florida and Kenney [45]

most of their capital close to home, and attract venture capital from other locations. Financial-oriented complexes, such as New York and Chicago, are located around concentrations of financial institutions and tend to export their capital, often to technology-oriented complexes. Hybrid complexes, like Boston, combine elements of both financial and technology-orniented venturing.

More importantly, venture capital firms which are located around areas of high technology comprise important components of what we term "social structures of innovation" -- integrative systems comprised of universities, technology-oriented enterprise, highly skilled labor, considerable public/private R&D expenditures, extensive networks of suppliers, manufacturers and vendors, support firms such as law firms and consultants specializing in high technology, strong entrepreneurial networks, and informal mechanisms for information exchange and technology transfer. Social structures of innovation provide an infrastructure for technology-based business formations and represent integrative mechanisms for reproducing highly skilled labor and continuously mobilizing information.

The Northern California (Silicon Valley/San Francisco) venture capital complex is the ideal-typical example of technology-oriented venturing. It controls the largest amount of venture capital of any complex, $5.3 billion and is comprised of approximately 175 funds. Venture capitalists in northern California make most of their investments in the immediate area. In fact, three-quarters ($280 million) of the $400 million invested by Northern California venture capitalists in 1982 was placed in California, while just 25 percent was exported, most of it going to New England and Texas. The Northern

California venture complex was an enormous attractor as well as a generator of venture capital. It claimed a disproportionate share of venture capital invested by other regions. Capital inflows of $136 million from New York and $118 million from New England helped push the total invested in California to $830 million -- more than 45 percent of all venture investments.

Venture capital in Northern California evolved gradually alongside the high technology enterprises that sprang up there. Its impetus came from informal groups of investors rather than from traditional financial institutions. During the early 1960s, these investor groups began experimenting with a variety of institutional mechanisms for for providing venture capital including rudimentary limited partnerships, SBICs, and other mechanisms for mobilizing capital. Gradually, key personnel from these original venture capital firms and also from technology based companies went on to launch venture capital operations of their own. Because of the difficulties faced mobilizing funds and the need to share information and expertise, these early independent actors quickly evolved into an interactive community -- sharing information and participating together in rudimentary syndicates [46].

Venture capital thus became an integral part of the "social structure of innovation" which to a large extent defines the Silicon Valley high technology complex. This opened up a unique window of opportunity for the emergence of a technology-oriented investment community apart from traditional financial institutions. Technologically-oriented finance then proceeded along a learning curve characterized by the gradual accumulation of investment and

management skills by venture capitalists and entrepreneurs alike. This in turn facilitated the development of extended networks for information sharing, deal making, and resource mobilization. It was only after the California industry was established that large financial institutions and firms headquartered elsewhere began opening up West Coast offices. Once in place, this technology focused complex began to attract entrepreneurs and accelerate the process of new business formation and innovation [47].

The New York and Chicago complexes offer ideal-typical examples of financial-oriented complexes. In contrast to California, both are dominated by venture capital funds tied to major financial corporations or other institutional sources of capital. The New York complex controls $3.2 billion in venture capital -- leaving it second to California, and is comprised of 95 venture capital funds. Venture capital in New York emerged in the 1930s and 1940s, when funds linked to wealthy New York families such as the Rockefellers (Venrock), Whitneys (J.H. Whitney and Co.) and Phipps (Bessemer Securities) began making venture investments. By the mid 1960s, large New York City commercial banks and investment houses began to establish venture capital subsidiaries. Many of the venture capital affiliates of large European financiers also opened offices in New York. Recently, venture capital funds headquartered in New York have begun opening remote branches in high technology regions like Silicon Valley and Route 128. Today, roughly half of all venture capital funds in New York are linked to financial institutions [48].

The Chicago complex is comprised of 23 funds which control approximately

$863 million, roughly half of all venture capital raised in the midwest. It emerged in 1960 when Allstate Insurance set up one of the first venture capital funds related to a large financial institution. Allstate made very successful investments in a host of high tech companies such as Control Data, Scientific Data Systems, and Memorex among others. These successes spurred Chicago commercial banks like the First National Bank of Chicago and Continental Illinois to become active in venture finance. By 1969, the former director of Allstate's venture capital affiliate left to start his own firm, Heizer Corporation, which in turn has been responsible for spinning-off a number of important venture capital companies. Like New York, Chicago exports most of its venture capital, with the bulk of it going to California [49].

Boston represents a hybrid venture capital complex. It controls $2 billion or 12 percent of the venture capital pool and is comprised of 60 venture capital firms. Boston was the home of the first institutional venture capital fund, American Research and Development (ARD) which was established in 1946. ARD was the creation of a group of prominent bankers and industrialists who saw such an entity as a way to more effectively finance technology oriented enterprises. By the early 1960s, large Boston financial institutions also became involved in venture capital. First National Bank of Boston established a program for providing loans to technology oriented businesses and formed an SBIC affiliate. Around the same time, Federal Street SBIC was established by a consortium of Boston banks. In additon, a significant number of early venture capital investments in the Boston area were made by private individuals and wealthy families both from the Boston area and New York City [50]

ARD's enormously successful investment in Digital Equipment Corporation (DEC) in the late 1950s provided a vital impetus to the inchoate Boston venture capital/high technology complex [51]. DEC played a significant role in the evolution of the Boston-Route 128 high technology center; it became an incubator for more that 30 spinoffs, most notably Data General. ARD itself became an incubator for venture capital funds. In 1963, Boston Capital Corp. was founded by ARD alumnus, Joseph Powell; and,by the 1970s, ARD alumni were instrumental in launching a host of top level partnerships such as Palmer, Greylock, Charles River Partnership and Morgan Holland. In 1968, Peter Brooke left his position as manager of First National Bank of Boston's high technology loan program and later went on to launch TA Associates which currently manages more than $1.5 billion in capital, making it the largest venture capital fund in the US.

As the technology base of the Boston region continued to develop, a host of partnerships were organized by veteran venture capitalists. Both Burr, Egan and Deleage and Claflan Capital Management were formed by former TA Associates employees, while the Venture Capital Fund of New England was established by the managers of First National Bank of Boston's venture group. The late 1970s and early 1980s also saw the formation of new funds such as Eastech and Zerostage and the movement of branch offices of funds headquartered elswhere, such as Bessemer Venture Capital, into the Boston area.

Our interviews with Boston venture capitalists indicate that the venture capital industry in Boston is not nearly as tightly organized as that of

California. There appears to be much less information transfer or coinvesting among Boston venture capitalists, although a number of Boston firms possess rather tight links to New York City venture capitalists. In contrast to California, a significant number of Boston venture firms are involved in large-scale financial transactions such as leveraged buyouts (LBOs) of established companies which clearly fall outside traditional venture capital activities. Boston venture capitalists also tend to export a greater share of funds than their California counterparts. They invest roughly one third of their funds in the New England region with sizeable shares going to California, New England and Texas. Even though Boston venture capitalists participate in a significant amount of long distance investing, the Boston venture capital complex remains an important component of the Boston-Route 128 innovation complex and the broader social structure of innovation which characterizes that area.

Investment syndication or coinvestment provides an important link between venture capital firms, especially those in different complexes. Syndication is the basic way that venture capital gets from financial complexes like New York and Chicago to technology centers such as Silicon Valley or Route 128. Coinvesting involves at least one "lead investor" located within commuting distance of the portfolio company, who provides technical assistance and functions to safegaurd the interests of the other venture investors. Syndication creates a symbiotic relationship between venture capital firms in financial and technology-oriented complexes. For the most part, venture capital firms located in financial complexes act as "passive investors,"

depending upon venture capitalists in technology-oriented complexes to assume the role of lead investor. While such firms are "free riders" on venture capitalists in technology regions, they provide significant infusions of capital thus allowing technology-oriented venture capitalists to initiate a greater range of investments and increase the overall scope of venture capital-financed innovation [52].

This is not to imply that venture capital-financed innovation takes place only in technology-oriented complexes such as northern California or hybrids like Boston. There are indeed numerous instances of venture capital financed innovation occuring in "remote" areas. It is just as clear however that a disproportionate share of innovative companies financed by venture capital are located in areas like Silicon Valley or Route 128 which possess high concentrations of technology-based enterprise, technology-oriented or hybrid venturing and rather well developed social structures of innovation.

LIMITS TO VENTURE CAPITAL-FINANCED INNOVATION

While venture capital-financed innovation accelerates the trajectory of technical progress, it can result in substantial misallocations of resources. A short term focus on capital gains means that portfolio companies may be moved into the IPO market without being afforded sufficient time to develop. Some commentators contend that increased availability of venture capital has given rise to "venture capital myopia" as venture capitalists duplicate one another's investments [53]. The recent shakeouts in the personal computer and computer disk drive industries provide recent as examples of the potentially

devastating consequences of this behaviour.

The existence of highly charged entrepreneurial environments fueled by venture capital heightens the incentives for job hopping, erodes employee commitment and seriously disrupts ongoing research or technological projects. Compounding this is what some observers have termed "vulture capitalism" [54], where venture capital firms actively target and entice corporate personnel and university researchers away from their regular posts. Such developments may pose serious consequences for the future of both corporate and university based innovation in the US by bidding up salaries and breaking up research teams.

Moreover, the remaining phases of the technology cycle are characterized by a significant reduction in the importance of venture capital-financed innovation. During the consolidation phase of the cycle, uncertainty over technological opportunities and market potentials diminishes and the emergence of significant scale economies means that large amounts of R&D and other investments become justified and shakeouts occur. At this point, most venture capital backed firms -- even ones that have grown significantly -- are poorly equipped to compete with large, vertically integrated corporations which possess significant internal resources. Over time then, the innovations pioneered by venture capital backed firms tend to be overtaken by large corporations either through sucessful imitation or via outright acquisition. And, because of the relatively low startup costs associated with most information intensive technologies and the relative openness of international technology transfer among the advanced industrial countries, this process is

more or less indiscriminate with regard to national boundaries [55].

CONCLUSIONS

The emergence of a formalized venture capital industry has transformed the nature of innovation in the US [56]. Venture capital-financed innovation overcomes a variety of barriers which stymie technological progress including: the risk aversion of established financial markets, the organizational inertia of large corporations, and the multifaceted technological, organizational and financial requirements of new business development. Generally speaking, venture capital financed-innovation accelerates the processes of technological innovation and business formation by combining resources and personnel drawn from a variety of organizations. In addition, venture capital financed-innovation occupies a particular niche in the technology cycle. It is of special importance during the early and chaotic stages of a technological thrust when the nature of nascent technology, its applications and market potentials are in flux [57].

Venture capitalists are agents of innovation, performing a technological gatekeeping function for the US economy. As focal points of social structures of innovation, they organize the myriad transactions and reduce the uncertainty associated with new business formation, and in doing so, catalyze the dynamic complementarities which exist between large corporations, universities, small companies and a variety of related organizations. They are not omniscient with regard to technological change but draw their power from the wide ranging contacts and networks at their disposal.

While venture capital financed-innovation has implications for the entire US economy, it generally takes place in a few specific areas. Technology-oriented, financial-oriented and hybrid complexes play distinct roles in this process. Venture capitalists in technology-oriented or hybrid complexes locate investments typically in local markets and then draw upon the resources provided through coinvestments with their counterparts in financial-oriented complexes. This symbiotic relationship increases the overall scope and power of venture capital-financed innovation.

However, the emergence of venture capital-financed innovation poses some serious implications for the competitive position of the US economy and its innovatory component. These revolve around the myopic development of young companies, the disruption of ongoing R&D in large institutions and the relatively open international context within which venture capital-financed innovation takes place. More importantly, the establishment of a set of powerful financial incentives for entrepreneurially-based (new company) innovation creates strong biases in favor of proprietary products or technologies and away from improvement innovations in manufacturing techniques and processes. In these ways, venture capital-financed innovation functions to skew the trajectory of sociotechnical innovation.

The innovation process in the US is currently distinguished by an evolving set of complementary relationships between large and small institutions, which are to a significant extent mediated by venture capital. Whether this set of ad hoc arrangements can be transformed into a coherent system of institutional relations which ensure that technological

breakthroughs can be diffused throughout the US economy remains one of the most crucial issues for the competitive situation of the US and its role in future global economic restructuring.

NOTES AND REFERENCES

1. We would like to acknowledge the information and assistance provided by the following venture capitalists in the Midwest, Northern California and Boston. David Morganthaler and Charles James who are headquartered in Cleveland and Columbus, Ohio respectively, gave us invaluable assistance in launching our research. Venture capitalists we interviewed in Northern California include: David Arscott, James Balderston, Frank Chambers, William Chandler, Thomas Davis, Reid Dennis, John Dougery, William Edwards, Mary Jane Elmore, Franklin Johnson, Burton McMurtry, Steve Merrill, Peter Roshko, Craig Taylor, David Wegman, and Paul Wythes as well as Henry Riggs of Stanford University. Those interviewed in Boston were: Peter Brooke, William Burgin, Richard Burnes, Craig Burr, Thomas Claflan, Daniel Gregory, Paul Hogan, Joseph Powell, Patrick Sansonetti, John Shane, and Courtney Whiten.

2. While the majority of venture capital financing has focussed on high technology industries, venture capitalists also make important investments in non-technology areas. For example, venture capitalists provided funding for Federal Express, the original overnight mail delivery service. Although this was not a purely technical innovation, Federal Express established an entirely new market for mail delivery and as such can be considered as to be a "sociotechnical" innovation. An excellent description of the dimensions of sociotechnical innovation is presented in H. Brooks, Social and Technological Innovation, In S. Lundstedt and E. Colglaizer (editors) Managing Innovation (Pergamon, New York, 1982).

3. For further discussion of venture capital flows to various industrial sectors, see, J. Timmons, N. Fast, W. Bygrave, The Flow of Venture Capital to Highly Innovative Technological Ventures, in J. Hornaday, J. Timmons and K. Wesper (eds.), Frontiers of Entrepreneurship Research, 1983 (Babson College, Center for Entrepreneurial Studies, Wellesley, MA, 1983) 316-35. Venture Economics, The Venture Capital Industry: Opportunities and Considerations for Investors (Venture Economics, Wellesley, MA, 1985). Venture Economics, Venture Capital Yearbook (Venture Economics, Wellesley, MA, 1985).

4. The idea of "gales of creative destruction" is of course associated with Schumpeter. See, J. Schumpeter in The Theory of Economic Development (Harvard University Press, Cambridge, MA, 1934); and J. Schumpeter as abridged by Reindig Fels, Business Cycles (McGraw-Hill, New York 1964). Basically, Schumpeter saw irregular clusters of innovation as crucial to the wave like expansions of capitalist societies. For Schumpeter, innovation occurs discontinuously and is spread unevenly over time and across industrial sectors. The technological and organizational innovations pioneered by exceptional entrepreneurs have strong band-wagon effects; it is these swarms of innovations that set the stage for a new round of economic growth. Clusters of innovation disrupt and destroy established ways of doing business (industrial organization) and redefine what is required to compete effectively. By germinating new industries and redefining old ones, these "gales of creative destruction" become vehicles for economic growth. A concise summary of the Schumpetarian schema is provided by N. Rosenberg and C. Frishtak, Technological Innovations and Long Waves, Cambridge Journal of Economics 8 (1984) 7-24. To quote Rosenberg and Frishtak: "In Schumpeter's view, technological innovation is at the center of both cyclical instability and economics growth with the

direction of causality clearly moving from fluctuations in innovation to fluctuations in investment and from that to cycles in economic growth. Moreover Schumpeter sees innovations as clustering around certain points in time -- periods that he referred to as neighborhoods of equilibrium, when entrepreneurial perceptions of risks and returns warranted innovative commitments. These clusterings lead in turn to long cycles by generating periods of acceleration (and eventual deceleration) in aggregate growth rates."

5. On venture capital as a form of investment see, A. Bean, D. Schiffel and M. Mogee, The Venture Capital Market and Technological Innovation, Research Policy 4 (1975) 380-408.

6. Survey data reported by the U.S. Congress Joint Economic Committee, Venture Capital and Innovation (U.S. Government Printing Office, Washington, D.C., 1984) indicates that approximately 90 percent of all venture capital investments involve coinvestors at some point.

7. See G. Kozmetsky, M. Gill, and R. Smilor, Financing and Managing Fast-Growth Companies: The Venture Capital Process (Lexington Books, Lexington, MA, 1985). U.S. General Accounting Office, Government-Industry Cooperation Can Enhance the Venture Capital Process (U.S. Government Printing Office, Washington, D.C., 1982).

8. In addition, loans which are made to new businesses generally carry high rates and short terms. Repayment is an onerous burden for young companies which require substantial inflows of capital during early growth stages and

cannot afford sizeable outflows to cover interest and principal. In addition, the loan officers employed by banks frequently do not understand the technical dimensions of high technology business formation. The literature on bank lending to start up companies and small business is extensive. A good summary of these materials is provided in. U.S. Small Business Administration, The State of Small Business: A Report to the President (U.S. Government Printing Office, Washington, D.C., 1986).

9. This data is based on an unpublished study by the consulting firm, Horsley, Keogh and Associates, which evaluated the performance of ten venture capital partnerships for the ten year period 1972-1983. During this time, the value of investments increased form $239 million to $823 million, representing a time weighted rate of return of 35 percent. The 56 successful investments (which returned at more than 5 times cost) accounted for a disportionate share of this increase; they rose in value from an original investment of $32 million or 10.9 percent of the total to $450 million or 54.7 percent of the final value of investments. Of the remaining 469 investments, 135 or 25 percent (which accounted for an original investment of $99 million) decreased in value returning just $26 million, while another 131 returned at cost ($40 million). An additional 200 investments performed slightly better than double original investment increasing in value from $122 million to $307 million. For further discussion, see B. McMurtry, Tax Policy Influence on Venture Capital, In R. Landau and D. Jorgenson (editors), Technology and Economic Policy (Ballinger Press, Cambridge, MA, 1986) 140-43.

10. A thorough discussion of limited partnerships can be found in Venture Economics [3]. Venture capital partnerships are also structured to prevent

partners from leaving the fund after the most important investments have realized their value. Basically, returns are vested over the life of the partnership so that gains are realized toward the end of the partnership term. The problem of "job hopping" is also mitigated by the small size of the venture capital community which creates strong disincentives for such blatantly self-interested behavior.

11. Three of these factors have been operationalized in a model developed by W. Bygrave and J. Timmons, An Empirical Model of the Flows of Venture Capital, In J. Hornady et al (editors) Frontiers of Entrepreneurship Research (Center for Entrepreneurial Research, Babson College, Wellesley, MA, 1985). Their model indicates a very strong positive relationship between activity in the market for initial public offerings (IPO) and the cyclical flow of venture capital. It also shows strong positive correlations between changes in pension fund legislation and reductions in the rate of taxation for capital gains and the recent increase in the total venture capital pool. See, also, Sahlman [25]; Case [23]).

12. Examples of funds tied to commercial banks include Citicorp and First National Bank of Chicago, while those affiliated with investment banks and brokerages include: Merrill Lynch; Drexel, Burnham, Lambert (Lambda); Smith Barney (First Century Partnership); and Donaldson, Lufkin and Jenrette (Sprout Group). Venture capital affiliates of investment banks operate more like traditional partnerships then those affiliated with large commercial banks. Since they have direct access to significant blocks of capital, venture capital concerns tied to large commercial banks do not face competitive pressure to generate funds from external sources. In addition, sponsoring banks often

encourage venture capital affiliates to commit capital which will generate rates of return in excess of that of the sponsor but which may fall short of the rate of return achieved by preminent venture capital partnerships. This point was reinforced in interviews with John Dougery, a former Citicorp employee who is now a member of the limited partnership Dougery, Jones and Wilder, and David Wegman, currently with Citicorp Ventures in Palo Alto, CA.

13. For further detail on venture capital subsidiaries, large industrial corporations see, Charles River Associates, An Analysis of Capital Market Imperfections, (Charles River Associates, Inc., Cambridge, MA, 1976). W. Mears, Corporate Venture Capital: Can It Be Successful (Master's Thesis, Sloan School of Management, MIT, Cambridge, MA, 1981). Venture Capital Journal (November, 1985) 6-13.

14. A thorough discussion of the history of the SBIC program is provided in C. Noone and S. Rubel, SBICs: Pioneers in Organized Venture Capital (Capital Publishing, Chicago, 1970).

15. The focus of this paper concerns the organized venture capital industry in the U.S. It should be noted however that independent investors referred to as "informal investors" or "angels" contribute significant amounts of pre-venture capital to early stage businesses. While the role of informal investors is clearly an important one, it is impossible to generate reliable data by which to analyze their role in technological innovation or economic development. For further elaboration, see W. Wetzel, Angels and Informal Risk Capital, Sloan Management Review (24) 23-34.

16. Further detail on the historical development of the venture capital industry is presented in the section on the evolution of venture capital complexes.

17. See especially, W. Abernathy and J. Utterback, Patterns of Industrial Innovation, Technology Review (June/July, 1978) 41-7.

18. A. Bean, D. Schiffel and M. Mogee, see [5].

19. T. Tyebjee and A. Bruno, A Model of Venture Capitalist Investment Activity, Management Science 30 9 (1984) 1051-66.

20. Executives of successful portfolio companies are particularly important to venture capital deal flows. Their industry experience and contacts afford them special access to high potential entrepreneurial groups and business proposals, which they in turn refer to venture capitalists. Law firms specializing in venture capital are also important; they provide a steady stream of referrals, match entrepreneurs to potential investors and are involved in negotiations that are critical to forging new business ventures. Law firms which specialize in new venture activity are retained by both venture capitalists and high technology startups. For example, one of the top West Coast venture law firms, Wilson, Sonsini, Goodrich and Rosati has a client list which includes venture capital firms such as Mayfield Fund, Hambrecht and Quist and Sequoia Capital as well as high tech companies like ROLM Corporation and Apple Computer. Other venture law firms in Silicon Valley include Cooley, Godward, Castro, Huddleston, and Tatum; and Brobeck, Phelger and Harrison. East Coast firms specializing in venture capital include Reavis and McGrath in New York City and

Testa, Hurvitz and Thibeault in Boston. For further information see Venture (January 1987) 48-54.

21. While business plans are generally financed from informal sources such as personal savings, family or friends, venture capital firms will at times provide "seed capital" to finance the development or improvement of a particularly promising proposal. When necessary, venture capital firms will utilize outside consultants or other venture capitalists to evaluate business proposals outside their areas of expertise. The crucial role of the entrepreneurial team in evaluations made by venture capitalists is illustrated by the conclusion drawn from an empirical study of venture capital decision making by I. Macmillan, R. Siegel and P. Narashima, Criteria Used by Venture Capitalists to Evaluate New Business Proposals, Journal of Business Venturing 1 1 (1985) 119-28.

22. W. Burgin (General Partner, Bessemer Venture Partners), Interview by authors (June 1987).

23. D. Case, An Overview of Venture Capital, Unpublished paper (Hambrecht and Quist, San Francisco, CA, 1986).

24. T. Davis, (General Partner, Mayfield Fund), Interview by authors (December 1986).

25. H. Soussou, Note on the Venture Capital Industry (Harvard Business School Case No. 9-285-096, Cambridge, MA, 1981); and H. Soussou, Note on the Venture Capital -- Update (Harvard Business School No. 0-286-060, Cambridge, MA, 1985).

26. There is a significant economic rationale for this. The venture capitalists usually receive a management fee of approximately 2-3 percent of paid in capital per year. Since this management fee only covers salaries and business expenses, the payoff for the professional venture capitalist comes after returning an agreed upon percentage to the limited partners, at which point an override share of approximately 20 percent of further profit is retained by the general partner.

27. For further discussion see C. Freeman, J. Clark and L. Soete, Unemployment and Technical Innovation (Francis Pinter, London, 1982). R. Rothwell, Venture Finance, Small Firms and Public Policy in the U.K., Research Policy 14 (1985) 253-65. R. Rothwell, The Role of Small Firms in the Emergence of New Technologies, OMEGA: The International Journal of Management Science 12 1 (1984) 19-29. R. Rothwell, Firm Size and Innovation: A Case of Dynamic Complementarity, Journal of General Management 8 3 (1983).

28. Freeman et al, see [27].

29. See, Freeman et al; Rothwell 1985, 1984, 1983, see [27].

30. A. Cooper, The Role of Incubator Organizations in the Funding of Growth Oriented Firms, Journal of Business Venturing 1, 1 (1985) 75-86.

31. For further discussion of these mechanisms see E. Roberts and O. Hauptman, The Process of Technology Transfer to the New Biomedical and Pharmaceutical Firm, Working paper (MIT, Sloan School of Management, Cambridge, MA, 1985). T.

Allen, D. Hyman and D. Pinckney, Transfering Technology to the Small Manufacturing Firms: A Study of Technology Transfer in Three Countries, Research Policy 12 (1983) 199-211.

32. The ability of large US firms (i.e., IBM, Radio Shack and ATT) as well as Japanese ones (i.e., Epson, NEC and Hitachi) to build upon and at times improve upon new technology illustrates another side of the symbiotic relationship between large and small companies. Recently, large and small corporations have struck up a variety of "strategic partnerships" for development, production and distribution of both microcomputer and semiconductor technologies. For example, IBM has recently taken a 14 percent equity interest in Intel, the exclusive supplier of specialized chips for the new generation of IBM personal computers. Venture capital backed firms have also entered partnerships with large European and Japanese companies. Fujitsu, the largest Japanese computer manufacturer recently made an unsuccessful offer to purchase Fairchild from Schlumberger, a Dutch company. Strategic partnerships pose problems for both large and small partners. The small company constantly faces the threat of absorption and/or abandonment by its larger counterpart. The large company faces the less serious threat of increased competition from its smaller partner. This issue becomes significantly more complicated when multinational partnerships and cross border transfers of technology are taken into account. For further discussion of strategic partnering see, D. Teece, Capturing Value from Innovation: Integration, Strategic Partnering and Licensing Decisions, Working Paper (University of California, Center for Research in Management, Berkeley, CA, 1986). D. Teece, Innovation, Trade and Economic Welfare: Contrasts Between Petrochemicals and Semiconductors (University of California, Center for Research in Management, Berkeley, CA, 1985). J. Friar and M.

Horwitch, The Emergence of a Technology Strategy: A New Dimension of Strategic Management, Technology in Society 7 (1986) 143-78. H. Brooks, Can Science and Technology Rescue the Faltering U.S. Economy, Unpublished paper (Harvard University, John F. Kennedy School of Government, Cambridge, MA, 1986).

33. The conception of venture capital in terms of networks has been suggested in L. Suran, M. Maidique and D. Smith, The Venture Capital Industry in Florida and the Southeast: In Search of the Seeds, Research paper (Innovation and Entrepreneurship Institute, University of Miami, Coral Gables, Florida, 1986).

34. R. Kanter, The Change Masters (Simon and Schuster, New York, 1984).

35. A sizeable body of neo-Schupetarian research focuses on the relationship between innovation and economic expansion. Empirical work by G. Mensch Stalemate in Technology (Ballinger Press, Cambridge, MA, 1979) indicates that major breakthroughs tend to bunch during economic depressions and that these basic innovations set the stage for a long wave period of accelerated technological change and economic growth. C. Freeman et al [27] come to a somewhat different conclusion placing greater emphasis on the role of imitative activity, increment innovation and technological diffusion during recovery phases, suggesting a more random distribution of innovation through a long wave period. J. Van Dujin, Fluctuations in Long Waves Over Time, In Christopher Freeman (editor), Long Waves in the World Economy (Frances Pinter, London, 1984), research also supports the idea of imitative swarming and bandwagon effects during long wave expansions. More recent research by S. Solomou, Innovation Clusters and Kondratieff Long Waves in Economic Growth, Cambridge Journal of Economics 10 (1986) 101-12, rejects Mensch's notion of tight

clustering and raises serious questions regarding the empirical validity of the swarming hypothesis as a causal explanation for the movement of long waves, although Solomou's work does not refute the conclusions of Freeman et al regarding the swarming of innovations during the postwar period. Despite these empirical disputes, there is wide agreement in the literature that once an original swarm or cluster of innovations is set in motion (and a set of dominant designs achieved), it creates significant sociotechnical constraints which guide further technological progress.

36. On natural trajectories see, R. Nelson and S. Winter, An Evolutionary Theory of Economic Change (Harvard University Press, Cambridge, MA, 1982). On technological trajectories see, G. Dosi, Technological Paradigms and Technological Trajectories, Research Policy 2 3 (1982).

37. C. Freeman et al [27]; Also, C. Freeman and C. Perez, The Diffusion of Technical Innovation and Changes of Techno-Economic Paradigm, Paper presented at the Conference on Innovation-Diffusion, Venice, Italy (17-22 March, 1986). Recent work by the Marxist regulation school of political economy makes a similar point, see, M. Aglietta, A Theory of Capitalist Regulation (New Left Books, London, 1979). P. Blackburn, R. Coombs and K. Green, Technology, Economic Growth and the Labour Process (St. Martins Press, New York, 1985). A. Roobeek, The Crisis in Fordism and the Rise of a New Technological Paradigm, Futures forthcoming. Also, M. Piore and C. Sabel, The Second Industrial Divide (Basic Books, New York, 1984).

38. R. Ayres, Technological Progress in Economics on Theories of Innovation,

Unpublished paper (Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA, 1986):16-18.

39. This does not imply that large corporations are unimportant in placing technology bets. Here, the historic role played by Bell Laboratories in pioneering a series of important innovations in the US is exemplary. However, recent years have seen large corporations -- especially US corporations -- recede from directly innovative activity, although they certainly help to establish the technological infrastructure within which innovative activity takes place. This is in part the result of venture capital-financed innovation which has generated increased incentives for employees to leave large corporations.

40. For a history of Fairchild Semiconductor, see E. Braun and S. Macdonald, Revolution in Miniature: The History and Impact of Semiconductor Electronics, Second Edition (Cambridge University Press, New York, 1982). On venture capital role see, J. Wilson, The New Venturers: Inside the High Stakes World of Venturing (Addison-Wesley Publishing, Reading, MA, 1985) 33-4.

41. In 1961, four members of the original Fairchild group founded Signetics with venture capital from Dow Corning. Two others -- Charles Sporck and Donald Valentine -- later moved to National Semiconductor Corp, while still another launched Advanced Micro Devices. Noyce went on and found the important semiconductor firm Intel in 1968 with backing from Rock. Rock also provided venture capital for Intersil, Inc. which was started by Jean Hoerni, another of Fairchild's original founders. See, Wilson p. 38, [40].

42. A. Braun and S. Macdonald, p. 126-7, see [40]. A. Markusen, Profit Cycles, Oligopoly and Regional Development (MIT Press, Cambridge, MA, 1985) p. 111.

43. On the personal computer industry, and Apple, in particular, see, J. Friar and M. Horwitch, see [32]. E. Rogers and J. Larsen, Silicon Valley Fever (Basic Books, New York, 1984) pp. 11-14.; T. Forrester High Tech Society (MIT Press, Cambridge, MA, 1987)

44. For further detail on the biotechnology industry see, M. Kenney, Biotechnology: The University-Industry Complex (Yale University Press, New Haven, CT, 1986). M. Kenney, Schumpeterian Innovation and Entrepreneurs in Capitalism: The Case of the U.S. Biotechnology Industry, Research Policy 15 (1986) 21-31.

45. Adapted from R. Florida and M. Kenney, Venture Capital, High Technology and Regional Development, Regional Studies (1987) forthcoming. R. Florida and M. Kenney, A Typology of the Venture Capital Industry: Financial Versus Technology Oriented Complexes, Working paper (Technology, Innovation and Social Change Project, Department of City and Regional Planning, Ohio State University, Columbus, Ohio, 1987). All statistics presented in this section are adapted from these papers.

46. Much of our discussion of the evolution of the northern California venture capital complex is based upon our interviews venture capitalists in San Francisco and Silicon Valley. Additional background was from J. Wilson [40], various back issues of the Venture Capital Journal and a poster depicting the

history of West Coast venture capital distributed Asset Management Associates, Palo Alto, California.

47. This "accelerator effect" occurs both indirectly and directly. Entrepreneurs are induced to locate in entrepreneurial environs where venture capital and other types of services which enhance to potentials for new business formation are readily available. Such areas are also characterized by a set of sociocultural as well as financial incentives that encourage entrepreneurial activity. For example, the development of a business plan is considered to be criteria of personal success in the Silicon Valley area. In addition, our interviews with venture capitalists indicate that they will at times suggest that promising startups relocate in order to reduce the opportunity costs associated with business development. Venture capitalists will provide office facilities for such relocations.

48. Our discussion of the New York venture capital complex relies upon Venture Capital Journal, January 1976 and October 1979 issues.

49. Our discussion of the Chicago venture capital complex relies upon Venture Capital Journal, (1975). G. Bylinsky, The Innovation Millionaires: How They Succeed (Charles Scribner's Sons, New York, 1976).

50. Our discussion of the Boston venture capital complex draws upon our interviews with venture capitalists in the Boston area. Supplementary information was obtained from P. Liles, Sustaining the Venture Capital Firm (Management Analysis Center, Cambridge, MA, 1977). J. Wilson, see [40].

Venture Capital Journal, various issues. R. Adams, The Boston Money Tree (Thomas Y. Crowell, New York, 1977).

51. On the Route 128 technology complex see, N. Dorfman, Route 128: he Development of a Regional High Technology Economy, Research Policy 2, 3 (1983) 299-316.

52. For more on investment syndication see Florida and Kenney [45].

53. W. Sahlman and H. Stevenson, Capital Market Myopia, Journal of Business Venturing 1, 1 (1985) 2-30.

54. J. Wilson, pp. 191-3, see [40].

55. This has led at least one commentator to point out the perverse impacts that flow from a U.S. technology strategy focussed near exclusively on venture backed, entrepreneurial startups. "There is little reason to suppose that further increases in entrepreneurial incentives -- say, through further tax advantages to new venture investment -- would increase the vitality or success of ... the American [semiconductor] industry. More likely, such policies would effect a net transfer from existing producers to some combination of new venture founders and Japanese industry, reducing the long-run growth of U.S. technology and production. This is not to say that small, entrepreneurial firms and the venture capitalists that finance them] serve no function in the market. But they serve many masters indiscriminately; and since Japanese firms are far more discriminating in return, the result ... is that the American startup sector hastens its own demise and that of American electronics

generally." C. Ferguson, American Microelectronics in Decline: Evidence, Analysis and Alternatives (Program on Science, Technology and Society, MIT, Cambridge, MA, 1985).

56. The role of "informal" networks of investors is not without historical parallels. Indeed, major transformations of the U.S. industrial structure have frequently called forth new sets of financial intermediaries. See B. Supple, A Business Elite: German-Jewish Financiers in Nineteenth Century New York, Business History Review (1957). For example, initial financing for major railroad expansions to the Midwest and South was provided by a tightly networked group of Boston merchants who located deals on the basis of contacts and pooled funds on the basis of trust. This discussion is contained in A. Chandler, Patterns of American Railroad Finance, 1830-1850, Business History Review (September 1954) 248-63.

57. Since the early 1980s policymakers in other OECD countries have tried to encourage venture capital. See, for example, Organization for Economic Cooperation and Development, Venture Capital and Information Technology (OECD, Paris, 1985). OECD, Venture Capital: Context, Development and Policies (OECD, Paris, 1987). Venture Capital Journal, The Internationalization of the Venture Capital Industry (Venture Economics, Wellesley, MA, November, 1985). The ultimate success of these efforts seems in doubt, though some success has been achieved in the United Kingdom. For discussion of the development of venture capital in the United Kingdom see, Venture Capital Journal, Special Report: The Venture Capital Industry in the United Kingdom, (Venture Economics, Wellesley, MA, August, 1984). For West Germany see, G. Fels, More Risk Capital for Private Enterprise, in H. Giersch, New Opportunities for Entrepreneurship:

Symposium 1983 (J.C.B. Mohr, Tubingen, 1983). Classical venture capital in Japan has had only marginal success and does not appear to be growing. P. Brooke, Interview by authors (1987). Y. Ayukawa (President, Technoventure, Inc.), Interview by authors (1985). For the best written discussion see, M. Kinefuchi, The Venture Capital Industries in the U.S. and Japan (Masters thesis, International University of Japan, Niigata, Japan, 1986).

Of course, with Western European and Japanese financial institutions and corporations have activley invested in U.S. venture capital funds. Most notable among these is TA Associates which has successfully attracted investors through its Advent International Corporation. TA Associates also manages European venture capital investments of Western European financial intersts, although it is difficult to assess the success of these investments at this time. P. Brooke, Interview by authors, (1987). In addition, numerous important venture capital limited partnerships also have received investments from Japanese and European sources.

The crucial role of interactive networks raises some serious questions regarding the efficacy of technology policy strategies premised upon the provision of public venture or equity capital in areas of the developed or the developing world which lack the requisite technology infrastructure.