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FINANCIERS OF INNOVATION:

Venture Capital, Technological Change, and Industrial Development

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Richard Florida

H. John Heinz III School of Public Policy and Management
Carnegie Mellon University
Pittsburgh, PA 15213
FAX: (412) 268-5161
e-mail: rlflorida@aol.com

Martin Kenney

Department of Applied Behavioral Sciences
University of California, Davis
Davis, CA 95616

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Preface and Acknowledgements

This book is the product of more than a decade of research and collaboration. While it is our third book, it comes from the initial project which brought us together. Our work on this book began in 1985, not long after we arrived on the Ohio State University campus as assistant professors. Martin Kenney had come from Cornell University where he completed a dissertation, later published as a book, on the evolution of the U.S. biotechnology. Richard Florida had come from Columbia University, where he was completing a dissertation on the impact of the deregulation of financial institutions on patterns of housing and regional development. We spent a lot of time in those days discussing our joint interests in technological innovation, finance, and regional economic development, and our idea to jointly explore the world of venture capital sprang from those discussions.

Debts are always incurred in research undertakings like this one, but in this case we have accrued more than usual. Our largest debt goes to a series of collaborators whose work is reflected in this volume. While we began the work on venture capital and regional development in 1985 and 1986, Donald Smith came aboard as a doctoral student at carnegie mellon University in 1988 and added immeasurably to that work. Smith helped to design and to supervise the construction of the database on venture capital investments and conducted the statistical analyses reported in Chapter 9 and in the Appendix to this volume. He collaborated on a series of journal articles and book chapters, which are reflected in that chapter and on two reports to the Economic Development Administration. Mark Samber collaborated on the historical analysis reported in Chapter 3, while completing his doctoral dissertation in Applied History at Carnegie Mellon University. David Talento conducted the interviews for the case study of MIT and

American Superconductor reported in Chapter 2, while he was a master's student in public policy and management at Carnegie mellon University. David Browdy collaborated with Richard Florida on the case study of flat panel displays, both in conducting the interview and in a jointly authored paper that appeared in *Technology Review*. MARTIN MENTION THE ROLE OF URS SOMEWHERE IN THIS PARAGRAPH. We also want to acknowledge those who have helped move this work through their invaluable research assistance: Mark Clark and Elizabeth Sechoka, who assisted in the creation of the venture capital database reported in Chapter 9 and Raphael Vesga and Jean Essner who assisted with aspects of the analysis in Chapter 10.

We were very fortunate to recieve generous financial support for this work from a variety of sources funders. Our initial work on this subject was supported by a series of grants from the Ohio State University made during the period 1985 through 1987. Those grants were invaluable to our being able to conduct the initial interviews and data collection that informed this project and related projects. Our work was also supported by two grants from the Economic Development Administration of the U.S. Department of Commerce. We want to acknowledge a special debt to Dr. David Geddes and Dr. John Feiser of the Economic Development Administration for supporting this work. We also want to thank, Jack Repcheck, our editor at Princeton University Press, for his support over the years.

We owe a huge debt to the many venture capitalists, researchers and engineers, entrepreneurs, managers, government officials, and workers, who gave selflessly of their time to engage in interviews with us. We hope that our work on this book can somehow repay the time, energy and ideas they shared with us.

Richard Florida would like to thank his colleagues at Carnegie Mellon University's Heinz School and Center for Economic Development for providing a stimulating and supportive environment, particularly Mark Kamlet, Don Smith, Wes Cohen, David Hounshell, Jack Thorne, Angel Jordan, Ron Rohrer and Ashish Arora. He would also like to acknowledge support provided by the Science, Technology and Public Policy at Harvard University's John F. Kennedy School of Government for a year-long sabbatical in 1995-1996, particularly Harvey Brooks and Lewis Branscomb for their comments and collegiality. And, he would like to acknowledge, Joyce-Nathalie Davis-Florida, for taking time away from her own projects to be a source of support and a sounding board for ideas.

MARTIN TO PLACE PERSONAL ACKNOWLEDGEMENTS HERE

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> "Venture capital is the business of developing new businesses. Venture capitalists like to start things, to create something from nothing, to stimulate and encourage innovation." Burton McMurtry, Technology Venture Investors, a leading Silicon Valley venture capital fund.[1]

> "I want to build great companies that's how I get my kicks. I look for people who want to do the same thing." Arthur Rock, venture investor in Fairchild, Apple and Intel.[2]

> "It is not venture capital that is the start of entrepreneurial activity. You can't simply put six venture capitalists in Butte, Montana and expect that the availability of venture capital will engender a Route 128." Daniel Holland, Morgan Holland one of Boston's leading venture capital funds.[3]

PART I: VENTURE CAPITAL, INNOVATION, AND INDUSTRIALIZATION

CHAPTER 1

FINANCIERS OF INNOVATION

In 1976, the venture capitalist, Robert Swanson recruited Herbert Boyer, a University of California-San Francisco scientist to form a new startup company in the emerging field of biotechnology. Working at the frontiers of academic science, Boyer along with Stanley Cohen of Stanford University had made the fundamental scientific discovery in the biotechnology field - the Cohen-Boyer gene splicing patent. A venture capitalist with the influential firm, Kleiner Perkins, Sawnson became aware of the huge commercial potential of genetic engineering and was looking to form a new company to exploit this possibility. With $100,000 in venture capital, Swanson joined with Boyer to found Genentech, launching the biotechnology revolution.

In January 1987, Gregory Yurek and John Vander Sande, made an important discovery. Working in their MIT laboratory over winter recess, the two professors had professors at MIT concluded that they could produce a new class of ceramic superconductors. On the look-out for research funding to continue their work, the two approached John Preston of the MIT Licensing Office, with the idea of patenting their innovation to generate research funds, perhaps through licenses on the technology. Seeing commercial promise, Preston immediately connected the two with the venture capitalist, George McKinney of the influential Boston firm, American Research and Development. And, in just few months, McKinney invested $100,000 in venture capital and a new company was borne - American Superconductor Corporation.

In late 1987, the seasoned venture capitalist, Donald Valentine, an original investor in

Apple Computer, heard about advances in the field of computer networking that were being made by a fledgling start-up, Cisco Systems. Formed in 1984, by a husband and wife team and Stanford, Cisco Systems pioneered the use of routers to connect two computer networks and share software and data. When Valentine found them, their fledgling company, still privately held by the two, had revenues of $250,000 per month and was growing rapidly. With Valentine supplying capital and business savvy, the company grew wildly and by the end of 1989 had over 400 customers worldwide. By 1996, its stock value equalled that of General Motors.

The list of companies financed by venture capitalists since the 1960s reads like a veritable who's who of American high-technology: Intel, Microsoft, Netscape, America On-Line, Compaq, Apple Computer, Sun Microsystems, Oracle, Cisco Systems, Genentech and countless others. By providing critical risk capital and a wide range of business assistance to fledgling enterprises, venture capitalists have accelerated and indeed catalyzed the rise of many of the key science and technology based industries of the late 20th and 21st centuries - semiconductors, personal computers, software, computer networks, internet services, and biotechnology. And, clearly, the vibrancy and rapid growth of California's Silicon Valley and the Route 128 area around Boston owe much to the powerful growth cycles powered by the venture capital and entrepreneurial high-technology.

The past two decades have seen a virtual explosion in venture capital. The total amount of venture capital in the United States surged from $2.4 billion in 1969 to $4.5 billion in 1980, and more than $35 billion by 1990, reaching $37 billion by 1995 **[see Figure 1.1]**. The amount of venture capital that is invested in companies annually also skyrocketed, increasing from less than $600 million in 1980 to $4 billion in 1987 **[see Figure 1.2]**. And, most of this capital -

more than three-quarters of it - goes to finance high-technology businesses. Topping the list of industries financed by venture capital in 1995 were computer software, biomedical products, telecommunications, biotechnology, computer hardware, and other high technology fields.

[Figures 1.1 and 1.2 about here]

Venture finance differs from more traditional forms of finance in several fundamental respects.[4] Venture capitalists invest in new, unproven enterprises, often without any collateral other than promising ideas. To do so, venture capitalists exchange equity for an ownership stake in the enterprise instead of providing more traditional forms of debt or loan finance which require real collateral and a regular repayment schedule. Venture capitalists are actively involved in the strategic development and management of the enterprises in which they invest. Thomas Doerflinger and Jack Rivkin describe venture capital as "smart money" - that is, "money that is imbued with the entrepreneurial savvy, business contacts, executive talent, and patience of financiers with long experience in helping small companies succeed."[5] *Venture Economics*, a leading authority on the venture capital industry, defines venture capitalists as "participating investors seeking to add value through long term involvement with continuing business development."[6] To spread risk and mobilize capital, venture capitalists seldom invest alone, but participate in co-investment syndicates comprised of two or more venture investors.

This book examines the role of venture capital in the processes of technological change and economic development. In writing this book, we seek to provide an analysis of venture capital which goes beyond the highly descriptive - some might say journalistic - analysis which pervades so much of the writing on this topic. Despite the importance of venture capital to the processes of technological innovation and economic development, there are just several books which examine this subject.[7] We hope to contribute to the understanding of venture capital's role in industrial development, by situating it in terms of theories of innovation and industrial development, particularly the theory of technological change and economic development associated with the economist, Joseph Schumpeter.

In the folliwng pages, we explore the historical factors which have shaped the origins and evolution of the venture capital system in the United States. We probe the key organizational innovations which have shaped that system and the logic and incentives which drive it. And, we examine the ways through which venture capital affects the broader processes of technological innovation, the rise of new industries and the development of regional economies.

Venture Capital, Technological Innovation and Economic Development

The basic argument of this book is that the modern venture capital system provides an institutionalized source of capital and capabilities which together formalize the roles historically played by the entrepreneur and independent financier and thus help to set in motion the gales of creative destruction which Schumpeter hailed as so vital to the expansions of capitalist economies. In this sense, we suggest that venture capitalists act both as capitalists and catalysts, setting in motion the processes of technological change, business formation and economic development. Through their work, venture capitalists assist new enterprises in overcoming a host of financial, technological and organizational barriers to innovation and growth. In doing so, they compress the time it takes to turn ideas into commercial realities and accelerate the pace of technological innovation.[8]

In developing this line of argument, we draw from the work of Joseph Schumpter. While the classical economists from Adam Smith to Karl Marx outlined the broad relationship between capital and industrial development, by far the clearest statement of capital's role in the processes of innovation and economic development was provided in Schumpeter's classic work, *The Theory of Economic Development*.[9] In Schumpeter's view, capitalism is an inherently dynamic economic and social system; the source of such dynamism lies in the process of innovation. Powering the process of economic development is the phenomenon Schumpeter referred to as *creative destruction*, which "incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one."[10] The linchpin of this process, Schumpeter observed, was the entrepreneur, whose function is to "carry out new combinations" of products, markets, supplies, raw materials, and business organizations required for technological innovation and economic growth. Schumpeter further explained that new financial forms at times emerge to assume the risk and uncertainty associated with technological innovations and the rise of new entrepreneurial firms and industries. He emphasized the role of new financiers in supporting entrepreneurs in their quest to carry out these new combinations in the process of creative destruction.[11] For Schumpeter, the provision of capital and credit to entrepreneurs is a vital element of a dynamic capitalist economy, indeed, "important enough to serve as its *differentia specifica.*[12]

Following Schumpeter, we argue that new forms of venture finance are typically required to finance the birth of new technologies and business organizations, and the more general process of technological and industrial development. This is part of the broad process of American industrial development, dating back far before the much ballyhooed high-technology revolution of the present day. In our view, the rise of new forms of venture capital correspond to the rise of new industries. Thus, with every major technological step forward, corollary shifts in finance occur and new forms of venture finance are created. These new financial forms emerge in response to the mismatch of capital and industrial needs, as older, more traditional forms of capital remain tied to older paradigms of industrial organization and growth. New mechanisms for providing capital - new financiers of innovation - thus emerge as part of the very process of technogical change and industrialization to support the rise of new technologies, new enterprises and new industries.

In this regard, this book argues that venture capital functions as a more or less symmetric counterpart to the process of entrepreneurial business formation that has defined the process American industrial development and economic growth. It is our view that the processes of finance or capital formation, technological change and industrialization occur in tandem over time. In fact, we believe that they are most appropriately conceptualized as different faces of an overall development process which grow up together, influence and shape one another, and are to some degree inseparable. In other words, they are part of as self-reinforcing, endogenous growth process: industrial growth generates new sources of capital which are in turn invested into subsequent rounds of industrial expansion and growth. The process begins with growth and development of local enterprises and regional industrial complexes. This growth dynamic in turns expands the economic base and generates wealth, creating a vibrant investment climate, and new opportunities for capital accumulation. The initial opportunities may well be filled by traditional financiers and investors from outside the region, in established banking and financial centers, such as New York City, where resources are plentiful. But, with time, the development of the new industrial complex creates a momentum of its own, helping to generate new sources of venture capital, articulated to the needs of its local industries and embedded within the social structure of innovation of the area. The new industrial complex is now able to finance itself and embarks on a period of self-reinforcing growth while, at the same time, retaining connections to outside sources of capital and investment.

Venture Capital and the Social Structure of Innovation

We advance the concept of the **social structure of innovation** to capture the function of venture capital in the processes of technolgical innovation and economic development. The social structure of innovation is essentially a network of organizations and institutions that comprise the broad envbiornment in which innovation and regional economic development takes place. The social structure of innovation is what powers the process of technological innovation and new business formation in areas like California's Silicon Valley and Route 128 area around Boston.

We define the components of the social structure of innovation as: an adaptable institutional structure, well-developed networks of innovators, a highly skilled and adaptable labor force, a concentration of technology-intensive enterprises, dense venture capital networks, considerable public and private R&D expenditures, an efficient system of information and technology transfer, and business support services.

Since innovation is, by definition, a new type of activity, an adaptable social structure is needed to stimulate it. An existing base of technology-intensive companies, combined with well-developed networks of innovators and venture capitalists, creates an environment that allows the innovative personnel from many companies to interact easily and frequently, promoting the transfer of technology and information. The design and production aspects of high technology industries require a skilled labor force, and the rapidly changing nature of these industries mandates that the labor force be adaptable as well. Venture capital provides a critical source of financial and managerial assistance for new projects. Public and private R&D expenditures help enhance the technology base and increase the concentration of scientists and engineers in the area. An abundance of business support services, particularly specialized legal and financial services, make it relatively easy to launch new innovative businesses and catalyze important breakthrough innovations. Networks for information transfer are important means to identify and access new technological opportunities and market openings.

The social structure of innovation can be thought of as a special case of an agglomeration economy. At the heart of such agglomerations lie a specialized set of economic, technological, social, and financial networks. These networks facilitate information transfer within the complex and are a vehicle through which services are obtained. Venture capitalists are critically dependent upon such networks to locate investments, put together investment syndicates, and build high technology businesses.

Venture capitalists occupy a nodal position in the social structure of innovation, helping to organize the various actors in the network while bringing important financial resources and business development skills to those networks. Venture capitalists sit at the centers of these networks and can be thought of as catalysts or technological gatekeepers who accelerate the process of high technology development by bringing the many components of those networks together.

Venture Capital and American Industrialization

Our third aim in this book is to understand the evolution of the modern venture captial system in light of the broader historical processes of technological innovation, industrialization, and economic development. While venture capital is associated in the popular imagination with information technology and biotechnology revolutions of the late 20th centuries, it has a much deeper history than that. Ever since the transition from feudalism to capitalism, and perhaps even before, the rise of new technologies, new ways of producing goods, and of whole new industries has required capital and credit, or what is more commonly referred to as venture capital. Throughout this industrial history, it has been more common than not for such capital to be mobilized by new providers rather than established institutions of finance. The role of these new institutions of venture finance has been to overcome the risks and other barriers associated with more traditional financial institutions and make the required investments in those new innovations and business opportunities which are the engines of technological change and economic growth. While at times traditional financial institutions have supplied the ultimate source of capital for these opportunities, the role of these new financiers of innovation has been to mobilize capital from these and other sources and to provide it to those entrepreneurs and risk-takers that have provided much of the impetus for technological progress and economic development.

Venture captial has been a fundamental component of American industrialziation. Early forms of venture capital played an important role in the first American industrial revolution mobilizing funds for the rise and development of the textile industry around Boston. Later, venture capitalists, like the Mellon interests in Pittsburgh, helped to finance the growth of a series of technology-intensive industries associated with the second industrial revolution. Venture capitalists also played an important role in backing a host of early automotive companies in and around Detroit Michigan. The contemporary venture capital system is an outgrowth - and evolutionary progression - from these early efforts. Over time, the venture capital system grew more organized and institutional, evolving through a long historical process of experimentation, adjustment, and learning into the institutional, formalized and professional venture capital system of the contemporary era.

Tensions and Challenges to Venture Capital

In developing our analysis and our agrument, we also seek to demystify the myths surrounding venture capital and to illuminate both the challenges and opportunities - tensions and benefits - brought on by venture capital and the patterns of technological change and industrial development which it informs. We hope to show not only how venture capital both accelerates the process of technological innovation, but how it may inform broader patterns of behavior which may bias or alter patterns of innovation and economic development in ways which are sub-optimal from the point of view of American society as a whole.

Despite its catalytic role, we suggest that venture capital, by itself, is not a panacea for American high technology. The logic of venture capital investment is to generate returns on their investments and to do so in a relatively short period of time, not to build companies for the long run or contribute to the nation's technological capabilities, although their efforts do at times help accomplish those objectives. The huge volume of contemporary venture capital has also contributed to an environment and incentive system which can lead to sub-optimal allocations of resources. William Sahlman and Howard Stevenson of the Harvard Business School have identified a process of **venture capital market myopia** - a follow-the-leader syndrome where venture capitalists duplicate investments and fund similar companies with detrimental effects.[13] Robert Reich and Charles Ferguson have called attention to the problem of **chronic entrepreneurship,** where the incentives to start new enterprises can lead to high rates of employee turnover which can lead to serious disruptions in the R&D efforts of existing enterprises.[14] Moreover, the contemporary venture capital system contributes to and reinforces the what we have elsewhere dubbed the **breakthrough bias** of American high technology.[15] While venture capital-financed innovation is well-suited to major breakthrough innovations, it can fail to generate the later stage improvements in product and process technologies that may be required to generate long-run wealth, value and growth.

Outline of the Text

To shed light on these issues, this book examines the venture capital's role in the innovation process, the origins and evolution of venture capital in the United States, its role in the birth and development of new industries, its effects on regional economic development, and the tensions and challenges it poses for the processes of technological change and economic development. Chapter 2 focuses on venture capital's role in the innovation process. It begins with a description of the structure of the contemporary venture capital industry, and then outlines the multi-faceted roles venture capitalists play in the process of business development and how they affect the innovation process.

We then turn to an historical review of the origins and evolution of venture capital in the second part of the book. Chapter 3 discusses the precursors to modern-day venture capitalists - wealthy individuals, independent financiers and new financial institutions such as the merchant banks who provided risk capital to early industrial development. This chapter traces the early forms of risk capital in the textile industry around Boston in the late 18th and 19th centuries, and provides a case study of the role played by the Mellon family as venture capitalists during the late 19th and early 20th centuries, including the formation of one of the nation's earliest venture capital firms, T. Mellon and Sons. Chapter 4 discusses the formative period in the evolution of modern venture capital stretching from the New Deal through the years immediately following World War II. The phrase venture capital was coined during this period, when influential business, financial and political leaders pressed for various mechanisms to provide risk capital for entrepreneurial enterprise in stimulate innovation and economic growth. Their efforts included both government efforts to provide venture capital and the creation of some of the nation's first organized venture capital funds, notably those associated with the Rockefeller and Whitney interests in New York City.

Chapter 5 examines the rise of venture capital and its role in the high-technology industrial development of the greater Boston area during the 1950s, 1960s and 1970s. While Boston was important for many reasons, we focus on the rise of American Research and Development, which contributed a number of important organizational innovations to the venture capital system. Chapter 6 explores the rise of venture capital in California's Silicon Valley. Venture capital in Silicon Valley grew up alongside and as part of the growth of high-technology industries, becoming a critical component of the social structure of innovation. Venture capitalists in Silicon Valley also contributed to the evolution of the modern venture capital system through the refinement of the limited partnership form as the dominant model for venture capital. This innovation enabled venture capitalists to mobilize huge sums of capital from large financial institutions and other sources, shaping the venture capital boom of the 1980s and beyond.

We then turn our attention to role played by venture capitalists in the rise of new industries in the third part of this book. Chapter 7 explores the role of venture capital in the new biotechnologies. Chapter 8 examines the role of venture capital in the rise of the computer networking industry.

The fourth part of the book examines the role played by venture capital in the process of regional development. Chapter 9 discusses the different roles played by venture capitalists in financial centers like New York City or Chicago and those in technology centers like Silicon Valley and the Route 128 area. While large amounts of venture capital can be found in California's Silicon Valley, Boston's Route 128 area, New York City and Chicago, only two of these areas - Silicon Valley California and the Boston-Route 128 area - are able to attract large sums of it. This chapter shows how venture capital works to generate regional industrial development only when it is embedded in a social structure of innovation.

The last part of the book examines the tensions and challenges posed by venture capital as we move into the 21st century. Chapter 10 examines a variety of these tensions, and Chapter 11 concludes the book with a summary of major lessons and a more general synthesis of the role of venture capital in the processes of technological change and economic development.

CHAPTER 2

VENTURE CAPITAL AND TECHNOLOGICAL INNOVATION

> "Outsiders marvel at the shear amount of money pouring into America's high-tech firms and at their technological prowess. But the real secret of this high-tech success lies in the way entrepreneurs and venture capitalists interact." *The Economist*[16]

The importance of venture capital to technological innovation in the United States is reflected in the fast-growing high-technology areas which companies backed by venture capital have virtually defined: semiconductors, personal computing, computer software, computer networking, biotechnology, and many others. And, the 1980s and 1990s have certainly seen an explosion of the volume of venture capital flowing to high-technology enterprises.

The modern venture capital system differs from earlier sources of risk capital in that it is a highly organized and institutionalized. In a useful analysis, William Janeway explored venture capital in relation to the theories of Marx, Schumpeter, Keynes and Braudel, concluding that venture capital is a new, institutionalized form of finance capital which has grown up to bear the high risks associated with the new high technology industries and to help organized the innovative process. He concluded that venture capitalists are "a hybrid species of capitalist and entrepreneur."[17]

Venture capitalists play a central role in the innovation process for several reasons. First, venture capitalists are able to mobilize resources required to establish new enterprise and stimulate technological innovation from their institutional position at the center of what we refer to as a *social structure of innovation* - a series of networks linking financial institutions, large R&D-intensive corporations, universities and entrepreneurs. Second, venture capitalists accelerate the innovation process, by moving fledgling enterprise quickly through the technology cycle. Third, venture capitalists are major actors in shaping the cluster of social choices of **technology bets** which inform the process of technological innovation and patterns of industrial growth and development.

To gain a deeper appreciation of the role played by venture capital in the innovation process, this chapter is organized as follows. We begin by describing the structure of the venture capital industry. We then discuss the functions performed by venture capitalists in financing, organizing and developing new enterprises. After this, we examine the role played by venture capital in the process of technological innovation, examining venture capital in light of leading theories of innovation.

STRUCTURE OF THE VENTURE CAPITAL INDUSTRY

The structure of the venture capital industry has changed considerably over the past three decades or so. Basically, the industry has grown in size, become increasingly institutionalized, and to some degree developing a more differentiated structure both n terms of the size and types of firms. There has been a substantial increase in the number of venture capital firms, occurring alongside the growth in the overall pool of venture capital . As Figure 2.1 shows, the number of venture capital firms increased from 237 in 1977 to 670 in 1989. The average size (that is the amount of capital controlled) has also increased substantially. As Figure 2.2 shows, the average size of venture capital firms (measured as average capital under management) rose five fold between 1977 and 1995, increasing from $10.6 million in 1977 to $36.8 million in 1985, hitting $51.4 million in 1990 and $60.9 million in 1995. Much of this rise can be attributed to the emergence of very large venture capital funds, as the median firm size only doubled over this period from $10.0 million in 1977 to $20.0 million in 1994. Figure 2.3 shows the firm size distribution for the venture capital industry as of 1995. As these data show, in 1995, the more than two-thirds of all venture capital firms managed less than $100 million in capital. There were 212 venture capital firms which managed more than $100 million, including 42 in the $249-499 million ranges, and 30 mega-funds with more than $500 million in capital.

[Figure 2.1, 2.2 and 2.3 about here]

A High-Technology Orientation

Venture capitalists' invest primarily in high-technology enterprises. This is illustrated in Figure 2.4 which shows the industry orientation of venture capital investments in 1995, and Table 2.1 which charts the industry pattern of venture capital investments from 1981-1995. During this period, technology-intensive companies in industries such as computers, software, telecommunications, and biotechnology received the majority of investments. There has been a shift in investments over this period from "hardware" investments in computer and semiconductor firms toward "software" investments in computer software and biotechnology. To shed additional light on the investment orientation of venture capitalists, Table 2.2 provides a comparison of venture capital-financed firms and Fortune 500 firms. The data come from a survey of 500 respondents to a survey of 1,800 venture capital financed firms conducted by VentureOne, an organization which tracks the venture capital industry for the National Venture Capital Association in 1995.[18] The survey findings reinforce the finding above that venture capitalists have come to favor investments in biotechnology and software companies. The Venture One survey also indicates that venture capitalists tend to invest in firms which are more R&D intensive, have a higher percentage of engineers and scientists, and which have a higher rate of growth in equity/ assets.

[Figure 2.4 and Table 2.1 and 2.2 about here]

Types of Venture Capital Firms

There are a variety of types of venture capital funds: private limited partnerships, bank related venture capital funds, corporate venture capital funds, Small Business Investment Corporations (SBICs), and informal investors or **angels**. The following sections examine each of these in detail. As Figure 2.5 shows, the industry has come to be dominated by private limited partnerships over the past two decades.

[Figure 2.5 about here]

Venture Capital Limited Partnerships

Private venture capital limited partnerships comprise by far the largest share of the industry, and have witnessed significant growth over the 1970s and 1980s **[see Table 2.3]**. In fact, limited partnerships accounted for most of the growth in venture capital over the past two decades, increasing the amount of venture capital under their control from $950 million inn 1977 to early $15 billion ($14.78 billion by 1985) and more than $30 billion ($31.0 billion) by 1994. The number of limited partnerships increased from 105 in 1977 to 286 in 1985 to more than 500 in 1990. In 1977, limited partnerships accounted for 44 percent of all venture capital companies and controlled 38 percent of the total venture capital pool. By 1994, limited partnerships accounted for more than 80 percent (84 percent) of all venture capital firms and resources (83.3 percent).

[Table 2.3 about here]

Venture capital limited partnerships are independent private funds and are composed of both general and limited partners. General partners are the professional venture capitalists who secure capital commitments for a fund and make and manage its investments, while limited partners are the financial investors in the fund, whose liability is limited to their investment in the fund. Figure 2.6 shows the way limited partnerships mobilize and channel venture capital funds from outside investors to entrepreneurial companies. Limited partnership provide a mechanism for mobilizing considerable sums of venture capital from outside investors, the limited partners. The general partners or venture capitalists make the investment decisions and monitor and add value to investments. Returns are achieved when the venture capitalists liquidate their investments and create value for the fund. The professional venture capitalists thus establish a track record which are the basis for rasing capital to form another venture capital limited partnership.

[Figure 2.6 about here]

While early partnerships were run by one or two venture capitalists and a skeleton staff, modern partnerships may have five to ten general partners, a dozen associates, and a sizeable support staff. To effectively manage their assets, modern partnerships have adopted increasingly formal organizational schemes. While early limited partnerships were governed by simple arrangements and contracts, more complex contractual arrangements have arisen over time to govern these relationships. These arrangements cover both the incentives offered to the venture capitalists an the restrictions on their activities, including restrictions on the size of investments, use of debt, outside activities of general partners, the sale of partnership interests, and the addition of general partners.[19]

On average, limited partnerships have a fixed life-span 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, mergers, or other forms of exit. Because of their limited life expectancies, partnerships seek to build companies rapidly, in order to realize large capital gains the proceeds of which are then invested into new venture funds or kept accordingly.[20]

The emergence of limited partnerships as the dominant form of venture investing was the result of a lengthy period of experimentation and evolution. Basically, the limited partnership eclipsed other models because it provided an effective way to mobilize large amounts of funds from outside investors and enabled venture capitalists to realize significant financial gains, as later chapters will show. There were a number of reasons for shift change. First, reductions in the rate of taxation on capital gains made venture capital partnerships a relatively more attractive investment vehicle for large, institutional investors. Second, the liberalization of federal restrictions on public pension fund investments made investments in venture capital limited partnerships increasingly attractive for these pension funds. Third, the high returns offered by venture capital funds attracted investment. According to one estimate the return on venture capital investments were more than five times greater than the return on corporate stocks and bonds in the late 1970s and 1980s.[21] Fourth, escalating stock market activity during the 1980s made it easier to take new companies into the new issues market, increasing the success of venture capital investments.

The past two or three decades have also seen a shift in the source of funds for limited partnerships **[see Figure 2.7, Figure 2.8 and Table 2.4]**. Since the late 1970s and early 1980s, capital supplied by families and individuals declined in importance relative to capital from financial institutions and corporations. By the mid-1980s and continuing into the 1990s, pension funds had become the single, most important source of funds to venture capital partnerships. Pension funds supplied just 15 percent of all venture capital fund in 1978. But, by the mid-to-late 1980s they were providing roughly half of all venture capital funds for limited partnerships. This reflects the changes in federal law governing public pensions funds, which liberalized federal restrictions on the investment of public pension funds into high-risk investments, as noted earlier The amount of venture capital provide by pensions funds increased from just $32 million in 1978 to more than a billion dollars in 1983 and $1.6 billion in 1986. While capital provided by pensions funds dipped somewhat in the early 1990s, it rebounded sharply thereafter to $1.7 billion or 45 percent of new capital committed to venture capital in 1994.

[Figure 2.7, Figure 2.8 and Table 2.4 about here]

The rest of the venture capital pool comes from a variety of sources, including corporations, insurance companies, wealthy individuals, endowments and foundations and foreign investors. The amount of venture capital provided by corporations increased from $22 million in 1978 to $274 million in 1985 and $341 million in 1994 **[see Table 2.4]**. There has been a substantial increase in the amount of venture capital from foundations and endowments, which grew from $19 million in 1978 to $181 million in 1985 and $805 million in 1994. Insurance companies provide $35 million in venture capital in 1978, $254 million in 1985 and $357 million in 1994. Venture capital funds from individuals and families increased from $70 million in 1978 to $303 million in 1985 and $444 million in 1994. Foreign corporations are another source of venture capital. Venture capital from foreign investors increased from $38 million in 1978 to $548 in 1985, before declining to $91 million in 1994. Part of the reason for this is that foreign investors have shifted their investment strategies from investing in venture capital partnerships to investing directly in entrepreneurial start-up companies.

A new set of venture captial insitutions have emerged as the venture captial industry has grown over the past two decades. These are the so-called "funds-of-funds" and investment advisors who deploy capital on behalf of pension funds and other insitutional investors in venture captial limited partnerships. According to a Venture Economics study, roughly a dozen investment advisors controlled an estimated $9.6 billion in venture funds in 1995.[22]

Rise of the Megafunds

The 1980s and 1990s saw the rise of venture capital **mega-funds** with values exceeding $500 million. Mega-funds are the result of piggy-backing partnerships one on top of one another. The original mega-fund was launched in 1969 by Ned Heiser when he left the venture capital arm of Allstate Insurance in Chicago to start a megafund with $81 million from 25 investors became far more common.[23] In 1994, limited partnerships managed an average of nearly $60 million in capital ($58.5 million). As we have seen, some 30 large mega-funds, however, managed more than $500 million; and at least one fund, TA Associates of Boston, had more than $1.5 billion under management.

Bank Venture Capital

A smaller group of venture capital funds are affiliated with banks and other financial institutions, such as Citicorp and First National Bank of Chicago, or investment banks and brokerage firms such as Merrill Lynch. Many traditional financial institutions, such as commercial and investment banks and brokerage firms, helped establish the venture capital industry when they founded SBICs, in order to take advantage of the new investment opportunities provided by the federal subsidiaries. These financially-affiliated venture capital funds have ebbed and flowed over the past two decades, increasing in number from 36 funds in 1977 to 85 in 1988 before declining to 33 in 1992 and then rebounding to 57 in 1994 **[see Table 2.5]**. The amount of capital managed by bank-related venture funds followed a similar pattern, increasing from $913 million in 19977 to $43.8 billion in 1989, before declining to just $614 million in 1992 and then rebounding substantially to $4.7 billion in 1994. Part of the reason for this topsy-turvy pattern is that the venture capitalists who manage bank-related funds have at times spun-off their activities into private limited partnerships.

[Table 2.5 about here]

Bank-related funds operate on different incentives than limited partnerships. Since they have access to significant blocks of capital, venture capital concerns tied to large commercial banks do not face competitive pressures 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 preeminent venture partnerships.[24]

Corporate Venturing

There are also venture capital funds which are associated with major corporations such as AT&T, IBM, Eastman Kodak, 3M, Eli Lilly, Johnson and Johnson and SmithKline Beecham. The number of corporate venture capital funds increased from 30 in 1977 to 86 in 1987 before slipping to 73 in 1994 **[see Table 2.6]**. And, the amount of capital controlled by corporate venture funds increased from $268 million in 1977 to $4.2 billion in 1993 before slipping to $2.5 billion in 1994, roughly 7 percent of the total venture capital pool.

[Table 2.6 about here]

The objectives of so-called **corporate venturing** are many. They range from pursuit of an attractive return on investment, to growth and diversification, to securing a window on technology, to enhancement of entrepreneurial spirit within the corporation, to acquisition or development of a strategic partnership with a successful small company.[25] A 1987 survey of 154 corporations by the Conference Board found that the most frequently cited objectives for corporate venture capital operations were to secure attractive return on investments (42 percent), obtain a window on technology (32 percent), stimulate corporate growth and diversification (30 percent) and enhance the company's entrepreneurial spirit (9 percent).[26] According to a Coopers and Lybrand survey of 52 corporate venture capital firms, the two leading objectives of corporate venture funds were "return on investment" which 56 percent of respondents reported as a major goal, "exposure to new technologies and markets" which 49 percent listed as a major goal. Corporate venture funds in the Coopers and Lybrand Study reported that acquisition opportunities, the potential to develop new products or to improve existing products to be less important to their activities.[27]

Corporate venture capital face a series of organizational and managerial challenges, according to existing studies of the subject.[28] The consensus view in these studies is that the key difficulties revolve around corporate bureauacracy fit and the compensation of corporate venture capitalists, e.g. their inability to share in the financial gains they generate. According to the Conference Board survey, 42 percent of respondents reported that lack of a clear mission for venture activity by their corporation had a significant or destructive impact on their corporate venture capital activity, 40 percent reported the clash between corporate adn entrepreneurial cultures as significant and destructive, and 39 percent said that an inadequate financial commitment was significant and destructive. Furthermore, corporate venture firms typically cannot offer the kind of compensation provided to professional venture capitalists in limited partnerships. The salary structure of most corporations makes it impossible for them to allow principals in their venture capital arms to share in the gains from their investments. The Conference Board survey found that less than one-quarter (24 percent) of corporate venture capitalists received compensation which was tied to their portfolio's growth either through participation in the venture fund or through bonuses related to long-term activity. The consequence is that the most effective corporate venture capitalists are lured away to join private venture capital partnerships.

Small Business Investment Corporations

Small Business Investment Corporations or SBICs were created by the federal government during the late 1950s. SBICs are privately organized and managed investment firms, licensed by the Small Business Administration. They have access to long-term federal loans in return for their agreement to invest solely in small businesses. Minority enterprise SBICS - or MESBICs were created in 1972 to make additional capital available to minority enterprises. As of 1986, there were 333 active small business investment companies (SBICs) and 140 minority enterprise small business investment companies (MESBICs).

SBICs and MESBICs provide a range of financing, including traditional venture capital funds, combined debt and equity, and long term loans. From the late 1950s and well into the 1960s, SBICs were a primary financial resource for small business development. But, their role has decline substantially since then. SBICs' contribution to the total venture capital industry pool of capital declined from 24 percent in 1977 to 8 percent in 1987. As a refection of their diminished importance to the venture capital industry, *Venture Economics*, the organization which tracks the venture capital industry, stopped publishing data on SBICs in 1989.

Angels and Informal Investors

Informal investors, known as *angels,* provide an additional source of venture capital.

Informal investors are typically wealthy individuals who invest in a small number of new ventures. These angels generally invest smaller amounts of capital in ventures with higher risks or lower rewards than traditional venture capital firms. Though the amount of individual angel investment is usually quite small, their aggregate contribution to the venture capital industry can be significant. An 1990 article in the *Wall Street Journal* estimated that informal investors contributed 35 percent of all capital to emerging growth businesses in 1988, compared to 15 percent for venture capitalists, 25 percent from corporations, 15 percent from federal small business innovation research grants, and ten percent from state and local economic development agencies.[29] A 1989 study by Robert Gaston estimated that there were approximately 720,000 informal investors or angels nationally, who controlled more than $36 billion in equity capital and invested in approximately 87,000 entrepreneurial businesses annually.[30] Others have estimated that angels may account for one-half to two-thirds of all venture capital investment.[31] William Wetzel, a professor at the University of New Hampshire, conducted done several studies of the role of angel investments in the New England economy.[32] According to Wetzel, the "invisible network of venture capital" composed of between 250,000 and two million "self-made, high-net-worth individuals" who invest between $10-20 billion per year.in 1995. In an analysis of 284 technology-based businesses in New England, Wetzel found that private individuals or angels provided 177 rounds of financing for 124 enterprises, while venture capital provided 173 rounds of financing for 90 companies. Further, according to Wetzel, angels provided a crucial source of seed and startup stage funds for new businesses.

WHAT DO VENTURE CAPITALISTS DO?

We now turn our attention to the activities and functions performed by venture capitalists. Venture capitalists are involved in a variety of tasks that are vital to technological innovation and economic development. Venture capitalists play an active role in the development of start-up companies by lending substantial managerial, legal, marketing, and financial assistance to fledgling firms. The following pages explore the various functions performed by venture capitalists, tracing the nature of their involvement from the inception of a new business concept until a viable business is formed.

Venture Capital Investing

Venture capital investing, as we have seen, differs substantially from more traditional forms of investing. Unlike banks which provide financing in the form of loans or debt, venture capitalists are equity investors. The provision of equity lies at the very heart of venture investing, as it enables venture capitalists to pursue high-risk investing. The basic operating principle is that venture capitalists need not win on every investment, in fact just one good investment can more than offset numerous losses. The large potential return provided by 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. The most successful investments are the ones that open up whole new areas for exploitation and create whole new industries. While such investments are rare occurrences, they can essentially make a venture capitalists and a venture capital fund for life. As Donald Valentine explained it: "Every once in a while you do an investment that is more than a company. Every once in a while we do an investment that's an industry. Apple was an industry."[33] And, Apple provided Valentine with handsome returns and a track record which enabled him to raise all the money they required for future partnerships.

A VentureOne study of more than a thousand venture capital-backed companies formed between 1980 and 1986 found that 15 percent were big hits having gone public, 20 percent were moderate successes having been acquired, 25 percent failed, and 40 percent remianedp[rivate and idependent.[34] A study of the performance of 10 leading venture capital funds by Horsley Keogh and Associates during the 1980s found that of 525 separate 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 **[see Figure 2.9]**.[35] In addition, a 1987 study by Claudia Schoonhoven and Kathleen Eisenhardt analyzed 45 semiconductor firms formed in Northern California between 1978 and 1983 and found that in terms of sales and jobs created those firms funded by venture capitalists were both the most successful and least successful.[36]

[Figure 2.9 about here]

Venture capital returns outperformed those of the stock market over the past decade. Figure 2.10 compares the returns on venture capital investments to those of the S&P 500 and the Value line Composite Index for the period 1985-1995. As these data show, venture capital returns increased their performance relative to other investments over this period. In 1994, venture capital returns were more than three times greater than the S&P 500 and nearly six times that of the value Line Composite Index. According to a Venture Economics, venture capital limited partnerships posted a 53 percent return to limited partners in 1995, based upon an analysis of the net returns to limited partners of 539 venture capital limited partnerships formed between 1969 and 1995.[37] This was significantly better than the average 20 percent returns of the previous four years.

[Figure 2.10 about here]

Stages of Venture Capital Investment

Venture capitalists invest in stages. The initial investments, referred to as **seed** or **zero stage** investments may come before a company is even formed. Venture capitalists target their investments at the **start-up** stage of the business, providing capital for the establishment and growth of the new enterprise. Venture capitalists then participate in a variety of financing rounds as the business develops, referred to as **follow-on** or **later stage** investments. Venture capitalists made nearly $4 billion in investments in 1,222 companies in 1995. As Figure 2.11 shows, of this total, $1.47 billion was for early stage investments, including $231 million for seed-stage investments. Another $1.6 billion went for expansion financing and the rest went for LBOs, acquistions, bridge loans and public purchase. 231 million was for seed-stage investments, $663 was for startup, $580 was for other early was invested in seed ese investments, 320 were in new start-up companies, or what is referred to in the industry jargon as **first-round financing**. Venture capitalists made 1,114 follow-on investments in 620 companies. Figure 2.12 shows venture capital investments by stage for the period 1980-1994.

[Figure 2.11 and 2.12 here]

It is also important to point out that the nature and financial requirements of investments change across the various stages of venture capital investing. A Coopers and Lybrand study of

85 high-technology companies that received venture capital between 1980 and 1986 found that companies tended to gain value with each stage or round of financing.[38] The average value of companies increased from $3.6 million to $5.7 million dollars during he first stage, to $15.5 million after the second stage, and $26 million in the third stage. Furthermore, the Coopers and Lybrand study found that the typical owner's share shrank from 50 percent after the first round to 37 percent after the second round, while the value of the stake doubled from $23.85 million to $5.7 million. After the third round, owners retained 25 percent with a value of $6.5 million. In other words, as companies gained value the size of the venture capitalists' financing grew, while the amount of ownership exchanged for funds shrank. The Coopers and Lybrand study concluded that entrepreneurs on average exchanged 37 percent of ownership for $2.1 million in the first round; in the second round, 22 percent of ownership was traded for $3.4 million in financing; by the third round, 15 percent of ownership as worth $8.9 million.

Venture capitalists play a variety of non-financial roles across the stages of a businesses development: including investment screening and evaluation, monitoring, management assistance, and ultimately liquidation or exit from their investments. Figure 2.13 portrays the role played by venture capital over the life-cycle of an enterprise - a process which proceeds through three stages: emergence (initiation and rapid growth), consolidation (increasing economies of scale and steady expansion), and maturity (oligopoly and decline). Our model of this life-cycle follows research by William Abernathy and James Utterback.[39]

[Figure 2.13 about here]

Venture capital plays a critical role 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 potentials, financial requirements, and organizational capabilities of new businesses and the products upon which they are based.[40] They also assist in the recruitment of management, location of production facilities, securing of legal counsel, and other services crucial to the business development. At later stages, venture capitalists arrange additional rounds of financing, attract coinvestors, redefine corporate strategy, assist with production scale-up, target new markets, create a skilled marketing department, and work to maintain an effective management team. In these ways, venture capitalists add value to new firms that transcends the provision of mere financial resources.

Narrowing the Field: Identifying Investment Opportunities

Venture capitalists select their investments from literally hundreds and, for some venture capital funds, thousands of business proposals each year. Only a fraction of these receive serious evaluation, and an even smaller percentage actually result in funding. For example, during 1987, the 100 most active venture capital firms received on average roughly 1,000 proposals each, with the actual number of proposals ranging from a minimum of 10 to a maximum of 6,500. Of these proposals, less than 4 percent received funding. When follow-on investments are excluded, this figure fell to only 2 percent.[41]

Venture capitalists rely heavily on personal contacts in their search for and initial screening of quality venture opportunities. These referrals are a critical factor in venture capitalists' investment decisions. Survey research indicates that nearly two-thirds of all proposals are referrals from other venture capitalists, personal acquaintances, banks, or investment brokers.[42] Executives of successful portfolio companies are particularly important to this referral process. Their industry experience and contacts afford them preferential 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 alliances. Law firms that specialize in new venture activity are retained by both venture capitalists and high technology start-ups. For example, one of the top West Coast venture law firms, Wilson, Sonsini, Goodrich and Rosati, had a client list during the 1980s that included venture capital firms such as Mayfield Fund, Hambrect and Quist, and Sequoia Capital, as well as high-technology companies like ROLM Corporation and Apple Computer.[43]

Cold calls are less important than refereed proposals. Though comprising an estimated 25 percent of the total number of proposals received, unsolicited plans have a particularly poor chance of receiving funding.[44] In fact, according to a survey by *Venture Magazine*, of 867 deals funded only 6 percent were over-the-transom deals.[45]

Venture capitalists evaluate business plans in light of a variety of criteria including: the originality of the proposed product or technology, its feasibility, market size, and projected sales, the availability of patent protection or other proprietary characteristics, the quality of the entrepreneurial group, and the options that are available. Donald Valentine of Sequoia Capital views the business plan as an introduction to the groups seeking funding.

> "We can't tell if the numbers are right, therefore we concentrate on how they reached the numbers, the thought processes that led them to conclude that their project was possible."[46]

Venture capitalists confer extensively with the management of potential start-ups. This is supplemented by a relatively formal process known as **due diligence** which involves a detailed search of references, the solicitation of outside information from potential customers, suppliers and competitors about the quality of the technology and the entrepreneurial group, and often lasts for several months. Venture capital firms frequently use outside consultants or other venture capitalists to help in this evaluation process.

Venture capitalists place different emphasis on the various risk components of a potential venture. These include the quality and experience of the management team, the quality and potential of the product and its market, and financial uncertainties. Most experienced venture capitalists view the people behind the business plan as the most critical factor in judging the potential success of a venture. Arthur Rock, a gray hair of the venture capital industry and backer of Fairchild, Intel, and many other companies explained that:

> "Good ideas and good products are a dime a dozen. Good execution and good management - in a word, good **people** - are rare. ...That's why I generally pay more attention to the people who prepare a business plan than to the proposal itself."[47]

His points were echoed by Donald Valentine.

"People are what makes the difference. We have financed more than 150 companies. Probably 25 more of those have gone public. ... Those people have been very good."[48]

The Start-up Phase

Once the business plan is accepted, capital is infused into the new enterprise. In return, venture capitalists receive a significant ownership stake in the new company, ranging from 10 percent to 90 percent, though 51 percent is common. By opting for equity investment over traditional debt financing, venture capitalists and their portfolio companies eliminate the problem of scheduled repayment. Loans that are made to new businesses generally carry high interest rates and short terms. Repayment can be an onerous burden for young companies which require substantial inflows of capital during early growth stages and, therefore, cannot afford sizeable outflows to cover interest and principal payments. In addition, the loan officers employed by banks frequently do not understand the technical dimensions of high technology business formation.[49] In contrast, equity investment allows young companies to reinvest all earnings in the company and provides an asset base which can be used to attract outside capital and enhance a company's credibility with vendors, suppliers, and traditional financial institutions.

Equally as important as the funding provided by venture capitalists is the significant management assistance they render to small, technology-intensive businesses. Generally, venture capitalists attempt to foster the growth of new companies with advice rather than becoming actively involved in the time-consuming, daily management of the company. Although if a venture capitalist believes that a venture is headed for disaster under the original founders, the venture capitalist will step in and assume control over a firm's operation. Along with their equity in the corporation, venture capitalists commonly gain active representation on the corporate board of directors. Donald Valentine has termed venture capitalists' managerial contribution as "intelligence equity," which he defines as "experience the companies don't have, contacts they don't have, perspectives they don't have."[50] Venture capitalists' substantial experience and extensive contacts 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. In an detailed account of the role of venture capital in the process of new business formation, the venture capitalist, Donald Case, of Hambrecht and Quist noted that:

> "increasing competition and contracting product life cycles in many emerging markets means start-up companies [can afford] fewer mistakes. venture capitalists who can help entrepreneurs avoid some of the common but crippling mistakes made by start-ups can be of invaluable assistance. Consequently, leading venture capitalists have a multi-disciplined professional staff that can provide portfolio companies with technical and marketing guidance, assist in strategy, financing and recruiting issues, and provide contacts with key potential customers, vendor and financial institutions."[51]

The provision of financing from a reputable venture firm in established technology regions, like Silicon Valley or Route 128, can function as a seal of approval for new companies which need to establish working relationships with suppliers, financial institutions and related businesses. Venture capitalists may also organize strategic partnerships between portfolio companies and larger corporations through technology exchanges, original equipment manufacturer, other customer agreements, and minority equity investments.

Perhaps the most crucial contribution to a new firm's development by a venture capitalist is its recruitment of managers for business start-ups. To assist with such efforts, most venture firms have executive search firms on retainer. A survey of 77 leading venture capital firms indicates that the venture capital community views management recruitment as the single most important form of assistance provided to young companies.[52] Indeed, the Mayfield Fund at one time hired a recruiting partner who specializes in filling management positions at portfolio companies.[53] Venture capitalists often lure top-level personnel from secure academic or corporate posts by offering them equity stakes in fledgling businesses and the concomitant possibility of realizing large capital gains, in return for their expertise.

Building the Business

The role of venture capitalists changes as new businesses and technologies proceed through the business development cycle. 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 the venture capitalist shifts from active intervention to one of advice and assistance. The venture capitalist's expertise in particular industries and prior experience with business expansion provides a reservoir of knowledge which can be critical for the survival of a growing company. "Real value is added in a venture activity," according to an Arthur D. Little report, "not on the front or buy end and not on the back or sell end, but through working with people in the company in the middle."[54] At times, venture capitalists may 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, their incentives are 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, long term economic security, sense of mission, and attachment to their enterprise. These different incentives can lead to significant differences over business strategy. 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. In some instances, the venture capitalists may assume direct operating positions themselves, though our interviews lead us to conclude that they will do so only in the most dire situations.

Investment Syndicates and Coinvesting

Venture capital is characterized by a process of investment pooling or **co-investment**. Co-investment links venture capital firms together in local, regional and national networks. A survey of venture capitalists found that approximately 90 percent of all venture capital investments involve co-investment partners.[55] According to Jeffrey Timmons and William Bygrave, co-investment enables venture capitalists to pool expertise, diversify their portfolios, and share information and risk.[56] The coinvestment process involves two types of investors: **lead investors** who identify and monitor investment opportunities and organize investment syndicates and **follow-on investors** who provide additional, external sources of capital. 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.[57] Coinvestment is also a mechanism by which venture capital firms ensure themselves of a steady stream of quality investment opportunities, exchanging a portion of a their deal flow for consideration in future investments.

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 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.

Getting Out: Bringing Companies to Market and Other Forms of Exit

Venture capitalists' participation in new businesses culminates when they exit from their investments. This is typically accomplished through a public stock offering or upward merger or acquisition by another firm. Between 1985 and 1995, more than 1000 (1,126) companies financed by venture capital were brought into the market for initial public offerings (or IPOs) **[see Figure 2.14]**.[58] Between 1991 and 1995, the number of IPOs for venture capital backed companies soared, averaging 186 IPOs per year. The amount of IPO dollars raised hit nearly $40 billion in 1992, $57.5 billion in 1993 and $33.8 billion in 1994 **[see Figure 2.15]**. Table 2.7 provides data on the characteristics of venture capital-backed IPOs for the period 1980-1994. During the period 1985-1994, another 857 companies financed by venture capital were merged or acquired **[Figure 2.16**].

[Figure 2.14, Figure 2.15, Figure 2.16 and Table 2.7 about here]

The push to go exit 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. There is a significant economic rationale for this. Venture capitalists usually receive a management fee of approximately 2 percent to 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.

The Process at Work: A Case Study of American Superconductor Corporation[1]

The case of American Superconductor Corporation (ASC), a spin-off from MIT, provides

[1] The case study is based upon field work and interview by David Talento, a former Carnegie Mellon student. Talento conducted interviews with initial investors at American Research and Development (ARD), employees, management and founders at American Superconductor Corporation, and principles involved in the start-up of ASC at the MIT Licensing Office. See, David Talento, "The Creation and Development of American Superconductor, Inc." (Carnegie Mellon University, School of Urban and Public Affairs, May 1989).

a useful illustration of the roles and functions performed by the venture capitalist. Briefly put, when two MIT professors approached the MIT Licensing Office with a new technology, the university which had close relationships with venture capitalists initiated a process for obtaining the patent, helped the founders obtain venture capital support, and licensed the new technology out to the start-up.

In 1986, Gregory Yurek and John Vander Sande were both professors at MIT in the Department of Materials Science and Engineering. Yurek was a full professor whose specialty was corrosion and oxidation of metals while Vander Sande specialized in the microstructure of materials. In January 1987, Yurek decided to shift the focus of his work with oxidation toward a new medium - perhaps new superconducting oxides which had just come on the scene. He sat down with Vander Sande to discuss the possibility of a new way of making metal oxides that would eventually result in a ceramic oxide. Using limited MIT facilities, they undertook a feasibility study of the new process to see if it could actually be performed in a laboratory. When their work went well, they approached the MIT Licensing Office with the idea for a patent based upon their work. Initially, Yurek and vander Sande had no inclination to start a company,, in Yurek's words they were "dedicated to the university forever types."[59]

But, John Preston of the Licensing Office saw commercial potential and referred the two to George McKinney, a venture capitalist with a premier Boston venture capital firm, American research and development with which MIT had previous relationships.[60] While MIT policy initially posed obstacles to such arrangements, the university fortuitously changed its policy to allow faculty inventors to take equity in start-up companies.[61] The associate director of the MIT Licensing Office, Lita Nelson, worked with both ARD and two professors in putting together the initial meeting. A typical start-up according to Nelson is a **zero stage** company. A zero stage company has three elements; a management team or structure, a business plan, and technology. In her words, the nascent ASC was at that time a **minus two stage** - with technology but little else. A minus two stage company requires a tremendous effort from a venture capital in the way of strategic direction and managerial assistance.

Yurek, Vander Sande and McKinney of ARD had their initial meeting on March 19, 1987, where they discussed the new technology and the process of forming a start-up company. McKinney was very interested. He had worked at Corning Glass Works for 18 years and later was one of the first venture capital investors in the field of high performance materials; he was the founding director of Ceramics Processing Systems Corporation, an ARD venture. McKinney recognized that this investment posed a double risk. The first risk was an embryonic unproven technology that would require a substantial development before the materials could be transferred to production. The second risk dealt with the lack of definition in the market for an brand new technology.

With a few phone calls through established networks, McKinney was able to look into the background of the founders and decide if they were reliable. McKinney had to not only look into the personal integrity of Yurek and Vander Sande, but they had to make judgements on their technical abilities as well. According to McKinney, "You particularly look for technical judgement. If someone says he thinks something will work in his field, what does that mean?"[62] McKinney ultimately believed in the potential of the research team and felt they would eventually succeed on their own merits.

ARD also looked closely at the technology itself. Once again, using established networks of companies that he and ARD had worked with, McKinney looked into the difference between low temperature and high temperature superconductors. He tried to get a road map of where the work of Yurek and Vander Sande would fit in. McKinney ultimately concluded that work on superconductors could form the basis of an "enabling technology logic." In other words, he felt the technology could work in so many different markets and places that the overall market risk will be greatly reduced. In addition to an analysis of the technical competence of the founders, McKinney recognized that ASC was clearly a minus two stage company. He would have to supply elements such as a business plan and market analysis. When he decide that the investment was promising, McKinney invited both Yurek and Vander Sande to the ARD offices to meet with each of the partners in order to gain their assessments.

In the interim, Yurek adn Vander Sande received an offer from Rothschild, a reputable venture firm. They now had to choose which to go with. Both firms had connections. Both had access to offices of large companies and networks that would move things along quickly. But, ARD seemed to have a longer-term view which appealed to the two scientists; and, a personal connection to McKinney had developed. In Yurek's words:

> "George had already demonstrated an interest in materials-type companies through his other dealings... so he had a personal interest in the materials and also exuded an excitement about moving forward...a brightness and quickness that Vander Sande and I could relate to well in those early days. ... I could relate to George personally, I think he's an honest person. We really admire his business sense, his abilities, structuring the deals early on. It was more George than ARD that we were going with."[63]

Once the decision to go with ARD was made, the MIT Licensing Office again came into the picture developing a basic plan for the company: a definition of the technology that was being transferred, "due-diligence milestones" of development that MIT had developed and assigned to a time scale of predicted growth for the new company, and the price and amount of equity that MIT and the founders would hold.

In April 1987, American Superconductor was formed. ARD provided an initial $15,000 to MIT to sponsor more research. In addition, there was an equity involvement of MIT getting a total of 30 percent of the company - ten percent for the academic department, ten percent to MIT directly, and ten percent to the founders. ARD received a 90 day option to form a company. Over the next two months, ARD provided an additional $100,000 to the company on a tightly controlled basis. The morning of May 20, 1987, George McKinney started the legal process towards officially forming the company. That afternoon Yurek and Vander Sande received the results of the technology they had been testing and contacted ARD. The results demonstrated not only that the technology worked, but that the scientists fully understood the process they were experimenting with. At that time two other MIT faculty joined the two founders: Dr. Yet-Ming Chiang, an associate professor of ceramics, and Dr. David Rudman, an associate professor with expertise in thin film superconductors. George McKinney became the temporary CEO, Greg Yurek took leave from MIT to become CTO and the others became senior researchers.

In June 1987, ARD began the first round of investment. At this point, ARD brought in Rothchild Ventures for a pre-seed round of investment which generated some $400,000. A board of directors was formed and in early September 1987, ASC hired its first employee outside of the founding group. The original office space for American Superconductor was one room in a laboratory complex in Cambridge, Massachusetts, approximately one mile from MIT. All of the staff from the CTO and senior researchers to the technicians and support staff shared the same room. The laboratory consisted of a few pieces of equipment modified and developed by the founders as well as a furnace area and small work area. In April 1989, the week of the second year anniversary of the company, Greg Yurek became the acting president and George McKinney became the chairman.

VENTURE CAPITAL AND THE INNOVATION PROCESS

We now seek to situate the functions and activities performed by venture capitalists in a broader context, providing a conceptual basis from which to understand venture capital's role in technological innovation. We can use Schumpeter theories of innovation to help us think about the way venture capital has affected the innovation process. In his work, Schumpeter tended to draw a distinction between two types of models of innovation: entrepreneurial innovation which takes place in small, newly formed enterprise and corporate innovation which takes place in the R&D laboratory of the large corporation. During the 1980s, Christopher Freeman, Roy Rothwell and others at the Science Policy Research unit at Sussex University rekindled interest in the distinction originally drawn by Schumpeter between **entrepreneurial** and **corporate** forms of innovation, which they referred to as Schumpeter Models 1 and 2 respectively.[64] Under entrepreneurial innovation, 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 lead to the creation of new industries, the revitalization of some older ones, and the disappearance of still others.

Under corporate innovation (or model 2), large corporations organize R&D within specialized research laboratories, thereby internalizing innovation. These corporations use internal R&D to remain at the forefront of new technology and to generate successive waves of innovation. According to Freeman and his colleagues, this creates "a strong positive feedback loop from successful innovation to increased R&D activity, setting up a virtually self-reinforcing circle."[65] The internalization of innovation within large corporations makes technological change a less sporadic, more continuous process.

Freeman and his colleagues elaborated upon this distinction with a concept they referred to as **dynamic complimentarity,** which they advanced to suggest that smaller, entrepreneurial firms and larger corporations may play different and important roles in the innovation process. According to their view, large corporations and universities establish the scientific and technological context necessary for innovation, functioning as incubator organizations of sorts for technological change. These technological opportunities are then exploited and commercialized by small entrepreneurial companies. Such interplay is facilitated by direct circulation of personnel and 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. Large organizations and small firms thus act in a dynamic and complementary manner to stimulate the innovation process.

Venture Capital and the Social Structure of Innovation

It is our view that venture capitalists play an important role in this process, by virtue of their strategic position at the center of a series of overlapping networks which make up the social structure of innovation - an interactive system or environment for innovation composed of technology intensive enterprises, highly skilled human capital, high caliber universities, substantial public/private R&D expenditures, specialized networks of suppliers, support services such as law firms and consultants, strong entrepreneurial networks, and informal mechanisms for information exchange and technology transfer. From their vantage point inside this broader structure, venture capitalists are uniquely equipped to match personnel and resources drawn from various organizations in the formation of new enterprises.

The role and function of venture capitalists within this social structure of innovation is portrayed in Figure 2.17. It can be thought of in terms of four overlapping networks. The first network is used to mobilize capital. This network 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 especially important since they have contacts that typically extend to the most promising potential start-ups. A third network cultivated by venture capitalists includes professional service firms such as law and accounting firms, as well as market research firms and consulting firms which serve as sources for industry relevant information. A final network is composed of sources of labor and other important inputs into the production process.

It consists of contacts that are used to recruit management and other personnel for start-ups, as well as sources for inputs into the production process and possible outlets for finished goods.

[Figure 2.17 about here]

In our view, venture capital-financed innovation helps to overcome a series of obstacles associated with both the entrepreneurial and corporate models of innovation. Under entrepreneurial innovation, innovation occurs in an ad hoc and unorganized way. The individual entrepreneur is forced to organize the process of enterprise formation, to 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.

Corporate innovation is often impaired by the organizational rigidity of large corporations.[66] Venture capital-financed innovation replaces the functional specialization and compartmentalized information flow characteristic of large corporations with a relatively fluid and flexible organizational environment. This flexible environment is characterized decentralized decision making and intense flows of information. This occurs both within and between venture capital-backed companies, creating significant incentives for innovation. The emergence of venture capital-financed innovation represents a partial response to the organizational rigidities of the innovation process in large U.S. corporations.[67]

Venture Capitalists as Technological Gatekeepers

In organizing many of the elements necessary for technological innovation, venture capitalists function to a large extent as **technological gatekeepers** - setting the direction of technological change. The idea of natural or technological trajectories suggests that the given path of technological development both channels and constrains future technological progress.[68] The organizational and institutional context of society acts as an additional constraint on technological change. Since innovation and technological change take place largely within these relatively fixed constraints, only critical technological or organizational breakthroughs can disrupt existing technological pathways and open up new technological frontiers. According to Robert Ayres:

> "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 little 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.[69]

Venture capitalists are a crucial part of the context within which such technological innovations 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 gate-keeping function, by intervening to help create new companies and actualize important breakthroughs. At the same time, they are able to capture the economic rents that come from 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 technological trajectories and opened up whole new frontiers for technological progress, setting the stage for clusters of imitative activity and swarms of improvements and innovations.

Venture capitalists seek to exploit the major discontinuities that occur in the process of technological change. These discontinuities open up opportunities which venture capitalists attempt to exploit. In the words of Donald Valentine the critical factor in the entire process - what determine fantastic success or utter failure - boils down to the timing of the investment.

> "To me, it's market timing. Our most successful companies in which we've made tens and hundreds of millions of dollars for all limited partners, when analyzed fairly and honestly in my opinion have been successes because of market timing - recognition of the market timing, and the exploitation of it. Apple Computer did not become the great company that it is because we had brilliant management in 1977 and 1978. The product didn't do anything. The first memory product in the Apple was an audio tape cassette ... You could leave for an hour and a half while the thing got ready to do something. We launched the company and indirectly an industry. It was great timing."[70]

This does not imply that large corporations are unimportant in placing technology bets. The historic role played by Bell Laboratories in pioneering a series of important innovations in the U.S. is exemplary. And, large corporations certainly help to establish the technological base from which innovative activity can originate. This is in part the result of venture capital-based innovation which has generated increased incentives for employees to leave large corporations.

In short, venture capital-financed innovation functions to overcome a series of obstacles or limits associated with both corporate and entrepreneurial innovation by bring together actors from a series of networks. In addition, venture capital-financed innovation plays an important technological gate-keeping function, by helping to identify new technological trajectories and thus setting in motion the gales of creative destruction which establish the context for economic change.

Examples of Venture Capital-Financed Innovation

The operation of this new model of venture capital-financed innovation can be illustrated through some case examples.

Semiconductors

The linkage between large corporations and venture backed companies is clearly evident in 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 Shockley's former employees catalyzed the nascent semiconductor industry. Fairchild was one of the first important venture capital backed start-ups. Its financing was arranged by Arthur Rock, who was then an investment banker with a prominent New York city firm.[71] 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. Fairchild alumnus Jerry Sanders launched Advanced Micro Devices on 1967. That same year Robert Noyce, Andy Grove, and Gordon Moore left Fairchild to found Intel with backing from Rock. Rock also provided venture capital for Intersil, Inc. which was started by Jean Hoerni, another of Fairchild's original founders.

In the early 1980s, another group of top Fairchild executives, led by then president Wilfred Corrigan, left Fairchild to launch LSI Logic, a leading producer of custom semiconductors. According to some estimates, more than 80 semiconductor startups can trace their origin to Fairchild. Moreover, Fairchild alumni have also gone on to form prominent venture capital partnerships. Eugene Kleiner, one of Fairchild's founding eight, is a key principal in Kleiner Perkins, while Donald Valentine runs the Sequoia Partnership.

Personal Computers

Venture capital was important to the birth of 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 embryonic market. At this point, the founders of Apple Computer, Steven Jobs and Stephen Wozniak, were building machines in a garage for sale to a small market composed 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.[72] Valentine then convinced the more 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.

Biotechnology

The biotechnology industry provides an example of the proactive role played by venture capital. Although a series of scientific breakthroughs occurred during the early 1970s, creating 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. In this capacity, he had learned about the important scientific breakthroughs in biotechnology. Swanson and Boyer received an initial $100,000 from Kleiner Perkins to fund what could still be considered basic research and launch their new company.[73]

The rapid success of Genentech and other small biotechnology companies provided the impetus for large chemical and pharmaceutical 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 start-ups. Large companies also 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.

By the mid-1980s, there were more than 400 biotechnology firms operating in the United States, mostly new, venture capital-backed startups.[74] 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, based on the experience they had gained in investments in other high technology industries. In contrast to the semiconductor and personal computer industries where venture capital was essentially provided to embryonic enterprises after the basic technology had been proven, venture capital played a more formative role in the biotechnology industry, seizing the commercial opportunities opened up by developments in biochemistry, such as recombinant DNA. This is 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's discovery of biotechnology has meant that venture capitalists have been willing to assume a greater amount of risk and an even longer view of their investments. In other advanced technology industries, venture-backed companies usually succeed in commercializing a product within a few years of the initial investment, and may be expected to produce a return for the investor in 5 to 7 years. In contrast, development of commercial biotechnology products has proceeded much slower. This is in part because the science involved is at an early stage of development. Consequently, returns to the venture capitalists are more uncertain and more distant, and the risks greater.

Venture Capital-Financed Innovation

As this chapter has shown, venture capital industry has a number of affects on the process of technological innovation. The intervention of venture capitalists in the early life of a firm has proved essential to the success of new, technology-oriented companies. Venture capitalists provide managerial, marketing, legal, financial and other types of experience that most likely would be unavailable though conventional sources of funding. In doing so, venture capitalists function as catalysts in the evolution of new technologies, new businesses, and even entirely new industries.

Venture capital-financed innovation overcomes a variety of barriers that obstruct 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 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.

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

PART II

ORIGINS AND EVOLUTION

CHAPTER 3

PRECURSORS:

VENTURE CAPITAL AND AMERICAN INDUSTRIALIZATION[2]

> "Problems regarding the entrepreneur in capital formation do not differ greatly from those in general economic growth....In the early phase of industrialization most initial financing was of local origin and there was an intimate relation between entrepreneurs and investors." Thomas Cochran, "The Entrepreneur in American Capital Formation," 1955.[75]

The very phrase venture capital calls forth the image of new financiers of innovation who back cutting-edge high-technology enterprises of the sort found in California Silicon valley or the Route 128 beltway around Boston. In the popular imagination and to some extent even in academic writing on the subject, venture capital is almost always associated with the sweeping technological revolutions of the past two or three decades - the rise of semiconductors,

[2] This chapter draws from the work of Mark Samber, who received his doctorate in Applied History from Carnegie Mellon University. It is an edited and revised version of the first several sections of a paper by Richard Florida and Mark Samber, "Capital and Creative Destruction: Venture Capital, Technological Change, and Economic Development," Carnegie Mellon University: H. John Heinz III School of Public Policy and Management, May 1994.

computing, software, and the new biotechnologies. But, venture capital has a much deeper and richer history than that. Indeed, as we show, the rise of new forms of venture capital to channel capital to new enterprises and new industries is a fundamental and defining feature of America's technological, industrial and economic development.

This chapter traces the rise of new forms of risk finance - precursors to what we now refer to as venture capital - alongside major industrial transformations in U.S. industry. While the limits of time and space preclude us from discussing the huge number of examples of venture capital's role in the rise of new technologies and industries, we orient this chapter around two useful examples which help to illustrate this broader process. We begin by exploring the role of new financial institutions and instruments in the growth and development of the textile industry around Boston in the late 18th century. Drawing from a wide body of research by economic historians, we illustrate how the development of textile production in and around Boston was related to a series of new financial mechanisms that economic historians such as Lance Davis, Robert Dalzell, and Naomi Lamoreaux have referred to as relationship banking or equity-financed "insider lending." We then turn to the role of the venture capital in the growth and development of technology-intensive industrial enterprises in and around Pittsburgh, Pennsylvania during the late 19th and early 20th centuries. Drawing from detailed archival research on this subject, by Mark Samber, a former doctoral student in history at Carnegie Mellon University, we examine the role of played by the Mellon interests in the growth and development of these enterprise. This research makes it abundantly clear that the mellon interests had evolved a series of financial and managerial functions which are in many ways comparable to the contemporary system of venture capital. In addition to providing capital, the

Mellon interests provided managerial and technological assistance to these new enterprise and helping to organize and interrelated complex of technology-intensive firms and industries capital to these enterprises and in helping to organize a technology-intensive industrial complex. Like contemporary venture capitalists, the Mellon interests encouraged companies in which they invested to re-locate to Pittsburgh. The Mellon interests worked to establish a broad environment for innovation in the greater Pittsburgh region, establishing established an world-class research organization, the Mellon Institute, to provide a central incubator organization for research and development by their portfolio companies.

Early Risk Capital for the Textile Industry

The textile industry, as many have noted, propelled the process of American industrialization. Centered around Boston and Lowell this industry provided the foundation for subsequent industrial growth and economic development, and according to Hindle and Lubar, "set the style of American mechanization, industrialization, and work."[76] The factory system accelerated the shift from piece-work to mechanized production transforming the workplace in fundamental ways. Beyond this, the growth of textiles elicited changes in the structure of industrial financing. With innovative developments in machinery, factory organization, and production, the textile industry required massive amounts of capital; but where would that capital come from? As many scholars of the New England industrial experience have pointed out, the cotton textile industry was one of the first industries organized with the aid of external capital, garnered in large part from the newly formed Boston Stock Exchange in the early 1820s. Merchants and banking institutions supplied the initial source of financing for the rise of textile industry's factory system, and as the requirements for more capital outstripped the ability of banks and merchants to supply it, many merchant houses reinvented themselves as manufacturing capitalists, with ties to their established trading networks, the new stock exchange, banks, and their own sources of private capital. Out of this melange of financing mechanisms emerged a credit market for Boston's burgeoning manufacturing enterprises.

A primary reason for Boston's rise to manufacturing excellence between 1815 and 1860 was the inventiveness of Francis Cabot Lowell, founder of the Boston Manufacturing Company - a pioneer in the textile industry of New England. The company represented the first successful implementation of the British proprietary technology known as power looms, implementing it on a scale unheard of in existing British or American mills.[77] This required not only innovative approaches to management and organization; it also taxed the conventional methods of entrepreneurialism.

Such a high level of capitalization was, according to Lowell, required to adequately equip the factory and provide a safe margin to cover operating expenses. Although capitalized at nearly ten times the amount of competing mills, Lowell and his associates at the Boston Manufacturing Co. kept tight reins on the management of the enterprise.[78] In fact, only seven stockholders controlled the entire capital stock of the company. This was rather significant, particularly as increasing scale tended to require new forms of organizational management and control. The Boston Manufacturing Company obtained its capital through an enormous subscription to the company's capital stock by a small group of local investors. The company authorized $400,000 of capital stock, which was issued in three subscriptions. The price was $1,000 per share, which most investors paid in installments over five years.[79] Boston Manufacturing Co. became a model for the financing of manufacturing enterprises. Furthermore, it enabled traditional mercantile capitalists to invest in new industrial opportunities promising previously unparalleled rates of return.[80]

Naomi Lamoreaux has argued that relationship banking or what she refers to as "insider lending" played a fundamental role in the industrial development of Boston and the New England region more broadly. According to Lamoreaux, as banks formed in towns and communities throughout the region, they provided basic savings and loan functions. These early nineteenth century banks only vaguely resembled their modern counterparts, having no branches, very few employees, and a handful of directors who in most cases were the stockholders. While they took deposits, most lending took the form of bank-issued notes and bank capital stock.[81] The most important type of early loan for commercial purposes was the accommodation loan. Under this arrangement, a borrower would request a loan from a bank, having guaranteed endorsers to sign the note. Nearly every bank portfolio had hundreds of accommodation loans on their balance sheets. As these transactions became more popular, some banks repeatedly renewed the notes effectively converting short term notes into long term debt.

In those years, banks played a role somewhat similar to that of venture capitalists, by lending funds to their directors who in turn funneled those funds into manufacturing enterprises. This process of insider lending overcame constraints in the financial markets, providing a much-needed spur to entrepreneurial enterprise. As Lamoreaux points out, "whenever banks maintain an arms-length relationship with their customers, they tend to avoid the risks involved in financing entrepreneurial ventures."[82] The rise of New England’s textile industry benefited from this close association between bankers and industrialists which enabled capital to be channelled to nascent enterprises.[83]

Early Venture Capital: The Mellon Interests

The investment activities of Andrew Mellon and his associates best captures the role of new forms of venture capitalism during the late 19th century and early part of the 20th century.[84] Indeed, the Mellon interests functioned to a great extent like a contemporary venture capital fund providing both financial resources and management assistance in helping to organize and incubate new industrial enterprises and an entire regional complex of industrial enterprises. As with American industry more broadly, Pittsburgh industry faced difficulty mobilizing capital during the mid-to-late 19th century.[85] However, by the turn of the century, Pittsburgh was home to and indeed an important incubator of a set of venture capital-like investors and organizations which fuelled the development of the region's increasingly diversified manufacturing complex.

The Mellons' provided a source of venture capital for industrial development. the first major investment by Andrew Mellon involved underwriting Henry Clay Frick's coke business, H.C. Frick Coal & Coke Co., in 1871. The Mellon's initially loaned frick 410,000, which he promptly repaid. Three years later, they deepened their investment with an additional $15,000 loan, a $25,000 line of credit, acceptance of a $76,000 mortgage on the frick property, and discounted business paper up to $24,000.[86] Unlike many of their later investments, the deal with Frick did not provide the Mellons with equity in the firms, not did it stipulate extensive managerial control of the firm.

In 1889, Charles Martin Hall, the inventor of an electrolytic process for aluminum production, approached the Mellons for a $4,000 loan to develop a full-scale manufacturing plant for commercial aluminum production. The Mellons provided the company with a higher loan amount, a line of bank credit, and real estate in Pittsburgh's metalworking district. In return, the Mellons demanded and received equity participation in the new firm.[87] Hunt and Hall and Captain Hunt later approached Andrew Mellon for $20,000 expansion loan for their Pittsburgh Reduction Company. But, Mellon offered instead was $1,000,000 in equity capital in exchange for a 40 percent equity participation in the new firm.[88] Mellon also insisted upon managerial control and named his own general manager, Arthur Vining Davis, in return for the investment.

Soon afterward, the Mellons were approached by George Westinghouse in late 1891 for a loan to help finance Westinghouse's new air brake plant. The Mellons demanded a high percentage of equity in Westinghouse's air brake and electrical equipment operations, as well as significant managerial latitude. Not about to relinquish control of his company, Westinghouse deemed the offer untenable and turned to the New York financial community for funds.[89]

Fueled by enormous profits from earlier investments, the Mellon's forays into venture capital began to take on a distinct formula which favored a preference from chemical process industry investments, high levels of equity participation, and significant managerial influence. In 1895, Edward Acheson, the inventor of a chemical abrasive known as carborundum came to the Mellons for loans to finance his small elctrochemical business. The mellons were impressed with carborundum and its cutting power. The immediately granted an interest free loan in return for company stock and directorships.[90]

Mellon also made venture investments in McClintic-Marshall, the steel-maker. The story of McClintic Marshall is similar to that of the Pittsburgh reduction Company. In 1899, two engineer-inventors, Howard McClintic and Charles Marshall, approached the Mellons looking for a loan to start a new business. The Mellons, aware of a boom in the early construction business and recognizing the potential to compete with industry leaders, responded with an offer of financing in return for equity participation and management control. McClintic-Marshall entered the bridge and structural steel segment of the market, competing head-to-head with Andrew Carnegie's American Bridge Company. For the next 32 years, McClintic-Marshall remained under Mellon control until it was sold to Bethlehem steel in 1932.

In 1915, the Mellons were approached by Heinrich Koppers, a German emigre, who had developed a new by-product coking process outside Chicago. The Mellons provided fund and convinced Koppers to relocate production to the Pittsburgh area, a demand that would later become common among Silicon Valley venture captialists. Two years later, during World War I, the Mellons assumed 70 percent of the firms's interest when Heinrich Koppers was forced to surrender his equity in the company under the Alien Property Act. On September 13, 1918, Mellon paid $300,000 for Koppers' 3000 shares, their 1914 value plus interest, the then-current market value of which exceeded $3,000,000.[91]

Between the 1880s and early 1990s, the Mellons made an impressive array of manufacturing investments in the chemical process and materials industries, oil exploration and railroad car companies. Nearly a dozen new enterprises, mergers and acquisitions were orchestrated by the Mellons' Union Trust Co. which underwrote and marketed corporate securities such as stocks and first mortgage bonds, including: McClintic Marshall, Mon River Coal & Coke Co. Pittsburgh Coal Co., Union Steel Co. all in 1899, Standard Steel Car Co. in 1902, Carborundum Co. in 1895, Crucible Steel Co. of America in 1900, Pittsburgh Steel Co. in 1901, and Gulf Refining Co. in 1903.

Mellon was not the only source of venture capital for Pittsburgh entrepreneurs. Andrew Carnegie's venture into steelmaking, for example, was funded through equity gained in partnerships with established iron producing families of Phipps, Kloman, and Shinn. Similarly, George Westinghouse's air brake concern received financial backing from Robert Pitcairn, a Pennsylvania Railroad Vice President, and brother of John Pitcairn who later teamed with John Ford to launch the Pittsburgh Plate Glass Company. Initial backing for H.J. Heinz was provided by L. Noble, a successful brick manufacturer, and the company was launched as Heinz & Noble Co. in 1869. That same year, Henry Frick obtained start-up capital from the A.O. Overholt Co. distillery.

Mellon's growing venture investments led him to undertake a number of efforts to restructure his financial institutions. In 1889, he organized the Union Trust Company, which he organized in 1889 with $250,000 in capital. Between its founding in 1889 and 1895, Union Trust barely registered a profit. But, in 1895, with commercial banking activity now part of its repertoire, Union Trust posted a $31,000 profit, initiating a long tradition of increasing profitability. Additionally, Mellon reorganized the T. Mellon & Sons bank, acquiring the City Deposit Bank, Pittsburgh National Bank of Commerce, and the Citizens National Bank and rolling them up into one colossal institution, the Mellon National Bank, N.A. in 1902. Later, T. Mellon & Son's would become the Mellon's vehicle for engaging in venture capital investment.

In his quest to build an integrated complex of finance, manufacturing, and cutting-edge innovation, Mellon sought to create a central source of technological innovation from which his various industrial holdings could draw. In 1909, he read an account of an Applied Chemistry laboratory at the University of Kansas. He spent the next two years convincing the founder, Robert Kennedy Duncan, to relocate in Pittsburgh. Duncan's book, *The Chemistry of Commerce*, outlined the financial rewards that could be realized by marrying scientific research and development and commercial manufacturing. In 1913, the Mellon Institute of Industrial Research was established as a center for metallurgical and chemical process research done in collaboration with Mellon's local industrial holdings.[92]

Mellon's venture investing practices represented an important advance in venture investing and to some degree presage the techniques that would be used by Silicon Valley and Route 128 venture capitalists nearly a century later. As we have seen, Mellon's used equity finance and provided managerial assistance, and at times managerial control, to portfolio companies. Mellon also put together networks or syndicates for investing. Sometime this involved pooling investments with local investors, and other times it meant using national capital markets as sources for funds. When it was to their advantage, as with the financing of Pittsburgh Coal, the organization of Crucible Steel Company, and Standard Steel Car Co., the Mellon's turned to the securities markets for capital.[93] In other cases, as with Union Steel in 1899 and Guffey Petroleum in 1901, they preferred to keep financial control within their close-knit syndicate. Furthermore, the Mellons strategy for venture investing reflected a keen sense of the advantages of industrial concentration and for building a supportive technology infrastructure for investments, as with the Mellon Institute.

T. Mellon & Son's: An Early Venture Capital Organization

By the middle of the 20th century, the Mellon interests developed and articulated a coherent strategy for venture capital investing, which formed an early model for many aspects of contemporary venture capitalism. The vehicle for this became T. Mellon & Sons.[94] T. Mellon & Sons was essentially a joint investment mechanism for coordinating the individual venture investments of family members. Its investment policy addressed national and community interests as well as commercial interest in enterprise such as Gulf Oil, Alcoa and Kopper Co. Its commercial investments were concentrated in innovative ventures in chemical and materials, which were related to its existing holdings and to the work of the Mellon Institute. In addition, T. Mellon & Sons aimed to undertake social as well as economic missions, particularly in the greater Pittsburgh region. It served as a coordinating mechanism for both charitable contributions and investments for its members. Its investment policy noted that its investments would aim to prove beneficial" to the general public and to the "stockholders interested in companies in which members of our family have investments. In her historical review of early venture capital investing, Martha Louise Reiner points out that "by alerting the family members to venture opportunities and by providing a standing joint investment mechanisms for those who chose to fund a venture, T. Mellon & Son's increased and improved the family's venture investing.[95]

Lessons: Venture Capital and American Industrial Development

The historical examples provided in this chapter shed light on the evolution of venture capital. Importantly, they illustrate the view that the processes of finance or capital formation, technological change and industrialization occur in tandem over time. This chapter has helped to illuminate a key theme of this book - that new forms of finance or more appropriately venture capital have been required to finance the birth of new technologies and business organizations, and the more general process of technological and industrial development throughout American industrial history. As we have seen, early forms of venture capital were important to both the historical examples presented here. The textile industry in and around Boston both required and reinforced the rise of a new set of financial institutions that economic historians such as Lance Davis, Robert Dalzell, and Naomi Lamoreaux have variously referred to as relationship banking or equity-financed insider lending. The early venture capital or insider lending of the New England textile industry was largely a regional system, built upon close personal ties between the region's financiers and industrialists. The Mellon interests provided risk capital to the technology-based metals and material and chemical industries that grew up in and around Pittsburgh. They provided managerial assistance as well as capital to these enterprise; and they put in place critical elements of the broad technology infrastructure of the region, including the Mellon Institute. In addition to all of this, T. Mellon & Sons functioned as what might be considered to be the nation's first organized venture capital fund.

These examples were by no means unique. Venture capital played an important role in the early automotive industry in and around Detroit.[96] Two of the most important individuals in the early years of the automotive industry - Henry Ford and Ransom Olds - turned to venture capital after being rejected by banks and traditional financial institutions. Financing for Old's ventures came from wealthy investors in his hometown of Lansing, Michigan and later from Samuel L. Smith of Detroit. In 1899, Smith became the principal investor in the Olds Motor Works Company, holding more than 90 percent of the new shares issued. Smith took an active hand in the management of the company becoming president and installing his son as vice-president and general manager. Henry Ford also secured venture capital for his first company, the Detroit Automobile Company, in 1899 from local investors including William Maybury and William H. Murphy who had made fortunes investing in real estate. When the Detroit Automobile Company was dissolved one year later, Ford established the Henry Ford Company with backing from Murphy and from James and Hugh McMillan who controlled a network of railroads, banks and insurance companies. Ford later received venture capital from Alexander Malcomson and other prominent Detroit investors.

While venture capital certainly played a role in earlier periods of technological innovation and American industrialization, it was not until the mid-to-late 20th century that a fully institutionalized and modern venture capital system would emerge. These new venture capitalists grew up alongside the high-technology centers of Silicon Valley and Route 128. As the next several chapters will show, by the closing decades of the 20th century, a highly institutionalized national system for venture capital system had emerged to finance and support a new series of technological and industrial revolutions. But, the contemporary venture capital system did not emerge fully-formed. Its evolution was the result of a long series of small steps and experiments with different types of venture capital institutions. It is to a discussion of those early experiments - endeavors which paved the way for the modern venture capital system - to which we now turn.

CHAPTER 4

RISE OF MODERN VENTURE CAPITAL:

FROM NEW DEAL TO HIGH-TECHNOLOGY

"The post-war prosperity of America depends in large measure on finding financial support for the comparatively small percentage of new ideas and developments which give promise of expanded production and employment and an increased standard of living for the American people. We cannot float along indefinitely on the enterprise and vision of preceding generations. ... To be confident that we are in an expanding, instead of a static or frozen economy, we must have a reasonably high birthrate of new undertakings." Ralph Flanders, President od the Boston Federal Reserve, U.S. Senator, and founder of ARD. [97]

"What we want to do is the opposite of the old system of holding back capital until a field or idea is proved completely safe. We are undertaking pioneering projects that with proper backing will encourage sound scientific and economic progress in new fields - fields that hold the promise of tremendous benefit." Laurence Rockefeller, founder of Rockefeller Bros.[98]

While venture capital is certainly bound up with the broad American pattern of technological change and industrialization, the rise of a modern, institutional venture capital system can be traced to the period stretching from the Great Depression to the years immediately following World War II. During this period, it became increasingly evident to many influential American business leaders and policy-makers that new mechanisms require to stimulate investment in entrepreneurial technology-intensive enterprises. A popular notion at the time - which was reflected the influential writings of the luminary economists Joseph Schumpeter, and New Deal planners Alivn Hansen and John Kenneth Galbraith - was that American industry had lost much of its dynamism and was headed toward more or less permanent stagnation, as Hansen often put it. Much of the blame lay with the overwhelming bureaucracy of the large vertically-integrated corporation, including its research and development laboratory which, according to Schumpeter, sought to routinize innovation. The solution for many - given the broad trends in the American industrial experience reviewed in the last chapter - was to stimulate technological innovation. To do so, required new forms of finance: in a word, venture capital.

Indeed, the very term **venture capital** was coined at the 1939 convention of the Investment Bankers Association of America (IBA), when Jean Witter, in his presidential address to the association, called for the creation of new forms of finance - or, as he put it, of venture capital - to spur economic growth and revitalization.

> "No one in the high income tax brackets is going to provide venture capital and take the risk which new enterprise and expansion require, and thereby help to create new jobs, if heavy taxes take most of the profit when a transaction is successful. ... That early financing must be done by individuals close to the management of new undertaking who are conversant with its risks and able to take an active part in the solution of its problems.

Jean Witter, presidential address to the 1939 Investment Bankers of America convention.[99]

There were a number of reasons for this turn toward venture capital during he depression. With the virtual collapse of the nation's industrial and financial structures during the Great Depression, large and influential segments of the financial, industrial, academic and political communities became convinced that new mechanisms were required to support and sponsor innovative, entrepreneurial enterprises. As the nation emerged from the depression and later from World War II and as the economy recovered, new forms of venture finance began to emerge. These new mechanisms for providing venture capital grew up to some extent independently - though the successes or failures of different models certainly informed the evolution of various forms. Some of these mechanisms involved federal intervention, while others were purely market-based. But, out of this period of transition and experimentation, the modern institutionalized venture capital industry was borne.

This chapter traces the emergence of various types of venture capital during this critical transition period. We begin with a discussion of the early efforts of two powerful organizations, the Investment Bankers Association of America (IBA) and the Committee for Economic Development (CED), in the debate over venture capital during the 1930s and 1940s and in later calling for a federal role in small business financing - an effort which eventually resulted in the establishment of the Small Business Administration and the Small Business Investment Companies (SBICs) during the 1950s. We then turn to efforts of wealthy New York families, the Rockefeller's and the Whitney's, in establishing two of the earliest professional venture capital funds in the 1940s. We close out this chapter with a discussion of the early evolution of venture capital in the years following World War II.

Venture Capital and the Great Depression

While changes in the investment climate began to work against venture financing during the 1920s, the Great Depression devastated the nation's financial system.[100] Financial intermediaries linked to the stock market toppled like dominoes, and the national banking system endured a massive panic. A major effort to reform and restructure the nation's financial system was undertaken. The thrust of so-called reform legislation like the Glass-Steagall Act was to draw strict lines between commercial and investment banking activity.[101] Investment banks were no longer allowed to accept deposits and commercial banks were “required to divest themselves of their security affiliates, and their underwriting activities were restricted to general obligation bonds of federal, state, and municipal authorities."[102]

The depression devastated the environment for venture investment. The general economic climate was not conducive to startups, and the stock market collapse virtually obliterated the new issues market. In addition to this, the New Deal financial reforms, which were arguably necessary to curb abusive securities' investment practices which contributed to the financial collapse, also constrained investment in innovative ventures. Indeed, smaller, start-up enterprises found it all but impossible to find capital.

Among the most vocal early advocates of the need for venture capital to overcome the depression and stimulate entrepreneurship and economic growth stood the Investment Bankers

Association of America (IBA). There were a number of reasons for this. On the one hand, local investment bankers had lost out disproportionately due as result of New Deal financial reform and the high concentration of investment banking in large private firms. They saw venture capital as a new avenue for business. On the other hand, there was the obvious need to stimulate the American economy; and government had already taken an active role in bolstering of host of industries and markets, both directly and indirectly through the creation of new enterprise that would eventually issue stock. Thus, the time was right to make the case for new mechanisms, including government mechanisms, were required to supply venture fiance and in doing so to stimulate entrepreneurial business formation and spur economic growth. There was clearly debate over the nature adn extent of government intervention, with some arguing for a direct government role in the provision of venture capital and others calling for indirect government actions, such as tax reform or liberalization of securities' regulation, to stimulate the private market for venture capital. As early as 1932, Ditlew Frederiksen proposed that Congress provide for "extensive financing of new business ventures, such as is needed in time of depression," by establishing a bank guarantee corporations owned by local banks, - a system that was similar to then newly established Federal Home Loan Bank system. The Reconstruction Finance Corporation (RFC), established in 1932 by the Hoover administration, to help refinance U.S. banks and industry, provided a small amount of loans for small business. With so many other activities, the RFC never had small business lending as a priority. Between 1932 and 1939, more than half of RFC small business loans were for amounts of $10,000 or less. For most of the 1930s, the RFC was restricted to lending to existing small businesses, largely to keep them afloat. Only in 1938 was it allowed to invest in new enterprises and for the expansion of existing businesses.[103]

In 1938, Joseph Nicholson, an industrial analyst, wrote an article on the problem of small business finance in the *Harvard Business Review*.[104] After surveying the issue, Nicholson concluded that neither existing financial institutions not government agencies could adequately address the problems of small business finance. He found existing equity markets too expensive for small companies and RFC loans plagued by high costs, bureaucratic delays, and dear of political implications. He called for the creation of a new institution devoted to small business finance, which he referred to as "local capital trusts." Nicholson envisioned this as a decentralized system drawing upon local resources. The local capital trusts would be financed as joint enterprises by local banks in communities across the country. Managed by staffs of professionals, the local capital trusts would not only provided capital, but would assist in the management of companies which they financed.

A host of proposals for stimulating risk capital quickly followed with a variety of government programs and private schemes being promoted. In his 1939, address to the IBA convention, Jean Witter outlined a private system for supporting venture capital in which government would act to stimulate private venture capital such as tax reform and by removing restraints on investment practices. In his address to the 1945 IBA convention, George Noyes of the illinois Company, Chicago, heralded the role of "free enterprise, the flow of private capital into privately owned business, the encouraging of new enterprises and small business - and the essential role of the investment banker in bringing this about. He went on to say: "If we had not had the invention, if we had not the ability to assume risks, if we had not had the imagination and the courage to go ahead, we would have never been able to become the industrial leader of the world today."[105] In 1945, the IBA proposed a venture system in which funds would be raised through the public stock market and where the Federal Reserve would lend to and supervise companies that would invest in new and small businesses. During the 1940s, the IBA continued to promote the idea that venture capital based on the stock market, by allowing the public to buy stock in venture capital funds. While the use of public stock for venture capital never took hold at the national level, as Chapter 5 will show, such a mechanism was created in Boston with the formation of the venture capital firm, American Research and Development, in 1946. In addition, there were a growing number of investment bakers and others who believed that new government supported institutions would be required for venture finance. John Fennelly, who directed influential studies of venture finance for the both the IBA's and the Committee for Economic Development, emphasized the need for new institutions to provide venture capital in testimony to the Congress in 1945. "There is a real gap in the machinery ... in connection with the ability to provide the needed capital, long-term capital and equity capital, for small business of this country." He went on to say that, "The situation calls for the creation of new institutional machinery in the form of decentralized investment funds."[106] This proposal pre-figured the rise of the federally-sponsored Small Business Investment Companies in the late 1950s.

The IBA helped to place the issue of venture capital on the agenda. As Reiner describes it in her detailed analysis, the IBA was effective both in developing a broad ideology for venture capital and in developing support from other interests.

> "In the IBA's campaign, venture capital became a rallying cry that linked with the overarching goal of reviving private capital with goals of such interests groups as small business and small investors. The financial community found much support when it

> campaigned for venture capital broadly defined. Organizations representing other interest lobbied alongside the financial community for policy changes that would strengthen established methods of financing industry through the public markets. the campaign absorbed many visions of venture capital but made little concrete progress - especially regarding investment in innovative ventures traditionally done by wealthy individuals."

The IBA effort did, however, set the stage for progress on other fronts - a series of concrete proposals, experiments and actions would soon be forthcoming.

The Case for Government Intervention in Small Business Finance

An important impetus for the rise of modern venture capital came from a group of influential bankers and industrialists who began to sketch out plans for a new government agency devoted to the problems of small business and small business finance. To lend legitimacy to their designs, they organized their efforts through a variety of organizations and associations, particularly the influential Committee for Economic Development (CED), a group concerned with the post-war planning and reconversion effort. Many of these elites were concerned with the increasingly conservative outlook of large corporations, and what Schumpeter referred to in his influential book of the period, *Capitalism, Socialism, and Democracy,* as the increasing bureaucratization of the innovation process. Many also believed that new mechanisms would be required to re-create the entrepreneurial impulse in the American economy - to nurture and support inventive new enterprises. While the push to develop new sources of capital for entrepreneurial endeavors proceeded on many fronts, the first and perhaps foremost of these efforts involved establishing a new federal program to support small business and provide small business finance.

There were a series of efforts during the New Deal to utilize the Reconstruction Finance Corporation to provide credit to small business. The Logan Vorhis bill of 1939 called for a system of intermediate credit banks to be established with deposits insured by the federal government. The Roosevelt administration later proposed federal insurance on up 80 percent of long-term loans to small business. Later, the Mead Bill sought to establish a "Federal Industrial Loan Corporation" overseen by the Federal Reserve Board to make equity investments in small business and guarantee bank loans to them. As early as 1939, the Boston retailer Lincoln Filene sponsored a study demonstrating the problems encountered by small business in securing long-term financing.[107] Filene was a co-author with Ralph Flanders of the influential 1938 study *Toward Full Employment*; Flanders who was President of the Boston federal reserve and would become chairman of the CED's research and policy committee during the war and a Senator from Vermont.[108] While Filene's report did not endorse direct federal intervention, it did call for steps to liberalize traditional banking practices and promote the private organization of small business trusts.

A spate of proposals for providing venture capital emerged during the early 1940s, calling for various levels of government intervention and private financing. In 1942, Rudolph Weissman, a staff member of the securities and Exchange Commission, proposed the establishment of the Federal Reserve Investment Corporation (FRIC) under the Federal Reserve System to provide equity finance to small business. Later that same year, Henry Kaiser, the

West Coast shipbuilder, outlined a scheme for providing $500 million in investment funds for small business under a National Industrial Credit Corporation. The National Industrial Credit Corporation was envisioned as a profit-making venture finance institution to be capitalized not with government money, but through a combination of public subscription and by regulatory relief which enabled banks and corporations to participate in its financing. In 1944, Senator James Murray introduced a bill to create the Smaller War Plants Corporation to assist small business in the post-war reconversion to a civilian economy. Shortly afterward, Senator Robert Wagner introduced a bill to amend the federal Reserve Act to guarantee loans by private financial institutions to smaller firms.[109]

In 1945, Ralph Flanders published an influential manifesto on the subject of small business finance, *The Problem of Development Capital*, which made the case for the creation of new institutional structures to provide capital for innovative, entrepreneurial enterprises.[110] In 1947, a CED study outlined the need for policy initiatives to address the problem of adequate capital for the small business community.[111] Five years later, in 1952, *Dun's Review* asked *Can Small Businesses Get the Capital They Need?,* concluding that capital markets were failing to provide required capital to entrepreneurial enterprises.[112] Furthermore, the study showed that small businesses faced interrelated managerial *and* capital crises, and that both must be addressed.

By the early 1950s, business and financial leaders, particularly those affiliated with the CED had made the case for some sort of government program to bolster small business start-ups.[113] And, by the close of that decade, they succeeded in getting the federal government to initiate a new program to create and to subsidize a new set of institutions, small business investment companies or SBICs, designed to provide finance capital to startup companies. In 1952, the Small business Administration was established. And, in 1958, the Small Business Administration was authorized to establish Small Business Investment Corporations (SBICs), which were private investment companies whose capital was leveraged against asset sources in the federal government. Many of the first venture capital funds actually emerged as SBICs. SBICs also benefited from mandated tax breaks and other investment incentives, which eventually enabled them to become an import source of venture capital, especially in new growth regions such as California and Massachusetts.

Both the federally sponsored SBICs and private investors saw a connection between the new emphasis on scientific research and commercial viability in the marketplace and sought to capitalize on it. Part of the solution was to forge closer links between entrepreneurship and scientific research and development. Vannevar Bush and others had effectively made the case for the importance of basic research in the war effort, and proposed to tap into the university as a source of new and potentially lucrative technologies. MIT led the way in the commercialization of academic research.[114] Led by Vannevar Bush, Karl Compton, and Horace Ford, MIT envisioned turning the greater Boston region into an incubator of technology-based economic development. Ironically, they looked to the example of the Mellon Institute in Pittsburgh, sponsored by Andrew Mellon for his industrial investments, as the model of a regional focal point for industrially sponsored research and development projects. To realize this vision, Compton joined forces with a private development agency, the New England Council, to address the decline of New England industries, such as machine tools by providing capital and managerial support.[115] Immediately after the war, this group of Boston industrialists and bankers established up a formal venture capital vehicle devoted to financing high technology enterprise - American Research and Development (ARD), which would have an enormous impact on the shape of the modern venture capital industry, as the next chapter will show.

Innovations in Private Venture Capital: Rockefeller Bros. and J.H. Whitney and Co.

More important innovations in venture capital came with the formation of several significant venture capital funds in the years immediately following World War II. The impetus for the creation of these new venture capital vehicles was similar to that outlined above. With the end of the war, wealthy individuals and families in particular undertook to create new venture capital mechanisms in order to capitalize on the commercial potential of the many scientific and technical advances that had been spurred on by the war effort. 1946 was a critical year in the development of these private venture capital institutions modern venture capital system. In that year, three seminal venture capital firms were formed: Rockefeller Brothers and J.H. Whitney and Co. in New York City, and American Research and Development (ARD). The following pages examine the first two, while the next chapter takes up the subject of ARD.

Rockefeller Bros. Inc.

Laurence Rockefeller became involved in venture investing during the late 1930s by investing in two aircraft companies. In 1938, he financed the acquisition of General Motor's airline subsidiary, by Eddie Rickenbacker, the World War I flying ace. GM was under court order to divest itself of the subsidiary and Rickenbacker had an option to buy it. While bankers refused to finance Rickenbacker's venture, considering him too great an investment risk, Rockefeller provided $125,000 in seed capital to back the creation of Eastern Airlines, later raising his stake to more than $500,000 and becoming director of the new airline. In 1939, Rockefeller provided venture capital to another aircraft venture, McConnell Aircraft, a company founded by James S. McConnell Jr., an aircraft designer whose first company had failed in the 1929 stock market crash. McConnell, who was working out of a small garage workshop to build fighter planes, showed Rockefeller the designs for a new military fighter; and Rockefeller provided an initial $10,000 in seed capital. By 1941, Rockefeller had invested $250,000 of his own money into the venture and convinced his brothers to invest an additional $200,000. Although its initial contract for a military fighter was cancelled when early versions of the plane crashed (and while Rockefeller was forced to sell his stock to avoid conflict of interest while in the Navy), the company prospered during the war as a subcontractor. After the war, Rockefeller invested another $300,000 in the enterprise which went on to develop its successful Phantom jet and become an important player in the aerospace industry. When Rockefeller sold his stake in the early 1950s, he had almost tripled his investment. Rockefeller's interest in venture investing was spurred by the mobilization effort for World War II, where he became captivated by the commercial potential of new science-based technologies in aircraft and aerospace, electronics and other fields.

In 1946, Rockefeller formed a formal venture capital organization, Rockefeller Bros., as a vehicle for venture investing. In his words, the new firm provided a mechanism for the "investigation and financing of new, productive, and constructive business and projects, the making of permanent or long-term investment and the management and supervision of such investments."[116] To capitalize the new firm, Rockefeller turned to his five siblings who provided $250,000 each, for a initial capitalization of $1.5 million. Laurence Rockefeller also leveraged another $1.3 million in assets, mainly from his earlier venture investments in Eastern Airlines, McConnell Aircraft and other holdings.

Rockefeller Bros. made a string of venture investments in the late 1940s and 1950s. In 1947, it invested $500,000 in Reaction Motors', a company developing liquid fuel rockets, and provided technical, managerial and financial assistance to the company and also helped it to identify military contracts for its products. The company later won a competition with General Electric to supply the rocket engine for the Bell X-1, the first plane to break the sound barrier; and, in 1948 it was acquired by Thiokol. Rockefeller Bros. also made investments in Piasekci Helicopters, renamed Vertol, and later acquired by Boeing, and in Marquandt Aircraft, a producer of ramjet engines. In the late 1957, Rockefeller invested in Itek Corp. which saw its stock soar from $2 to $345 per share two years later. In 1961, *Barron's reported* that Rockefeller had invested a total of $9 million in venture capital and generated returns of some $40 million in 15 years of venture investing.[117] Rockefeller did not limits his risk capital investments to technology-based fields. He would also go on to make significant venture investments in the development of a series of famous vacation resorts in the Caribbean, Hawaii and elsewhere under the Rockresorts name. The Rockefeller family transformed its family-run venture interests into a formal venture capital firm, Venrock, which remains an important venture fund, during the 1960s. Venrock later provided early stage financing for a host of important high technology companies such as Intel and Apple Computer.

Rockefeller Bros. contributed a series of organizational innovations to the venture capital industry. It was one of the first venture capital firms (along with ARD) to recognize the strategic value of investing in high-technology industries - a strategy that would become the cornerstone of modern venture capital investing. "What we are trying to do," Rockefeller said in a 1951 profile, "is clothe engineering and creative brains with financial aid and managerial strength."[118] Rockefeller Bros. was formed as a limited partnership corporation, and may well constitute the initial use of the limited partnership form for venture investing. Interestingly, the early use of the limited partnership form by Rockefeller Bros. differed markedly from the way the limited partnership form would later be used as a vehicle for mobilizing and investing venture capital. For Rockefeller, the limited partnership was a way to limit the liability of his siblings and provide modest tax advantages. It was not used as a mechanism to mobilize funds from outside investors. Indeed, Rockefeller Bros. was conceived from the very start as a mechanisms for using family funds as a source of long-term investments in start-up enterprises. Thus, it did not, by its very design, face the time pressure associated with later venture capital limited partnerships which must generate returns to initial investors in order raise new funds. Furthermore, Rockefeller assembled a team of professionals - perhaps the first group of professional capitalists - to guide venture investments for the firm. This group included Harper Woodward, a lawyer, Randolph Marston, a banker, and later Teddy Walkowicz, a former air force officer with contacts in the research community, and Peter Crisp.[119] This team had expertise in aircraft and aerospace technology and performed the systematic research and due diligence which would become key features of contemporary venture investing.

J.H. Whitney and Company

J. H. Whitney and Company was launched in February 1946 with $10 million from John

Hay (Jock) Whitney.[120] Its goal was to invest in new, risky ventures that would face difficulty raising capital through established financial institutions. Whitney became involved in venture investing as a young man during the late 1920s and 1930s, after inheriting a part of his father's estate of $178 million, the largest ever appraised in the United States at that time. Whitney made his first venture investment, albeit an unsuccessful one, in the American rights to a "miracle plant" that could be turned into cattle feed or newsprint in 1926 while studying at Oxford University. He did however make large profits in airline stocks, including a major successful investment in an early expansion of Pan American Airlines, a company founded by his cousin Vanderbilt Whitney. In 1929, he took a $500,000 stake in Freeport Texas Co., which later became Freeport Sulphur Co., the value of which more than tripled by 1951. During the 1930s, Whitney and his sister, Joan Whitney Payson, developed a variety of investment vehicles, including one called **Wild Cat**, to make "angel" investments in Broadway plays, including the successful, *Life with Father*. In 1933, the Whitneys' partnered with other relatives to invest in a company, Pioneer Pictures, to make films with a then new film a process, **Technicolor**. They later bought Selznick International Pictures, which David O. Selznick had formed, and which produced *Gone With the Wind*.

Upon returning from World War II, Whitney formed J.H. Whitney and Co. as a vehicle for venture investing. He had come to the conclusion that the venture investing he had been doing in an ad hoc manner could be done more effectively in a more organized manner. J.H. Whitney and Co. made a number of successful investments during the late 1940s and early 1950s. In 1947, J.H. Whitney and Co. acquired Minute Maid, the company which pioneered frozen orange juice. The firm also invested $1.25 million in preferred stock and $250,000 for common stock to convert a chemical plant, Spencer Chemical, that had been operated by the government during World War II to commercial production of fertilizer and other products. The business grew rapidly and Whitney concluded that it alone was worth more than the $10 million which he had used to capitalize the venture firm. J.H. Whitney and Co. made other successful investments in General Signal, Memorex and Corinthian Broadcasting.

J.H. Whitney and Co. contributed several important organizational innovations to the venture capital industry. Like Rockefeller Bros., Whitney recruited a staff of professional venture capitalists, including financial, technical and legal specialists with professional experience and degrees from MIT, Wharton and Harvard Business School. Moreover, Whitney was the first venture capital firm to set up a partnership structure where the professional venture capitalists were able to share in the profits generated through the firm's investments.

From Finance to High-Technology

As we have seen, two of the most important early venture capital funds - Rockefeller Bros. and J.H. Whitney and Co. - emerged in New York City, the nation's financial center. In 1947, a third significant venture fund was formed there, when Joan Whitney Payson and Frederick K. Trask, as classmate of J.H. Whitney, formed Payson and Trask with $5 million. By 1949, Payson and Trask had coinvested in four ventures with J.H. Whitney and Co. along with other investments. New York City became an important center for early venture capital. With close proximity to accumulated family wealth and major banking and financial institutions, New York in fact became dominant location for venture capital during the late 1940s and 1950s and even into the 1960s. Over time, New York City gave rise to more than 50 venture capital firms tied to banks or investment houses and another 40 or so, linked to financial institutions such as large commercial banks, such as Citicorp, Bankers Trust and Irving Trust, or investment banks such as Merill Lynch; Drexel, Burnham, Lambert (Lambda), Smith Barney (First Century Partnership), and Donaldson, Lofkin and Jenrette. New York City also became home to funds like Rothschild and CMNY, which were affiliated with European investors.[121]

Chicago was another important source of venture capital, also stemming from its history as a center for personal wealth and financial institutions.[122] Allstate Insurance, for example, was very important to the rise of Chicago venture capital. In 1960, it became one of the first financial institutions to set up a venture capital fund.[123] Allstate's director, Ned Heizer, made very successful investments in young high tech companies such as Control Data, Memorex, Scientific Data Systems, Teledyne, and others.[124] In 1969, Heizer spun off from Allstate and formed what was then the largest venture capital fund in the country, Heizer Corporation. Heizer Corporation became a training ground for venture capitalists and was in turn responsible for spinning off a number of important venture capital funds. Chicago banks became active in venture capital during the late 1960s with the First National Bank of Chicago spawning two venture capital affiliates, First Capital Corporation of Chicago and the Institutional Venture Capital Fund, and Continental Illinois also creating two venture capital units, Continental Illinois Equity Corporation and Continental Illinois Venture Corporation. Major Chicago corporations, for example, Sears and Amoco, also became involved in venture capital. Later, Chicago also spawned important venture partnerships, such as Golder Thoma.[125]

While venture capital emerged early on in these leading financial centers, it was not invested there. The early venture capitalists in New York City and later in Chicago made the majority of their investments outside of those two regions, and increasingly in the emerging high-technology centers of Silicon Valley California and the Route 128 area around Boston - areas with the greatest potential for technology investing. Entrepreneurs in these regions frequently looked to venture capitalists in New York as sources of venture funds. When Fairchild Semiconductor, was formed in 1957 in Silicon Valley, for example, venture capital was supplied by New York and Connecticut venture investors - Arthur Rock and Fairchild Camera.[126] Venture capital in the early years was characterized by a flow of funds from major financial centers of New York and Chicago to the newly emerging high-technology regions [see Chapter 9 for our discussion of invetment flows].

The early venture capitalists contributed a number of important organizational innovations to the emerging venture capital system - early forms of the limited partnership, the employment of professional venture capitalists, investment screening and due diligence, and the participation of professional venture capitalists in financial gains. These and other institutional changes combined to fuel the growth of the venture capital industry and eventually to bring about salient changes in its organization and geography. The rise of SBICs allowed for some diffusion in the geographic sources of venture capital, because they allowed commercial banks and other financial institutions to become involved in venture capital. As Chapter 5 will show, early and important SBICs were established in Boston, particularly by the First National Bank of Boston, which became an incubator of sorts for Boston area venture capitalists. The same is true of San Francisco and the Silicon Valley, where SBICs were created by large banks e.g. Bank of America and small investment companies e.g, Continental Capital Corporation and Draper and

Johnson, as Chapter 6 will show.[127]

Many of the organizational innovations contributed by the early financial venture capital firms set the stage for the later rise of venture capital in high-technology centers. These innovations allowed venture capitalists outside the financial centers of New York and Chicago to generate capital from external sources, local financial institutions, and perhaps most importantly from the capital that was accumulated in local growth industries. The emergence of the limited partnership as the dominant form of venture capital institution allowed a new breed of local venture capitalists to collect and mobilize funds from distant investors and financial institutions, and thus functioned to loosen the geographic constraints on the location of venture capital funds. Venture capitalists could now raise money from outside limited partners, banks, corporations, pension funds, and wealthy families. The Hillman industrial interests in Pittsburgh, for example, which had long operated a venture capital unit in Pittsburgh to make investments in the growing semiconductor and computer industries, was now able to channel investments through hands-on venture capital funds in Silicon Valley. As Chapter 6 will show, the Hillman interests became an original investor of the major Silicon Valley venture capital fund, Kleiner Perkins.[128] These innovations gradually contributed to a shift in the loci for venture capital from the financial centers toward the high-technology centers such as California's Silicon Valley and the Route 128 area around Boston. By the 1980s, California became the nation's leading center of venture capital, eclipsing both New York and Boston.

As the next two chapters will show, by the 1970s and 1980s, the wealth generated in the new high-technology centers gave rise to their own centers of venture capital embedded within broader social structures of innovation. In this way, capital that was originally accumulated in financial centers and in older basic industries found its way into the new growth sectors of the U.S. economy.

CHAPTER 5

BOSTON AND ROUTE 128

"The only assets we had in Massachusetts were brains. We had no raw materials, high labor costs and the markets were moving away. If we were going to rejuvenate New England, it would have to come from the minds of people at MIT and Harvard." Peter Brooke, Boston venture capitalist and founder of TA Associates, date????).

"The American Research and Development Corporation has been formed to aid in the development of new or existing businesses into companies of stature and importance. It is a builder of new enterprises. It encourages research. In addition to supplying equity financing, it makes available to business the technical and administrative experience of its management and boards of Advisors and Directors. It is the hope American Research and Development Corporation that those who read this brochure will agree with the Company's objectives and policies and will show their interest by referring to it promising new project which fall within the field of its operations."[129]

Boston emerged quickly in the years following World War II as a center for venture capital. During the 1930s and 1940s and continuing into the 1950s, New York City had been the dominant source of venture capital for technology-based enterprises, mainly as a result of the early venture capital activities of wealth individuals and families like the Rockefeller's and the Whitney's. While Boston certainly had its share of wealthy families, it did not generate independently wealthy venture capitalists, certainly not on the scale of New York, who would channel high-risk investment funds into technology-intensive enterprises. As early as the 1920s, leading bankers, industrialists, university leaders and political officials began to ponder various efforts and plans to generate some sort of risk finance in the greater Boston area. With the growth of engineering and technology research, there was the thought that new enterprises might spring from the important innovations being made at MIT. And, as the previous chapter has shown, Boston area figures led the push for federal government intervention in venture capital and the creation of the Small Business Investment Corporations or SBICs.

Most significantly, as this chapter will show, the Boston area was home to one of the nation's most important early venture capital firms - American Research and Development or ARD. ARD would have a momentous impact on the evolution of the modern venture capital industry. It was, according to many astute observers, the nation's first professional venture capital fund. ARD also set the tenor for venture capital investing, developing over time the model of technical and managerial involvement in the enterprise that would come to typify modern venture capitalism. And, ARD both helped to spawn the high-technology industrial complex of the Greater Boston area through its investments and just as importantly became a virtual breeding ground for Boston area venture capitalists. ARD thus provided much of the impetus to the self-reinforcing pattern of venture capital finance, the formation of entrepreneurial technology business and the broader patter of high-technology regional development they set into motion.

This chapter traces the rise of modern, institutional venture capital in the greater Boston region, which includes Cambridge and the Route 128 beltway surrounding the city. Boston is important to our analysis for two reasons. First, Boston emerged as a major source for both the supply and investment of venture capital, developing into a center for both venture investment and high-technology industry. Second, Boston played a critical role in the evolution of the broader venture capital system as a center for key experiments and innovations in the institutional structures and mechanisms for providing venture capital.

Early Venture Capital Efforts

While Boston had a long history of private individuals, wealthy families, and banks extending investments to entrepreneurs aiming to explore new business opportunities, it lacked the venture investors like Rockefeller's, Whitneys's and others in New York City. I fact, early Boston startups often turned to venture investors outside the region, and particularly in New York City. In 1920, MIT Professor Vannevar Bush established the American Appliance Company, later Raytheon, with backing from J.P. Morgan and a group of Boston investors to commercialize thermostatic controls for irons.[130] In the 1930s, Edward Land, a Harvard graduate who had been conducting research at the university, established the Polaroid Corporation with $375,00 in venture capital from a group of investors which included James P. Warburg, W. Averill Harriman and Lewis Strauss.[131]

The lack of local venture investing prompted early efforts by leading Boston figures to develop local venture capital. As early as 1911, the Boston Chamber of Commerce was providing financial and technical assistance to new enterprises.[132] Another early effort to stimulate innovation, entrepreneurship and venture capital came from the efforts of the New England Council. Founded by retail magnate, Lincoln Filene and a number of his contemporaries in the late 1920s, the Council was a mechanism for reviving the greater Boston and New England economies. After examining various ways of reviving the economy, the Council finally concluded rather than trying to aid existing companies in “sunset”industries such as shoe-making and textiles; it would be better to provide financial resources to start new firms in “sunrise” industries. Horace Ford, then treasurer at MIT, envisioned a research row between MIT and Harvard on Cambridge’s Memorial Drive of technologically based firms.”[133] In 1940, the New England Industrial Development Corporation was launched to provide various kinds of assistance to new ventures.

In fact, MIT was a primary factor in the move to establish new venture capital institutions in the greater Boston area. One of the primary proponents of technology as a source of wealth and economic development, then MIT president, Karl T. Compton. Compton had participated in the efforts of the New England Economic Council advocated that academic institutions and industry should collaborate and link scientific research to industrial development. According to the sociologist of science, Henry Etzkowitz, who has studied MIT extensively, when Compton failed to convince the Roosevelt administration of the wisdom of these ideas, he decided to try to implement his ideas on the regional level.[134]

Furthermore, there was great concern in Boston during the New Deal years and through the period following World War II, echoing Joseph Schumpeter, Alvin Hansen and John Kenneth Galbraith, who were all at various times members of the Harvard faculty of economics, that the United States industrial economy was stagnating and would likely fall back into depression. For some, the solution lay with the development of entrepreneurial enterprises and risk-taking.

Two factors lie behind these various efforts to establish venture capital in Boston. The first was stimulated by problems of the Boston economy, particularly the deindustrialization of the region as the textile and shoe industries began to move to the Southern United States. The obvious remedy was to stimulate the development of new, entrepreneurial enterprises which would generate economic development, wealth and jobs. This was only exacerbated by fears of impending class struggle emerging from the social and labor movements of the Great Depression. Simply put, venture capital came to be seen as a way to stimulate technological innovation, the formation of new entrepreneurial business, and regional economic revitalization.

The second factor revolved around the potential to apply university science and technology for industrial ends. The Boston-Cambridge area was certainly bestowed with formidable academic assets. The early part of the 20th century had sen MIT grow into an engineering powerhouse, and it had already proven able to incubate important commercial technologies and several spinoff businesses. The War effort had brought massive government funding of university research in science and technology. Venture capital, it was thought, would provide a vehicle for commercializing university-based advanced in science and technology. which would in turn contribute to the broader growth and development of the greater Boston region.

The First National Bank of Boston had been actively involved in lending to entrepreneurs in years immediately prior to World War II. In his analysis of the venture capital industry, Matthew Bullock found that the First National Bank of Boston actually used a method of lending on the basis of accounts receivable that it had developed earlier from its long involvement in the Massachusetts textile and shoe industries to provide capital to newly established firms.[135] In 1943, the First National Bank of Boston "decided to support the companies that were emerging from MIT by lending them money ....against V (for Victory) contracts placed by the Government during the Second World War."[136] Because of its position as a premier bank, it had a constant flow of entrepreneurs seeking loans. The Bank frequently channeled promising investments to New York venture capitalists such as the Rockefeller, Phipps and Whitneys during this period, due to the lack of interest among Boston investors.

American Research and Development

The Boston area made an important step forward in the history of financing innovation by its creation of a professional organization for funding startup firms. A signal event in the development of the modern venture capital industry was the formation of American Research and Development or ARD in 1946. The impulse to establish ARD came from many of the same individuals who had played a central role in the national debate over small business financing discussed in the previous chapter: Ralph Flanders, of the Boston Federal Reserve and the Committee for Economic Development, Merrill Griswold, chairman of the Massachusetts Investment Trust, and Karl Compton of MIT. When the idea of using public markets as s source of venture capital failed at the national level, they decided to implement it locally. In October 1945, Edward Chase, a New England investment banker adn President of the New England Council, presented a report of the Council's Special Committee on the Financing and Ownership of New England Business Enterprises. To maintain free enterprise and private ownership in New England, the Committee of 42 influential New England bankers, industrialists, labor leaders and educators thought hat the industrial structure of the region would have to be revitalized by new industries financed by venture capital. The committee was adamant that such funds should be provided by the private sector rather than by government. Later that year, Ralph Flanders outlined the basic plan for ARD, initially called the "Development Capital Corporation" - a private firm capitalized by the sale of stock to finance and assist in the creation of new, entrepreneurial enterprises. Flanders then approached a variety of key figures including Karl Compton of MIT and Donald david, Dean of the Harvard Business School and General Georges Doriot, an HBS professor and former assistant dean who had recently returned from wartime service as Deputy Director of the Research and Development Division of the War Department.

On June 6, 1946, ARD was established by Flanders, Horace Ford, Frederic Blackall and Bradley Dewey. Ford was treasurer of MIT. Blackall was president and treasurer of Taft-Pierce manufacturing, president of the New England Council, a director of the federal research Bank of Boston, and a term member of the corporation of MIT. dewey was cofounder and president of Dewy and Almy Chemical corporation and president of the American Chemical Society.[137] Flanders became president and treasurer of ARD, while he, Blackall, Dewey and Ford joined the board of directors. The board of directors also included Merrill Griswold, chairman of the board of Massachusetts Investment Trust, Oscar Haussman, partner in a leading Boston law firm, Ira Mosher, chairman of the board of the National Association of manufacturers, adn Warren Motley, a Boston lawyer and counsel for the National Association of Investment companies. Four other individuals served as advisors to the board: Doriot, Compton, the president of MIT, Edward Gilliland, a professor of chemical engineering at MIT, and Jerome Hunsaker, head of the Department of Mechanical and Aeronautical Engineering at MIT. Doriot took over as president of ARD, when Flanders was elected to the Senate in November of 1946.

ARD was incorporated as a private venture capital firm and sought to raise money by issuing stock. Its initial subscription of $3.4 million (including $225,000 from universities) fell considerably short of its goal of $5 million. According to a major study of ARD by Patrick Liles, ARD had two overriding goals: the first was to encourage new firm formation, and the second was to make a profit.[138] These dual purposes were in fact one reason why ARD experience difficulty securing capital. The conundrum of whether ARD was a business development organization or a profit-seeking enterprise plagued the firm from the start.

ARD's initial investment strategy did not focus exclusively on high technology and its investments covered a wide range of industries. Indeed, during the first five years of investing, ARD developed no real specialty or focus for its investments. ARD made a number of early investments in the food-processing industries. Most of these were losers, including shrimp deveining equipment (a loss of $337,000), tuna fishing (a loss of $261,000) and frozen apple concentrates.[139] ARD invested in a number of firms in traditional manufacturing activities through investments in Ohio, New York and Mississippi. Many of these industrial investments were failures or provided only minimal capital gains. ARD invested $64,604 in the Paul Valve Corporation in October 1950, which declined to $15,501 in 1954.[140] It would take time to identify the types of investments that could yield the capital gains that would justify the risks of venture capital investing. And, in contrast to today's venture capital funds, ARD tended to utilize a both equity investment and loans **[see Table 4.1]**.

[Table 4.1 about here]

ARD was, however, able to learn from its early difficulties. One thing that became clear was that investments in high-technology were attractive for two reasons: companies tended to become profitable (or fail) relatively quickly and exit was relatively easy. Among ARD's early winners were a series of companies launched by MIT professors. High Voltage Engineering Company, for example, was established by an MIT professor in December 1946.[141] By 1952, ARD's investment in High Voltage Engineering doubled in value from $200,000 to $400,000.[142] Tracerlabs was founded in March 1946 by an MIT professor and MIT graduates to use radioactive tracers for various medical and industrial purposes. The entrepreneurial group had initially negotiated with New York venture capitalists, but these investors wanted control of firm.[143] So, the group turned to ARD which provided capital in December 1946. Tracerlabs became one of ARD's most successful investments. By 1952, ARD's initial $236,830 investment in the company had nearly tripled to $622,500.[144]

Ionics is a particularly interesting case, since ARD basically started the company. ARD had heard about Walter Juda's work in Palestine on ion-exchange to render brackish water suitable for irrigation. When Juda returned to the United States from Palestine, ARD approached him to establish a company to commercialize his developments. To do so, ARD established Ionics in December 1946 with Juda as vice president and brought in Edwin Gilliland, an MIT professor of chemical engineering, as president. By 1952 the Ionics investment had tripled in value, increasing from $264,254 to $698,900.

ARD made important contributions to the venture capital process in a trial and error fashion, developing an understanding of what worked and what did not as it went along. ARD also learned the advantages of focusing on high-technology investments. In a 1952 article in *Fortune* magazine, Merrill Griswold, a director of ARD and one of its first investors, was quoted as saying:

> Some of our friends began to say, "Oh, Lord, not another longhair project. Why doesn't A.R.&D. back something commercial and make some money?" We learned our lesson. Now we realize that our best things are longhair. If they click we're not trying to do something that everyone else can do.[145]

By the early 1950s, with the successes of Tracerlabs, Ionics, and High Voltage Engineering under its belt, ARD found the formula that would underscore the development of modern venture capital - that technology-related investments provided the level of returns that could justify the high risk of equity investment. Moreover, they discovered that the key to successful venture capital investments was to support firms that could discover unexploited market niches, preferably those in which the startup could leverage its intellectual capabilities.

There was at least one high-profile investment opportunity which ARD decided not to pursue. In the late 1940s, ARD visited Eckert-Mauchly, the pioneer mainframe computer maker in Philadelphia.[146] At the time Eckert-Mauchly had what many considered to be the most advanced, operating business computer in the world. Though Eckert-Mauchly seemed ideal for a venture capital investment, ARD decided not to invest. Later, Eckert-Mauchly ran out of money and was sold to Remington-Rand.[147]

While a number of ARD's investments performed well during the 1950s, its publicly traded stock did not. According to Liles' analysis of the company's records, in 1958, ARD's net asset value reflected a compound growth rate of 7.6 percent for initial capital invested. But, the share price of ARD stock showed a growth rate of 5 percent, better than inflation but not good enough to compensate for ARD's considerable risk.[148]

ARD's lackluster performance changed with one important investment. In 1957, ARD invested $70,000 in two MIT entrepreneurs, Ken Olsen and Harlan Anderson, who intended to build a smaller, less expensive computer than the mainframes then available. In return for the investment, a $30,000 loan and a $300,000 line of credit, ARD demanded 70 percent of the new company, Digital Equipment Corporation (DEC). The company was wildly successful, growing to be the second largest computer company in the world. DEC literally made ARD: The value of DEC as a share of ARD's portfolio increased from $1.1 million or 3.1 percent in 1961 to $77 million or 83 percent in 1966.[149]

By the late 1960s, ARD was making fewer investments and generating a huge cash flow. In 1969, it had a peak value of $555 million (including some $30 million in cash), with more than 80 percent of its assets coming from DEC.[150] With its stock trading at a substantial discount to the value of its assets, ARD became a target of takeover raids. In 1971, ARD agreed to be acquired by Textron.[151] The merger of ARD marked the demise of the pioneer of venture capital investing. In 1985, a member of the Mellon family purchased ARD from Textron and reinstated it as an independent venture capital fund.

ARD and the Rise of Professional Venture Capital

ARD had a series of powerful effects on the development of the modern venture capital system. While the model of a venture capital fund financed by public stock would ultimately be supplanted by the rise of the limited partnership model in Silicon Valley, as the following chapter will show, ARD established an early model of the professional venture capital firm, using professional criteria to screen and evaluate investments, through its focus on high-risk, high-technology investment, and by providing technical and managerial assistance to enterprises as well as equity capital. ARD also became a spawning ground for professional venture capitalists, as many of its key staff members went on to form or to manage a host of leading venture capital funds in the Boston area. And, ARD had a powerful impact on the broader process of high-technology industrial development in the greater Boston, Cambridge and Route 128 area during the region's golden years of the 1950s, 1960s and 1970s, both by funding important companies like DEC and through its role in spawning other venture capital funds. ARD thus became a focal point and catalysts for the broader social structure of innovation that grew up in the great Boston area and propelled its patten of high-technology industrialization.

ARD pioneered the professional approach to venture capital investing based upon close screening and evaluation of business proposals and the provision of managerial and technical assistance to start-up companies. One of Doriot and ARD’s major contributions was to provide companies with advice and counsel. ARD played an active role in monitoring the operation of firms and giving advice to entrepreneurs. For ARD, the role of the venture capitalist was not simply to provide funds and wait idly by for its investments to grow and generate profits. In fact, it was the opinion of some observers at the time that General Doriot in particular spent to much time assisting marginal firms, which would consume precious time but never produce the growth that could generate substantial capital gains. ARD emphasized the use of objective criteria and the application of intelligence to both investment analysis and business development. And, Doriot placed a clear priority on recruiting and attracting astute business minds, or what he termed "operating men," to build successful enterprises. This often meant helping to form a entrepreneurial team which supplemented the innovative skills of leading technologist with solid business types. In Doriot's words:

> "In small companies, human failures and weaknesses are magnified in inverse proportion to the size of the company. ... Early success often develops an unwillingness to learn from business history. Scientific intelligence does not always bring business modesty. Success would be attained more often if good idea men would entrust their ideas to good operating men."[152]

ARD's experience also helped to clarify the limits of various aspects of venture investing. It was quickly realized that equity rather than debt would be the preferred mechanism for venture investing. In its early days, ARD, as we have seen, provided a mixture of equity and debt financing. It became evident that the loans ARD extended to startups were of little benefit either for the entrepreneurial or the venture capitalist. With loans, ARD was essentially getting a guaranteed low rate of return on its investments. This made little sense in the high risk world of venture investing, where large gains were required to offset many losses. As venture capital matured, loans, debentures and other sophisticated financial instruments were increasingly abandoned for simple common stock or distributed to the limited partnerships that could be easily sold when the company went public. In its early days, ARD also charged firms for management services. It did so largely because as a public company it was constantly under pressure to show profitability.[153] But, fledgling firms are beset with cash flow problems, and are hardly in a position to meet these fees.

Second, ARD failed to compensate its staff of professional venture capitalists in a way that motivated them and aligned their interest with that of the enterprise. ARD, as a public company, compensated its venture capital staff with salaries. Eventually, it became evident to a number of key staff that this method of compensation preclude them for sharing in the enormous gains made by these enterprises and frequently realized by their management teams. This, as the next section will show, helped to set in motion a series of defections from ARD. Later venture funds would follow the model of J.H. Whitney and Co. to devise mechanisms which allowed venture capitalists to share in the gains they generated.

Moreover, ARD showed the limits of using the public stock market to underwrite venture capital, and thus opened the door for the further evolution of venture capital institutions. As a publically owned and trade venture capital fund, ARD faced constant pressures to generate quick profits. This was made difficult by the very nature of venture investing which requires a gestation period of several years before investment become profitable - in fact a typical pattern is for investments to lose value before starting on an upward trajectory. While venture capitalists are certainly not long-term investors, venture capital requires a time frame that is substantially longer than the quarterly reports of a publically traded concern.

A Breeding Ground for Boston Venture Capital

ARD played a crucial role in the development of Boston area high technology in two ways. First, ARD alumni formed the core of the Boston area venture capital industry. ARD became a veritable breeding ground for Boston area venture capitalists **[see Figure 5.1]**. The departures of key people was stimulated both by expanding opportunity and by the relatively low salaries offered by ARD and the fact that venture capital professionals did not share in capital gains.[154] The first to depart was Joseph Powell, who joined Harris Intertype Corporation in Cleveland as a Vice President and Director, where he received stock options and other benefits.[155] In 1960, when a group of Boston investors decided to form an SBIC, the Boston Capital Corporation, they hired Powell as its first president, making this the first venture spinoff from ARD. In 1965, another ARD venture capitalist, William Elfers, joined Daniel Gregory to form the important Boston venture capital firm, Greylock Management Corporation. Later, Henry Hoagland, another ARD venture capitalist, left to form Fidelity Venture Association. A year after that William Congleton left ARD with a colleague to form Palmer Partners. In 1981, James Morgan, left to form Morgan Holland Ventures. To this day, ARD and its spin-outs constitute the most important lineages of Boston venture capital.

[Figure 5.1 about here]

Second, ARD invested in a series of high-technology companies which formed the nucleus of the regional technology complex which evolved in the Boston Route 128 area. DEC played a significant role in the evolution of the Route 128 high technology center; it became an incubator for more than 30 spinoffs, most notably Data General.[156] But, ARD's investments were certainly not limited to Boston. In fact, several ARD investments helped to establish key nodes in the Silicon Valley high-technology complex.

From Bank of Boston to the World's Largest Venture Fund: The Role of Peter brooke

The career of Peter Brooke, one of Boston's and the nation's leading venture capitalists and architect of what is arguably the world's largest venture capital fund, sheds important light on the evolution of venture capitalism in Boston and the United States as a whole. After graduating from the Harvard Business School, Brooke assumed a position as lending officer at the First National Bank of Boston, the region's leading financial institution. As a young lender, Brooke began to focus on high-technology enterprises.[157] In personal interview with us, Brooke told us how he saw the region's technology companies as a gold mine for investment. He was particularly interested in the scientific and technically based companies associated with MIT. He thought that the military contracts possess by many of these fledgling firms provided a form of collateral that made them virtually risk-less. Brooke encouraged the bank to form an SBIC specializing in high-technology financing during the early 1960s. In fact, with the launching of the SBIC program in 1958 many Boston-area banks established small business investment companies to invest in the technology-oriented businesses that were springing up in the region. The Federal Street SBIC was also established by a consortium of Shawmut National Bank and First State Street Bank. Furthermore, like ARD, the Bank of Boston played an important role in fostering a number of venture capital firms **[see Figure 5.2].**

[Figure 5.2 about here]

While Brooke clearly saw the limits of using debt to finance entrepreneurial high-technology companies, he was instrumental in providing capital to nascent technology enterprises and in providing many of the critical networking and assistance functions of a venture capitalist in a time that was critical to the growth and development of high-technology industry in the Boston area and across the United States.

Brooke had an important and lasting impact on Boston area high-technology. While at the bank, Brooke discovered Wang Laboratories - then a fledgling enterprise with twelve employees. To assist Wang in securing sufficient capital to continue to grow, Brooke went far beyond his duties as a bank loan officer. When risk capital could not be found in Boston, he located a machine tool company in Cleveland that was willing to purchase 25 percent of Wang Laboratories for $50,000 and provide a credit line of $100,000. - an investment that would end-up being worth $100 million.[158] For the next three decades, Brooke remained on the Wang Laboratories Board of Directors, even though in the interim he left the Bank. Brooke made early loans to two high-technology firms, Damon and Unitrode, and both grew very rapidly.[159] Brooke often worked with other Boston area venture investors - in particular Boston Capital Corporation - to arrange loan financing for their portfolio companies.[160] According to one analysis, in a four year period at the bank, Brooke lent $10 million to various high technology companies and lost only $15,000.[161] In effect, Brooke performed many of the assistance and networking functions, even while at the bank.

In the early 1960s, Brooke left the bank and embarked on a foray into private venture capital. In 1961, Brooke joined Bessemer Securities, a leading New York City venture fund. Two years later, he joined Tucker, Anthony and R. L. Day, Inc. to run its investment banking operation, specializing in high technology placements.[162] In 1965, when William Elfers left ARD to form the venture capital fund, Greylock, he asked Brooke to join him, but Brooke declined.[163]

Brooke formed his own venture capital partnership, TA Associates, in 1968 with $6 million. TA scored a huge hit early on with its investment in Continental Cabelvision. In 1972, TA raised another $10 million, and then raised a number of other funds. By 1983, TA was on its fifth partnership with committed capital of $168 million, making it one of the nation's first venture capital mega-funds, providing a huge pool of capital for Boston based enterprises and for enterprises around the country. While Brooke made countless successful investments, perhaps his biggest hit was a non-technology company - the wildly successful, Federal Express.

TA Associates not only provided a huge source of capital, but contributed to the rise of professional venture capital in the Boston area. The growth of TA into a mega-fund meant that it had to employ an increasing number of professional venture capitalists and support staff. In 1987, for example, TA Associates employed 25 professionals of which 8 were general partners and 7 were partners. By 1996, TA had 32 professionals -a CEO, 8 managing directors, 4 principals, 2 vice presidents, an associate vice president, a director of business development, 5 associates and five others. According Brooke, as TA Associates grew it actively attempted to curb bureaucracy by hiring partners with special expertise in technology. While venture capital funds often accomplish their work in teams, TA Associates formalized the team approach to venture capital. Under an early model, junior staff would scout for deals and do background research on them. They would then prepare potential deal for review by one of the senior partners. If the deal passed that stage of approval, a deal qualification memorandum was prepared and circulated to everyone for comments. By 1996, TA organized itself into four teams consisting of a partner, a senior associate and a junior associate. While it might appear that such a structure would slow down the investment process down, Brooke maintained that TA could move very quickly.[164]

By the late 1980s and early 1990s, TA Associates had grown so large that it no longer thought of itself as a venture capital firm. Rather in its own words, TA Associates had become "one of the largest private equity capital firms in the country. . . Unlike traditional venture capital firms, TA Associates seeks to be the first institutional investor in established companies." Based on its success with Continental Cabelvision and other media investments, TA developed an entire division that invested in media communications leveraged buyouts. Success in leveraged buyouts in the late 1970s and throughout the 1980s prompted TA to make this a larger part of its business. Brooke's TA Associates may well have been first venture capital partnership to evolve into a full-blown private investment banking partnership.[165]

Despite its large size, relatively few of TA Associates' venture capitalists went off to found their own venture capital funds. It did not become a significant source of venture capital spin-outs - certainly not on the order of ARD. The most important venture capital spin-out from TA Associates was Burr, Egan and Deleage (BED) which rapidly became a highly respected venture capital firm with offices in both Boston and Silicon Valley. (Jean Deleage was the founder of Sofinnova, the first French venture capital firm, which had ben established in cooperation with TA Associates in 1971).[166] Claflin Capital Management, another influential Boston venture capital fund, was founded by Thomas Claflin, a TA Associates' alumnus.As we have seen, TA Associates tended to grow through vertical integration. Its most important impact on high-technology in the Boston area tended to come from the huge volume of funds under its control.

In the early 1980s, TA participated in the development of venture funds in England, Belgium, Sweden, Southeast Asia, German, Japan, France and Austria aimed at investing in the home market. By 1987, TA Associates and its international arm, Advent International, was managing in excess of $500 million.[167] In the 1990s, Advent separated completely from TA Associates. In building Advent, Brooke made an important organizational innovations in the globalization of venture capital. Advent was perhaps the most important event in internationalizing the venture capital industry - surely more important than the establishment of indigenous funds backed private sources or government. Brooke also developed a system for doing strategic venture investing for major multinational corporations around the world. In doing so, Brooke built was is surely the world's first global network of venture capital. In an interview with us, Brooke discussed the rise of Advent and global venture capital, which is worth quoting at length.

> "I came from the venture capital industry, having started TA Associates in 1966. I became interested in building this network in the mid-seventies. I became knowledgeable about innovation in Europe, when I started a French venture capital company in 1972. I gathered my data and decided that when conditions were right, which they were in the late seventies and early eighties, that I could replicate TA Associates in Great Britain and throughout the world. I put the network together. I formed a core company which helped the network to come together and become more effective. That was Advent International in 1985. Up until 1990, we operated only through our affiliates. In 1990 we, started to open our own offices, which helped supplement the capability of our affiliates and made

the system much more interactive. So what we have now is an infrastructure of companies in Europe, Asia, and the United States, and in Israel, and soon, hopefully, in Latin America and in Eastern Europe, which will all act as advisors and investors of private equity capital. We, in effect, could become the universal merchant bank. Not moving goods, but moving technology and moving businesses to those areas where they are not, and where they are applicable."

The reason I didn't do all of this in TA Associates was the fact that my partners in TA Associates didn't want to invest their money in R&D. They wanted to put it all home, take it all home and buy boats and stuff like that. That's why I started Advent International. But right now, I will have the same debate with my existing employees that I had with my fellows at TA Associates. They will say to me, "Well, Jesus, we're becoming very successful in Asia, the United States in investing, and we're making a lot of money. Why do we have to go any further?

Advent is a global investment organization. It receives capital from two sources: from institutional sources and from corporate sources. The institutional capital is invested through its network of affiliates and through its direct offices in Europe and Asia, in global private equity deals, mainly later-stage deals. The capital from corporate sources is invested in early-stage investing, mostly in the United States but also in Europe and in Asia, in deals that satisfy the strategic objectives of the corporations. These corporate funds are separate accounts, with a charter to invest in a company's areas of strategic interest. For instance, Hoffman-LaRoche has a major account, a $60 million account with us. That account invests solely in biotechnology. Now most of that biotechnology investing is done in the United States, but we also do some in France through our network members in France and Germany, and Britain as well.

We manage around $245 million of money from corporations in areas of strategic interest to those corporations, such as Hoffman-LaRoche, Asea Brown Boveri, NTT, Nippon Steel Corporation, Alcoa, Monsanto, Apple Computer, the Finnish Oil Company, and the Dutch PTT, the Dutch state telephone company. Now those accounts break down into certain sectors: telecommunications, healthcare and biotechnology for Monsanto, new materials, and fine chemicals, Monsanto. That's where we invest; those are minimum-sized accounts of $15 million apiece. Most of those accounts have been doubled up and they've been added to, because the activity has been successful. .. The reason our corporales selected us is that we have this network of affiliates in our own offices around the world that are identifying both later-stage deals to invest in for our institutional clients, but also early-stage deals of a technology nature that's available for corporales.

I started international investing 15 years ago when I formed a network of affiliates around the world. It started actually in 1980, when we formed an affiliate in Great Britain called Advent Limited. It was on the TA Associates model. I replicated TA Associates first in Great Britain, and then I moved it throughout Europe and then the Far East. We're represented in 20 countries around the world: Britain, Belgium, the Netherlands, Sweden, Norway, France, Germany, Switzerland, Austria, Spain, Japan, HongKong, Taiwan, Singapore, Malaysia, Thailand, Indonesia, Australia. Each affiliate is someone we started from scratch. It's a management company that we own a piece of, that manages venture capital, raised from the country, say from Great Britain or from Belgium or from France or from Germany, raises it from institutions within those countries, invests in deals within those countries, managed by nationals of those countries that we have trained and worked with. And in each instance, we have a share interest in the management company and sit on their investment committees. We have an office in London, and branch offices in Milan and Frankfurt, and we have an office in HongKong, wholly-owned office. And those are staffed with people that help our affiliates in their due diligence on technologies and deals."

We do the due diligence with our local affiliate right from the beginning. The analytical group would include two or three people from our staff, and two or three people from our affiliate's staff. They would provide the local knowledge, the cultural compatibility... All the local lore and knowledge that is important to come into a decision on a deal. We would supply more of the global perspective. You know, is the technology or is the company viable outside its own market, what are the competitive elements that affect it. Our methodology and due diligence is usually a hell of a lot more rigorous than our affiliates."

We have the infrastructure in place that no one else has in this industry to vet private equity financing on a global basis. Now what we've just got to do is to make that infrastructure provide better analysis of results than anyone else, and then we've got the best organization in the world. We're in the process of proving that, but we've got a long way to go. ... We create value by helping.

A company that we invested in five years ago called Aspen Technology that has a software simulation system for chemical plants, and we've helped them open their facility. When we invested in that company, it was doing $4 million worth of volume, all in the United States. Now it does about $40 million in value, ... 40 percent in Europe, 40 percent in the U.S., and 20 percent in Asia. We helped it make an acquisition in Great Britain. We helped introduce its technology through our affiliate in Japan, and our affiliate in HongKong. We opened up those markets for its software. We opened it by establishing a subsidiary, hiring people in that subsidiary. Those people went out and introduced their technology throughout Southeast Asia and in Japan. That was what we did with them in the Far East. In Europe, we helped them acquire and downsize a company that had a product that was quite similar, with the result that there has been this tremendous growth in volume and there has been this representation in markets where the company wasn't represented before."[168]

Venture Capital and High-Technology Development In Boston

The Boston venture capital community both developed alongside and helped to fuel the development of high-technology industry in the greater Boston area.[169] Figure 5.3 charts the growth of venture capital resources and investments for Massachusetts, a reasonable proxy for the greater Boston area, from the late 1960s through 1995. As these data show, the supply of venture capital grew from less than $350 million in 1977 to nearly $900 million in 1982, before reaching more than $5.2 billion in 1995. Venture captial investments grew from roughly $66 million per year in the late 1960s and early 1970s to $224 in 1977 and $429 million in 1987, before falling off slightly to $344 in 1994.[170]

[Table 5.1 about here]

As the pool of venture capital expanded, Boston area venture capitalists became part of a broader social structure of innovation in the Boston-Cambridge-Route 128 area. An important component of this social structure of innovation was MIT. MIT provided the scientific and technical capabilities which undergirded and supported the rise of high-technology industry in and around Boston. Many MIT professors and researchers became entrepreneurs: As we have seen, nearly all of ARD's early successes involved MIT. MIT graduates were also central to staffing the Boston area startups. A 1989 study by the Bank of Boston estimated that 636 businesses founded by MIT alumni between 1867 and 1988 were in existence as of 1989, with sales totalling $39.7 billion and employment of nearly 200,000.[171] Furthermore, MIT's leaders from Vannevar Bush to Karl Compton played critical roles in the creation of early models for high-technology start-ups (Bush's Raytheon) and venture capital (Compton's role in ARD). High-technology enterprise were also important to this social structure of innovation. Venture capital-financed firms such as DEC, Data General and Prime Computer, made Boston the center of the mini-computer industry and played crucial roles in incubating further generations of innovative entrepreneurs that contributed to the evolution of the Boston high technology complex.[172] And, venture capital firms - particularly ARD - became vehicles not only for mobilizing capital to technology based enterprises, but for learning about how to make technology-based investments and for developing new generations of venture capitalists.

The emergence and evolution of venture capital played a number of important roles in the evolution of the modern venture capital system. As earlier chapters have shown, the Boston area had long been a source of technological innovations, entrepreneurship, and venture finance, dating back to the textile revolution of the 18th century. During the 20th century, Boston based venture capitalists contributed to the evolution of the modern venture capital system with the formation of ARD. ARD later beget a host of influential venture capital firms and startup companies, shaping the evolution of venture finance in Boston and the nation as a whole.

Venture capital in Boston was shaped by the region's long history as a center for banking and finance. Banks played an important role in the rise of a modern venture capital system in Boston and in shaping its broader social structure of innovation. Under the leadership of Peter Brooke, the First National Bank of Boston became an early source of venture capital-like functions, and ultimately spawned the influential venture capital firm, TA Associates. As we have seen, in the early 1960s, large Boston financial institutions also became involved in venture capital on their own and through SBICs.[173]

Venture capital in Boston also illuminates a tension between civic responsibility and private wealth generation. The impetus to venture capital complex in Boston came to a large extent from a froward looking civic leadership group seeking to rebuild the technological and industrial base of the region. After stumbling around with a series of quasi-public ventures, like the New England Council, they made an important advance with the formation of ARD. But, ARD was torn between its original civic mission and its need to generate profits. By the 1980s, venture capital had succeeded on market terms. The civic responsibility of Doriot eventually faded, and venture capitalism became much more business-like.

Still, there remained a tradition of government involvement in venture capital and entrepreneurship. This was established early in by the activities of the New England Council and other activities. In 1978, the State of Massachusetts chartered the Massachusetts Technology Development Corporation (MTDC) to invest in Massachusetts-based high technology seed situations. MTDC was launched with approximately $5 million in loans from public sources, the MTDC had generated total funding of $10 million by 1990. By 1990, the fund was worth $19.8 million and the public loans had been largely repaid. Since inception MTDC has funded 80 companies, including Powersoft, Interleaf and Xylogics. Its typical investment was between $100,000 and $250,000 and is always undertaken with coinvestors. Originally, MTDC did not participate in follow-on investments. In the wake of 1987 stock crash, it felt compelled to do follow-on investments to nurse its portfolio companies through the venture capital drought of the early 1990s. In 1995, MTDC began to invest $2 million from the state pension funds and began a partnership with to which the Bank of Boston and Fleet Bank contributed $1 million each and MTDC contributed $3 million.[174] While MTDC can be considered a success, it is difficult to say whether it can be replicated outside the Boston context with its supportive social structure of innovation, enormous supply of technical and entrepreneurial talent, and considerable number of investment opportunities.

Venture capital was certainly important component of the post-war economic development of the greater Boston area and its surrounding Route 128 beltway. And, Boston's venture capitalists like General Doriot and Peter Brooke have certainly contributed important organizational evolutions to the modern venture capital system. But, Boston was not the only area to advance the institutions and practice of venture capitalism. There was one other area that was at least as important to the evolution of modern venture capital, if not more so. That place was the California Bay Area - or what has come to be known as Silicon Valley - the topic to which we now turn.

CHAPTER 6

SILICON VALLEY

"The network of supporting infrastructure of Silicon Valley is the most sophisticated outside Wall Street. The catalyst for that network is the venture capital community, which has evolved to become a strategic planner, management consultant, and corporate watchdog. The network is put to work for new companies and many members of the network have been well honed on dozens of startups. ... In fact, one of the reasons ... many companies do succeed is because the network goes to work to help companies survive: they help them find new customers, they help them do refinancing, they help them find new managers if necessary, they help them merge with other companies to be successful." Regis McKenna, high tech marketing expert and venture capitalist.[175]

"Very few people understand why what works here and in Boston works. It's very difficult to clone those environments. Too many people think that the criticality in the environment is the money. For me the criticality in the environment are the entrepreneurs." Donald Valentine, venture capitalist and founder of Sequoia ...., and a founding investor in Apple Computer.[176]

California - most notably its Silicon Valley - is home to the largest concentration of venture capital in the world. By the 1994, the amount of venture capital in California exceeded $10 billion dollars - just slightly less than the amount of venture capital in New York and Massachusetts combined. California companies also attract a huge share of the venture capital that is invested across the nation - more than $1.1 billion in 1994 - 40 percent of all venture investments and more than the next 8 leading states combined.

This wasn't always the case. In the late 1950s and early 1960s, when the microelectronics industry of Silicon Valley was being borne, there was very little in the way of organized venture capital in region. In fact, on the now infamous when eight young engineers left the early semiconductor company formed by William Schockley and establish Fairchild Semiconductor launching Silicon Valley's semiconductor industry, they had to turn to venture capitalists in New York and Connecticut for funds.

This chapter explores the role of Silicon Valley in the evolution of the modern venture capital system. Silicon Valley has been important for a number of reasons. the rise of venture capital in the Silicon Valley provides a clear and important illustration of the relationship between venture capital and the broader process of technological innovation and regional industrialization. As this chapter will show, venture capital in the Silicon Valley area evolved tandem with its technology base and became an integral part of the region's **social structure of innovation.** The process of high-technology industrialization created both the wealth and the opportunity for venture capital in Silicon Valley. And, as we will see, Silicon Valley venture capitalists pioneered the limited partnership - arguably the single the most important organizational innovation of the modern venture capital system and contributed to the formalization and institutionalization of modern venture capitalism.

Getting Started

As in so many other places, San Francisco had a history of entrepreneurial enterprises that were financed by angels or wealthy local individuals. According to the economic geographer, Timothy Sturgeon, the Bay Area generated a number of important electronic startups in the fields of telegraph transmitters and transmission in the period prior to World War II. Of particular importance was Lee de Forest's development of the vacuum tube.[177] Many of these early companies were purchased East Coast companies and some were actually relocated from the area. While it is difficult to establish the precise sources of capital to many of these early start-ups, Sturgeon provides the following example of early sources of venture capital. During the mid-1940s, the First National Bank in San Francisco provided credit to Alexander Poniatoff, founder of Ampex Corporation, which developed the first tape recorders.[178] After the First National Bank was sold to Wells Fargo Bank, Poniatoff heard of a consultant at Wells, Stanfield Rayfield, who specialized in assisting struggling young companies. Rayfield then introduced him to a wealthy investor, Henry McMicking, who invested $365,000 in Ampex in a 50-50 partnership. McMicking took an interest in the company and recruited a general manager and reorganized the marketing structure. In other words, McMicking took an active role in the enterprise - comparable in some respects to that of a contemporary venture capitalists. The Ampex investment was important for other reasons. Dean Frederick Terman of Stanford University was a member of the board from 1953 to 1964. In addition, Reid Dennis, a young executive at Fireman's Fund Insurance Company, who would become one of the Bay Area's leading venture capitalists, talked his way into being allowed to invest $15,000 in a private placement for Ampex, an investment which was eventually worth $1 million when he liquidated.[179]

World War II transformed California from a relatively small provincial backwater into a state boasting a significant high technology complex centered around the electronics and aerospace industries.[180] Still, in the years immediately following World War II, there were concerns in California, similar to those we have described elsewhere, over the need for risk capital to finance innovative new enterprises. While leading Californians recognized the need to develop mechanisms to fund startups, there was far less concern for the civic aspects of venture capital and entrepreneurship that preoccupied East Coast financial elites. The main concern was that reconversion from war-time production would devastate the California economy. The California State Reconstruction and Reemployment Commission commissioned a report by a University of California professor, Paul Wendt, on "the availability of capital to small business in California."[181] Wendt's report, published in 1947, reflected and reinforced these concerns. Wendt described the situation this way,

> "The market for equity capital for the small enterprise in California is predominantly local and informal in character. Investment bankers, who occupy a key position in furnishing equity and loan capital to large corporations are an unimportant source of equity capital to the small concern. Consequently, equity funds are obtained through investment of owners' savings and sale of stock privately to friends, relatives, and associates."[182]

The report also quotes McMicking, the venture investor in Ampex, to the effect that it was difficult to purchase equity in the small electronics companies, such as Varian or Hewlett Packard.[183]

While the report highlighted the early venture capital efforts of the Rockefeller Brothers, J.H. Whitney and Co., and ARD, it went on to describe two privately-held venture investment companies in California: Industrial Capital Corporation and Pacific Coast Enterprises Corporation. The Industrial Capital Corporation was formed in 1946 with $2 million in capital by five businessmen who had been involved in privately financing small businesses in California. One of these, Edward Heller, who would become something of the grandfather of California venture capital, had worked with Boston's Ralph Flanders and knew of his advocacy of venture capital and role in founding of ARD. Pacific Coast was founded in 1946 with $1 million in capital and made loans of between $5,000 and $100,000 and was involved in providing managerial assistance to the enterprise it financed. According to one of its directors, Pacific Coast Enterprises Corporation generated better results "with established concerns than with new enterprises," and with loans that carried the privilege of stock purchase rather than by purchasing equity directly.[184]

The Pioneers

A venture capital community began to emerge in Silicon Valley during the late 1950s and early 1960s. There were numerous reasons for this. As Sturgeon points out, the relocation of major pieces of the electronics industry and the emergence of a series of startups during the early part of the 2oth century made the region an important center for electronics production by the

1950s. This opened up enormous opportunities for investment, creating the demand for venture capital. The rise of Stanford university after the war only added to this infrastructure. As Stuart Leslie points out, Dean Frederick Terman used a strategy of leveraging defense contracts both to build Stanford as a center for world class engineering research and to develop steady stream of contracts for spin-off businesses, mots notably Hewlett Packard and Varian (???). But as Sturgeon notes, Terman was as much a product of the emerging electronics complex of Silicon Valley as he was its catalyst. The rise in federal spending on science and technology in the wake of Sputnik opened up enormous opportunities for small firms to get lucrative Department of Defense contracts for various electronic devices.   The stock market was also receptive to the growth potential of high technology companies. The passage of the Small Business Act of 1958 provided leverage and an entre for a number of budding venture capitalists. In other words the time was particularly propitious for investing in high-technology.

Bank of America was an early institutional player in the development of venture capital in the San Francisco Bay Area. Bank of America was active in financing start-ups at the time through its Small Business Enterprise Corporation, headed by Thomas Clauson, who would later become President of the bank.

Frank Chambers formed an early SBIC, Continental Capital Corporation that was also important. Chambers, a graduate of the Harvard Business School in 1939 and a student of General Doriot, began investing family funds in Bay Area startups after the War. Using personal and borrowed money he started a company, Magna Power Tools which made Shopsmith power wood working tools. In 1950, he successfully invested in a company, Signboard Trim, and in 1956 he invested in Guardian Packaging. In 1959, Chambers set up a publicly held SBIC, Continental Capital Corp. While Chambers had originally pursued a generalist strategy of investment, by the early 1960s he changed to focus on high technology startups. One of his greatest successes was Dataproducts, a Southern California company, he invested in partnership with Greater Washington Industrial Investments and Bank of America's Small Business Enterprise Corporation which located the investment.[185]

The first venture capital partnership in California was Draper, Gaither and Anderson (DGA) founded in 1958 as a privately-funded limited partnership which later failed. m In a interview with us, John Wilson, founder of the Silicon Valley law firm, Wilson, Sonsini and Rosati explained that Draper, Gaither and Anderson collapsed after one of its major investors, Laurence Rockefeller withdrew his money.[186] The venture capital firm, Sutter Hill, was formed in 1961. Originally formed as a privately held real estate development firm, Sutter Hill received an SBIC license in 1962. The same year another SBIC was formed by Bill Draper, the son of William Draper of DGA and an original associate at DGA and Franklin "Pitch" Johnson, a former Doriot student at Harvard, who would later become an important venture capitalist . While Sutter Hill all but ignored commercial investing for its first two years, in 1964, the firm acquired the assets of the Johnson and Draper's SBIC, and hired Paul Wythes, also to become an influential venture capitalist, to manage its venture investments.[187] Johnson in turn used his gains to form Asset Management Company, a hugely successful venture fund which invested in Coherent, California Microwave, Cromatronix, Boole and Babbage, Accurex (a spin-out from a company he and Draper initially invested in) and SBE. Reflecting the importance of relationship investing that would come to characterize venture investing in the San Francisco Bay Area, Johnson took on the same co-investors in each of these deals - Bryan, Edwards and the Hale

Brothers were coinvestors in each of these investments.

These early years also saw the rise of an important informal network of investors. Previous successes and a flow of new opportunities attracted a number of relatively wealthy, Stanford-educated young men to begin to invest collectively in small scientific startups in the Palo Alto area. Reflecting the informality of their dealings, these young investors dubbed themselves "**The Group**." Based on interviews we conducted with many of its members, virtually all of the members of The Group would become key players in the venture capital community: Reid Dennis (using his gains from his Ampex investment), William Bryan, William Edwards, William K. Bowes, and Daniel McGanney, who later became more involved as an asset investor, rather than venture capital.[188] While The Group mainly used personal assets to underwrite investments, some of its members were able to leverage their professional activities as a source of additional investment. Bryan, Edwards, and McGanney started family funded SBICs in 1962. Dennis remained at Fireman’s Fund, which had been purchased by American Express Company, but he now managed their venture capital subsidiary, AMEXCO Venture Associates.

While these early venture capitalists were crucial to creating the venture capital community in the Silicon Valley, it is important to point out that the area's most important early investment, Fairchild Semiconductor, was made by East Coast investors. The key investor was Arthur Rock, who at the time was an investment banker at Hayden Stone in New York. When the core group of eight founding engineers who had left Bell Laboratories to form Shockley Semiconductors tired of Schockely, they sent a letter to a stock salesman at Hayden Stone and he showed it to Arthur Rock. Rock and his boss visited the firm and agreed to try to raise $1.5

million. Rock then approached "about 25 industrial corporations with the idea of setting up a separate division or subsidiary," but they all turned the opportunity down. Rock then approached Sherman Fairchild, the owner of Fairchild Camera, who agreed to invest.[189]

The success of Fairchild success piqued Rock's interest in venture capital. Rock's next success occurred in 1960 when he secured investors in the new firm, Teledyne, established by Henry Singleton, of Litton Industries. In 1961, Arthur Rock relocated from New York to the Bay area and established an important venture capital fund with Thomas (Tommy) Davis, a Harvard educated lawyer then a vice president of Kern County Land Company. Davis was looking to get out of real estate and had independently made a successful investment in the high technology firm, Watkins-Johnson, particularly since his employer had little interest in high-technology investments.[190] Rock and Davis formed a limited partnership. which was capitalized with $3.5 million from individuals including Henry Singleton and several of the Fairchild founders.[191]

The returns from these early venture funds were astronomical. For example, Paul Wythes investment of $10 million for Sutter Hill returned $100 million.[192] Nearly all of the venture capitalists that invested and survived this period generated returns of 70 to 100 times by the early 1970s. The high rates of returns that this original group of investors achieved by investing in Bay Area high technology firms attracted more investors. Moreover, as many of the original firms went public or were acquired, newly rich entrepreneurs were released to become venture capitalists or to establish new startup firms. In other words, a base of venture capitalists and others rich enough and experienced enough to spinoff was being created. In addition, East Coast investors such as the Rockefeller and Whitney family funds became involved in more Bay Area deals as coinvestors, allowing local venture capitalists to leverage substantial external sources of funds. In this way, venture capital became nodal point in the social structure of innovation that was developing in the region, as an evolutionary outgrowth of the process of high-technology industrialization.

This formative period also saw venture capital industry in the Bay Area develop greater formal organization. A sign of this growing organization was the formation of the Western Association of Small Business Investment Companies (WASBIC) was formed in 1962.[193] In 1969, WASBIC was reorganized into the Western Association of Venture Capitalists (WAVC) and had 31 voting members.[194] A list of voting members compiled in 1970 and 1971 showed 39 corporate members and a further 16 individual members including important venture capitalists, such as Eugene Kleiner and Franklin Johnson. The WAVC was not confined to local investors: Heizer Corporation and Continental Illinois Venture Corporation (both from Chicago) and Northrop Technology (Los Angeles) were also members.[195] Interestingly, as Reiner points out, the WAVC was formed before there was a national venture capital organization.[196] During the late 1960s and 1970s, the WASBIC and the WAVC provided an important organizational forum for venture capitalists to discuss deals and evolving models for investment.

This early period also saw significant organizational evolution in other components of the technology infrastructure of the region. Of particular importance were innovations in the institutional and legal structures of start-up corporations. The source of these innovations was John Wilson, the founder of Wilson Sonsini, a leading law firms specializing in high-technology issues and an important component of the social structure of innovation in Silicon Valley. Working closely with entrepreneurial groups and venture capitalists, Wilson developed legal mechanisms necessary to give entrepreneurs an ownership stake in their firms.[197] The motivation for this important innovation came from problems encountered by the founding group of Fairchild Semiconductor. Fairchild's founding agreement enabled its the corporate venture investors in the firms, Fairchild Camera, to buy the company stock from the founding group at a prearranged price, which it did when the start-up proved successful. This spurred the founding group to leave and they Robert Noyce and Gordon Moore left Fairchild to form Intel, they worked with Wilson to devise a stock ownership plan which became a model for later venture capital-backed start-ups. Eugene Kleiner, the venture capitalists who was also one of Fairchild's founding eight explained it this way:

> "When Fairchild financed us, they gave us one hundred percent ownership of the company. But, they reserved the right to buy the company back at a predetermined price. Once they exercised that option, once they bought back the company, they were slow to give out options. That's one reason people left. That was also about the time, John Wilson [of what would become an important Palo Alto law firm Wilson Sonsini that specialized in new firm legal work] began developing plans to give entrepreneurs ownership."[198]

Expansion and Growth

Venture capital in Silicon Valley virtually exploded during the late 1960s and 1970s. Between 1968 and 1975, approximately 30 new or reconstituted venture capital operations were established in the region. This growth occurred through a complex process of division and re-combination, as existing venture capital fund and entrepreneurial enterprise spawned spin-off funds, which in tune gave rise to new funds, in a complex and cumulative process. Rock and

Davis split in 1968. Rock brought in C. Richard Kramlich who was working with a small East Coast investment firm as a partner.[199] Tommy Davis formed the very important partnership, the Mayfield Fund, with Wally Davis (no relation), an aeronautical engineer who had started his own company which was bought by the Rockefeller-funded Itek Corporation. The two Davis's were introduced by John Wilson, the prominent Palo Alto lawyer.[200] Similarly, Burton McMurtry joined Jack Melchor, who was already investing independently, to form the Palo Alto Investment Company. In 1968, George Quist left the Bank of America's SBIC to join William Hambrecht in establishing Hambrecht and Quist, which would go on to become one of the premier high technology brokerage firms. In the late 1960s, William Bryan and William Edwards merged their two family SBICs into the limited partnership, Bryan and Edwards.

The pattern of growth by division and recombination continued into the 1970s. In 1974, Reid Dennis left AMEXCO and co-founded Institutional Venture Associates with Burton McMurtry of Palo Alto Investment. Two years later, Institutional Venture Associates split into two partnerships: McMurtry's Technology Venture Associates and Dennis' Institutional Venture Partners. In 1977, C. Richard Kramlich's partnership with Arthur Rock ended and Kramlich formed New Enterprise Associates with two friends from T. Rowe Price.[201] A host of other new partnerships (i.e., Idanta Partners and WestVen Management) were formed during this period.

Venture capital also grew by attracting the offices of venture funds headquartered elsewhere. In 1968, Bessemer Securities became the first East Coast firm to open a California office. In 1973, Citicorp, the giant New York bank, opened a venture capital office in Silicon Valley.[202] In the past, East Coast firms such as Venrock and J.H. Whitney had become involved in California deals as later stage investors because of their deep pockets and strong connections to Wall Street. But, the growing supply of venture capital in the region and the increasing pace of investment made it increasingly difficult for East Coast-firms to participate in the best deals. Since entrepreneurs could easily secure funding from the firms within driving distance, there was no need to travel to New York. As a result, the establishment of West Coast branches was imperative to outside investors who wanted access to the best opportunities.

The growing group of successful entrepreneurs in Silicon Valley also fueled the rise to the venture capital industry there. While Fairchild Semiconductor is well-know as a source for technology-based companies - sometimes referred to as the "Fairchildren" - it was also an incubator of leading venture capitalists. Eugene Kleiner, one of the Fairchild founding eight, was introduced to venture capital when he was asked to participate in the Davis and Rock fund as an investor and a limited partner called upon to help evaluate deals, though with no formal decision-making role. Later, when Henry Hillman, the Pittsburgh millionaire, asked Tommy Davis to manage his Silicon Valley venture capital investments, he recommended Kleiner. Hillman talked with Kleiner agreed to invest $4 million. Kleiner then called upon Sanford Robertson, a founder of Robertson Coleman, to raise another $4 million. Robertson agreed to help and also recommended that Kleiner meet Thomas Perkins who wanted to leave Hewlett Packard and start a venture capital partnership. In 1972, Kleiner and Perkins began the operation of what would be one of the most successful venture capital partnerships in history.[203]

In 1972, Donald Valentine, formerly a Fairchild marketing executive, formed the venture capital limited partnership, Capital Management Services, which later became Sequoia Capital. The initial capital of $7 million was contributed by a Los Angeles money management firm, Capital Research and Management, now known as the Capital Group.[204] Valentine's first investment was Atari which needed money to enter the home video game market - a market that did not exist at the time. In 1976, Warner Communications bought Atari for $30 million and Sequoia quadrupled its original $600,000 investment in less than two years. In 1976, Valentine would help define the market for another new industry, personal computers, through his discovery of Apple Computer which he financed and helped to build.[205]

Banks and financial institutions became another source of venture capital firms in Silicon Valley. Beginning in the late 1960s and continuing throughout the 1970s, the bank-owned venture capital SBICs experienced an exodus of their venture capitalists, who found that they could earn more money by launching limited partnerships. The reason for this was simple. They could make far more money working in an independent partnership than as a salaried employee of a bank. It was almost impossible for a bank to provide a large enough salary to compensate for the large capital gains a venture capitalist could earn in a successful limited partnership.

Citicorp and Bank of America were especially important breeding grounds for future venture capitalists. Bank of America's SBIC was a training ground for a number of venture capitalists, as Figure 6.1 shows.[206] New York-based Citicorp became another hot-bed for Silicon Valley venture capitalists, being plagued by defections after it opened a West Coast office in 1973. In 1978, David Arscott, a former Citicorp venture capitalist, co-founded Arscott, Norton and Associates with Leal Norton also of Citicorp. In 1981, John Dougery co-founded Dougery, Jones and Wilder, all of whom were from Citicorp. In 1983, Paragon partners was founded by ex-Citicorp venture capitalists. Citicorp alumni were also partners at Welsh, Carson, Anderson & Stowe; James Swartz, founding partner at Accel Partners. In fact, John Wilson quotes the then president of Citicorp Venture Capital Ltd. as saying that there were twenty-three Citicorp alumni had become independent venture capitalists in Silicon Valley.[207]

[Figure 6.1 about here]

The late 1960s and 1970s saw a series of cycles in venture capital investing. There were lean periods and growth periods. After an excellent IPO market in 1968, the early and mid-1970s were a difficult period for venture capital. In 1974, Congress tightened the rules for pension fund investments in the Employee Retirement Income Security Act (ERISA), in an effort to curb the abuses of employee pension funds. With the tightened rules, pension fund managers became wary of investing in high-risk investments. The depths of the difficulties in fund raising were evident in 1975, when only $10 million were raised for new investment.[208] Even successful companies, like KLA Instruments the semiconductor equipment manufacturer, had difficulty securing financing.[209]

Two major changes in public policy during the late 1970s had an enormous positive impact on the environment for venture capital in Silicon Valley and in the nation as a whole. The first was Congressional action to reduce the capital gains tax rate from 49.5 percent to 28 percent, this change was strongly supported by venture capitalists and by the American Electronics Association.[210] As a consequence of this change, entrepreneurs and venture capitalists could keep more of their capital gains, making stock options a more attractive source of income. Second and perhaps more important was the Department of Labor's efforts to ease the ERISA fiduciary responsibility guidelines for pension funds which relieved pension fund managers concerns about investing in venture capital partnerships.[211]

These changes made venture investment more attractive and increased the potential sources of funds for Silicon Valley venture capitalists. Silicon Valley venture capitalists could now raise funds from huge pensions funds. And, as Chapter 2 has show, pensions funds quickly came to replace banks, corporations and wealthy individuals as the leading source for venture capital. This enabled Silicon Valley venture capitalists to mobilize funds from major East coast markets. The amount of money that could be raised by partnerships sky-rocketed, leading to the emergence of the venture capital mega-funds.

This huge inflow of resources into venture capital, in turn, had important impacts on venture capital in Silicon Valley and elsewhere. On the one hand, the new sources of capital meant that Silicon Valley venture capitalists were less dependent upon limited local sources of funds or on East Coast funds as co-investors. On the other hand, it led to larger funds and the increasing professionalization of the venture capital industry. Personal contacts to wealthy individuals and trust among investors diminished in importance, as fund-rasing increasingly turned upon making formal presentations to major financial institutions and pensions funds. It also meant that fund-raising was more dependent upon sophisticated performance analysis of the returns on previous funds. In other words, the investment track record became far more important. As Eugene Kleiner explained it:

> "The late 1970s opened up the pension funds, and we got a lot of money. All of a sudden we were very pushed into attempting large amounts of money. In my first fund for instance, we did not have any pension funds. We only had insurance money and university endowment money, but now it's all the pension money. They like to amass in confidence a prudent track record. So the track record became very significant."[212]

But, changes in federal law on taxes and pension fund investments were not the whole story. Silicon Valley's venture capital community was doing what it took to make itself attractive. The returns on venture capital investments were astonishing and attracted substantial interest. Apple Computer was one of the most successful venture capital investments of the era. The initial round of Apple investments in January 1978 included Venrock $288,000 (or 9.6 percent, Sequoia Capital $150,000 (5 percent), and Arthur Rock $57,600 (1.92 percent), making the total valuation of the company $3 million. When Apple went public in December 1980, Venrock's stake of less than $1 million was worth $129.3 million and Rock's investment of $57,600 had increased to $21.8 million.[213] Moreover, the returns on Silicon Valley venture capital partnerships during the 1970s were astronomical. Take the case of Kleiner Perkins for example. The annualized returns on original Kleiner Perkins fund started in 1972 reached nearly 40 percent in 1977; the next two Kleiner Perkins funds were similarly successful **[see Figure 6.2]**.

[Figure 6.2 about here]

The 1970s saw a shift in the focal point for Bay Area venture capital from San Francisco to Silicon Valley. By this time, Silicon Valley was the center of high technology electronics activity and investment. In fact, the very name, Silicon Valley, was coined in 1971 by a reporter for a semiconductor industry journal, based on the area's remarkable success in the semiconductor industry.[214] Perhaps the signal event was the construction of a major new office complex at 3000 Sand Hill Road in Menlo Park, whose developer aimed at attracting venture capitalists. Among the first tenants in the new Sand Hill Road complex were the early members of The Group - Reid Dennis, William Bryan, and William Edwards. Soon, other important venture capital firms such as Sequoia Capital, New Enterprise Associates and Menlo Ventures are also located there. By the late 1980s, 3000 Sand Hill Road was home to more than two dozen venture capital firms making it the largest single enclave of venture capital in the U.S.[215]

Venture capital in Silicon Valley continued to grow and expand during the 1980s and into the 1990s. And, as Silicon Valley consolidated its position as the nation's center for a host of high-technology industries, venture capitalists located in other regions who did not already have offices in Silicon Valley, moved to open them. TA Associates established a west coast branch in 1982, J.H. Whitney, L.F. Rothschild, and General Electric Venture Capital followed in 1983. Between 1973 and 1987, nearly 150 (149) venture capital offices were established in California, the great majority of them in the Silicon Valley and San Francisco.[216]

[Table 6.1 about here]

The 1980s also saw the rise of a new, more specialized type of venture capital fund - the **seed-stage fund** - a fund that focussed exclusively on locating and investing in very early stage companies. Interestingly, the rise of seed fund was a direct reaction to the enormous level of venture capital resource pouring in the Valley and the emergence of the megafunds. One of the first venture capitalists to create a fund specifically targeted at seed stage deals was Wally Davis. Davis left the Mayfield Fund in 1982. He felt large mega-fund were under pressure to do larger deals. This in turn made it increasingly difficult to invest in small and nurture seed-stage companies, which he felt were key to innovation and growth. Davis formed a new venture capital fund, aptly named, Alpha Partners, to invest in seed stage companies. The idea was to get back to the roots of venture capital investment - locating and financing small, early stage companies. He raised $17 million for Alpha I and recruited two partners. Alpha Partners was designed to finance small local companies - in the early 1980s the average Alpha investment was $750,000, this later increased to $1.5 million. A second partnership, Alpha II, raised in $22 million in 1984. Alpha rarely took on other venture capitalists in its early stage deals, preferring to go it alone. This type of investing is obviously risky. When we interviewed Davis in 1988 he said "half of the money is lost, so you have to have big winners to make up for the rest."[217] Following Davis' lead, by the mid 1980s, other seed stage funds - such Crosspoint Ventures and Onset Partners - were formed in the Bay Area.

The 1980s also saw the formation of a specialized banking institution, the Silicon Valley Bank, devoted to providing debt finance and a range of other banking services to Silicon Valley companies. This was an important addition to the infrastructure of Silicon Valley because it provided a source of banking services articulated to the needs of technology based enterprises. Silicon Valley Bank pursued a strategy of developing close relationships with the venture capital community and of developing contacts with startup companies well before they were in need of loans. During the early 1990s, drawing upon its success in Silicon Valley, the bank opened branches in three other technology regions, Route 128, Newport Beach, California, and Beaverton, Oregon. By 1993, Silicon Valley bank had roughly 1,000 high-technology clients and nearly $1 billion in assets, and estimated that it controlled roughly 80 percent of the market for emerging businesses in its major market areas.[218]

Venture capital in the Bay Area underwent tremendous growth between the late 1970s and the 1990s. Figure 6.3 charts the growth of venture capital resources and investments in

California (which is a reasonable proxy for Silicon Valley from the late 1960s to 1995. The amount of venture capital grew from roughly $500 million in 1977 to $1.5 billion in 1982, before surging to more than $10 billion in 1995. Venture capital investments drew from roughly $200 million in the late 1960s to more than $800 million by 1982 to $1.8 billion in 1987, before falling back to roughly $1 billion per year in the early 1990s.

The increase in venture capital in Silicon Valley during this period led to a number of changes in the nature of venture capital investing. The emergence of larger venture capital partnerships which had the capital to base to invest in larger deals meant that venture capitalists became less dependent upon coinvestors, at least in comparison with earlier periods in the development of the Silicon Valley venture capital industry. This in turn led to increased competition for promising investment opportunities of good deals; and, in the eyes of a number of veteran Silicon Valley venture capitalists, to heightened competition and a erosion of earlier patterns of cooperation and collaboration. According to Paul Wythes of Sutter Hill:

> "I think today the industry is much more institutionalized, much more structured that it was in 1964. In 1964, or in that time frame, we could find a wonderful entrepreneur or group of entrepreneurs that were starting a company and husband them or warehouse them with the idea that they would do an investment with you, Sutter Hill, and not talk with any other venture firms, because there were very [few] venture firms.
>
> If you're talking about somebody around here today, [the entrepreneur can] go a lot of places to raise his money; so you don't end up being able to warehouse a deal like you could in 1964. Ergo, it's much more competitive, a very much more competitive

business than it used to be."[219]

Franklin (Pitch) Johnson of Asset management Co., another long-time, Silicon Valley venture capitalist reinforced this point, highlighting the balance between competition and cooperation in the venture capital industry.

> "In the early days, there was not a lot of capital around. We welcomed other investors and you could call around and get into any deal you wanted to. There was competition, but there wasn't enough capital to be really that competitive. The way competition is now, people do cerate deals; it's not always easy to get in another deal."[220]

Lessons

Silicon Valley played a critical role in the evolution of the modern venture capital system. Venture capital in Silicon Valley grew by a process of combination, division and recombination - as successful enterprises gave rise to wealthy entrepreneurs who would become venture capitalists, and existing venture capital funds gave rise to new venture funds, in a virtuous cycle of investment, growth and capital accumulation. In this sense, venture capital in Silicon Valley grew up in a far more organic way than in Boston, where financial institutions and the strategic efforts of key elites played a more important role.

Silicon Valley venture capitalists pioneered what is arguably the single the most important organizational innovation of the modern venture capital system - the limited partnership model for venture investing. The use of the limited partnership form was born of necessity. Lacking a substantial base of finance capital like New York or Boston or Chicago, Silicon Valley investors searched for new forms which would enable them to mobilize funds from other investors in other places. The limited partnership loosened the dependence of Silicon Valley venture capitalists on limited local sources of funds and also on outside co-investors, by enabling them to mobilize greater and greater sums of capital from national markets. Over the course of the past three decades, Silicon Valley venture capitalists refined this model to successfully generate outside funds from banks, pensions funds, insurance companies, foundations, and wealthy individuals. The rise of the limited partnership made other types of venture capital institutions obsolete.

The rise of the limited partnership in turn contributed to the increasing professionalization of the venture capital industry. The limited partnership meant that venture capitalists were increasingly tied to national sources of funds from large institutional investors, and to some extent dependent on outside venture investors. As Chapter 2 has shown, pension funds rapidly became the dominant investors in venture capital, supplanting wealthy individuals, families and personal fortunes. Consequently, fund-rasing became more formal, organized and professional, turning more on an established track record than personal ties.

Silicon Valley contributed to the evolution of another key venture capital practice - venture capital co-investment. This too was born of necessity. With limited capital, early Silicon Valley venture capitalists were forced to pool their funds. They first did so informally and frequently with other local investors. But, when their needs grew large, they began to turn to larger investors on the east coast. Gradually, out of these efforts, a pattern emerged where Silicon Valley venture capitalists would identify, select and monitor investments, combining their investments with capital from eastern sources who would function as passive co-investors. Here, it is important to point out that these organizational innovations did not occur overnight. They were the product of a gradual, evolutionary process of trial and error during which unsuccessful approaches were winnowed out.

More than anything else, the rise of venture capital in the Silicon Valley provides a clear and important illustration of the relationship between venture capital and the broader process of technological innovation and regional industrialization. Venture capital in Silicon Valley did not grow up on its own. And, Silicon Valley did not have a huge base of large banks and financial institutions, like New York City or Boston. Venture capital in Silicon Valley evolved gradually, over time, as an element of the endogenous growth of the region. The region's high-technology revolution generated the capital and wealth that underwrote the venture capital industry there. Simply, venture capital in Silicon Valley developed out of and as a part of high technology industrialization.

Venture capital since its inception in Silicon Valley was oriented to local investment, plowing the capital it has mobilized into the region. As Chapter 9 will show, venture capital in California and Silicon Valley in particular is unique in the fact that it both utilizes virtually all locally raised funds and attracts an enormous amount of fund raised in other centers. According to Donald Valentine, this reflects the fact that Silicon Valley can generate the demand for venture capital, as its complex of high-technology industries generates an enormous volume of investment opportunities with the potential for considerable capital gains.

> "Generally speaking, whenever our plane we're in leaves the Bay Area, we're flying to some place that has less quantitatively, less things to invest in, and qualitatively

massively less to invest in. It is not an accident that money migrates from wherever it does to here. It's a qualitative recognition of the alternatives. We have lost very good opportunities, most of which in our opinion were in the Greater Boston area, as the only consistent other vein of resources that has been productive over a period of 15 to 20 years, where significant companies have been created and significant returns realized. Virtually no other part of the country has any history of yield on any kind of a consistent basis. After 150-odd investments we have almost never crossed that frontier. We stay with what Frederick Jackson Turner says to stay."[221]

In general terms, venture capital in the Silicon Valley area thus evolved tandem with its technology base and became an integral part of the region's **social structure of innovation.** The process of high-technology industrialization created both the wealth and the opportunity for the emergence of technology-oriented investing apart from traditional financial institutions. The growth of technology venturing then proceeded along a learning curve characterized by the gradual accumulation of investment and management skills on the part of venture capitalists and entrepreneurs alike. This in turn facilitated the development of extended entrepreneurial networks and the broader social and institutional structure that became conduits for sharing information, making deals, and mobilizing resources. As a central component of these institutions and networks, venture capital played a critical role in incubating entrepreneurial activity, attracting entrepreneurs, accelerating rates of new business formation, and stimulating regional growth and development.

This section of the book has examined the rise of venture capital and the evolution of its modern institutional form. The next part turns our attention to the role venture capital has played in the rise of new technologies and in the birth of a series of new industries associated with the contemporary age of high technology.

PART III

VENTURE CAPITAL AND THE RISE OF NEW INDUSTRIES

CHAPTER 7

VENTURE CAPITAL AND THE NEW BIOTECHNOLOGIES

Certainly, one of the most important new industries to be launched venture capital is the biotechnology industry. The idea of commercially exploiting genetic engineering was conceived the venture capitalist, Robert Swanson. During the 1970s. Swanson, an MIT chemistry undergraduate and Harvard MBA, was a member of the leading venture capital firm, Kleiner, Perkins, Caufield and Byers. There, he had managed the fund's investment in Cetus, a company involved in cell selection technology. In this capacity, Swanson became aware of the enormous commercial potential of genetic engineering. He left Kleiner-Perkins, seeking to form his own company to exploit the commercial opportunities of genetic engineering.[222] Swanson, after contacting a number of professors, discovered Herbert Boyer, a professor at the University of California, San Francisco, and principal in the Cohen-Boyer gene splicing patent. At this early stage, the esoteric skills required to use the techniques of genetic engineering were only available in the laboratories of a select few professors in the life science departments of the world's best research universities. The scientific basis for the new biotechnology industry was built in the molecular and cellular biology, virology, and immunology laboratories of the world's research universities. The single most important invention was made by Boyer and Stanley Cohen of Stanford University, who succeeded in reprogramming a bacterium's DNA to express a foreign DNA sequence.[223] This invention would spark a multi-billion dollar industrial investment in biology. Together, Swanson and Boyer formed a partnership and launched Genentech with a $100,000 investment from Kleiner Perkins.[224] With this and further investments Herbert Boyer's team working in his university laboratory succeeded in 1978 in inducing a bacterium to produce a human hormone, somatostatin.

The biotechnology industry is an important case study for understanding the role of venture capital in the birth and development of new industries.[225] On the one hand, it illustrates the pro-active role played by venture capitalists, like Swanson, in the birth and development of a new science-based industry. On the other hand, the biotechnology industry illustrates the relationships among institutions which comprise the social structure of innovation - universities, large R&D intensive companies, entrepreneurial businesses and venture capitalists.

The chapter begins by recalling Schumpeter's theory of innovation and the role of entrepreneurs. We then look at the founding of the industry and the partnerships formed between entrepreneurs, university scientists, and venture capitalists. We next discuss the obstacles to innovation faced by entrepreneurial enterprises in their efforts to create this new industry. We take up the role of the large established companies in the industry, focussing on their late entry into the field.[226] We conclude by reconsidering the pattern of venture capital-financed innovation in biotechnology in light of Schumpeter's theories of innovation and entrepreneurship.

Schumpeter: Innovation and Entrepreneurs

Schumpeter's most extensive discussions of the role of innovation in the growth of capitalist economies are found in *Business Cycles* and the *Theory of Economic Development*. It is important to note that Schumpeter was very careful to separate the concept of inventions from that of innovation, "the making of the invention and the carrying out of the corresponding innovation are two entirely different things."[227] The social processes involved with producing inventions and innovations belong to different spheres with complex interrelationships and "do not stand in any invariant relationship to each other."[228] Important inventions or scientific breakthroughs can occur without being incorporated into innovations affecting industry.[229] The innovation is the outcome of a process of combining production factors in novel ways to produce old products more efficiently or to create entirely new products. For example, tissue culture has been available for over 20 years as a scientific tool, but only became an innovation as industrial applications have been developed in the last four years.[230] Tissue culture was transformed from being an invention to being an innovation by business's application of the technique to production.

The process of innovation is not unproblematic, rather the innovator whom Schumpeter terms the "entrepreneur" or "New Man" is the central actor in transforming inventions to innovations.[231] The motivations of the entrepreneur fall into three categories: The first is to be successful financially and secure the possibly very large capital gains or entrepreneurial profits. The other important and, perhaps, vital motivation for the entrepreneur is an overwhelming desire to succeed and conquer. The joy of creating a company is vital to the entrepreneur.[232] Schumpeter repeatedly emphasized that his entrepreneur need not necessarily be the inventor nor need he be an investor in the new company.

Schumpeter's entrepreneur is a visionary who has had to struggle heroically against obstacles including: A lack of interest and skepticism among potential capitalists, prohibitions upon the use of the new machinery, a dearth of customers, and inadequately trained labor.[233] The vast majority of the entrepreneurs are not capitalists (i.e., holders of large amounts of investable funds) and, therefore, must convince capitalists to provide sufficient capital to purchase the inputs necessary to establish the company. The critical input of the entrepreneurs is not managerial expertise, but it is rather his vision and energy that is so necessary to a fledgling company. In the Schumpeterian scheme entrepreneurial activities are the key to economic development and progress, because they open the economic space into which capitalism will expand.

In his earlier works Schumpeter thought that the new firms would grow and eventually displace firms whose growth had been based on earlier innovations. In fact, Schumpeter argued that:

> Most new firms are founded with an idea and for a definite purpose. The life goes out of them when that idea or purpose has been fulfilled or has become obsolete, it has ceased to be new. That is the fundamental reason why firms do not exist forever. Many of them are, of course, failures from the start. Like human beings, firms are constantly being born that cannot live."[234]

But Schumpeter was careful not to argue that all old firms would expire:

> "For some of the 'old' firms new opportunities for expansion open up: the new methods or commodities create New Economic Space. But for others the emergence of new methods means economic death; for still others, contraction and drifting into the

background."[235]

Schumpeter's last work, *Capitalism, Socialism and Democracy*, argued among other things that large industrial organizations had bureaucratized the innovation process. The strength of these companies led Schumpeter to despair of the potential for new entrepreneurs to succeed in establishing new firms in the face of the growing power and research capabilities of the trusts.[236] The creation of the new firm by the entrepreneur is an individual act, but Schumpeter argued that these innovations tended to cluster in certain historical periods.[237] So, for example, biotechnology was first envisioned as a pharmaceutical technology, but by 1981 other entrepreneurs perceived the market opportunities in industries such as agriculture and waste processing and founded companies to exploit these markets.

The market potential created by new technologies and possible new products encouraged a rush of entrepreneurs into what Schumpeter termed a **new economic space**. The rush into this new space is not limited to new firms. Older firms that have more farsighted management and have provided internal entrepreneurial space will also expand into this growing new area. These larger established firms have advantages over the new firms in that they have superior facilities and ready access to cash. This reality was the basis for Schumpeter's conclusion that smaller companies had little opportunity to be successful.

Birth of the Biotechnology Industry

Table 7.1 lists the founding dates for small biotechnology start-ups between 19.. and 19. It is interesting to note that until 1980 the large established chemical/pharmaceutical companies made very few investments in biotechnology.[238]

[Table 7.1 about here]

The four social roles: the entrepreneur, the inventor/technician, the manager, and the capitalist that Schumpeter saw as critical for the creation of new firms have been present in all of the new biotechnology companies, though in certain companies the roles have been combined in one individual. A scientist must be involved in forming the company, but the scientist may also be the entrepreneur with the vision and dedication to go out and seek funding. In these cases, the professor usually approaches a venture capital fund which evaluates the proposed company, its employees and product targets, and decides upon its commercial potential. The capitalist must make his funding decision on the basis of a business plan and the evaluation of the personnel involved, because the proposed company has no assets - a decision fraught with risk.

Swanson referred to Genentech as "a kind of marriage between science and business."[239] In this partnership, Swanson developed the criteria for commercial feasibility and Boyer decided what was scientifically possible. The product goals were the result of an iterative cooperative process between Swanson and Boyer. In nearly all of the biotechnology startups, there was a blurring of the entrepreneurial role between the senior researcher who possessed the scientific vision and the entrepreneur who provided the economic vision and goals that motivated the new firm. The extreme complexity of the technology made it unlikely that a scientist could also be the entrepreneur. For example, Walter Gilbert, formerly a professor of biology at Harvard University and then president of Biogen, resigned as Biogen's chairman possibly because of the enormous losses Biogen was sustaining.[240] At the managerial level, in many cases, a professional manager was hired to undertake corporate day-to-day management, as in the case of

Genentech where Robert Swanson turned over the presidency and chief operating office roles to G. Kirk Raab, formerly an executive at Abbott Laboratories, in 1985.[241]

Obstacles to Innovation

The launching of a company based on a new technology is not a simple task; and, in many ways, it was more difficult in biotechnology than it in other industries. We now turn the obstacles to innovation faced by biotechnology startups - obstacles that in large measure were overcome.

The first obstacle was capital. In few cases do the founding entrepreneurs risk large amounts of personal capital. For example, Swanson and Boyer contributed only $500 each to form Genentech in 1976.[1] Estimates of start-up costs in 1980 for a small genetic engineering research facility were in the range of $6-7 million for the first three years. A larger more economically viable company would require $10-12 million financing for the first three years.[1] A small hybridoma business venture was slightly less expensive - approximately $3.5-4 million over three years, with the bulk of these expenses in the form of salaries.[1] Clearly, capital investments of this magnitude were too large for most individuals, making outside sources of capital mandatory.

In the very early stages of biotechnology, between 1976 and 1979, neither large corporations nor banks exhibited interest in investing in such an untested technology. This forced the fledgling companies to seek financing from venture capitalists, who specialize in providing the initial capital to prospective companies in return for significant blocks of equity. Interestingly, venture capital was provided even though the industry had not produced any products.

A important significant obstacle came from the public outcry regarding biohazards,[245] until the 1980 Chakrabarty Supreme Court decision, uncertainty regarding the patentability of living organisms. In this case, the new machinery of production, microorganisms, became the subject of controversy that at various points could have led to stringent regulation or a moratorium on scientific and commercial development. The debate regarding recombinant DNA, particularly in the period from 1974 to 1978, discouraged some companies, especially larger established companies, from attempting to enter the genetic engineering field. These prohibitions, though initially important obstacles, were overcome and the fledgling industry went forward.[246]

The lack of sufficient qualified labor was another obstacle.[247] The primary source of experienced labor was the university, and wages were bid-up substantially in efforts top lure top academics. In the frenzy among both small and large companies to secure scientists in the period from 1979 to 1982 salaries rose to "more than $50,000 per year along with fringe benefits and stock options" for "promising relatively inexperienced scientists.[248] In later phases industry's growth, labor shortages eased. Companies and universities developed explicit strategies to develop the labor supply for the new industry. The University of Houston launched an early program to familiarize undergraduates with simple recombinant DNA procedures.[249] The University of Maryland, Baltimore County, established courses in applied molecular biology.[250] Companies used automation and machine technology to replace workers. As the industry developed, some of the skill requirements changed. During the earliest period, demand was greatest for immunologists, microbiologists and molecular biologists. Demand shifted over time to fermentation, separation, and biochemical engineers. This reflected the maturation of the industry to full-scale commercial production.

The problems discussed above correspond to the sorts of obstacles identified by Schumpeter in his analysis of nearly a century ago. Interestingly, in contrast to Schumpeter's emphasis on the scarcity of capital as the most important limiting factor, this was a bottleneck only in the very earliest days of the industry. The limited availability of labor was another constraint. Societal institutions addressed this constraint by developing training programs.

Entrepreneur and Venture Capitalist

The venture financier, a capitalist whose sole purpose is to invest in new firms is a unique role not envisioned by Schumpeter. As Chapter 2 has noted, venture capital investors contribute capital to the company in hopes of being able to realize a capital gain upon resale of their holdings to a large company or the public through an equity offering. As mentioned earlier venture capitalists hope that their individual investments will bring a 10-fold return or, even better, the jackpot returns that can soar another order or magnitude higher. Thomas Sager of Rothschild, Inc. is quoted as saying, "We're going in for five to seven years.[251] A long-term investment by most U.S. corporate standards, but in deploying a new technology this is not long-term. Venture capitalists provide the capital that allows the entrepreneur to form a company in the hopes that it will become self-sustaining. For the venture capitalist the new company and its expertise become the commodity to be sold.

The venture capitalist is apt to become involved if the company has difficulties. In some privately held biotechnology companies such as Biologicals or the International Plant Research

Institute (IPRI), the founder and entrepreneur was replaced by better managers due to the founder's inability to properly manage the firm.[252] In another case, Bethesda Research Laboratory (BRL) was formed by Stephen Turner, an entrepreneur. In late 1981, the company experienced cash-flow problems and was forced to seek further financing from venture capitalists. An important element of the refinancing was the "transfer of power, no matter how limited, from the entrepreneur to outsiders."[253] An even more striking case of the potential struggle between entrepreneur and capitalist was that of the new defunct Armos. Frederick Adler, the president of Adler and Co., a venture capital fund, was quoted as saying:

> "The people [at Armos] turned down capital. It was the biggest mistake they made, but you can't blame them. Their price was too high due to a wrong perception of the market for investment money For them to raise money, moreover, would have meant giving up control of the company, something Sheehan and Carlock (the founders) apparently were unwilling to do. If somebody refuses money they can retain control but lose the company."[254]

The relationship between venture capitalists and the entrepreneur is not always one-sided. Genentech, the most successful of the new companies, used stock offerings, contract research with large companies, and the first royalties on insulin produced by Eli Lilly Pharmaceuticals to move to the next stage in its plan to become a full-fledged company. It also used offers of research and development partnerships (RDLPs) to raise capital through private placements. RDLPs provide investors a non-equity return, similar to royalties, on any products developed. The RDLP was an important step because it reduced the dependence of a fledgling company on an outside company for the development and testing of its products with the result that a greater proportion of the production process is brought in-house. The RDLP permitted the small company to move from a research mode to a production and distribution mode - to become a viable growing corporation that is financially independent.

Large Companies

There can be no doubt that the genetic engineering companies carved out a new economic space. Initially, the strategy of the large companies was to refrain from investing in genetic engineering. However, their response changed as the success of the new companies became apparent and the large companies, such as Abbott Laboratories, Allied Corporation, Baxter Travenol, Damon, Dupont, Exxon, General Foods, W.R. Grace, Johnson and Johnson, Monsanto, Merck, Schering-Plough, Stauffer, and others, began to make a number of biotechnology investments. The implication that many observers drew from this was that large firms would soon overtake the small firms. Dow Chemical's director of biotechnology, Dr. Donalds, now president of Collaborative Research, Inc., a small biotechnology start-up agrees:

> "The small companies of every new industry start out running circles around the old companies, but they still need size to do certain things. Don't think [recombinant DNA] will revolutionize the way business is done. The technology is revolutionary, but it will get sorted out in the end."[255]

Similar comments were made by, Dr. Howard Simmons, Dupont's director of central research:

> "Recombinant DNA is just a way to synthesize things. As soon as you've inserted the

gene, it's identical to what you would do in the chemical industry anyway. [The small firms will] play an important role in the early years, but less so down the line. In the early years, people will buy discoveries, but why buy from somebody and share the profits when you can do it all yourself?"[256]

Both of these companies used relatively passive strategies concentrating on developing in-house programs to spearhead their efforts in the biotechnology. It is interesting to note that Donalds later became president and chief executive officer of Collaborative Research, Inc., a small biotechnology firm.[257] Dupont lost its director of biological research, Ralph Hardy, to Biotechnica International, Inc., a small Massachusetts company.

There was significant investment by large companies in the small biotechnology companies, between $500 million and $1 billion, between ???? and ????. Monsanto and Schering-Plough invested large sums in all aspects of biotechnology research and development **[see Table 7.2 and Table 7.3].**

[Table 7.2 about here]

The relationship between the large established companies and small biotechnology firms is contradictory. The small company has technology the large firm wishes to secure. Conversely, the small company's strategy is thus to attempt to transfer as little technology as possible and to build its in-house skills while working for the large company. To do so, small companies try to sell marketing rights or even to deliver a recombined organism, but not technology. As the small company gets stronger, it may also secure the right to provide a percentage of the large company's product requirements, thus learning to scale-up production. Similarly, the small company may sell overseas production and marketing rights while keeping its domestic ones. Further, the small company is not merely the pawn of one large company, but, in fact, nearly all have contracts with a number of different companies thereby ensuring more flexibility and independence. The motivation of the small company is to maximize its equity value and to do this it must become more than a contract research operation.

The large company is motivated by a different set of criteria. First, most large companies did (do) not have access to the best university scientists and contracting with the small companies provided(s) this access. The large companies need access to new products to keep their marketing pipeline full and if these products must be purchased, so be it. However, the large companies have also developed in-house research staffs and obviously would like to bring the research in-house. There are cases in which large companies have abruptly canceled contracts when they secure the knowledge they required and were able to do the remainder of the research in-house. The arrangements between the small and large companies are marriages of convenience with both partners needing each other for the movement.

[Tables 7.3 and 7.4 here]

Leslie Misrock, a lawyer specializing in recombinant DNA litigation, has described the environment in the new biotechnology firms thus "The real innovation comes out of the hothouse atmosphere at universities and small companies, but is stifled at large companies."[258] Robert Luciano, a Schering-Plough executive vice-president, said about Biogen, "You just couldn't hire people (Biogen's scientists) like that to work in an industrial setting."[259] The small biotechnology companies with university-like atmospheres were much more conducive to creative scientific research. For some reason, entrepreneurs were better able to create an internal corporate environment that makes mental laborers more innovative. Further, large corporations were mainly unsuccessful in their attempts to develop small venture capital divisions.[260]

Lessons

Schumpeter correctly described the exploitation of a new economic space by the earliest entrepreneurial companies. Large companies and many smaller companies have since moved into this space. Schumpeter's observations that entrepreneurs appear in swarms is certainly borne out; in 1976 there was only one true genetic engineering firm, but by 1982 estimates were that up to 250 firms in the U.S. alone were using the new genetic engineering techniques.[261] Clearly, this swarm-like behavior was facilitated by the pioneering successes of the first companies which then prompted other entrepreneurs to launch their own companies.

This chapter has shown that the entrepreneurial role in genetic engineering has usually been a partnership between an entrepreneur and a scientist. This is due to the very complex nature of genetic engineering. This division of labor reflects the new realities of both science and finance - only a specialist can handle either of these areas. For all these companies research is critical. As Genentech's Swanson puts it, "if the research goes well we can handle the rest of the problems of the world.[262] In biotechnology, venture capital appeared in part as a response to the rigidities of the large U.S. companies, many of which found it difficult to provide an internal environment conducive to radical innovation. Once again in American capitalism, the role of the unattached entrepreneur financed by venture capital has proved crucial to commercializing this major new technology and launching a new industry.

CHAPTER 8

VENTURE CAPITAL AND THE RISE OF COMPUTER NETWORKING[3]

> "There was no company [when we invested in Cisco]. There was no competition. There was a giant problem. And, they had implemented a solution around an emerging standard, TCP IP. They understood and learned very quickly. We put a management team in place that knew how to implement." Donald Valentine, lead investor in Cisco.[263]

Cisco Systems was formed in late 1984 by a husband and wife team, Leonard Bosack and Sandra Lerner. While at Stanford University, the two had developed a router to conncet two computer networks to share software and data.[264] By 1987, the small, fledgling company, still privately held by the two, had revenues of $250,000 per month and was growing rapidly. While the two were content to build the business slowly, the entry of venture capital changed things dramatically. When the venture capitalist, Donald Valentine of Sequoia Capital, heard about the company from a colleague in late 1987, he saw boundless opportunity and decided to invest. By the end of 1989, Cisco had over 400 customers worldwide in the industrial, financial, government, and university markets with more than 4,000 Cisco networking systems.[265] Its 1990

[3] This chapter was jointly authored by Urs von Burg and Martin Kenney. For further discussion of the development of the LAN industry see, Urs von Burg. 1997. Plumbers of the Internet, Department of Economics, St. Gallen University.

IPO was amazingly successful. Its 1996 valuation was nearly $32 billion with revenues of $4 billion.[266]

The computer networking industry, which emerged during the late 1970s driven by the need to connect computers to one another, was worth billions of dollars by the mid-1990s. In February 1996, *The Wall Street Journal* reported that in less than a year during 1995-1996, venture investors had bet more than $50 million on a dozen startups, making it the gold rush area of the 1990s: "The funding spree rivals the rush to finance companies in biotechnology when that field emerged in the 1980s."[267]

This process took time to develop. Originally, venture capitalists were uninterested: It was hard even to imagine what a computer network might be - nevermind, conceptualize a market based on these networks. But, eventually the rise of personal computers created the market opportunity. Small computers were so much more powerful when they were networked together. Computer networking required a host of technical solutions. And, with each of these major developments, venture capitalists reaped enormous capital gains. As companies grew and the industry matured, a cycle of sorts emerged. New startup companies would grow, become profitable, go public or be acquired, releasing their founders to start the process over again. In the process, another new set of companies would be built - additional fortunes made.

At the center of this maelstrom were the venture capitalists. Prescient venture capitalists, like Valentine, played a crucial role in funding the firms that laid the foundations for computer networking. The vibrant community of entrepreneurial, innovative firms funded by venture capital were able to improve computer networking technology and surmount difficult problems, such as the IBM Token Ring system. This essentially turbo-charged the development of the technology. and created still more opportunities for venture capital investment and entrepreneurial business formation.

This chapter examines the role of venture capital in the formation of the new industry of computer networking. We trace the historical development of the computer networking and outline the crucial role played by venture capital in the emergence and development of this new technological area and industry.

Rise of Computer Networking

There are two dimensions to computer networking: the local area networking (LAN) business that was developed almost entirely in the private sector and the wide area networking (WAN) that consists telecommunications system. The WAN was formed in the public sector with funding from the Department of Defense Advanced Research Project Administration (DARPA) and was called the ARPANet. The first commercial networking technology was the LAN. Venture capitalists were key in funding the early LAN startups.

The first interactive computer-to-computer network was the ARPAnet.[268] The ARPAnet was established in the late the late 1960s due to the Department of Defense concern about the ability of the U.S. communications systems to survive a nuclear first strike. Paul Baran of the Rand Corporation studied the communications systems' survivability and concluded in a public report in 1964 that a distributed network of computers without central control and linked over redundant communications lines would be the most reliable communications network in which many links were likely to fail, as in the event of nuclear war. This became DARPA's which began funding the linkage of computer centers at various universities and military research institutions through high speed telephone lines.

The DARPA funding would have some significant spin-offs. Time-shared computing developed by DARPA-funded projects became an independent business serving the private sector. Technologies such as packet switching methods and high-level protocols such as TCP/IP were also adopted for commercial purposes. But, probably the most important commercial contribution of the DARPANet was that it supported the training of some of the key people in the development of the LAN industry including early computer networking visionaries like Robert Metcalfe, Robert Taylor, Ronald Crane, and David Liddle.[269]

In the mid-1960s, timesharing for commercial purposes was developed at DEC using its PDP-8 and PDP-10 with the aim of lowering computing costs.[270] The shift from batch-processing to time-sharing minicomputers encouraged the use of graphical terminals and computer monitors.[271] A user need no longer deliver stacks of computer cards to an input device, thereby loosening the bonds of distance to the actual computing device. Time-sharing computers proliferated as more and more people developed applications that used computers, but could not use a computer's full capacity.

Time-shared computers required distance access. In the mid-1970s a number of companies were started to take advantage of the opportunity to provide lines for switching computer information packets. For example, George Quist, then at Bank of America's venture capital arm, invested in the startup, Tymshare.[272] Another packet-switching company formed in 1975 was Telenet Communication Corporation which received $21 million in venture capital from Bessemer Securities (New York), the Palmer Organization (Boston), and Time, Inc.[273] These investments were very successful, but in the end, packet switching was capital-intensive business and there was little way for the companies to differentiate their business, so profitability fell. Most packet-switching companies either failed or were absorbed by larger firms, but not before they provided low-cost computing for a new generation of computer users including people such as William Gates and Paul Allen.

In the 1960s and 1970s, the computer business was still dominated by mainframe producers, though the venture capital-financed minicomputer firms, such as DEC and Data General, were growing rapidly. In the computer industry, there was increasing interest in developing methods to interconnect computers. However, the dominant paradigm remained based on large central computers doing the computing for users at dumb terminals. Another blockage was the telecommunications system which was still monolithically controlled by AT&T. And, AT&T was far more interested in voice communications than in the far smaller data communications market.

Building an Environment for Computer Networking Entrepreneurs

Xerox PARC was to be at the center of the creation of a workable system for distributed computing. By the late 1960s, Xerox management believed that the new digital technologies such as computers would provide fast and powerful means to process, store, organize and communicate information - what many began calling “the office of the future.” Because of the copier’s central position in the office market and the danger it would be outflanked by new technological developments, Xerox decided to pursue the office of the future by setting up a research center in 1970. Xerox located its research center close to Stanford University, because the area was becoming the center of a growing electronics industry.[274]

In the 1970s, the Xerox Palo Alto Research Center (PARC) was developing another vision of computing. The new vision was made possible by the recognition that computers were shrinking in size and cost and that this meant it would be possible to put computing power on the desktop. This scenario of distributed computing power meant a very different network would be necessary. Xerox PARC designed a microcomputer, the Alto, and then began a project to link it to other computers, storage devices, and printers into a LAN that would become Ethernet. The Xerox PARC Alto workstation was the prototype of a desktop computer and Ethernet was a network protocol to connect them. Linking desktop computers through a network made possible a new vision of computing of distributed, but interconnected processing power.[275]

The first microcomputer based LAN was developed, only four years after the Altair microcomputer was introduced. The microcomputer LANs were not developed by the fast-growing vendors of microcomputers, but by a separate set of start-up companies, most of which were also located in Silicon Valley. Because the microcomputers were still in their experimental phase in the late 1970s and had not found their main market in office automation, LAN technology vendors could not see their market. While these pioneers had a technology, but no clear market had formed.

In the late 1970s, a number of different computer networking systems had been introduced by various firms. The majority of these were offered by computer or peripheral vendors, that developed a communications protocol for linking their own machines, while locking others out, i.e., closed systems. Established companies such as Wang and Datapoint wanted to exclude other firms from their proprietary installations and smaller companies such as Ungermann-Bass and Nestar were simply developing networks that were usable. A wide variety of networks were built, and the problem was that these networks could not communicate. There was no dominant design or stable platform to provide firms with a clear sense of direction or to give venture capitalists a clear vision of the market possibilities in computer networking.[276]

The large number of protocols meant that building a network was difficult. For computers to communicate, they must speak the same language, i.e., use the same protocols. Too many different communications protocols create a babel and frustrated communication. Customers are afraid to purchase products, because they cannot be sure they can communicate with other computers. Vendors find it difficult and costly to link their product to the large variety of protocols. In such an environment, agreeing on a standard is desirable, but there is no incentive for firms to agree to another company's standard. Often customers are also nervous because a proprietary standard leaves them vulnerable to the firm that controls the standard. Therefore, the standard owner has a significant advantage. It is in every other vendor’s interest to resist any standard controlled by another company.

Xerox took an interesting strategic step to overcome this problem. It decided that its strategic interest would be served if Ethernet was adopted widely. So, it eschewed royalties and set a very low licensing fee for Ethernet. Then it joined DEC and Intel in seeking formal IEEE (Institute of Electrical and Electronics Engineers) approval for Ethernet as an approved standard. This made it possible for other firms to develop Ethernet compatible products that could simply be attached to an Ethernet network. The open standard meant that changes and innovations to devices to be connected to the network could occur simultaneously and autonomously without jeopardizing other parts of the network. Ethernet was a platform for which other firms could make products. Almost immediately, Ethernet attracted third party producers. For DEC which intended to sell mini-computers and Xerox which wanted to sell printers, this meant that network hardware would become open to competition lowering prices and encouraging innovations and in the process lowering the cost of attaching their products to the network. In effect, DIX group laid the foundation upon which an industry could be built.

The IEEE Ethernet standard provided a set of stable and predictable specifications upon which third party vendors could build LAN products. The IEEE involvement assured the vendors of LAN components that no arbitrary manipulation of technical features would be made by a dominant computer system vendor. This guaranteed that any company producing for Ethernet was safe from having their business controlled by an outside company. Being early and workable, Ethernet quickly attracted fledgling companies such as Ungermann-Bass, 3Com, and Interlan that wanted to enter the computer networking market.

There was much to do to create a viable economic space. Users had to be educated about the value of computer networking. A computer network requires an operating system and application software to be useful, but there was little then available. The software had to be developed simultaneously with the hardware. Finally, users were confused by the variety of technical options for designing and building a computer network.[277]

This confusion was aggravated by the fact that the computer networking technology was reaching a new and much larger audience when it moved from the mainframe and minicomputers into the microcomputer market. Mainframes were controlled by corporate MIS departments, minicomputers by divisions and departments, but microcomputers penetrated offices where there was little sophisticated computer knowledge. This was exacerbated because various vendor claims and counterclaims were often made with the intent to confuse customers.[278]

The initial amorphousness also made it difficult to identify market segments, competitors, and to generate effective corporate strategies. James Swartz, the lead investor in U-B, remembers: "sitting in U-B board meetings talking about Novell (the firm that developed the dominant network operating system) and nobody having a clue what the hell they were doing and why they were being successful."[279] The computer networking industry pioneers established their companies in a field that was relatively formless and full of contradictions. These entrepreneurs believed in the future of computer networks, but could not understand exactly what the business opportunities were.

Network Systems - Networks for Mainframes

Before Ethernet there were already startup firms networking computers. One of the earliest companies was Network Systems founded in 1974 in Minneapolis by a group of mainframe computer engineers.[280] Their market niche was developing very powerful, high-speed LANs to connect incompatible mainframes. When they launched Network Systems, it was very difficult to find venture capital. One reason was most people believed that existing data communications systems using the telephone operating at speeds of 900 to 9600 bits per second were adequate. Their initial seed capital was provided by individuals in the Minneapolis and St. Paul area. It was only in 1976 that venture capital firms led by Minneapolis' Norwest Venture Capital Management gave Network Systems its first injection of venture capital. In November 1980, Network Systems went public raising approximately $15 million of new capital.[281]

As one of the earliest LAN companies there was little knowledge or understanding of the potential. Moreover, the market for mainframe LANs was limited by relatively small number of organizations that needed to link multiple mainframes on a LAN. Therefore, the niche Network Systems proposed to exploit was limited. For most venture capitalists, given the number of mainframes, computer networking hardly appeared to be a market that would grow rapidly. And, in fact, Network Systems never did become a very large company, for example, sales in 1996 were approximately $200 million dollars per year and was only a modest success for the venture capitalists.

Nestar - Pioneer but No Venture Capital

In October 1978, inspired by the feverish experimentation with microcomputers in the Silicon Valley area, Harry Saal and Leonard Shustek among others started a company to build LANs for personal computers. Saal, a physicist by training, had worked for IBM Palo Alto and later IBM Santa Theresa Laboratory. At IBM, he was involved with interactive time-sharing systems, but he was also following the development of the early microprocessors and the initial personal computers built by hobbyists in Silicon Valley. The computing power and responsiveness of what many thought were simply toys impressed him. He recognized that an important problem was that peripherals such as hard disks and printers were too expensive for the relatively low-cost PCs. This intrigued him, and Saal became "interested in the idea of building large distributed systems of personal computers, networking them, and connecting them together."[282] Saal tried to convince IBM to let him work on these ideas, but IBM was not interested. According to Saal: "[IBM] did not get it. They were quite, I would say, arrogant about the possibilities [of microcomputers] and maybe conceived that minicomputers might have some future, but surely not toy computers."[283] Saal disagreed with IBM and decided to start a company centered around building LANs for microcomputers.

While building a first LAN prototype for the Commodore PET in 1978 Saal tried to raise venture capital in the Silicon Valley and in New York. However, there was little interest. He said, "I think they really did not believe that these types of computers would ever be used in a real commercial-type environment or that people would have large numbers of them being networked together. I got a fantastic rejection from all of them. They said this [company would] not go anywhere, that these toy computers were never going to be serious and if they were serious, nobody would have many of them at a time together." Further, they wondered why IBM did not invest, if his idea was so good. This reaction among venture capitalists is not surprising, most of them are risk-averse and not willing to invest in entirely new ideas. Only later, Nestar received capital from the UK-based company. In actuality, Nestar was too early. To be successful at selling networks, it was necessary to have a sizable installed base of microcomputers and it did not yet exist. Nestar never had sales of more than $10 million and was eventually absorbed by another company and closed.In 1986, Harry Saal and Leonard Shustek left Nestar to start another LAN company, Network General, with "with a blank piece of paper."[284] Saal and Shustek controlled nearly 60 percent of the Network General stock. For the most part, they boot strapped the company and only brought in TA Associates of Boston as venture capitalists later. Network General went public in 1987 and became a medium-sized LAN company. Nestar and Saal were the typical pioneers that ended up with "arrows in their backs." Nestar had to wait for the microcomputer market to develop and to create a network it had to develop all of its own hardware and much of its software. Then, three years later they found themselves competing with Ethernet backed by DIX and Token Ring backed by IBM.

Without a clear sense of the market, venture capitalists failed to provided the necessary funds to this pioneering startup.

Zilog: A Source of Entrepreneurs

> "[We] tried to build a company around an area with great potential but no entrenched competition. We also wanted to avoid an extended pioneering effort." Ralph Ungermann, one of the founders of Ungermann-Bass.[285]

> This new [computer system] architecture that could best take advantage of VLSI technology would be highly parallel in the sense that it would include a number of more or less independent processors and other resources, all interconnected to permit communication among elements of the architecture." Frederico Faggin, one of the founders of Zilog in 1978 predicting the distributed computing architecture.[286]

One of the earliest companies to experiment with computer networking technology for microcomputers was Zilog. Located in Silicon Valley's Cupertino, Zilog was founded in November 1974 by Ralph Ungermann and Federico Faggin, both Intel alumni, with funding from Exxon Corporation.[287] While at Intel, Ted Hoff had invented the microprocessor and Faggin had helped design its architecture. Zilog's initial business focused on microprocessors and it developed the Z-80, a popular 8-bit microprocessor. Soon, a number of popular microcomputers were based on the Z-80 such as the TRS-80 (Tandy Radio Shack) microcomputer, the portable Osborne I, and the Kaypro appeared in the market.[288]

In the mid 1970s Zilog began developing a LAN, because it had developed a very successful communications peripheral chip for input/output devices.[289] Faggin foresaw a new computing architecture that would be based on computers connected to networks. He thought that the costs of microprocessors would decrease dramatically and make it possible to have a microcomputer on every office desk. The result would be a radical change in computer architecture using microprocessors that were inter-linked over a high-speed network and that applications would be distributed over many processors.

Zilog was an incredibly ambitious pioneering company that overflowed with new ideas. It was active in an incredibly wide variety of fields including: operating software, microprocessors and other chips, computer hardware, and LAN development. In the late 1970s Zilog shifted its business strategy from focusing on microcomputer components to being a systems integrator manufacturing its own microcomputer line.[290] The company hired a group of engineers to actualize Faggin's vision of networked microcomputers. This group included Charles Bass. Zilog then developed not only an operating systems called Leo for controlling various microprocessors, but also a personal computer LAN, the ZNet. However, Zilog's network was not successfully marketed. Zilog was too diversified in its efforts to fulfill Exxon's quixotic quest to develop the office of the future and it foundered.

As Exxon's interest in Zilog decreased and the company weakened, leading engineers began to leave the company. This exodus would be very important for the creation of the LAN industry. Figure 8.1 indicates that Zilog became a source of successful entrepreneurs. Ralph Ungerman and Charles Bass were the first to leave in 1979. The next group to leave was William Carrico, Judith Estrin and Eric Benhamou who founded Bridge Communications in

1981. Kanwal Rekhi was hired by Zilog to continue the work of those who left for Bridge Communications, but he left within a year to found Excelan. Another firm created by Zilog alumni was Orchid Technology which was founded in 1982 and remained private. In sum, Zilog rivaled Xerox PARC as the source of the most important Silicon Valley LAN entrepreneurs.

[Figure 8.1 about here]

Ungermann-Bass - Pioneers Ethernet Adopter

Ungermann-Bass provides another example of the difficulty pioneers encounter in trying to secure venture capital in infant industries. In 1979, Ralph Ungermann and Charles Bass left Zilog with the intention of starting a company to build LAN systems. They searched for over a year and a half for venture capital with little success. Ralph Ungermann pointed out that: "everybody in the venture community turned us down because they believed that the OSI standard was coming and the computer companies would build the network that would interconnect each other's equipment. So, there was no room for a stand-alone networking company." Ungermann said he contacted virtually "every venture capitalist in the United States and in the world really" with no success despite of his record as a leading Intel engineer and co-founder of Zilog.[291]

In 1979 and 1980, few understood the potential for LAN technology because the market remained small and confined to minicomputers. There were customers. General Electric, for example, retained UB to upgrade the throughput of the existing connections to a higher speed by replacing the telephone lines and modems by a LAN and interconnecting all of their computing resources.[292] Nevertheless, there was great uncertainty regarding the market, technology, standards, and competitors. In other words, risk was high and the primary investment criteria had to be acceptance of the entrepreneur's vision.

For most venture capitalists, there was little reason to believe that money could be made funding LAN startups. However, Bessemer Securities said it would invest in UB, if another venture capitalist would also invest. Eventually, Ungermann and Bass were contacted by James Swartz, a former Citicorp venture capitalist who had resigned and partnered with Fred Adler.[293] Swartz heard about UB when he attended a McGraw-Hill conference on data communications in New York. One of the seminars was given by Robert Metcalfe, formerly of Xerox PARC and the inventor of Ethernet. Metcalfe displayed one slide with a list of the small companies that had been started to exploit Ethernet. UB was one of those companies. Because Swartz had become interested in computer networking, he decided to visit the listed companies.[294]

Swartz was uniquely prepared to see the potential of LANs because he had made an earlier investment in Amdax, a company trying to commercialize a broadband technology. Soon after the investment, the founder died and Swartz had to manage the company. In the process he became convinced of the potential for computer networking. So, by the time he visited UB, he was primed to make an investment. Swartz described his meeting with the two founders:

> "I met Ralph and Charlie and at the end of the day I said, "Jesus, this is terrific. I really like what you guys are doing you are absolutely right on everything. I can tell you I want to do this ." So, I called Fred [Adler, his partner] that evening and told him what I was doing he said, 'fine go do it.' And, so that evening or the next day, I called Ralph and committed to him."[295]

Since Bessemer Securities had already committed to invest in UB, the deal was quickly finalized with Oak Investment also joining.[296] Swartz, Neil Brownstein of Bessemer Venture Partners, and Stewart Greenfield of Oak Investment Partner invested an initial $1.5 million. In total, the investors committed $10 million before the company went public in June 1983 with a total valuation of $48 million.[297]

In the period when a market has not really formed the decision to invest can often be a gut decision. In the case of UB, when asked whether in his due diligence process he contacted personnel in large companies and his response was "if I had tried to do that kind of due diligence, I would have been absolutely convinced that [the UB investment] was something I should not do." In this case since Swartz understood the technology because of his prior experience, he described the process in this way, "[the investment] became a people thing, who [the founding team] are and what they have done - classic resume tracking. And then it becomes a very gut level feel of, "gee, are these credible people. Do they have the right integrity and right ethics?" He believed in the founding team of Ralph Ungermann and Charles Bass and that convinced him to invest.

UB was a very significant and profitable success. In a sense, UB was one of the companies that defined the LAN space, however it was born a little too early and focussed on networking minicomputers using Ethernet. In 1982, two significant events occurred that would make personal computing a reality. The first was the introduction of IBM PC and the second was creation of Sun Microsystems, which rapidly became the workstation leader.[298] Within five years, the PC and the workstation had ravaged the minicomputer industrial space and become a far more significant end-market for LAN equipment, especially, adapters and the dominant types of computers on the network. For the most part, UB missed this transformation by concentrating on its mainframe and minicomputer enterprise-wide market niche - initially the entire market, but soon to become only a small portion.[299]

The venture capitalist often has the duty to encourage management, which is usually so involved in the day-to-day struggles for survival, to change strategies to cope with market changes. As the market changed from minicomputers to PCs and workstations, Swartz said that he had “many tough discussions” at the Board of Director meetings, but it was difficult for UB’s senior management to see the next wave of LAN customers - the desktop computer users. BY 1987 the environment had changed dramatically because of the success of desktop computing and UB was not properly positioned. In response, the management decided to sell the company to Tandem Computers.

As with so many companies after the merger, Tandem began to lose key UB personnel, who left to start new firms. In 1993, Ralph Ungermann founded First Virtual Corporation aimed at bringing ATM, a new high-speed protocol, to the desktop. And, not surprisingly, James Swartz, a founding partner in with Accel Partners, was a lead investor. Charles Bass left Tandem to become a venture capitalist and has made many investments in the networking business area. Bass helped establish Starlight Networks in 1990 and Accel Partners was one of the founding investors and an Accel partner serves on the Board of Directors.[300] Other UB alumni were James Jordan who went to found Kalpana in 1987 and Telebit. He was also a private investor in StarBurst Communications. Still other UB alumni were Gregory Hopkins who went on to Win Data and Amber Wave, William Sickler to Gadzooks, and Frank Wang to Xpoint. Once again, success and merger released waves of new venturers.

3Com - The First Startup Dedicated to Ethernet and PC

3Com was founded by Robert Metcalfe, the inventor of Ethernet at Xerox PARC, and Gregory Shaw on June 4, 1979.[301] The company was named '3Com' which stands for Computer - Communication - Compatibility.[302] Its initial location was at 3000 Sand Hill Road in Menlo Park where many venture capitalists are located, though it later moved to Mountain View, California.[303] Before starting 3Com, Metcalfe had been consulting for DEC about Ethernet and helping design its compatibility for DEC's new VAX product line. In part due to his efforts Xerox joined DEC and Intel in an alliance to open the Ethernet protocol and have it approved as a standard. Being the inventor of Ethernet and completely committed to its commercialization, Metcalfe built 3Com to exploit the Ethernet standard. Moreover, because the DIX group had not released the standard specifications of the upgraded 10 Mbps Ethernet, 3Com continued Metcalfe's consulting practice and their most important customers were General Electric and Exxon Office Systems.[304]

With the release of the Ethernet standard 3Com began actual prdouction of hardware. However, developing Ethernet hardware products required capital. Because consulting fees could not support the investments necessary for either to start manufacturing or R&D, 3Com began to search for venture capital. None of 3Com's founders had ever started or managed a company. Although Metcalfe was very charismatic, he had spent his entire life in an university and research environment and had no experience as a manager. The other members of the management team also had limited management experience. Howard Charney, a fraternity brother of Metcalfe at MIT, was a patent attorney with an MIT undergraduate degree in mechanical engineering and some corporate experience working for disk drive firms. David Spiller, a neighbor of Metcalfe, was a top administrator with the County of San Mateo. Ken Morris was an expert in doing business with China. None of them had raised venture capital or written a business plan. Howard Charney, the original Secretary and Vice President of Operations, looking back, described their presentations to the venture capitalists as "meandering." In an interview he said, facetiously, they would describe how they would foster network connections, "sell products to people who want to buy them," and have fun.[305] They intended to target desktop computers, but as of October 1980, there was only a very small installed base and the IBM PC was not yet introduced. Written in the last quarter of 1980, their initial business plan was necessarily vague. This made it somewhat difficult to find venture capital.[306] According to the 3Com venture capital briefing document put together for David Arscott and Leal Norton on October 6, 1980, 3Com wanted to capitalize on Xerox's Information Outlet (Ethernet) to provide multi-vendor compatibility in local networks.[307] But, given the vagueness of the business plan, the lack of clear market, and the normal risk averse nature of the many VCs; Arscott and Norton turned the deal down as did many others in the venture capital community.

There was some interest, however. Wallace Davis at Mayfield offered $7 per share to Metcalfe who quickly turned him down. Richard Kramlich at New Enterprise Associates put together an offer for $13 a share and Metcalfe turned him down, also. Metcalfe then managed to get an offer of $21 per share from a Boston venture capitalist. However, the Boston firm never seemed able or willing to close the deal. After presentations to nearly 40 venture capital groups, Metcalfe returned to the Silicon Valley venture capitalists; Jack Melchor of Melchor Venture

Management, Richard Kramlich, and Wallace Davis and closed the deal.[308] At the end of this six month search period 3Com received $1.05 million on February 28, 1981.[309] According to Howard Charney this was the same day 3Com actually ran out of money.[310]

Few venture capitalists believed 3Com's optimistic business plan or were exactly sure of the dimensions of the market 3Com was entering.[311] As Kramlich explained it, Metcalfe came in and described his background and sketched out the Ethernet idea. The 3Com business plan, which was similar to the one Arscott and Norton rejected, was very vague and it was difficult to understand exactly what 3Com planned to do. Kramlich recalled meeting Robert Metcalfe and discussing investing in 3Com:

> "He told me all about his background and where he had been. He sketched out his Ethernet idea and I will never forget because he brought in his business plan and it amounted to a series of clouds and I was trying my best to understand what he was talking about and I had a vague understanding of it. But, I did not know any of the technology at the time."[312]

Figure 8.2 provides a reproduction of Metcalfe's map of the future of Ethernet that Kramlich saw in the 3Com presentation.

Kramlich nonetheless invested in 3Com because he was impressed by Metcalfe, the technical expertise of his team, and the management of the firm. Kramlich noted that his involvement in Apple Computer alerted him to "the logic of going from a personal computer to a network. Resource sharing was going to be the wave of the future."[313] As with Swartz in the UB deal, Kramlich appears to have had an experience that prepared him for this pioneering investment.

[Figure 8.2 about here]

Metcalfe and the venture capitalists felt that they needed to bring in an experienced manager to help run the company. After a search, they found William Krause who ran Hewlett-Packard's $60 million general systems division of approximately 500 people.[314] At Hewlett-Packard, he was one of the key figures in convincing the company to shift the personal computer business from minicomputer division. His strategic plan for the PC business at Hewlett-Packard was to create an alternative architecture to time-shared minicomputers by networking microcomputers with Ethernet. He was a seasoned manager, who actually shared Metcalfe's vision of where the computer business was going. Having these experiences Krause could see that "minicomputers have become a more preeminent growth business than mainframes and felt that personal computers were where the computer industry was going, and that the primary reason for networks was to connect these personal computers."[315]

3Com did not become a general purpose LAN supplier like U-B and Sytek, another early firm, building large enterprise-wide LANs centered around the minicomputers and terminals. 3Com was not established to support what Metcalfe believed was a "dying" technology, he had invented Ethernet to carry high-speed traffic among personal computers and believed connecting terminal and hosts was a poor utilization of the technology.[316] Hence, 3Com decided to just provide components to allow Ethernet connectivity. However, providing Ethernet connections for microcomputers was not a very fast growing business. This meant that 3Com's annual sales grew only from $0.1 million in 1981 to $1.7 million in 1982. In comparison, Ungermann-Bass had sales of $11.3 million and Sytek had sales of $6.6 million in 1982.

The world changed for 3Com in August 1981 when IBM introduced the IBM personal computer. Almost immediately, 3Com decided to make an Ethernet adapter card for the IBM PC. And, they quickly designed a small adapter card using integrated circuits. This decision has meant that to this day 3Com is the world's largest producer of adapter cards. For the venture capitalists 3Com proved to be an excellent success when it went public in early 1984 at a market valuation of $80 million and the first round investors experienced a fourteen fold return. Now, Metcalfe's original 1.6 million shares were then worth nearly $10 million.[317] 3Com continued to grow rapidly and has become one of the largest computer networking in the world with 1996 sales in excess of $2.3 billion.

Bridge Communications

Bridge Communications was another of the pioneers and was founded in September 1981 by William Carrico, Judith Estrin, and Eric Benhamou, all of whom had worked on Zilog's Z-Net. Prior to joining Zilog in March 1979 William Carrico had been with Fairchild Semiconductor since 1972. Judith Estrin worked from 1976 to 1981 for Zilog before she joined Ungermann-Bass for a few months in early 1981. Eric Benhamou had been with Zilog since October 1977.[318]

The Bridge Communications founders believed there would be many different types of LANs and that there would be a need to interconnect them, hence, the name, Bridge Communications. However, during the funding process they realized that their business plan was flawed because there were not yet enough LANs to interconnect. As a result, they complemented their product line offering networking equipment and not just focusing on internetworking.[319] Moreover, they also believed that Ethernet was going to become a standard, so they implemented their products for Ethernet.[320]

Securing venture capital was difficult and the team had a series of setbacks. While they were searching for capital, report was released saying Ethernet would fail and Wangnet, a proprietary office networking protocol developed by Wang Computer in the Boston area, would succeed. Judith Estrin, one of the founders, believes that many venture capitalists did not understand the technology and seemed to think that Bridge Communications was developing a sophisticated modem.[321] Locating capital was a slow process. But, after a six month search, they closed the deal in December 1981, with $1.8 million from Weiss, Peck & Greer Venture Partners (WPG); Merrill, Pickard, Anderson & Eyre (MPA&E); and later were joined by Warburg, Pincus Investors.[322] (The initial valuation of Bridge Communications, $1.8 million for 60 percent equity, was low by more recent standards).[323] Judith Estrin felt that, in the case of Bridge Communications, the venture capitalists made their decision on the basis of the people involved, because of all the investors only Robert Loarie of WPG actually understood the technology.[324]

The idea of interconnecting LANs was a little too early. In 1982, there were not enough LANs to be interconnected and Bridge Communications had to produce networking gear such as communications servers in addition to interconnection devices such as gateway servers. Its first gateway was introduced in November 1982 and could interconnect remote Ethernet LANs via public data networks such as Telenet, Tymnet, or Uninet. Its next gateway was designed to interconnect remote Ethernet LANs using various channels such as telephone lines. Eventually, the market caught up with Bridge Communications as more LANs were installed. As with some of the other vendors of general purpose LANs, Bridge Communications was late in recognizing the significance of the PC. Thereby, it missed the biggest wave in the development of the LAN business.

In the mid-1980s there was a consolidation as the general purpose LAN vendors were acquired. First, in 1985 Interlan was acquired by Micom; in 1987 Bridge Communications merged with 3Com; in 1988 U-B was purchased by Tandem **[see Figure 8.1]**. 3Com purchased Bridge Communications for $325 million providing substantial capital gains for both the venture capitalists and the founders.

[Figure 8.1 about here]

After the merger, there was a debate between the 3Com executives and Bridge Communications executives about the direction of the company. Carrico and Estrin left 3Com, partly as a cosnequence of this debate. After leaving 3Com, William Carrico and Judith Estrin left Bridge Communications and planned a holiday. However, they received an opportunity to take over a six month-old startup, Network Computing Devices (NCD), that was floundering. When Carrico and Estrin joined NCD they were able to raise $5 million by calling WP&G and MPA&E.[325] Their next start-up, Precept Software, Inc. was started after they left NCD in September 1994. Precept's first-round funding of approximately $900,000 of the new firm was provided in May 1995 by WPG and private investors including the founders. According to Philip Greer, one of the founding partners at WPG, when Carrico and Estrin decided to create Precept Software, he called them up and told them it would be "bad luck" to start the firm without WPG. As a result, WPG was able to purchase 5 percent of the founder's stock.[326] A second-round of approximately $5.5 million in October 1995 attracted WPG, Foundation Capital, Kleiner Perkins, Morgan Stanley and Sequoia Capital.[327]

Bridge did not make the transition to the networked, distributed computing paradigm. However, it was another of the early computer successes that helped lay the groundwork for future growth. Most importantly, it is one of these firms that actually clearly saw the future of interconnecting LANs, the only problem is that it was a little too early and after the merger its vision of interconnection got lost in internal battles at 3Com. And, as a part of the battle, William Carrico and Judith Estrin went left and became involved in two other startup situations.

Other Early Firms

The companies discussed above were not the only computer communications startups during the early 1980s. There were a number of smaller companies that were formed to exploit the business opportunities in computer networking. Four of the most important firms were Interlan, Excelan, Proteon, and Sytek. Generally speaking these companies did not have a significant impact on the marketplace. But, for the venture capitalists, nearly all had good returns.

One of the earliest was the Boston-area company, Proteon, which developed a token ring LAN tailored for DEC's mini and microcomputer lines. In June 1981 Proteon began to sell this system (called Pronet) as a commercial product to other institutions. When Proteon wanted to branch out into the commercial market, they required venture capital. In December 1983, it received $2.3 million venture capital from Sevin Rosen and Kleiner Perkins. With the venture capital came a number of demands to change the management team including bringing in a new CEO. These changes failed, but Proteon continued to grow and was able to go public. Proteon continues to operate today.[328]

Another very early startup was Sytek. In order to move away from consulting and to begin manufacturing a proprietary LAN system it had developed, Sytek began looking for capital in mid-1981. According to its founder, Michael Pliner, Sytek needed about $8-$10 million from an outside investor to realize its plans. In September 1981 Sytek decided to accept a $6 million investment from General Instruments (GI), rather than investment from Continental Illinois' venture capital arm.[329] This seemed to be a good match because General Instruments supplied about 75 percent of all broadband cable to the TV industry. Also, GI had a field service arm with a 350-member staff in over 60 cities, manufacturing expertise, credibility, and access to new markets that the venture capitalists could not provide.[330] Sytek never went public and in 1989 was purchased by Hughes Aircraft, a subsidiary of General Motors.

Excelan was another early LAN company that spun-out of Zilog in 1982. It was the first company to include TCP/IP protocols on its Ethernet boards. This turned out to be an excellent decision when Unix was bundled with TCP/IP in Sun Microsystems workstations and DEC introduced Unix-based VAXs. This allowed end-users to connect their workstations and personal computers with the installed base of DEC minicomputers. Excelan quickly became a leader in TCP/IP and revenues grew to $22 million in 1986.[331] And yet, finding venture capital was not so easy. According to Kanwal Rekhi, one of the founders, the venture capitalists were reluctant to fund them because the team consisted of three Indians. After a search taking six months they secured funding from Bay Partners, Dougery, Jones and Wilder, Hambrecht &

Quist, and Ventech Partners.[332] The company grew, but never became one of the giants and was purchased by Novell in 1989. However, the venture capitalists did well on their Exelan investment.

The period from 1979 through approximately 1983 was chaotic. There was no dominant design and no understanding of how large the market might be.[333] In addition to these firms there were many other firms that were formed to exploit various proprietary LAN systems. However, as Ethernet became a standard, a "bandwagon" effect was established and increasingly, new startups concentrated on developing products that were Ethernet-compatible.[334] By the end of this period ventru capitalists could see that there was ample opportunity in computer networking and they also joined the Ethernet bandwagon. The expanding the market space provided more opportunities for new entrants and for venture capitalists.

Interlan, Wellfleet and Agile Networks - An Example from Boston

An early Boston area startup was Interlan which was founded in 1981 to build products to the Ethernet standard. Very early, Interlan also decided to emphasize general purpose LANs built to serve minicomputers. Raising venture capital was not too difficult because Paul Severino, the president and one of the founders, had been the vice president of engineering at Data Translation and before that one of the original Prime Computer engineering staff.[335] The first round lead investor was J.H. Whitney of New York. The J.H. Whitney partner, Russell Planitzer, had managed corporate marketing at Prime Computer until about the end of 1980 and knew Severino from their time together Prime.[336] By 1984 Interlan had fallen behind 3Com largely because it was late in seeing the switch from minicomputers to the desktop computing environment and Interlan was sold to Micom in 1985.

Severino and Seifert, founders of Interlan, stayed about six months at Micom and then left. According to William Seifert about six to eight months after leaving Interlan, he rejoined Severino in November 1985 and discussed starting another firm. Severino suggested they get into factory automation, a hot area at the time. They began visiting companies and Seifert remembers sitting in the office of a president of a robotics firms and having him say "this is a tough business, GM does not pay their bills. So, I looked at Paul and said, 'you know great technologies are wonderful, but if nobody buys it who cares'."[337] Just as they were about ready to give up, some venture capitalists called Severino up and asked him to look at a small startup company that was failing. After looking at this company they got the idea of doing multiprotocol routing and bridging for Ethernet. It then was only thirty-five days from having the idea to getting a handshake and their first round of financing. Wellfleet Communications was established in June 1986. Once again, Russell Planitzer of J.H. Whitney was a lead investor, though this time Whitney was joined by Calvert Capital in the first round.

Wellfleet rapidly became the second most important router company in the computer networking industry. The problem was that a company in Silicon Valley, Cisco Systems had a headstart and grew far more rapidly than Wellfleet. In 1995, to overcome its weakness Wellfleet merged with Synoptics to create Bay Networks. Severino stayed on after the merger as CEO. In 1991, William Siefert, one of the founders of Interlan and Wellfleet, left Wellfleet and in November formed Agile Networks.[338] In 1996, Agile Networks was sold to Lucent.

The Boston area became the second most active location for computer networking startups. However, it trailed Silicon Valley, which had the advantage of having both Xerox PARC and Zilog as a source of entrepreneurs. Moreover, in the computer networking field successful entrepreneurs have often been able to reproduce their successes a second time. Whereas, Silicon Valley has had a number of these repeat successes, the Severino-Seifert team is one of the few to have accomplished this in the Boston area.

Synoptics

Synoptics, initially called Astra Communications, was incorporated in June 1985 by Andrew Ludwick, Ronald Schmidt, Shelby Carter, and Xerox.[339] Synoptics had its origins at Xerox PARC. In 1980, Xerox PARC had hired Ronald Schmidt to develop an Ethernet version for fiber optic cable. While experimenting with fiber optic Ethernet, Schmidt replaced Ethernet's bus topology with a hub-based star topology to enhance reliability and ease of use. To publish a few academic papers and to help Xerox PARC, which had come under attack in the press for its unsuccessful commercialization track record, Schmidt developed a fiber optic Ethernet product prototype. Xerox, however, decided against commercialization even though their real estate consulting unit believed it could solve the cabling nightmares in its office buildings.[340]

Even as Xerox rejected Schmidt's business plan, IBM had announced in May 1984 the IBM Cabling System as part of its forthcoming but long delayed Token Ring.[341] The IBM Cabling System was IBM's wiring scheme for office buildings. The topology of the IBM Cabling System was very similar to Schmidt's hub-based fiber optic Ethernet. Because of these similarities, Ronald Schmidt and Andrew Ludwick, who had become involved with Schmidt's project while managing new business opportunities at Xerox, decided to adapt their initial project. Within a few weeks, Ronald Schmidt improved his previous prototype so it could implement Ethernet on either the IBM Cabling System or fiber optic cable.

Despite its now apparently broader market appeal, Xerox again rejected their improved business proposition. Rather than manufacturing hardware components, Xerox preferred to adhere to its traditional business strategy of selling integrated office computer systems. Xerox, however, permitted Schmidt and Ludwick to license some of technology Schmidt had developed and to spin out a company in 1985. In return, Xerox received an equity stake in the start-up.[342]

In 1985, Synoptics earned a profit of $485,000 on $1.18 million in sales.[343] In early 1986, Synoptics began its search for venture capital. But, as with the previous companies, Synoptics had considerable difficulty raising venture capital.[344] Many of the most successful and prestigious venture capitalists turned the deal down or missed it. For example, Richard Kramlich at New Enterprise Associates said he saw the Synoptics deal early because one of his partners was a fraternity brother of one of the founders. Kramlich, an immensely successful venture capitalist, recalled, "we should have done it. I knew it was going to be a great deal." However, in the end for a variety of reasons many of which had to do with valuation and disagreements among partners, NEA did not invest.[345] Donald Valentine also saw the deal and thought it was a good opportunity. But Valentine was unable to invest because of his prior commitment to Cisco Systems, another computer networking company.[346]

There were various reasons for the reluctance to invest in Synoptics. Many venture capitalists thought that the market for Ethernet-based fiber optic cable networks and the IBM Cabling System would be small.[347] In this they were probably right, but Synoptics had developed a new innovation, a hub-based, 10 Mbps Ethernet LAN on telephone wire.[348] Still the product itself was relatively low technology and there was reason to be concerned about the barriers to entry that could be erected to protect their market from other vendors. Most venture capitalists perceived the product to be not sufficiently high-tech and software-intensive enough to deter the larger, incumbent LAN vendors such as 3Com, H-P, or U-B.[349]

During the venture capitalists' due diligence process, the incumbent LAN vendors had responded that the Synoptics’ product was trivial and easy to imitate. Ronald Crane described it this way:

> "The VCs all look at the winners. They went and talked to 3Com. 3Com said it’s trivial what they are doing, we can do it with our hands tied behind our back and one-eye blindfolded. And then, that went out to the entire VC community. So you had to find people who would not think as part of the herd instinct."[350]

To escape this “herd” instinct, they found John Lewis of Paragon Partners in Austin, Texas who agreed to invest. Lewis was then joined by Thomas Bredt of Menlo Ventures which really solidified the deal. The final VCs to join the deal were Rust Ventures, another Austin, Texas venture capital partnership and the investment was closed in August 1986.[351] Bredt, who had been involved with LAN technology during his previous employment at H-P and Dataquest, said it was obvious that Synoptics' implementation of Ethernet had significant advantages over coaxial Ethernet. He was willing to invest in Synoptics, because it radically simplified installing and maintaining an Ethernet LAN. This was necessary if the network was to become the data communications highway for Corporate American - they would demand a reliable, easy-to-install system.

Although Ethernet had the largest installed base of any LAN in late 1985, Ethernet lacked network management capabilities and was quite cumbersome, as Thomas Bredt vividly described:

> "The way Ethernet worked was you strung a yellow cable about as thick as your thumb through the crawl space in the ceiling or through the walls. And any place you wanted to attach a workstation to the Ethernet you used what was known as a "vampire clamp" which had prongs on two sides. You would position it on either side of this cable and then tighten it down so that it pierced to the cable and made contact with the appropriate levels of the yellow cable to establish connectivity. The problem of this architecture is: first of all you don't have any clue as to where the taps are located; and second, this piercing and everything is not very reliable."[352]

Ethernet was gaining in market share, but it still had considerable problems or what Hughes discussing the development of the electrical power network called a “reverse salient.”[353] It is this reverse salient that the Synoptics solution addressed and the venture capitalists decided to fund.

Though Synoptics had a successful product and a crucial patent, they still had to have their solution accepted by other vendors. This is because few companies would support a proprietary solution. Therefore, Synoptics had to make some critical decisions about whether to open its patent. Its venture capitalists were actively involved in the decision to open the patent. Thomas Bredt of Menlo Ventures explained his position in the internal corporate debate:

> "When we initially made the investment, Synoptics had a patent on this architecture,

which Xerox Corporation had filed for them. [The patent] basically would have precluded anyone else from implementing Ethernet hubs. And so in one sense, you might look at this patent and say: 'That is a powerful barrier of entry. It will keep competitors away from the door.' Unfortunately, in the networking business [a central patent] works against you in that the IEEE will not allow any company to have a patent on something that is going to give that company an advantage, if the technology covered by the patent is to become an industry standard."

So Synoptics had sort of a dilemma: If we retain the patent rights and defend our exclusivity, we basically have to give up the idea of becoming the industry standard. On the other hand, if we want to have our technology and architecture adopted as the industry standard, we basically have to throw our patent on the pile and offer a free license to anyone.

So we decided to go for the standard and to give free license to the patent. By becoming the standard, the market acceptance of this technology would be dramatically increased. In fact, had we kept the proprietary standard, I believe someone else would have gone to the IEEE and a different approach would have been adopted, and we would have been left in the dust."[354]

The venture capitalists were actively involved in this crucial corporate strategy decision.

As the market evolved, vendors were looking for ways to differentiate their hub products to escape commodification. Bredt described the situation that Synoptics faced after it opened its technology to the IEEE:

> "Then the challenge was to out-execute the competition. We were first to market with products and being first to market means you are farther down the learning curve than the competition. You learn more because you have more customers, there is more feedback, you see more problems, and you solve more problems. So that keeps you out in front for a period of time. Now, it is fair to say that over time I think the Hewlett-Packards and the larger companies are going to catch up and probably get down the learning curve as far as you are. So to make Synoptics a successful company, we knew - the management knew, the board knew - that we had to do more than just win the standards battle. The next strategic question for the company was how do we differentiate ourselves from the competition given that this product, which we pioneered, was now going to become a commodity."[355]

Synoptics is interesting, because it provides us an example of a deal in which not only the venture capitalists could not see the company's potential, but the firms' founders also could not see how big the company would become. What one or a few venture capitalists say they saw as obvious can be missed by many others. So, two phenomenon operate simultaneously, venture capitalists operate as a herd in that almost all reject a deal, but often a few break ranks. These are often the most successful. Also, Synoptics shows the involvement of venture capitalists in critical discussion about fundamental strategies such as the disposition of the patent.

Routers and Cisco - The Biggest Hit of All

In the mid-1980s a technology called bridges was being used to interconnect various LANs, but it had important disadvantages in building the large complex networks that corporations and other organizations wanted. The next technological step that would provide, yet again, a new market-defining innovation, the multiprotocol router, and it was exploited by Cisco Systems. Cisco's success occurred because, in the words of Bandel Carano "it was at the intersection of a dislocating long-term advantage and explosive or compelling market application."[356]

Cisco is unusual in that it is the first significant computer networking firm that was a Stanford University spinoff, though the founders, Leonard Bosack and Sandra Lerner, were not professors. Lerner managed the computer system at the Stanford's graduate school of business and Bosack, her husband, was the manager of the computer science department's computer laboratory. The computers within their own departments were linked by a LAN, however the computers in the two departments could not communicate with each other. Bosack developed a router for connecting the two Stanford department networks so they could share software and databases.[357]

This router attracted peer engineers at other universities experiencing the same limitation in their systems. Recognizing the potential, in December 1984 Lerner and Bosack started Cisco Systems and in 1986 they sold their first router. By 1987 Cisco had revenues of $250,000 per month and was growing rapidly. However, the founders recognized that they needed more capital and professional management to build a much larger company.

The Cisco deal was never shopped in the venture capital community. Donald Valentine of Sequoia Capital learned about Cisco from one its special limited partners, Edward Leonard who is also a senior partner at Brobeck, Phleger & Harrison, one of the premier Bay Area high technology law firms. Leonard was assisting Cisco's founders in negotiating the movement of their router invention that had been developed at Stanford into the private sector. Leonard told Valentine of this promising young company and its needs. The Sequoia partners visited the firm and found it needed financing and organizational assistance. At the time Valentine visited the company it did not even have a business plan. Its business plan was written under the aegis of Sequoia Capital.

In December 1987 Sequoia made its investment and Valentine joined the board.[358] Donald Valentine described Cisco as, "one of those traditional companies that start in a living room or a garage. . . But they also understood they needed help making the company grow. Among the first things we did was begin to build a board."[359] Eventually, the new board would replace nearly all of the initial employees including the founders. Valentine clearly had an idea about Cisco's potential. John Morgridge, who was recruited to be president, was told by Valentine "You know, this is a great opportunity. Don't screw it up."[360]

Valentine described the process of making the Cisco deal as having five or six meetings over a month with the founders discussing the expectations on both sides. He remembered talking with the founders about how big the company could become. One of the founders

> "was very concerned that we do the right things to achieve $500 million. I asked, 'is that $500 million in revenue or $500 million in valuation.' And they answered, '$500 million in valuation, definitely valuation.' I said, 'we will get the $500 million in valuation and I forecast the number of years it would take.' [Cisco] now [1995] has a valuation close to

$15 billion and revenues approaching $2 billion."[361]

Cisco's 1996 valuation was nearly $32 billion with revenues of $4 billion.

In his exercise of due diligence, Valentine called persons knowledgeable in the field such as Robert Metcalfe, a founder of 3Com, Charles Bass, a founder of UB, Judith Estrin and William Carrico, two founders of Bridge Communications. Not only did he question them, but he asked for further names to contact “widening the circle, finding all the experts, and finding the customers that have opinions and problems; until we begin not to get anymore new information.” At the end of this process he said that Sequoia probably contacted fifty to sixty different persons.[362]

The sign of Cisco’s success can be seen in their 1990 initial public offering prospectus, where it said that Cisco was only encountering “limited direct competition.”[363] With its leadership position, Cisco sold to cutting edge users and they provided the company the feedback necessary to identify problems. As in the case of Synoptics, the first-to-market advantage provided them with a unique opportunity to learn from the market. Cisco’s real take-off occurred as corporations began to network many incompatible networks at various distant sites. By 1989 these networks had grown sufficiently large and numerous so as to make it difficult to efficiently integrate them. Cisco provided a solution for this problem.[364] By the end of 1989, Cisco had over 400 customers worldwide in the industrial, financial, government, and university markets with more than 4,000 Cisco internetworking systems.[365]

Almost simultaneously with Valentine’s investment in 1987, Cisco’s sales accelerated **[see Figure 8.3]**. The only major competitor would be the Boston company, Wellfleet, however it was never able to overtake Cisco's lead. Cisco seemed better able to see many of the trends early and react to them.[366] This is consistent with Valentine's strategy of trying to get a company acquainted with the most knowledgeable, proactive customers so it can learn what the market wants. The other strategic difference between the two companies was that Wellfleet focused much more on hardware, whereas Cisco understood the routing business much more as a business where software and software implementation mattered most. Hence, Cisco was faster at implementing the various standards and was able to grow more rapidly than Wellfleet. Cisco had a profound influence on other venture capitalists' appreciation of computer networking. Its success and rapidly growing sales and market valuation made it plain to all venture capitalists that the industry space could be a extremely lucrative.[367]

[Figure 8.3 - Cisco Sales]

The Proliferation of New Startups

> "When [Cisco] began showing such phenomenally high multiples, sort of a rising tide raising all ships [occurred]. You know we in venture capital are a victim of our downstream customers. So when you find an area that is hot, it is relatively easy to make money." William Davidow, a leading venture capitalist.[368]

Cisco's success encouraged the "herd" instinct among venture capitalists as they rushed to find other data networking plays from 1989 to the present. Venture capitalists could see that nearly all the previous investments in networking had excellent returns. This contrasted with the disastrous investments in the mid-1980s that venture capitalists had been making in various computer hardware deals such as workstation and super-minicomputer startups. These bad deals absorbed tens of millions of venture capital dollars only to go bankrupt. One of the first venture capitalists to see the opportunities in this space and act upon it was James Swartz of Accel Partners, who in 1986 raised a $40 million fund from investors such as AT&T, Northern Telecom and Kleiner Perkins to focus on telecommunications and data communications deals.[369] Success reinforced venture capital interest in the industry. Bandel Carano described it this way.

> "If you are a venture capitalist you had to work at losing money. There have been literally hundreds of companies funded and I have a hard time counting on the fingers of my right hand the failures within the LAN networking space in the last five years. So its been a category that's had such an enormous rising tide that in the last few years it has been almost impossible to lose money. And so its getting to a point where everybody thinks they have the Midas touch.
>
> There is an incredible analogy between what we are doing today, my generation in the last several years, and what our predecessor generation did in the disk drive PC business back in the late 70s and early 80s. And that is, you know, our predecessors made their names, got rich funding these disk drive businesses in the late 70s. And they flamed out, hit the wall, and had to retrench when they started funding the fiftieth-fifth drive company and the fiftieth PC company in the early eighties. And, that was the big blow-off in the 1983. Likewise, our generation has gotten very rich, made our name funding data communications LAN networking companies last several years and the risk we run is that we're now funding the 150th hub company or the 150th router

company."[370]

Interestingly, while the proliferation of disk drive companies led to a devstating shake out, the proliferation of computer networking companies led to venture capitalists and entrepreneurs making huge sums of money as companies such as Cisco purchased these companies by issuing stock. This enabled Cisco and the other larger LAN companies expand without using their capital. [See Figure 8.1 which shows the small and medium-sized Silicon Valley firms that Cisco purchased betwen 1993 and 1996]. A joke in Silicon Valley was that the business plan for new networking startups reads - "establish company, sell company to Cisco."

[Table 8.1 about here]

The proliferation of computer networks and the need to move ever larger amounts of data created the demand for ever faster hardware and increasing opportunities for software to manage networks. The earlier firms created a market so large and growing so rapidly that there are many significant niches to be exploited. There was also investment in technologies to replace the Ethernet which was too slow. If a new protocol succeeds it will certainly be open and thereby will create yet another large market space. Networking start-ups such as Kalpana, started in 1987 and purchased by Cisco in 1994, or Grand Junction, started in 1992 and purchased by Cisco in 1995, were established to overcome bottlenecks in computer networking. But, these were only two of the most successful, in terms of return on investment, of the many companies launched in the last decade.

By the late 1980s, the data communications business space had become better defined.

This meant that, though there was uncertainty, the pervasive chaos of an unformed market that existed in the late 1970s and early 1980s had been eclipsed. The decision to fund a startup was less of a leap of faith. Donald Valentine talked about two of the companies, Centillion, which was later purchased by 3Com, and Crescendo, later purchased by Cisco, in which he had successfully invested. He said that these companies made "terrific product lines" for the larger companies.

These newer startups were much more professionally put together than in the earlier period, though often they targeted smaller market segments. Part of the reason was that entrepreneurs had considerable experience in the industry and were able to identify the next step in the technology's development. Grand Junction, for example, was founded by Howard Charney and Lawrence Birenbaum, both 3Com alumni, to develop a low-cost Fast Ethernet switch. Cisco was willing to pay $348 million for the small firm. Venture capitalists are extremely eager to fund these "next step" firms, because of the excellent returns and low risk.

With larger companies purchasing small startups at enormous mark-ups there are many opportunities to quickly achieve excellent returns. The hot initial public offering market and the desire among existing firms to keep abreast of the rapidly changing technologies is forcing new startups to ramp-up quickly to exploit the market environment. The founder of a company describes the environment in late 1996:

> "'It's weird,' said Joe Kennedy, co-founder of the five-month-old start-up Rapid City Communications, a developer of gigabit intranet switches in Mountain View, Calif. 'What used to be two-and-one-half years for a start-up's business cycle is now being condensed to between six and nine months.' For instance, Rapid City accelerated its

plans to hire a VP within the first six months of being in business. The company will announce its new VP at the end of the month.[371]

By the mid 1990s the growth in LANs merged with the exploding Internet market space. The commercial discovery and increasing home use of the Internet combined with the increased need to transfer graphics and video material only increases the demand for faster and better ways of transferring data, managing large networks, and using the Internet for commercial activities has provided enormous opportunities for new venture capital investments. The chaos Donald Valentine mentioned or the dislocating technologies and compelling markets Carano refered to are a feature of the computer networking space. New technologies vie for their place, better software is being developed at a very fast pace, new models of commercializing cyberspace are being experimented with and there is an incessant demand for faster, smarter physical hardware. In such an environment, the returns to venture capitalists can be astronomical. The venture capital firm, Accel, which made important investments in this technology, had realized annual returns of more than 100 percent per year as of 1996.[372]

Venture Capital's Role in Computer Networking

Venture capitalists played a crucial role in the rise of the computer networking industry. providing capital for the firms that laid the foundations for the industry. backed by venture capital, a vibrant community of entrepreneurial, innovative firms funded by venture capital were able to improve Ethernet sufficiently to overcome IBM’s Token Ring and create a computer networking industry independent of the computer industry.

The computer networking business was established in Silicon Valley and the Boston area because the technology base was there - in the form of individuals with technological expertise. The source of entrepreneurs in Silicon valley came from Zilog and Xerox PARC. Surprisingly, the venture capitalists as a group were clearly not prescient. In fact, in the early days, they were conservative. Many industry leaders spent months fruitlessly trying to find funding and the valuations were low. At the time, most venture capitalists did not understand and were not interested in computer networking. Donald Valentine commented that it was exactly the time before venture capitalists became aware of a technology that he relished the most, because it was during this period that the potentially giant successes can be found.[373]

Venture capitalists were reluctant to fund these early firms, and for obvious reasons. There was no real industry or apparent market. At the time, it was difficult to envision what a LAN would be. Moreover, the large established companies such as IBM, DEC, Wang and HP said they would provide the computer networks. In addition, many of the early LAN technologies were a proprietary part of an integrated computer system such as Datapoint's ARCnet, Prime's Primenet, Apollo's DOMAIN, or Wang's Wangnet. As a result there was tremendous uncertainty about whether there was enough economic space for independent companies to market LAN equipment.

A venture capitalist had to believe that the network could be a business separate from the computers. For most venture capitalists this was sufficient reason to not invest in the field. From the perspective of the LAN industry this appears foolish, however it is understandable. Many fields of high technology initially appear as though they will support independent firms, but that proves to be wrong. Examples of such technological dry holes include pen-based computing and artificial intelligence. At the early stage the risks are high, because there are no signposts regarding the direction or form the technology will take.

The converse is also possible, namely that the new firm defines an entirely new economic space and the company becomes a spectacular success. What is interesting in the computer networking space is that its tremendous growth came about because of another technological trend that the venture capitalists were funding - the move to desktop computing. These myriad small computers were so much more powerful when they were networked together. As the price of Ethernet adapter cards decreased, due to economies of scale and increased competition, the market size increased, and this created the increasing network economies. The growing market attracted yet more entrepreneurs, who developed new innovations that made the network even more useful. The most important of these were Synoptics, which solved the Ethernet wiring problem, and Cisco, which simplified the interconnection of various LANs on a organization-wide basis. With each of these major developments, venture capitalists reaped enormous capital gains. But, most importantly, these solutions opened up yet new entrepreneurial possibilities. For example, Synoptics' star-wired topology became an enabling technology for switching which would become another component of the computer network.[374]

The early startups funded by venture capitalists were pitted against far larger and more sophisticated rivals, especially IBM. After an initial period of chaos during which many transmission protocols were offered, two alternatives for a dominant design emerged: the Ethernet standard backed by DEC, Xerox and Intel and Token Ring standard engineered and backed by IBM.[375] Ultimately, the standardization struggle would be decided in favor of Ethernet. The reason for Ethernet's success would be its extremely rapid technological development. The crucial firms in driving Ethernet's success were the venture capital-funded startups that adopted and took advantage of the Ethernet standard. Within five years, these startups sufficiently improved Ethernet to the point at which it would perform most of the functions of the initially superior Token Ring system and still retain its low cost attributes. In the process significant new companies would be built and fortunes were made.

The market creation period ended around 1988 and the networking space became better defined. For an increasing number of venture capitalists it became clear that this economic sector offered the potential for large returns. The original companies had gone public, a number of companies such as UB and Bridge Communications had been acquired, so the first generation of founders and other key persons were wealthy as they sold their stock. They began to leave these companies and start new companies. With the computer networking space growing so rapidly there were many new opportunities to begin businesses. There was a proliferation of new niches and new possibilities. This attracted more venture capital and set-off a Land Rush-style wave of investments. As the new companies went public or were purchased by larger firms, more entrepreneurs were released.

The feature of this industry that made it such a lucrative investment field is that after a slow beginning sales grew extremely rapidly. The industry is knowledge-intensive and would expand in such a way as to provide many new commercial possibilities. This combination offered entrepreneurs and venture capitalists repeated opportunities to fund new companies. Expansion on one level - for example, the number of computers linked to a single network - created new business opportunities in linking networks, building a network operating system, and software for managing networks. The proliferation of LANs created opportunities to build businesses providing the equipment and software to link LANs to WANs. The complexity of these networks created new market spaces for software makers building network management software. As the networks grew and the number of nodes increased, there was even more utility for the entire network.[376] The increased use created information log jams that created demand for new transmission technologies having greater bandwidth, such as switched Ethernet, ATM, and gigabyte Ethernet. These new transmission technologies provided new business opportunities encouraging new waves of startups.

By the beginning of the 1990s a technological trajectory and an infrastructure for local computer networking and the "on-ramps" for wide area communications had been built. This formed the base for the massive explosion in the use of the Internet. What happened at the end of the 1980s was that the local area networking business that was completely privately funded and pioneered by the startups would become inextricably fused with what had been until then the federally funded Internet. The Internet was privatized creating an enormous new economic space for potential commercialization. So, now another generation of venture capital-funded startups such as Netscape, Yahoo, and E-Trade are taking advantage of the computer networking infrastructure that has been built. This latest generation of startups helped to fuel the venture capital industry and ignite another bout of frenzied firm formation.

The intense speed with which the computer networking industry has grown and the technology developed, ensures continuing upheaval and ample opportunities for firm formation, venture investment, and growth. Computer networking changed the very paradigm of information circulation within organizations and continues to profoundly affecting the operation of organizations. The result has been the emergence of a major new industry and a new communications medium - a process of technological development and industry creation in which venture capital has again played a central role.

Venture capital, as we have seen, clearly played a powerful and propulsive role in the development of path-breaking technological innovation and in the rise of whole new branches of industries. But, the role of venture capital goes beyond the confines of idvidual industries. Venture capital has also had powerful effects on the growth and development of regional economies. It is to an examination of the way that venture capital shapes regional ecnomic development that we now turn.

PART IV:

VENTURE CAPITAL AND REGIONAL DEVELOPMENT

CHAPTER 9

VENTURE CAPITAL AND REGIONAL DEVELOPMENT[4]

> "It is not venture capital that is the start of entrepreneurial activity. You can't simply put six venture capitalists in Butte, Montana and expect that the availability of venture capital will engender a Route 128." Daniel Holland of Morgan Holland.[377]

> "We have been amused for years by people who started funds in the Pacific northwest or in Denver with the concept committed to the limited partners that they were going to be differentiated by investing in the northwest. Well, when you look at the history of their investments five or six years later, well over more than 50 percent of them are in the 408 [Silicon Valley] area code." Donald Valentine.[378]

Clearly, the vibrancy and rapid growth of California's Silicon Valley and Boston's Route 128 area owe much to the significant amounts of venture capital available there. In fact, these success stories are so appealing that in both the popular mind in much of the academic literature

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[4] This chapter draws from research conducted in collaboration with Donald F. Smith, Jr., particularly, Richard Florida and Donald Smith, "Venture Capital, Innovation and Economic Development," *Economic Development Quarterly*, 4, 4 (November 1990, pp. 345-60; and Florida and Florida and Smith, "Venture Capital Formation,investment and Regional Industrialization," *Annals of the Association of American Geographers*, 83, 3 1993, pp. 434-451.

it is frequently thought that venture capital can somehow magically generate economic growth. During the 1980s, states and cities around the United States - and a number of foreign countries - launched government supported venture capital efforts in the hope of emulating the economic success of these two high-technology regions. And, virtually all of them failed to deliver the goods. So it is with fads in economic development policy-making.

There is clearly much that is misunderstood about the ways that venture capital helps to shape regional development. If the policy entrepreneurs and academic experts had only looked a little deeper - if they had only examined the behavior of the private venture capital industry, they would have found one important thing. At least two places that have been historic centers for venture capital - New York City and Chicago - failed to generate anywhere near the level of high-technology development found in Silicon Valley and Route 128. From this it may have become clear that venture capital, by itself, is not enough to spur regional industrial development. To be an effective catalyst of regional development, venture capital must be a product of - and embedded within - the broader social structure of innovation which can be found in leading high-technology regions. That is the message of this chapter.

This chapter aims to broaden our understanding of the ways that venture capital affects regional economic development. In it, we focus on three key questions. First, where is venture capital located and what accounts for it? We then turn to the dynamic of venture capital investment, posing the question: Where is venture capital invested and why? After doing this, we explore the process of venture capital coinvestment and its impact on regional flows of venture capital investment. To answer these questions, we draw from a range of research projects we have conducted with various collaborators on these issues, particularly Donald Smith of Carnegie Mellon University. Only after tackling these issues, do we return to the broader question of the relationship between venture capital and regional development.

Venture Capital and Economic Development: What Others Have Had to Say

Economists have generally assumed that capital markets, including the market for venture capital, are perfectly free and thus mobile.[379] From this perspective, there is the expectation that venture capital flows more or less freely from place to place, seeking out the best opportunities. But, as we have seen, venture capital is a unique form of finance, combining elements of financial and industrial activity. As we have seen, venture capitalists are significantly involved in the oversight and management of their investments. While the free flow of capital depends crucially upon perfect information, venture investing is characterized by high levels of uncertainty, high risk, and ambiguous information. Geographic proximity to investments provides a way for venture capitalists to cope with uncertainty and reduce risk. Indeed, surveys have found that venture capitalists prefer to be close to their investments to screen, monitor, and assist in managing them.[380] Others have argued that investment flows are subject to market imperfections and spatial rigidities. Gunnar Myrdal suggested that investment is a cumulative process shaped by the existing distribution of productive activity, previous investments, and subject to incremental change.[381] Gordon Clark, Meric Gertler, and John Whiteman conceptualized the investment process as one of dynamic adjustment where previous investment patterns influence and shape new investments.[382]

Geographers and regional scientists have long noted the tendency of financial institutions to agglomerate. In their classic work on New York City, Edgar Hoover and Raymond Vernon observed that the clustering of financial institutions was a product of the specialized, information-intensive, and transaction-intensive nature of finance capital.[383] Wilbur Thompson, in his seminal writings on urban economics, suggested that established financial centers serve as incubators for new financial services.[384] There are compelling theoretical reasons to expect the demand for venture capital to be geographically concentrated. Ever since the seminal wok of Alfred Marshall, regional economists and geographers have been captivated by the tendency of similar activities to cluster together - or agglomerate.[385] And, geographers have long noted the importance of agglomeration or localization economies, a form of external scale economy, in the location and organization of industrial activity. In the late 1980s and 1990s, a number of leading economists rediscovered the idea of agglomeration. MIT's Paul Krugman made a strong case for the regional specialization of industrial activity based on increasing returns and simple pecuniary externalities.[386] Brian Arthur of Stanford University and the Sante Fe Institute noted that locational clusters are likely outcomes, given increasing returns, historical **path-dependence**, and locational **lock-in**.[387] Thus, both from the viewpoint of classical industrial geography and from the increasing returns perspective in economics, one would expect to see spatial concentration of the industries which comprise the main source of demand for venture capital.

There are a number of studies of the regional dynamics of venture capital and high technology industry. The consensus view of these studies is that venture capital is geographically concentrated and that venture capital investments are unevenly distributed.[388] Most studies of regional patterns of venture capital supply and investment are limited since they rely on highly aggregate data (available from *Venture Economics*) which give an inadequate picture of investment flows at the state or metropolitan level and from which it is hard to generate general findings.

The conventional wisdom assumes that venture capital is coincident with high technology industry. This is partly true, at best. On the one hand, some high technology centers, like North Carolina's Research Triangle, have very little in the way of venture capital, being comprised mainly of high-technology branch plant operations.[389] On the other hand, a number of venture capital centers, like New York and Chicago have generated very little in the way of high technology development.

The majority of research on venture capital is devoted to the supply of venture capital, as measured by the number of firms or amount of resources concentrated in different areas. This work highlights the fact that venture capital is highly concentrated in just a few areas, such as New York, Chicago, Boston, and San Francisco, but for the most part does not provide answers as to why this is so.

The literature on venture capital investment is less extensive, and it too tends to be mainly anecdotal or descriptive in nature. Good data on venture capital investment has been virtually unobtainable. *Venture Economics*, the main source of venture capital data, publishes only highly aggregated numbers for a few baseline states and some regions. It has been impossible to get any numbers on flows within or among states or at the sub-state level. Some researchers have relied on aggregate data, while others have tried to surmount this problem by using venture capitalists' investment preferences as a proxy for actual investments. Thomas Leinbach and Carl Amrhein used aggregate data on venture capital investments for one year to analyze regional variations in venture capital investment.[390] From this, they found that the Pacific Southwest, New England, and the Gulf Coast or Southwest regions attract the greatest volume of investment. Thomas McNaughton and Milford Green used SBIC investment data as a proxy for venture capital investment and found that SBICs tend to make local investments.[391] But, SBICs are a relatively unimportant type of venture capital institution whose investment patterns differ markedly from those of the broader universe of venture capital institutions. While their conclusion that venture capitalists invest locally may be appropriate for SBICs, there is little reason to expect that it will hold for other types of venture capital institutions, such as limited partnerships. Green used venture capitalists' investment preferences (as published in Venture Economics, *Guide to Venture Capital*) to derive a set of preference indicators to develop a model of venture capital investment.[392] Based upon this, he came up with findings which directly contradicted his earlier work with MacNaughton - that venture capitalists have no geographic preference in their investments. This is problematic because the preferences reported by venture capitalist are not necessarily followed in practice - a fact the author acknowledges. Chapter 6 has shown how Silicon Valley venture capitalists plow their investments into the local environment. They may have no stated preference to do so, and they may well examine investments in other regions, but their behavior is to invest locally.

During the 1980s, a number of studies examined the factors at work in high technology location and the formation of high technology industrial complexes. While interesting and insightful, these studies neglected venture capital's role in high technology complexes. Empirical research on high technology location by Ann Markusen, Peter Hall and Amy Glasmeier did not include a venture capital variable.[393] While many researchers have suggested that a technological infrastructure comprised of high technology businesses, universities, specialized labor pools, suppliers, vendors and consultants is an important prerequisite for high technology development, few - if any - of them has examined venture capital's role in this process.[394]

To shed further light on these issues, the following pages use a variety of data to trace patterns of venture capital supply, investment and coinvestment, before returning the more general question of the relationship between venture capital and high technology development. For the more technically minded, an appendix summarizes the results of econometric models of the geography of venture capital supply and investment.

Where is Venture Capital Located?

To get a handle on where venture capital is located and how it has changed over time, we employed two measures of venture capital supply: the dollar amount of venture capital and the number of venture capital offices. The first is a measure of resource concentration and the second provides a measure of the number of potential venture investors. We examine the location of venture capital supply at three levels or geographic scales, the regional (multi-state) level, the state level, and the sub-state or metropolitan level.

We begin by looking at the location of venture capital supply at the regional level **[see Figure 9.1]** The supply of venture capital is highly concentrated by region. The Northeast and West Coast regions together accounted for three-quarters of the total venture capital supply in 1995. The supply of venture capital exhibits an extreme bi-coastal pattern, with major centers on both coasts and lesser activity in the nation's interior. Within this general bi-coastal pattern, there has been especially strong growth of venture capital supply in the West Coast region. Between 1977 and 1994, the West Coast region increased its share of the venture capital pool from 21 to 30 percent **[see Table 9.1]**. Much of this shift is attributable to the dramatic rise of venture activity in California, especially the Silicon Valley area. Growth in the West Coast region has come mainly at the expense of the Northeast region, which saw its share of venture capital supply decline from 55 to 45 percent between 1977 and 1994.

[Figure 9.1 and Table 9.1 about here]

Venture capital is also highly concentrated at the state level, as Figure 9.2 shows. Just three states, California, New York and Massachusetts were home to more than two-thirds of all venture capital supply. [Table 9.2 shows the dollar volume of venture capital for all 50 states as of 1994]. California was far and away the leader among the states with $10.3 billion or nearly 30 percent of all venture capital in 1995. It was followed by New York with $6.8 billion or 20 percent, and Massachusetts with $5.56 billion or 16 percent. Illinois, Connecticut, New Jersey and Texas were the only other states with more than $1 billion in resources. Together, the top seven states accounted for slightly more than 80 percent of the nation's venture capital resources in 1995.

[Figure 9.2 and Table 9.2 about here]

Table 9.3 brings an historical perspective to this analysis, showing the change in the dollar volume of venture capital supply between 1977 and 1994 for the six largest states. Here again, what is most striking is the tremendous rise in the amount and share of resources controlled by the leading high-technology regions, most notably California. In 1977, California controlled $524 million or 21 percent of the total venture capital pool; by 1994, the state controlled more than $10 billion in venture capital, 30 percent of the pool. Massachusetts registered a slight increase in share from 13 to 15 percent. However, the financial centers saw their share of the venture capital pool decline significantly. New York which was the leading center for venture capital in 1977 with $718 million or 28 percent of the pool, saw its share of the pool decrease to 20 percent. Illinois' share of the venture capital fell from 10 to 7 percent of the total pool. Taken together, these data illustrate the shift of venture capital supply toward the new centers of high-technology industry. Table 9.3 shows the amount of venture capital resources controlled by the 50 states for the period 1990-1994.

[Tables 9.2 and 9.3 about here]

Table 9.4 supplements this analysis, showing the location of the offices of venture capital firms in leading states for the period 1973 to 1987. During this period, there was a shift in the location of venture capital offices from established financial centers to the new centers of high-technology industry. Over this period, the number of venture capital offices in California increased from 98 to 247, while the number of offices in New York experienced a modest decline from 164 to 158. California's share of the national total of venture capital offices increased by 9 percent, while New York's share witnessed an 11 percent decline. Illinois, another traditional financial center, witnessed a 2 percent decline in the national share of venture capital offices.

[Table 9.4 about here]

The venture capital industry is also concentrated at the sub-state or metropolitan level as well. Table 9.5 shows the location of venture capital offices for the 27 leading MSAs in 1986.

New York was the lading centers for venture capital offices with 125, followed with San Francisco and Boston both with 81. However, the San Francisco/Silicon Valley complex (the San Francisco and San Jose MSAs) was home to a combined 118 venture capital offices in 1986. These were followed by Chicago with 38 venture capital offices, Dallas with 29, Houston with 24, Los Angeles and Washington DC with 22 each, and Minneapolis with 15, rounding out the top ten MSAs. The supply of venture capital at the metropolitan level was clearly uneven with the top 5 MSA's controlling roughly 46.5 percent of total offices in ????. Indeed, twenty-seven MSAs in seventeen states possessed 7 or more venture capital funds (one percent of the national total). These include rustbelt locations such as Pittsburgh PA, Cleveland OH, Newark NJ, and Rochester NY; sunbelt locations such as Atlanta GA, Denver CO, Dallas and Houston TX, and Phoenix AZ; as well as the high-technology centers of San Jose CA and Boston MA; and established financial centers such as New York City, Chicago, Los Angeles and San Francisco.

[Table 9.5 about here]

The locational structure of the venture capital industry can be understood as follows. Venture capital originally grew up around established concentrations of financial institutions where resources were plentiful, as a small group of financial actors began to channel funds into high-risk, high potential return investments in high-technology industry. This is line with traditional geographic theory which suggests that established concentrations of finance will tend to incubate new forms of financial services. Over time, venture capital spread to, or more appropriately grew up around, the new outposts of high-technology industry. It did so as the more general processes of industrial and regional development generated significant indigenous pools of capital. Furthermore, the nature of the venture capital process itself acted in favor of the development of indigenous sources of capital. The uncertain, high-risk nature of venture investing made it increasingly necessary to have local financial actors on the spot to identify, monitor, supervise and assist with investments. Local venture capitalists help to overcome bounded rationality and reduce investment risk by providing specialized knowledge, supervision and hands-on assistance in the process of actually building businesses. These specialized knowledge and assistance functions are enhanced by the wide web of contacts and networks venture capitalists possess in the industrial and financial communities. Ultimately, the geography of venture capital system was built up in layers over time: the end result being a system of actors which began from one or two central points and later penetrated into the new growth areas.

Venture Capital Investment

We now turn to the location of venture capital investment. Although a logical assumption might be that venture capital investments tend to concentrate in areas of venture capital supply, our results indicate that this is only partly true. Basically, our findings indicate that venture capital investments flow mainly to the nation's premier high technology centers, California's Silicon Valley and Route 128 around Boston. In contrast, venture capital centers like New York City and Chicago receive a much smaller share of venture capital investments.

We begin by looking at venture capital investment at the regional or (multi-state) level **[see Figure 9.3]**. Venture capital investment is even more concentrated than venture capital supply, exhibiting pronounced bi-coastalism. The West Coast ($1.15 billion or 42 percent) and

Northeast ($575 million or 21 percent) regions together attracted more than two-thirds of the $2.74 billion invested by the venture capital industry in 1994. The Northeast region placed a distant second behind the West Coast with $575 in venture investments or 21 percent. Table 9.6 traces the change in venture capital investments by region for the period 1968-1994. The West Coast increased its dominance in attracting venture capital investments over this period, increasing its share from 28 percent of all investments in the 1968-175 period to more than 40 percent during the 1980s and 1990s. The Northeast saw its share of venture capital investments decline from 28 percent in the 1968-75 period to 20 percent in 1992. The Midwest share fell from 20 percent in 1968-75 to 9 percent in 1992. The South registered a considerable gain in its share of venture capital investments over this period.

[Figure 9.3 and table 9.6 about here]

Venture capital investment is also concentrated at the state level **[see Figure 9.4]**. California attracted the lion's share of all venture capital investment in 1995, $1.8 billion or nearly half (47.2 percent) of all venture capital investments made that year, It was followed by Massachusetts with $337 million or roughly 9 percent. Table 9.7 shows venture capital investments for all 50 states in 1994. Again, California led all states with $1.1 billion or 40 percent of the total, followed by Massachusetts with $343 million (12.5 percent) and Texas with $225 million (8.2 percent). Just two other states, Colorado and New Jersey, attracted more than $100 million in investment in 1994. New York, which was the second largest center for venture capital supply, ranked 21st in venture capital investment, with just $25 million, a figure which was similar to Missouri **[see Table 9.7].**

[Figure 9.4 and Table 9.7 about here]

Table 9.8 shows the change in venture capital investments for the ten leading states between 1968 and 1994. The data show a massive shift of investment to high-technology centers, particularly to California. California saw its share of venture capital investment nearly double, from 26 percent to roughly 47 percent of all investments. Massachusetts saw its share hold constant at 9 percent. New York and Illinois, two major centers of venture capital supply, saw their shares of investment drop off markedly. New York's share of investment declined from 11 percent in 1968 to just 1 percent in 1994. Its absolute level of investment declined from a high of $182 million in 1986 to $25 million in 1994. Illinois share of venture investments fell from 7 percent in 1968 to 2 percent in 1994. Indeed, the combined investment share for New York and Illinois dropped from 18 percent in 1968-1975, to 6 percent by 1987, and less than 3 percent by 1994.

[Table 9.8 about here]

Figure 9.5, compiled from our database, provides the first available picture of the national pattern of venture capital investments at the sub-state or metropolitan level for 1987. These data cover the period 1982 through 1987 and are based upon a 40 percent sample of all investment decisions made by venture capitalists during this period [see Appendix I, for a discussion of these data]. The data in this map examine investment in entrepreneurial enterprises. To do so, these data count investments in portfolio companies as a single event. In other words, if a company gets an inflow of investment from a syndicate of 4 venture capitalists, this is counted as one investment event. As this map shows, venture capital investment is extremely concentrated at the MSA level, mainly around centers of high technology. Silicon Valley was by far the leading recipient of venture capital investments with more than 500 investment events, followed by Boston, the greater Los Angeles area (los Angeles and Anaheim), and San Diego.

To get a picture of investment flows, we also used the micro-level data to examine investment decisions of venture capitalists. In this analysis, we count every investment decision made by venture capital firms. Using the example above, when 4 venture capitalists invest in a company, this is counted as 4 investment decisions. Table 9.9 provides a matrix of venture capital investment flows (based on the data on investment decisions for the six major venture capital centers making investments: San Francisco, New York, Boston, San Jose (Silicon Valley), Chicago, and Los Angeles.[395] As above, these data cover the period 1982 through 1987 and include all investment decisions made by venture capitalists during this period.

These data identify a dual pattern of venture capital investment **[see Table 9.9].** On the one hand, venture capital is highly mobile. Venture capitalists in four leading MSAs, New York, San Francisco, Los Angeles and Chicago, exported between 85 and 95 percent of their investments. The flow of venture capital was overwhelmingly toward high-technology centers such as San Jose and Boston which attracted 2462 and 884 investments respectively. The newer, high-technology centers of Dallas, San Diego, Boulder and Los Angeles-Anaheim received lower levels of investment. Together, the San Jose and Boston MSAs attracted almost two-thirds (63 percent) of the investments made by San Francisco venture capitalists and roughly one half (47 percent) of the investments made by New York venture capitalists. On the other hand, a small number of MSA were characterized by a high level of local investment by venture capitalists. San Jose venture capitalists, for example, made a large share of their investments locally. San Jose venture capitalists made 45 percent of their investments locally.   these figures suggest an overall pattern of mobile capital flows, overlain on a landscape which is defined by spatial concentration of investments.

[Figure 9.5 and Table 9.9 about here]

In short, venture capital investment is highly uneven. Venture capital generally flows to areas where investment opportunities and potential investment return are high - that is, to established concentrations of high-technology business. The flow of venture capital toward such areas would appear to suggest that venture capital is completely mobile. However, the mobility of venture capital is contingent upon the existence of active venture capitalists within established high-technology regions who identify potential investments, reduce imperfect and/or ambiguous information, minimize investment risk, and provide on-going investment monitoring and supervision. In these areas, venture capital functions as an integral component of the social structure of innovation. Hence, we end up with a process of geographic mobility which occurs through the well-developed institutional and spatial structure of venture capital.

Coinvestment Patterns

To examine the coinvestment of venture capitalists, a separate database for venture capital coinvestments was compiled. The database included information on all of the coinvestors in venture capital investments. It measured investment decisions rather than the actual dollar amount invested; that is, each time a venture capitalist from a state participates in a deal, that was recorded as one investment decision. For example, a venture capital deal in which four venture capitalists participate was recorded as one investment decision for each of the venture capitalists.

Coinvestments patterns for the three most active states are depicted in Table 9.10, and detailed maps of coinvestment flows at the MSA level for San Jose (Silicon Valley), New York, and Boston are provided in Figure 9.6. These data inform four basic findings.

[Table 9.10 and Figure 9.6 about here]

First, venture capitalists in California tended to invest mainly with one another. California venture capitalists made more than 12,000 investments with each other. This high level of internal coinvesting reflects the abundance of good deals and the well developed internal information-sharing networks which are part of the Silicon Valley social structure of innovation. Such high levels of coinvestment further highlight the embeddedness of California venture capitalists within the social structure of innovation of Silicon Valley.

Second, venture capitalists outside of California invested remarkably frequently with California venture capitalists. Venture capitalists in New York, for example, coinvested frequently with California (3434) venture capitalists, as did venture capitalists from Massachusetts, who made 1941 coinvestments with their counterparts in California. This was just slightly less than the number of coinvestments they made at home (2420). The ability of California to attract venture capital coinvestment is driven by the high number of investment opportunities afforded by its well-developed social structure of innovation.

Third, next to California, Massachusetts was the second leading focus of venture capital coinvestment. Massachusetts venture capitalists invested frequently in their own state and also in

California. New York venture capitalists were frequent coinvestors with their Massachusetts counterparts. Massachusetts attracted coinvestment for much the same reason as California. The well-developed social structure of innovation in the Route 128 area is a generator of investment opportunities that attract venture capital.

Fourth, New York venture capitalists coinvested frequently with California (3434) and Massachusetts (1004) venture capitalists, using these coinvestments to participate in investments initiated and supervised by lead venture capitalists in Silicon Valley and route 128. This shows the importance of coinvestment as a mechanism for moving venture capital across long distances.

Taken together, these findings inform a basic conclusion. Coinvestment is the major vehicle for the mobility of venture capital and for overcoming so called gaps in venture capital supply and investment. Coinvestment forms a link between active venture capital investors who are embedded inside the social structure of innovation of Silicon Valley and Route 128, and passive outside coinvestors located in financial venture capital centers like New York and Chicago. Active coinvestors play a lead role in locating and supervising investments, while passive investors supply external funds. Coinvestment allows passive venture capitalists to participate in deals originated by active venture capitalists in established high technology regions. Coinvesting thus facilitates long distance flows of venture capital and reinforces the flow of venture capital toward locations with the most potential investment opportunities, those with a well developed social structure of innovation.

It is clear from this analysis that coinvestment is a crucial factor in the geography of venture capital. It provides an important link between venture capital investors who are located near the production centers of Silicon Valley and Route 128 and export-oriented investors in financial venture capital centers like New York. Coinvestment facilitates long distance flows of venture capital, allowing a significant subset of venture capitalists to locate away from the specialized production activities they finance. In doing so, it facilitates the flow of venture capital from geographically dispersed collection points, including established financial centers, to the specialized locational centers of high-technology. This spatial and organizational structure thus reduces, indeed in many cases it eliminates, the need for transportation access since it allows a subset of financiers to perform hands-on investing with others functioning as passive financial investors with little need for direct contact or easy access. The coinvestment process, and the venture capital networks upon which it is based, thus facilitate mobility of venture capital, and reinforce the flow toward locations with the most investment opportunities - high-technology centers with a well-articulated social structure of innovation. Furthermore, we have shown how the venture capital system takes the form of a network system - with a set of well-defined centers or nodes and peripheries. It is this network system of actors that plays a key role in relating the two dimensions of venture capital, the location of supply and investment.

Venture Capital and High Technology

In order to understand the relationship between venture capital and high technology economic growth, we looked in detail at the eight major centers of venture capital activity: California (San Francisco/Silicon Valley), Massachusetts (Boston), New York, Illinois (Chicago), Texas, Connecticut, Minnesota (Minneapolis) and Colorado. We examined the relationship of both the supply and investment to two basic indicators: a measure of the high technology base (the number of high technology firms and a measure of the concentration financial resources (the dollar volume of commercial bank assets). The number of high technology firms represents the strength of a region's technology base, and hence opportunities for technology-oriented investing. Commercial bank assets are a proxy for the relative size of the financial sector in a complex. We normalized these variables to take into account the significant variation in population size among the 8 venture capital centers. Table 9.11 summarizes the results of Pearson product moment correlation coefficients. [For those readers who are more technically inclined, the appendix to this chapter provides the results of econometric analyses originally accomplish by Donald Smith of the Carnegie mellon University, center for Economic Development of venture capital supply and investment, the results of which support the findings discussed here].

[Table 9.11 about here]

To explore the determinants of venture capital supply, we ran correlations between the number of venture capital offices and the number of high technology firms in the state, and between the number of offices and the dollar amount of bank assets for all 50 states as well as the 8 major complexes. For all 50 states, correlations were relatively strong across both dimensions. There was a correlation of .954 between the number of venture capital offices and the number of high technology firms, and .830 between the number of venture capital offices and bank assets. These indicate that the supply of venture capital tends to concentrate in areas with a well developed technology base and/or a high concentration of commercial bank assets.

We also ran the same correlations for the 8 major venture capital centers. Here, the correlation between venture capital offices and high technology firms was again strongly positive (.943). However, the correlation between the number of venture capital offices and bank assets was weaker (.720). When the variables were normalized for population, the correlation between venture capital offices and high technology firms remained strong (.874), while the correlation between venture capital offices and bank assets was quite weak (.054) and insignificant.

We ran another set of correlations to gauge the relationship between the dollar amount of venture capital resources (another measure of supply) and the number of high technology firms and the dollar amount of bank assets. Because data for all 50 states is unavailable, we did this for just the 8 major venture capital centers. Here again, there were strong positive correlations with both high technology firms (.903) and bank assets (.708). When the variables were adjusted for population, the correlation between venture capital resources and high technology firms remained strong (.870), while that between venture capital resources and bank assets was weak (.222).

We next ran correlations to explore the relationship between venture capital investment and the same two variables. Here, the results were interesting. The correlation between high technology firms and venture capital investment was strong (.982) and remained strong when the data are normalized by population (.955), an indication that a well developed high technology base draws venture investment into an area. But, the correlation between venture capital investment and the volume of bank assets in a region was weak (.348) and insignificant. When we adjusted for population, the correlation was negative (-.259) and insignificant. This indicates that even though these areas possess a significant amount of venture capital resources, they do not attract a significant flow of venture capital investment. Based on these findings, we are led to conclude that while venture capital supply is related to both the high technology base and financial resources, venture capital investment is related to the former only.

Government Programs to Enhance Venture Capital: What Can Be Expected?

Between the real contributions of venture capital to high technology development and the folklore that has grown up around high technology regions like Silicon Valley and Route 128, it is not surprising that government has become enamored with venture capital as a mechanism for generating technology-based economic development. Indeed, a growing number of state and local governments now view venture capital as an essential ingredient of economic development. According to a 1988 study, the number of states with venture capital programs has increased from just 2 in 1980 to 23 by 1988.[396] According to a 1988 report by the U.S. Small Business Administration, the states spent more than $400 million on public grant, equity, and early stage financing efforts.[397]

These state programs have taken a variety of forms. The two longest-running programs are the Massachusetts Technology Development Corporation (MTDC) and the Connecticut New Product Development Corporation (CPDC) which invest directly in technology-oriented businesses.[398] A number of states use public money to underwrite privately-managed venture capital partnerships. Public entities generally function as passive limited partners in these arrangements, placing few strings on the type or location of investments. The New York Business Venture Partnership, for example, is a $40 million limited partnership backed by 2 public pension funds and managed by Rothschild Ventures. The Primus fund in Cleveland, Ohio is a $30 million limited partnership backed in part by public capital which is constrained (though not limited to) investments in Ohio. Some states - including Ohio, Pennsylvania, Michigan, New York, Utah, Oregon and Washington - allow public pension funds to commit a small percentage of assets to venture capital partnerships without regard for location. A number of others, most notably Ohio and Michigan, have experimented with direct investment in new enterprises. Still others use tax incentives to stimulate private venture capital pools.

The analysis presented in this chapter suggests that there are serious reasons to question the efficacy of government involvement in venture capital. The reason for this is simple. Venture capital is just one of a host of necessary inputs to technology-intensive economic development. As the cases of New York and Chicago illustrate, the presence of abundant venture capital does not necessarily translate into high technology development. These two centers export venture capital to established high technology regions. The consensus view in the literature on high technology regional development is that only a very limited set of areas possess the attributes needed to generate and sustain a high level of high technology-based economic growth.[399] Increasing the volume of venture capital in areas which lack such conditions is likely to have little effect on their technological capabilities and can have perverse effects if this capital simply flows to established centers of high technology. It is possible that models of public venture capital will confer disproportionate benefits to already advantaged regions, enabling them to consolidate their hold on high technology development. Despite the important contribution venture capital has made to high technology regions such as Silicon Valley and Route 128, public venture capital is not a solution to the serious technological and economic woes faced by many regions and localities.

Given the realities of the U.S. venture capital system, public venture capital programs are likely to face the following catch 22 situation. On the one hand, programs which try to encourage local venture investing by placing tight restrictions on the investment activities of public venture capital pools will be problematic because they narrow potential investment opportunities and may cause public funds to invest in local companies which are not competitive. The absence of a supply of entrepreneurial human capital and a supportive institutional environment of law firms, accounting firms and other business service firms are likely to increase the difficulties that these type of investments will encounter. On the other hand, if no strings are attached to public efforts, venture investments will flow toward areas with the most attractive rates of return (eg. Silicon Valley and Route 128). In such cases, publicly subsidized venture capital funds will mimic the export behavior of New York and Chicago venture capitalists. This may result in large outflows of venture capital and further depletion of local resources.

The findings of this chapter contradict the underlying rationale upon which public intervention in venture capital is premised; the concept of an imperfect venture capital market, where large gaps in venture capital supply deny high technology firms the capital source they need to develop. Contrary to this assumption, the findings of the research presented here indicate that venture capitalists are quite proficient in locating the high technology investment opportunities where they exist and providing capital to them. Hence, it may be more appropriate to conceptualize capital gaps as a function of an area's underlying inability to generate high technology firms, or more fundamentally, to establish the social structure of innovation from which high technology development stems.

There are other reasons to be wary of state involvement in venture capital. It is important to note the extremely high failure rate associated with venture investing. Our cases studies and interviews indicate that even the most experienced venture capital funds evidence a success rate of roughly 1 in 10 investments. Private venture capitalists are able to survive and prosper because they are equity investors who generate huge profits on a few big successes or home-runs. Beyond this, the benefits of venture investments tend to be quite narrow, going disproprotionately to entrepreneurs and business founders.

The basic implication for policy is that public venture capital is likely to be appropriate in only those limited number of areas which already possess or are beginning to solidify the social structures of innovation which underpin high technology development. The success of the Massachusetts Technology Development Corporation which makes many of its investments in the Route 128 area tends to support this view.[400] Since venture capital is just one of many important inputs into the technology development process, public intervention in venture capital will be most successful in areas which already have a supply of the other inputs, but do not have sufficient venture capital. In these few cases, and only in these cases, relief of the venture capital constraint is likely to have a significant impact.

In the end, venture capital is not a panacea for the serious economic development problems facing most states and communities. In light of our findings, economic development policy makers would do well to avoid quick fix remedies like venture capital programs, and get back to the business of building integrated strategies to bolster the underlying economic and technological capacities of cities, states, and regions.

Lessons

This chapter informs a number of insights on venture capital investment, its effect on high technology development, and public policies designed to stimulate technology-based economic development by increasing state or local venture capital. The major findings of the research can be summarized in four major points.

- Venture capital is extremely concentrated. The major centers of venture capital in the United States include California's Silicon Valley, New York City, and Route 128 around Boston. Less important, though still significant concentrations of venture capital are found in Chicago, Texas, Connecticut, Minneapolis, and Colorado.

- Venture capital investments flow mainly to established high technology centers, Silicon Valley and Route 128. Other venture capital centers, which are not high technology centers, such as New York and Chicago, primarily export their funds to technology centers.

- Venture capital's impact is context sensitive. In areas with an established high technology base or social structure of innovation, venture capital fuels the growth of that sector. In areas without such a base, venture capital alone is not likely to stimulate innovation and high technology development.

- Public policies must recognize that venture capital is only one element of an area's technology base or social structure of innovation. Public efforts to stimulate high technology by enhancing the supply of venture capital, without influencing the other elements of a region's technology infrastructure, are not likely to achieve success.

Not surprisingly, venture capital firms tend to cluster near established financial centers like New York and Chicago, where resources are plentiful, and around established high-technology regions, like Silicon Valley and Route 128 around Boston. But, venture capital investment flows overwhelming to high-technology regions. Indeed, local venture capital investment is not necessarily related to having a supply of venture capital offices. This is important because it contradicts a major notion running through both he academic literature and upon which a good deal of high-technology economic development policy rests, that a local supply of venture capital will generate high-technology development, or conversely that gaps in the supply of venture capital are a major reason for the lack of high-technology development in those places.

The reason is simple: Venture capital is a part of the well developed social structure of innovation which developed in high technology regions. Venture capitalists draw from and enhance such infrastructures by acting as both catalyst and capitalist, providing the resources and the contacts to facilitate new business start-ups, spinoffs and expansions. Because they sit at the center of the extended networks linking financiers, entrepreneurs, corporate executives, headhunters and consultants, venture capitalists have a propulsive effect on rates of business formation. The availability of venture capital and the existence of such networks also has the effect of attracting entrepreneurs and technical personnel to such regions creating a self reinforcing cycle of innovation and economic development.

Coinvestment is central element of the regional dimensions of the modern venture capital system. Coinvestment allows venture capitalists in various geographic centers to participate in each others' investments, facilitates long-distance capital flows, and in doing so loosens the overall spatial constraints on venture capital investment. The reason for this is rooted in the process of venture capital investment itself which is characterized by high levels of risk, uncertainty, and ambiguous information. Venture capitalists and the networks which they create are conduits for information as well as capital; indeed money is a far more easily transportable commodity than information. The opportunity costs associated with travel to portfolio companies creates an additional incentive for co-location of venture capital and high-technology industry. The venture capital industry exhibits a heavy reliance upon personal contacts across every phase of investment activity. Rapid and continual circulation of information through personalized networks is necessary to locate potential investments, assist in business formations and mobilize resources over the various stages of business development. Information sharing of this type is premised upon mutual trust that is earned through long-term interpersonal contact. Reliance upon personalized networks for information sharing, deal making and resource mobilization significantly enhances the phenomenon of tight geographic clustering. Proximity to investments helps reduce uncertainty and minimize risk by facilitating close investment screening, ongoing monitoring, and direct involvement in the management of business investments. Indigenous venture capitalists who are embedded in local social structures of innovation have the tacit knowledge, can access crucial on-the-spot information, tap into information and resource networks, and provide the face-to-face contact required to overcome bounded rationality and reduce investment risk. The active and highly participatory nature of venture capital investing makes location near established technology centers imperative.

The modern venture capital industry has evolved into a network structure with one set of centers located around established financial centers where finance is plentiful and another embedded in the new centers of production where investments are located. Key nodes in the network include New York City and Chicago which mobilize huge sums of capital and Boston and Silicon Valley which also amass venture capital but more importantly locate, identify, monitor and assist in developing venture capital investments. This network structure enables venture capitalists in the financial nodes to export their capital effectively an it also allows venture capitalists in technology regions to finance a broader range of investments and than they otherwise could.

Understanding these regional dimensions of venture capital allows us to move beyond theories of neoclassical financial economics which explain simply assert the mobility of investment as the product of abstract free-market forces. Focusing instead on relationships that occur in real networks - such as the relationships between hands-on venture capitalists in Silicon Valley and the Route 128 area and passive financiers in financial centers - allows us to understand that mobility of venture capital works institutional networks which are strongly rooted in specific places.

PART V:

TENSIONS AND CHALLENGES

CHAPTER 10

TENSIONS AND CHALLENGES

> "I've been in business for about 17 years and there's been too much money for 17 years. My opinion has always been [that there has been] too much money." Donald Valentine.[401]

Venture capital is generally seen to be an enormous strength of the American economy. In so much of the popular imagination, it is what has propelled America to the top of the pack in so many high technology. During the late 1980s, however, a growing number of commentators and experts began to identify several negative aspects of the U.S. system of venture capital-financed high technology. In a series of books and articles, Robert Reich and Charles Ferguson raised important questions about the possible downsides of a venture capital financed high-technology, arguing that venture capital may weaken U.S. technological capabilities by contributing to the over-funding of companies and to a more general pattern which they referred to as **chronic entrepreneurship**.[402] In our own 1990 book, *The Breakthrough Illusion*, we pointed out that venture capital financing plays a role in the **breakthrough bias** of U.S. high technology, drawing resources and talent toward radical new product innovation and away from incremental improvement innovations in products and manufacturing processes.[403]

Concerns were also raised during the late 1980s and early 1990s that foreign venture capitalists were gaining greater access to U.S. high-technology and that more and more U.S. high-technology start-ups were being controlled or acquired by foreign companies. A number of politicians and analysts complained that the U.S. was essentially giving away precious technological and commercial assets.

And, by the early 1990s, with the coming of the Clinton administration, number of key government officials began to argue that there had been a change in the nature of venture capital investing. In their view, the tremendous growth in the venture capital pool and the rise of the huge mega-funds had led venture capitalists to focus on larger, later-stage investments in existing companies. This created a huge gap in what was previously venture capital's most important function - to channel of seed capital for truly innovative entrepreneurial enterprises changed the nature of venture capital investing. The solution they advocated was for government to play a larger role in directly providing this seed capital.

What tensions does venture capital pose for the development of high-technology industries? What challenges does it entail for the broader process of American economic development? Should government be more involved in the provision of venture capital or less so? This chapter turns our attention to these questions. We begin by exploring some of the limits of venture capital investing, examining to what degree and in what ways the contemporary venture capital system may pose negative implications (as well as positive implications) for technological innovation and industrial development in the United States. After outlining a number of key dimensions of these venture capital limits, we provide a case study to illustrate some of these issues, focussing on problems encountered by Westinghouse and a series of venture capital backed spin-off companies in attempts to commercialize flat panel displays. We then turn our attention to the issue of foreign participation in venture capital. It is our view that foreign participation is not a significant problem of the U.S. venture capital system. The last section of this chapter takes up the question of government intervention in venture capital markets. Our review of the evidence suggests that government intervention is unnecessary, because the venture capital market has already corrected the problems government intervention was supposed to address. In fact, we suggest that given the logic and speed of the modern venture capital system, government intervention is not only unnecessary, it is likely to generate perverse results and be counter-productive.

LOGIC AND LIMITS OF VENTURE CAPITAL

To understand the limits of venture capital investing, it is important to understand the logic and objective of venture capital investment. With very few exceptions the overriding objective of venture capitalists is to make money, not to generate regional development, bolster national competitiveness, generate employment, or other more civic minded concerns. And, they will go to great lengths to make sure that their investments achieve extraordinary returns. As Donald Valentine explained it:

> "I don't think entrepreneurs start companies because they want to impact the economy. Very, very few of them have any vision at all of that kind of thing. And none of the venture people that I know over the last 20 years have those kinds of interests either. We can wax eloquently 15 or 20 years later as we rewrite history about what our motivations were. But that's a bunch of bullshit. People start companies when they really have an

idea and passion about their idea. And they do it during recessions, they do it during good times. The interest rate could be 2% or 21 percent. The entrepreneurs of the world don't detect those kinds of economic symptoms, and wait and choose. They are very dedicated, passionate people who are a: economic basically, the vast majority of them. We finance very, very specialized people, most of whom are technicians and not general business people. They have very little sensitivity about these kinds of things. It's only in recent times that, because some of the venture guys have gotten as much press as we have that we've become pundits and economic forecasters and interpreters and all that."[404]

However, some of these practices venture capitalists use to build their investments and generate returns may be problematic for the long run development of high-technology firms and industries. During the late 1980s, a number of experts and venture capitalists began to identify some of the limits of venture capital financed high-technology in the United States. In a 1985 book on the venture capital industry, John Wilson pointed to the debilitating role of so-called **vulture capitalists** who orchestrate raids of R&D scientists and other personnel from established companies.[405] The loss of key people can damage smaller companies and disrupt of on-going research and development efforts. A number of leading venture capitalists concur with aspects of this assessment. Arthur Rock, one of this country's preeminent venture capitalist and a vehement critic of vulture capitalism, summed it up this way.

"There is a great deal of pressure on venture capital funds to show results and make money, so they keep on risking companies....They force companies to show profit too quickly and force them to go out and hire the wrong people. The amount of time an engineer spends at a new company is less than the time it takes to develop a new product."[406]

As we have seen, venture capitalists have tremendous pressure to liquidate their investments. In order to ensure adequate returns to limited partners and establish the kind of track record needed to launch future funds, they must build up companies and sell them off in a short period of time, say five to seven years. Venture capital financed companies are typically being positioned for an initial stock offering or merger at a point where most companies have barely got their feet off the ground. Many companies cannot generate the kinds of growth necessary to become self-sufficient in this short time frame. Fledgling companies which are based upon a single product can fall flat when that product becomes obsolete. These companies may lack the internal capital base needed to develop a second generation product or a wholly new product line.

Given the significant opportunity costs associated with monitoring and assisting investments, venture capitalists tend to ignore companies which are not perceived as potentially large successes. Unfortunately, only about one in ten venture investments are successes, though the returns they generate are more than enough to cover the out-and-out failures and stagnating companies which comprise the living dead. The implications of this are rather basic. Venture capitalists will be extremely quick to identify winners and losers and divvy up their work effort accordingly. There is tremendous pressure to pull the plug on weak starters. Often a self-fulfilling prophecy is the result: companies which do not perform up to some threshold level are quickly scuttled, while others are built up. This may unnecessarily sacrifice some companies that have the seeds of important innovations or at least the potential for steady growth.

Many venture capitalists we interviewed were extremely concerned with what they saw as an increase in **me-too** investing. Part of the cause was the rapid increase in the total pool of venture capital during the 1980s which created an over-abundance of money around to finance multiple start-ups. According to Valentine, such lemming-like behavior on the part of venture capitalists is a constitutes a significant collective action problem.

> The sopping up of resources by multiple start-ups is detracting from ... competitiveness. It used to be that the only competition we ever faced was from larger, well established companies that didn't recognize a market niche or opportunity. It took most of us to finance one company, two at most. Now...each group feels it has to have one of every kind of investment."[407]2

In a highly influential 1985 article which traced the role of venture capital in the computer disk drive industry, two Harvard Business School professors, found that the huge increase in venture capital in the early 1980s helped to set in motion a process of "capital market myopia" leading to business failures and a devastating shake-out in that industry. A similar patter occurred in the personal computer industry where virtually hundreds of new were launched in the late 1970s and early 1980s.[408] This led to intense competition and a devastating shake-out which caused many companies to go under including relatively large ones like Osborne. While such investing may appear rational from the point of view of each investor, it can and does lead to serious misallocations of resources. Donald Valentine provided a view into how this process works in another sector of the computer industry in our interview with him which is worth quoting at length.

> "There's a product called a mini-super computer. ... We started one of these companies five years ago. There are either 10 or 12 of them. Each one of them takes approximately $30 million to get up to where you have a company. Big product. Big computer with lots of software. Big development job. So it should make the math simple and multiply 10 X 30, which is $300 million, invested. Now all of the people in these companies will argue that each one of them is different, but except for a minute my opinion that common denominator is so similar that the product differentiation our marketing hype of features that are not that different. In the normal evolution of whatever kind of industry you want to look at, the world only needs 2 or 3 of these companies. Let's assume for a minute the answer is 3. You subtract $90 million from $300 million and we've just blown up $200 million dollars. Not tragic on a scale of the amount of money the government can lose in a minute, but to me $200 million counts as real money.
>
> But what's worse to me, there may be 100 people that are really good at this stuff. We have now divided that community by 10, and when we should have divided it by 3. So we're cutting our own throat vis-a-vis the most significant industrial competitor, Japan. The Japanese government does not allow 10 companies to be in the same business and dissipate their human resources this way. Our free enterprise system allows it, encourages it. And, our financial reward system facilitates it. I participated in creating it.
>
> My estimate is that the venture community as I know us, is maybe capable of investing $400 million. And it has $4 billion. Why do we have 10 companies instead of 3? We have $3.6 billion dollars too much, annually. And we keep doing this thing of

> making the same company, mistakes that are surely ruining our companies. Those human resources really are deployed incorrectly, if you think about national best interest. I can take that position because we financed the first company."[5]

Valentine is not alone in his belief that there is too much venture capitalists. Some experts and venture capitalists believe that the enormous increase in venture capital funds during the 1980s had a series of negative impacts on the venture capital industry. Among the most significant was the fact that the increased availability of capital brought a many new and inexperienced venture capitalists into the business. The large volume of funds also increased competition for good investments. In 1988, Arthur Rock offered this critique.

> "Business is gradually changing because of the amount of money that venture capital funds have raised for the last 7 or 8 years. With the megafunds they have to get that money invested, and as a result I think the venture capitalists are becoming more portfolio managers than actually venture capitalists. . . There are all these funds, all these monies available in all these funds, it's just literally impossible to spend much time with the companies. . . . If you have 3 or 4 partners you don’t have much time to spend with each company. . . The venture capital companies need to show some results to keep on raising their money, so they keep on pushing the companies."[409]

[5] Personal interview with Donlad Valentine, March 29, 1988, by authors.

Vinod Khosla, the venture capitalist with Kleiner Perkins, offered this perspective.

> "1982-83 was a boom time for venture capital. It became very much of a fad to be in venture capital, so lots of chumps sprung up, and more importantly, a lot of money went into venture capital. The new money pouring into venture capital started a bad trend, because there weren't four times as many good deals. So the money started going into marginal deals - into bidding up the price of good deals. And I think both those resulted in relatively poor investments in the 1983-1986 time frame for the industry as a whole. Four years after those commitments were made - five years later - it started to become clear that funds weren't going to do quite as well as people had hoped. In fact, the median funds were starting to look negative in rates of return as opposed to positive or great."[410]

In our view, this venture capital glut caused five problematic trends to emerge. First, investments of less than top quality, which would have not been funded in other circumstances, received venture money. This violated the cream-skimming principle that is essential to good venture capital investment: only a very low percentage of the alternatives under consideration should be funded in a typical year. The fact that there was too much money chasing too few good ideas led to poor investments.

Second, fund managers were forced to look for bigger deals, and therefore to move away from startup companies. Investing in startups is a hands on business that imposes heavy burdens of oversight and assistance upon the management of venture capital firms. As the amounts of capital under management by the funds grew well beyond previous standards, fund managers realized that they would not be able to use these resources to finance small startup units. The size of individual investments had to be increased to reduce the burden of oversight of portfolio companies. Funds turned their attention to latter-stage deals, such as mezzanine financing and LBOs, which consume more capital and less time. In addition, both the increase in the size of funds and the ability of venture capitalists to pyramid funds on top of one another caused a shift in the nature of the revenues stream for venture capital from return on investment to escalating management fees. According to Paul Wythes,

> "We think you can have too much money in this business. ... If you have four or five funds running in parallel each with a management fee that runs parallel, all of a sudden a lot of ordinary income is coming in as fees. You can spend it on fancy offices and fancy cars and huge salaries, which is tempting."[411]

Third, attractive investments became more costly for venture capitalists. Greater amounts of funds to invest and new investors competing for the same opportunities meant that venture capitalists were forced to either accept lower equity stakes in return for their investments, or invest higher amounts of funding to secure their typical 51 percent shares.

Fourth, the capital glut exacerbated a problem that plagued the established high-technology companies for years - defections of key people to start new firms. Despite the merits of entrepreneurship, these defections may prove to be detrimental for the economy as a whole. An entrepreneur's former company may be forced to abandon promising projects and find it difficult to pursue previous breakthroughs. On the other hand, startup companies, with their limited capital base, lack of distribution and marketing networks, and less experienced management teams, often are unable to sustain any initial success they achieve. In short, although venture capital may result in the commercialization of an idea or product that would have not be developed otherwise, it can also pull ideas out of strong, established, well financed companies and put them in the hands of entrepreneurs who are not capable of fully exploiting them.

Fifth, the influx of new capital brought a sizeable number of inexperienced venture capitalists into the business. Indeed, just one-quarter of all funds have one partner with more than ten years experience.[412] Many of these new venture capitalists lacked the savvy, or the contact base, or the judgement to identify good deals. A herd mentality developed as venture capitalists copied each other's investments. This follow-the-leader syndrome meant that more startup companies were being funded than could hope to survive.

As we argued in *The Breakthrough Illusion,* venture capital investing tends to reinforce the **breakthrough bias** that has come to characterize the American system of high-technology innovation. Because of the nature of venture capitalism - the way it is financed and the mathematics of success - venture investing is especially well-suited to breakthrough innovations: radical new product innovations those which come from research, can be quickly achieved by small companies, and which hold out the potential for extraordinary returns. The lucrative financial rewards these offer exert a powerful pull on top researchers and technologists taking them away from work on process improvements and systems innovations and focusing their activity on breakthroughs. Vinod Khosla provided a useful perspective on the strengths and limits of the breakthrough bias of venture capital financed high technology.

"Start-ups are good at high-leverage items. They're not as good at mass deployment.

Would a start-up be good in designing some parts of these systems that have high leverage, which may be too long a cycle or too compromised to get done inside a large company? Yes. Could a start-up add creative areas of technology or content types? Could a start-up show the way in how you do interactive storyteller? Yes. Will a start-up be the best guide to compete against Nintendo in manufacturing 20 million units to go into homes? No. Would a start-up be great at setting up a communications infrastructure like a cellular network? No. You didn't see a lot of venture investments in the cellular business."[413]

A Case Study of Venture Capital Limits: Flat Panel Displays[6]

Flat panel displays provide a useful case study the limits of venture capital-financed innovation. U.S. corporations which invented and incubated this technology have over the past two or three decades squandered a seemingly insurmountable lead to top foreign mainly Japanese competitors. Our case study explores this issue by providing a detailed analysis of the gestation and development of active matrix technology (which use advanced microelectronics technology to produce flat-panel, high-definition displays) at Westinghouse, and two spinoff companies, Panelvision and Magnascreen.[414] What we find is the somewhat typical pattern of a large company which is able to incubate a revolutionary technology but is unable to develop the high-volume production capability required to make it a commercial success. But, this is not a

[6] This case study is based upon personal interviews conducted by David Browdy and Richard Florida, and is revised and edited version of Richard Florida and David Browdy, "The Invention That Got Away," *Technology Review,* September-October 1991, pp. 42-55.

case where entrepreneurs and venture capitalists were able to jump in and save the day. In fact, the venture capital backed start-ups were similarly unable to develop the industry.

During the 1960s, Westinghouse had a small R&D group working on active matrix displays based on thin-film transistors for what Westinghouse executives came to call "the screen on the wall." Westinghouse was not alone in those early days. A number of competitors - RCA, GE, Hughes, Raytheon, and Zenith along with the computer makers, Burroughs and IBM - were active in the field. RCA at one time had large scale efforts in both thin film technology and flat panel displays. The University of illinois demonstrated a gas plasma display, and later licensed this technology to Owens Illinois. Burroughs actually commercialized a small plasma display in the late 1960s.

In the late 1960s and early 1970s, scientists at Westinghouse put in place a large scale effort to use thin-film transistors to create active matrix displays. Westinghouse's R&D team was headed by T. Peter Brody. Born in Hungary and educated in England, he became an R&D department manager at Westinghouse in Pittsburgh in the mid 1960s. Brody put together an active R&D group and wrote some important technical papers on this subject.

Brody was able to generate support for his work both inside and outside of Westinghouse. As one Westinghouse executive put it: "Peter was very skilled at bouncing around the company and getting support."[415] One of the applications the group seized upon early on was active matrix displays for televisions and other uses. Outside of Westinghouse, the group received three contracts from the military: one each from the U.S. Army Electronics Command and Wright-Paterson Airforce Base to develop small flat panel displays for military applications such as cockpit displays, and another from the Office of Naval Research to develop a floating gate memory TFT device. Westinghouse's large Consumer Electronics Division, and later its Electron Tube Division, became the main supporters of Brody's work. These units provided support to Brody's group. The Consumer Electronics Division saw flat panel displays as a way for Westinghouse to gain ground on RCA and others in the television business where Westinghouse was losing market share. William Coates, an executive in the Consumer Electronics Unit, saw the "screen on the wall" as a way to do this and made flat panel displays one of the divisions two main strategic thrusts. Coates in effect became Brody's champion.

> "We were very much enthused about Peter's work. We saw it as a fantastic breakthrough in developing the tube on the wall. We paid for the research. We put in millions and millions. We never did keep track of all the money we put into development, but it was a huge amount."[416]

But, by the mid 1970s, these efforts had reached a crossroads. A major blow came in the early 1970s (roughly 1971) when Westinghouse decided to stop making television sets and liquidate its television set business. For Westinghouse, the choice was obvious: Either the flat panel display effort would be supported by developing manufacturing capability or be dropped. A Westinghouse committee was commissioned to review this work and in 1979 the decision was made to kill the project. As a Westinghouse executive who served on the committee put it: "The basic issue was should the corporation invest in a pilot manufacturing facility for Peter Brody's active matrix display technology. He and his group had made a proposal....The result was that we turned thumbs down on this thing and said Westinghouse should get out of it."[417]

In 1979, Brody left Westinghouse and moved to start a company to develop active matrix display technology. Over a two-year period, he made presentations to more than 40 venture capitalists and electronics corporations. One of the first firms Brody approached after splitting with Westinghouse was 3M, mainly because of its reputation for internal entrepreneurship and its record for getting out innovative new products. The technology was well-received by 3M scientists, and six operating divisions expressed interest in it. But the project soon fell prey to the bureaucratic maze of the large corporation. The proposal passed from division to division. Each agreed that it was promising, but none would commit to sponsoring the project. After more than nine months, 3M reported that it was not interested.

Brody then got the attention of a Wall Street venture capitalist, the Anderson of the venture capital fund of Welch, Carson, Anderson and Stowe. As is so often the case with successful venture capital investments, Brody did not go in cold but was recommended by Carl Machover, a well known consultant to the computer graphics industry. Anderson, the venture capitalist, suggested that one of his major limited partners might be willing to fund the outfit. That limited partner, it turns out, was 3M. Even after being told about the previous turndown, the venture capitalist still decided to proceed.

In the brief interim since it had rejected Brody's earlier proposal, 3M had restructured. A new vice president headed technology development, and the proposal the venture capitalist brought became his first opportunity to launch a visible new product. It helped greatly that the project had been so well received by 3M researchers. 3M was, and is, a major producer of overhead projectors and wanted to use active matrix technology to make LCD overhead projector pads. The board of directors took only three weeks to approve the investment.

Six months later, in November, 1980, the start-up, called Panelvision, was launched in a

Pittsburgh suburb with $1.5 million in venture financing. The venture funds were sufficient to begin work at the prototype level. Panelvision bought equipment from Westinghouse's old thin-film transistor labs, and by the summer of 1981, rented a building and began work to develop a production process.

Panelvision quickly ran into production problems. The group began working with a sophisticated machine developed jointly by them and Westinghouse to produce thin-film circuits in a completely automated fashion.[418] But, it became apparent that the equipment could not produce what Panelvision needed, and that a radical process change was required. This forced the company back into an R&D mode and delayed the project by two years - which might as well have been a lifetime in the venture capital process. For this, a new round of financing was required and it brought in an additional $4 million in preparation for pre-production. With this capital infusion, the venture capitalist pushed to enlarge the management ranks of the firm, arguing that good management was more important than the technology.

In January 1982, three additional managers were hired in expectation of an expanded pre-production process. One of these managers was Tom Maloney who was brought in as vice president of marketing from Burroughs where he had been in charge of an engineering group which had successfully commercialized an early gas plasma display. Although the board knew at the outset that difficulty scaling up the process to production levels was a risk of the project, the investors had no previous experience with such a pioneering technology before. They were frustrated at the prospect of a $4 million investment with no payoff in sight. One of the three new managers, the vice president of operations, attempted to turn the setback to his advantage by convincing the board to turn leadership of the company over to him. He was able to enlist the controller in his attempted palace revolution.

The board responded by firing the insurgents and demoting Brody. One reason is that for all his technical brilliance, Brody was not a skilled manager. Brody, they concluded, was not the person to safeguard their investment. In this crisis situation, the board promoted another of the new hires, Tom Maloney, the marketing vice president, to chief operating officer in an effort to stabilize the company. Maloney was close to Brody and was able to work well with him, even in such stressful circumstances.

With Maloney at the helm, Panelvision was reasonably successful. The company successfully completed two more venture financing rounds, raising an additional $7 million. Overall the company raised roughly $13.1 million in six or seven rounds of venture financing between 1979 and 1984 from heavy weight venture capitalists such as Welch, Carson, Anderson and Stowe, Drexel Burnham, First Chicago's venture arm, and several Boston area venture capitalists. Panelvision became the first company to bring active matrix display screens to market. By 1984, the firm had begun selling experimental products and lab prototypes. They now had 80 customers in 12 industry segments.

But it was impossible to break even, much less turn a profit, selling what in effect were laboratory prototypes. What was needed was to develop a real manufacturing process and high-volume production capability. And this meant that more capital was required. After squabbles between the board and management over how to do this, a new president, Tim DeSilva, Panelvision's third in three years, was hired from outside. A new business plan was prepared to raise $5 million and move into actual production.

By this time the Japanese had entered the picture. Seiko introduced a color pocket television in the U.S., infringing on the original Westinghouse patents for active matrix displays (to which Panelvision held exclusive rights). While the U.S. International Trade Commission encouraged the firm to bring suit, the fledgling company did not have the resources and was too distracted by crucial internal issues. Japanese entry sounded the death knell for Panelvision. If investors were hesitant about investing to ramp up manufacturing before, they now thought it utterly foolish to try to compete with the Japanese on their strong suit of manufacturing production. (This was not only true of Panelvision's venture capitalists, but of the venture capital community as a whole.) The board of directors decided to recoup their investment by putting the firm up for sale. A team from 3M came in to evaluate the firm for a takeover, and despite their recommendation to acquire the company, top management declined. After negotiations with a series of firms, Panelvision was sold to Litton Industries in 1985 which wanted to use its technology to develop advanced cockpit displays.

While Brody left the company, Maloney stayed on for a time serving as director of marketing on an inside consultant basis for Litton-Panelvision. A number of other original Panelvision employees went on to work for the new company which continued to operate out of Panelvision's original Pittsburgh facility. Litton-Panelvision began to produce display products for its own defense avionics systems but never ventured into the commercial markets. Litton made some small improvements, but it was not in the business of advancing the technology. In April 1989, Litton moved Litton-Panelvision to its main corporate facility in Toronto, where it continued to operate as an in-house source of cockpit displays.

After a brief hiatus following the sale to Litton, Brody formed a consulting firm, Active Matrix Associates, and then by late 1985 tried to get backing for a new start-up firm. The idea was to pick up where Panelvision left off, especially since Litton was focussing exclusively on cockpit displays. He drew up a new business plan, but U.S. investors and venture capitalists were not interested. They cited Panelvision's track record as a problem, and were concerned about competing against large, well-financed Japanese corporations.

A number of major U.S. computer makers were excited by the possibilities offered by flat panel displays. Apple, IBM, DEC, and Compaq, each indicated that they would purchase large quantities once available, but balked at becoming involved in the extremely expensive undertaking of building the kind of factory required to produce large volumes of flat panel displays. The most receptive company was Apple, which was planning its Macintosh portable. Highly enthused about active matrix displays, Apple indicated that it was very interested in establishing a supplier relationship. Apple told Brody to bring back a proposal for a factory capable of producing 50,000 units per month. When he did, the company balked at the price tag which they felt was too high. Apple ultimately decided to go with a Japanese supplier of screens for its Macintosh portable.

Brody decided to re-think his strategy. Realizing that no U.S. industrial corporation or venture capitalist would back a firm in a market targeted by the Japanese, he targeted a new area -- large area, active matrix displays. The Japanese had been concentrating on small displays (10-14 inches across), to be used in laptop computers. Brody decided to move into 20- to 40-inch displays for use in military systems and corporate teleconferencing. From his perspective, such large screen flat panel displays were the key to the next truly big horizon, high definition television. The idea was to use tiles or modules to make seamless large screens.

In 1987, a Boston investment group, whose technical advisory board was chaired by Dr.

Jerome Wiesner, was approached with the new business plan. Wiesner, the highly respected former science advisor to presidents Kennedy and Johnson and past president of MIT, was already familiar with the technology. In the 1970s, one of the junior faculty at MIT was working on a project for the Navy and ran across some of the work on active matrix displays done by Brody's Westinghouse group under its Navy contract. He reported back to Wiesner that he had "seen the future" in these active matrix devices.

Wiesner was excited by the project. He touted its promise and importance, insisted on the investment group's participation in the project, and stated his willingness to commit personal funds. Despite Wiesner's strong support, the venture capitalists were not interested. Wiesner, however, made good on his promise, and with a close friend, Richard Leghorn (a Boston-area entrepreneur, founder of Itek and cable television entrepreneur), committed $125,000 each of their own money. The new company attracted significant funding from important individual investors who are close to Weisner and Leghorn, including a former chairman of Xerox, John Sculley of Apple, and from VenWest, the venture capital arm of Westinghouse. All told the company raised $2.3 million in start-up capital.

The new company, called Magnascreen, began operating in 1988. It bought the old Panelvision facility in Pittsburgh from Litton, and began work with a number of subcontractors. In November 1988, Brody rehired his old collaborator, Tom Maloney, as a consultant, and in April 1989, Maloney came on full-time. Magnascreen pursued funding from the Defense Advanced Research Projects Agency (DARPA) to develop a 45-inch diagonal color display. DARPA awarded a two-phase, $7.8 million contract to Magnascreen of which it has funded $2 million.

In 1990, Brody once again found himself at odds with his board and investors. But now the reason was different. The Magnascreen board, or more appropriately a majority of the members, wanted a hands-on CEO who would focus all of his time and attention inside the company. Brody then resigned, and Leghorn, the major investor in the company, became CEO. Maloney once again assumed responsibility for the day to day operations of the company, since Leghorn commuted from the Boston area.

The experience of Magnascreen, Panelvision and Westinghouse was not unique by any means. In fact, it mirrored the more general evolution of the flat panel display industry in the U.S. Like Westinghouse, the largest and most powerful American industrial corporations in the field - RCA, GE, Burroughs, IBM, Raytheon, Zenith, Hughes, Burroughs, Texas Instruments, NCR, AT&T, and even Exxon - had originally incubated and later abandoned this crucial technology. As with Panelvision and Magnascreen, the remnants of these efforts gave rise to a host of new start-up companies: Plasma Graphic, a spinoff from Burroughs; Electro-Plasma from Owens Illinois, and a raft of small start-ups: Cherry, Coloray, Crystal Vision, Ovonic Imaging Systems, Photonics, Planar, Plasmaco, and Sigmatron Nova **[see Table 10.1]**. Some survived, but the bulk failed: None were able to develop high volume production capability. As of early 1996, there were still no significant active matrix LCD production facilities in the U.S. Virtually all of this production capacity was in Japan. A number of Japanese corporations - Hitachi, Matsushita, Seiko Epson, and Sharp - made $100 million plus investments in active matrix LCD factories in Japan. And, IBM formed a joint venture with Toshiba, Display Technologies Inc., to produce color active matrix displays in Japan.

[Table 10.1 about here]

The case of flat panel displays sheds light on some of the important tensions and limits of the U.S. model of venture capital-financed high technology. One is that we should not expect entrepreneurship and venture capital to drive us forward in all areas of high technology. Venture capital backed entrepreneurship is good at some things, but it is ill-equipped at others. In the case of active matrix display technology, venture capitalists proved less, not more, effective than big corporations. Venture capitalists are interested in turning technologies which are close to commercialization into commercial home-runs. Their horizon is the short term - three to five years - not the long haul. If the market for a technology does not open quickly, venture capitalists will abandon it. If it requires huge capital investments to develop manufacturing capabilities, they generally won't touch it. Venture capital is not the mechanism for providing the massive amounts of investment and process development to build state-of-the-art manufacturing capabilities. According to the now venture capitalist, Coates, the task of developing large screen flat panel technology was simply too big for venture capital. "There aren't many venture capitalists who can shovel in money like that. With venture capital you usually have a product and it's a matter of refining or tweaking it, or getting money for production of sales, you can't do the long-term research and development work that you can in a large corporation."[419] The case of flat panel displays illustrates the limits of venture capital-financed innovation in developing and nurturing these sorts of industries.

It is important to point out that the tensions and challenges outlined here are mainly associated with the rise of the large pool of institutionalized venture capital during the late 20th century, and are not fundamentally related the nature and function of venture investing. While venture investing has tended to be oriented to radical product innovation throughout its evolution, earlier periods did not experience similar problems associated with he capital glut of the 1980s and 1990s or the payoff periods associated with the modern venture capital limited partnerships. Furthermore, in previous epochs of industrialization, there appear to have been mechanisms in place which allowed for the development of major process and organizational innovations which enabled and powered long-run industrial development. Similar mechanisms may be in place today, however, it may be too early in many instances to observe the outcomes of those mechanisms.

FOREIGN INVESTMENT IN VENTURE CAPITAL

The late 1980s also saw increased concern over rising foreign participation in venture capital. A number of commentators both inside and outside of government argued that foreign venture capitalists and corporations, particularly those from Japan, were seeking to buy-up American start-up companies and gain access to important technologies.

But these arguments have proven to be more hype than the reality, as a look at the available data suggest. Despite warnings about the threat posed by foreign investment in high-technology firms, the available data show that foreign investment peaked by the end of the 1980s and fell precipitously during the 1990s. The participation of foreign investors in U.S. venture capital peaked in 1984 at $573 million, roughly 18 percent of all new capital committed to the venture capital industry in that year **[see Figure 10.1]**. Foreign investment in venture capital then fell off substantially, declining to less than $100 million or just 2.5 percent of all new capital in 1994. The number of foreign acquisitions of U.S.venture-backed companies fell from a high of 33 in 1989 to just eight in 1991, considerably lower than at any point since 1987.[420] **[see Table 10.2]**.

[Figure 10.1 and Table 10.2 about here]

Japanese investment in U.S. venture capital and high-technology emerged as a particularly sensitive issue in this debate. Japanese investment in U.S. high technology became quite visible in the 1980s and was interpreted as dangerous by some commentators. According to this view, the Japanese strategy was to buy what they have not been able to produce by themselves, and in doing so, to take possession of the last competitive stronghold of the U.S. Part of this was simply related to the tenor of the times, and the feeling that certain key segments of U.S. industry had fallen badly behind their Japanese competitors. Now, it appears those fears were greatly exaggerated.

Japanese investment in venture capital in the U.S. did in fact grow during the second half of the 1980s. As Table 10.2 shows, Japanese investments in U.S. venture funds grew from $18 million in 1983 to $54 million in 1989. But, according to Venture Economics, Japanese investment in U.S. venture capital partnerships was reduced to virtually zero by 1991.[421] Even at its high point, Japanese venture capital investment was a small proportion of the total sources of venture capital in the U.S. The Japanese contribution of $52 million in venture capital commitments represented just 2.25 percent of the $2.4 billion in new venture capital raised in 1989. Over this period, direct equity investments by Japanese firms in U.S. companies grew from $7 million in 1983 to $320 million in 1989.[422] But, even when the $320 million of direct investments are added to this figure, Japanese participation remained a fraction of U.S. investment in venture capital activities.

[Figure 10.2 about here]

Furthermore, by the early 1990s, it became clear that in many cases - if not most - that many Japanese companies were losing badly on their venture investments. Kubota Corp, the heavy industrial equipment producer, lost its $130 million investment in Stardent Computer when this firm closed.[423] Mitsui & Co. lost close to $30 million in its investment in Gain Electronics Corp., a maker of gallium arsenide chips, and retired from the venture in 1988. Kobe Steel gave up its investment in PraireTek, a maker of disk drives for laptop computers, after having committed $19 million. Japanese companies virtually abandoned venture capital in the early 1990s.

Foreign Funding of Entrepreneurial Startups: A Case Study

One of the most important - and least understood - dimensions of foreign involvement in venture capital is that it can bring substantial benefits in addition to capital. Partnerships between U.S. start-ups and foreign companies can bring much needed manufacturing support and distribution into major Asian markets. In addition, it is often the case that foreign investors provide a source of long-term patient capital, when U.S. venture capitalists na corporations refuse to invest. In fact, our interviews with high-technology firms lead us to the conclusion that U.S. firms turn to foreign sources as investors of last resort - turned to only after these firms have been unable to raise funds from U.S. sources.

The following example from our field work can help shed light on these issues. It involves a partnership between a highly-innovative U.S. start-up and a large Japanese industrial corporation.[424] It illustrates some of the reasons why foreign investment may be beneficia and why start-up firms may at time seek our foreign investors. The startup is a producer of high density static RAMs, serving the workstation and high-end personal computer markets. Located in the Silicon Valley, it was founded in 1987 by two entrepreneurs, and became a world leader in this market. The original capital came from two U.S. venture capital funds, and the number of U.S. investors grew to five during the following years. By 1990, the company had gone through three rounds of financing from U.S. venture capitalists. After the second round of financing, the company had built its first fabrication facility, a low-volume factory with a cost that was close to $50 million. Its main products of the firm were high-speed, high-density static RAMs produced for three distinct markets, military organizations the workstation market, and the high end personal computer market. The size of this market grew as high capability standards reached lower ends of the computer market.

In 1990, the company and the original partners sought the involvement of a new investor, one capable of acting as a strategic partner. By this point, it was clear that a strategic partner was needed to attain the firm's long term goals, which not only meant more capital, but other types of support such as expanding manufacturing and securing distribution channels overseas. The search for a strategic partner encompassed the U.S., Europe, and Japan. During this stage the company used the services of a U.S. investment firm - or match maker - which had wide experience in high-technology ventures. The match-maker helped the company clarify its strategic needs and define the profile of the desired partner. The match maker eventually identified a large Japanese company seeking an investment in their field as part of its efforts to diversify into high technology markets. The Japanese company had already initiated a large project related to semiconductor production, including the construction of a factory, and was itself seeking a strategic partner to provide a stable, ongoing technology base for this project. A cooperation agreement was attained and under it the U.S. partner received capital, the support of a huge industrial organization in different areas, and access to high-volume manufacturing capabilities in Asia.

Foreign investment provided five major benefits according to the U.S. principals: (1) capital in the form of a direct investment in the firm's equity, (2) licensing revenue for use of its technology, (3) support for the development of next generation technology, (4) distribution in the large markets of the Pacific Rim, and (5) access to world-class manufacturing capability. Under the agreement, the U.S. facilities were used to produce lower volume products and pilot lines of new products, while the facilities of the Japanese partner in Asia were used to produce high-volume, low-cost products. The Japanese partner maintained a team of technologists to upgrade U.S. manufacturing capabilities.

The principals also emphasized that foreign investment had a number of additional advantages over traditional venture capital financing. While U.S. venture investors usually require a majority stake in startup firms, the Japanese investor preferred to work with the U.S. firm in ways that are somewhat less constraining to the U.S. entrepreneurs. The Japanese investor did not try to act as a manager of the firm, but rather has tried to build up the strengths of the high-technology enterprise as a strategic partner. This provided substantial autonomy for the U.S. managers. As we have seen, entrepreneurs have complained that venture capitalists bring multiple constraints, for example, they demand that the company ramp up quickly so that it can be liquidated via the IPO market. Entrepreneurs may feel that they are pushed in directions in which they do not want to go, or are forced to move too fast, without a chance to work out the production processes or the design bugs, steps that are key to delivering a high-quality product. Through the agreement with the Japanese investor, the company found a supplier of patient capital. Association with a large Japanese investor also provided the firm with an intangible but extremely valuable asset - prestige and credibility. Not only did this help to improve relations with creditors, suppliers and clients who came to see this firm as one that can achieve stability and growth in the long term, but it also acted as a magnet to attract top technical and managerial talent. The prospect of working for a firm that has the financial backing to survive in the long term, the clout to be a major world player, and the capacity to concentrate in the development of new generations of technologies was extremely attractive to highly qualified engineers and managers. In our interviews, a number of employees indicated that the existence of the Japanese partner was a major factor in their decision to join the firm. The fact of the matter is that foreign investment can provide important benefits to U.S. firms.

While politicians and experts were quick to condemn foreign involvement in venture capital during the 1980s, out analysis suggests that most of those fears were either unfounded or misguided. After a brief increase in foreign involvement in venture capital and in acquisitions of U.S. entrepreneurial companies during the early-to-mid 1980s, there was substantial fall off in foreign investment. Foreign capital simply is not a major component of the U.S. venture capital system. As this book has shown, venture capital is most effective when it is mobilized and embedded within leading high-technology regions. While capital from outside places can be combined with local venture capital, it simply (in most cases) cannot substitute for the many important non-financial functions provided by venture capitalists who are embedded within local social structure of innovation. Furthermore, in some instance, foreign capital can actually bring important benefits to entrepreneurial firms. These benefits include not just the provision of a steady stream of patient capital but access to key offshore markets and state-of-the-art production capabilities.

Based upon our analysis of the available data, we are led to conclude that to date foreign capital has played a limited role ad mainly supportive role in the American venture capital system. Furthermore, it is important to point out that foreign capital has been a source of risk finance fo American enterprise for some time. A study of the sources of financing for the railroad industry conducted by the historian Barry Supple during the late 1950s found that New York investors used perosnal ties to European bankers and investors to mobilize funds for railroad development during the 19th century.[425]

GOVERNMENT VENTURE CAPITAL: MYTHS AND REALITIES[7]

The notion that government should intervene to provide venture capital came powerfully to the fore in the United States during the late 1980s and particularly during the early years of the Clinton-Gore administration. As earlier chapters have shown, there was a tendency in the United States to believe that government can help to solve problems in the provision of venture capital.

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[7] This section draws from work conducted in collaboration with Donald F. Smith, Jr., particularly, Richard Florida and Donald F. Smith, Jr., "Keep the Government Out of Venture Capital," *Issues in Science and technology*, Summer 1993, pp. 61-68.

This was most prominent during the years immediately following World War II, but state governments had initiated venture capital programs in attempt to spur regional economic development during the early 1980s. Still, for the most part, federal policy during the 1970s and 1980s had tended to shy away from direct government provision of venture capital and instead to use a variety of mechanisms including tax policy and pension policy to create a stronger market for private mobilization and provision of venture capital. This, it took many observers by surprise when the notion of a federal fund to provide venture capital to early-stage startup companies emerged in the House of Representatives during the early days of the Clinton Administration under the auspices of a major piece of technology policy - the National Competitiveness Act of 1993.

The argument for greater government involvement in venture capital turned on the notion that private venture investors were under-investing in new startup companies and that government intervention was required to fill this gap. According to this view, venture capitalists were placing an increasing share of their time and resources into so-called later stage activities, such as follow-on investing and leveraged buyouts (LBOs). Therefore, an insufficient amount of venture capital was going to seed and startup activity, creating a growing capital gap in the funding of new startup companies. Government venture capital was seen as required to generate entrepreneurial business formations, increase the pace of innovation and, in doing so, stimulate economic growth.

The belief that the U.S. economy was underinvesting in startup companies and other forms of high technology as simply wrong. In 1992, the total pool of venture capital in the U.S. ($35 billion plus) was more than 10 times greater than that of Japan or Germany, the world's second and third largest economies. Indeed, the cumulative amount0 of venture capital in Japan ($2.2 billion) or Germany ($2 billion) is roughly equal to what the U.S. raises in any given year.[426]

A big part of the case for government involvement in venture capital turned on the simple fact that venture capital investment, particularly investment in new startup companies, declined during the early 1990s. Although this did happen, it was - and is - a mistake to read this as sufficient reason for government intervention. As Chapter 1 has shown, venture capital investments increased sharply during the mid eighties, then fell just as dramatically, before rebounding substantially by the mid-1990s. However, even during the so-called lean years of 1990 and 1991, venture capitalists invested about $3 billion in more than 2,000 entrepreneurial companies. This was two to five times the amount of venture capital invested during the late 1970s, when some of the most innovative and successful high-technology startups in history including DEC, Intel, Apple, Microsoft, and Genentech were formed. Moreover, U.S. venture capital investments rose to more than $2.2 billion, as the country pulled out of recession.

Proponents of government involvement also argued that private venture capitalists were abandoning investments in new businesses in favor of proven companies or LBOs. In testimony before the House Subcommittee on Technology Environment and Aviation in early 1993, W. Andrew Grubbs, of Venture First Associates, a fund that specializes in startup investments stated that: "The amount of money from this pool that we call 'venture capital' that actually goes into starting new high-tech companies is less than 2 percent. 2 percent!"[427] The 2 percent figure was frequently repeated by proponents of government venture capital adn came to accepted as a fact on Capitol Hill. But, a look at the evidence indicates that it was incorrect. It is true that the amount of venture capital devoted to seed and startup investment declined from an average of about $500 million per year in the mid-1980s to about $150 million in the early 1990s **[see Figure 10.3]**. However, the portion of funds going to seed and startup investments remained roughly 10 percent of all venture capital investments in both years. The biggest decline, in fact, occurred in LBO and acquisition financing, which fell from about $1 billion in 1988 to just $40 million in 1991. This reflected a refocusing of venture capitalists' efforts toward the creation of new entrepreneurial firms and the development of innovative technologies - the very investments that proponents of a greater government role called for. Venture capital investments in some high-technology fields, like software, actually increased during the early 1990s. In 1991, venture capitalists invested more that $330 million, roughly one-quarter of all investments, in 185 software companies.

[Figure 10.3 about here]

Part of the explanation for the temporary fall-off in venture capital investment can be found in a related decline in the amount of money committed to the venture capital industry. The data on venture capital commitments presented in Chapter 1 clearly showed a decline in new commitments in 1990 and 1991, particularly when compared to the boom years of 1986 and 1987 **[see Figure 1.2]**. However, the average $1.4 billion in new capital commitments in 1990 and 1991 was more than six times greater than the roughly $250 million per year committed to venture capital during the mid-to-late 1970s and considerably more than the $950 million committed in 1980 or the $1.1 billion committed in 1981. And, it was just slightly less than the $1.6 billion committed in 1982. Venture capital commitments exploded after 1982, fueled by changes in the tax code and the economic boom, reaching exceptional highs during the mid- to late-1980s. In fact, these swings in venture capital investments provide considerable evidence of the market's ability to adjust quickly to changing economic conditions. Thus, government intervention to correct the mythical capital gap of the early 1990s was not only unnecessary, it was based upon a misreading of historical trends in the industry.

Government intervention might be justified if venture capital was the only or even the primary source of capital for new business formations. But it is not. Venture capitalists are a relatively minor source of capital for new enterprises. Although comprehensive data on the actual level and breakdown of funding sources for new enterprises is impossible to obtain, a few proxy measures help convey the role played by institutional venture capital in the financing of new enterprises. According to the annual White House report on the *state of small business*, between 600,000 and 700,000 new businesses are incorporated in the United States each year.[428] The Small Business Administration estimated that an average of 10,000 new high-technology companies were formed each year between 1976 and 1986.[429] However, venture capitalists invest in only 1,000 to 1,800 new companies per year, 10 to 20 percent of high-technology companies and less than 1 percent of all business startups. Most of capital for new enterprises comes either from entrepreneurs themselves using personal savings and ongoing earnings to bootstrap their businesses, or from wealthy relatives, friends, and other angel investors.

In addition, it is important to keep in mind that venture capital investment comprises just a small fraction of the nation's overall commitment of resources to innovation. While venture capitalists invest between $1.5 and $4 billion each year, which is spread across a wide range of activities, the nation as a whole spends more than $150 billion per year on research and development, nearly $80 billion of which comes from the private sector.[430] During peak years, venture capital investment, which covers a much wider range of activities than just R&D, represents less than 5 percent of private sector R&D spending, and just 2.5 percent of total R&D spending.

Furthermore, U.S. corporations began to supply more capital directly into startup companies during the early 1990s. From the beginning of 1990 to the middle of 1991, an 18 month period, corporations provided over $1.4 billion in direct equity investments in startup companies, more than 50 percent of the total venture capital investments during the period. The role of direct corporate investment for venture capital can be seen as, on balance, a positive development. Direct corporate investment provides a steady stream of patient capital for startup companies, as well as access to corporate capabilities and facilities in manufacturing, marketing, and distribution. In doing so, it allows startups to avoid the high degrees of corporate control frequently demanded by venture capitalists. Furthermore, alliances between fledgling startups and larger companies make sense for the U.S. economy as a whole, because they offer the means for helping turn new innovations into successful commercial products.

Proponents of a greater government role also said that the venture capital market was an inefficient and a problematic allocator of capital to critical high-technology sectors. The evidence of the 1990s, however, indicates that the venture capital market is extremely efficient at getting capital where it needs to go. The real question that needs to be considered - and the one that should inform the debate over government's role - is not whether the share of venture capital going to startups has moved up or down, but quite simply: What is the efficient level of venture capital in the U.S. economy?

The intervention of government as a supplier of venture capital has been proposed as a way to replenish the pool of resources available for high-technology firms. But this pool may not need to be refilled to its past peak levels. Venture capital was widely available in the mid to late 1980s; indeed, as we have seen, some venture capitalists argued that there was an over-supply. The venture capital industry responded the way financial markets are supposed to: it corrected itself. Profits on venture capital investments went into a virtual free-fall, and investors redeployed their capital. As Figure 10.4 shows, the internal rate of return for venture capital funds, which hovered in the range of 25 to 35 percent for funds formed in the mid-1970s, and 15 to 25 percent for those formed in the early 1980s, plummeted to less than 5 percent for funds established during the mid-to-late 1980s.[431] Investors began pulling their money out of venture capital and investing it elsewhere. The venture capital market fell off sharply in 1990 and 1991. It only recovered in 1992, when it reached a total of $2.3 billion, spurred by record markets for initial public offerings which increased from an average of just 39 between 1988 and 1990 to 116 in 1991, and by the general economic recovery.

[Figure 10.4 about here]

In sum, as we have seen earlier in this chapter, the lesson of the 1980s and early 1990s is that more for the system of venture capital-backed innovation to succeed, a delicate balance must be maintained. Too much venture capital, although it may lead to more startups, may hurt the economy as a whole. Indeed, the market proved that it was quite capable of regulating itself to supply the appropriate levels of venture capital.

Past Government Venture Capital Failures

Federal, state and local governments have made stabs at the direct provision of venture capital with slim to disastrous results. The history of the major federal effort, the Small Business Investment Company (SBIC) program, founded in 1958 and often touted as a model of good government, is littered with mismanagement, failure, and abuse. In the program's heyday during the early 1960's, more than 700 SBICs were established. But, by the late 1960s, they were failing by the hundreds, with just Less than 10 years after 272 still operating in 1972.[432]

Evaluations of the program have been harsh. A 1961 study states that the benefits were so greta and the controls so few that the program had essentially created a "license to steal." Other evaluations found that SBICs generated significantly lower rates of return than private venture capital funds, and that their lending practices were more parochial than their private counterparts. Another examination of the first 25 years of the SBIC program provided an especially pointed descriptio of the pitfalls of direct government intervention in venture capital. The study, by Venture Economics, noted some positive aspects but said that the program

> "attracted a lot of people - many with ideas for using their Uncle Sam's money to leverage real estate deals and very few with any experience in investing in small business. This not surprisingly resulted in abuses and losses that necessitated the imposition of a whole slew of federal regulations that, in the process of warding off the piranhas, also hobbled many of the founders of today's venture capital industry."

Reforms during the late 1980s adn early 1990s, however, eliminated many abuses and boosted the effectiveness of the remaining SBICs.

By the early 1980s, the role and function of the SBICs had been eclipsed by innovations in the private sector, particularly the emergence of the venture capital limited partnership as a mechanism for attracting private funds to the venture capital industry. By the mid-1990s, SBICs made up just 5 percent of the total venture capital pool.

State governments also entered the venture capital business.[433] In fact, during the 1980s, the number of programs exploded as states made major efforts to spur high-technology development. According to a 1991 study by Peter Eisinger, 23 states were running 30 different direct venture capital programs in 1990.[434] Eleven of these state programs used private managers to invest state funds, and 19 were organized as state corporations with authority to select and manage direct investments in advanced technologies, targeted businesses, or products. By 1990, the states had generated a total of $192 million in public venture capital.

States created these venture pools to compensate for what they argued were regional gaps in the availability of venture capital that were contributing to disparities in high technology industry location and employment. This thinking, however, was misguided, largely because it ignored the fact that capital is highly mobile and flows to the technologies and areas that promise the highest rates of return, those with a well-developed social structure of innovation. Not surprisingly, the most successful programs that exist have operated in states such as Massachusetts, where the technological infrastructure to support high technology business development exists. Also, not surprisingly, in state venture capital programs managed by private venture capitalists, much of the locally subsidized venture capital was exported to high-technology enclaves like Silicon Valley and Route 128. And, sates that have tightly restricted investments to local firms have seen much of their money invested in marginal or poor deals.

State venture programs fail to measure up to privately provided capital on every relevant measure of performance. Evaluations indicate that most state programs have lost money or generated rates of return considerably below those of private venture firms. The programs have also failed in terms of more conventional economic development criteria, such as business generation or job creation. Even the most favorable evaluations conclude that the programs have created a very small number of new businesses and generated only a limited number of jobs. One survey by a University of Wisconsin team of 14 state venture capital programs found that some 17,500 jobs were generated at an average cost of $7,632 of public investment per job.[435] Other studies suggest that these findings considerably overstate the extent of job creation from these programs. A comprehensive audit of nine state and local investment programs in Illinois found a huge discrepancy between the number of jobs reported as being created and the number of jobs that were actually created.[436] The audit concluded that public investment produced just 611 jobs, less than 10 percent of the 7,501 jobs claimed to have been created by these programs. In the 1990s, states began reducing their involvement in venture capital.

In sum, the results of these state and federal efforts indicate that government is out of its element in the high-risk, high-return world of venture capital, where tremendous profits from one or two home-runs offset nine or ten losers. Government managers are simply not suited to the tasks required. For instance, nurturing even one success story requires venture capitalists to become intimately involved in the management of startup enterprises. They must make hard-nosed decisions on increasing investments in promising companies, thus putting more money at risk, as well as closing down laggards. Government on the other hand tends to avoid termination of any sort, and it often pours ever more money into existing projects. And, of course, government venture capitalists are like to face pressure to invest in pet projects in key congressional districts. As the economist, Allan Meltzer, pointed out in an article in the *Wall Street Journal*:

> Why, in general, is government less efficient? One big reason is that products and companies do not leap from the drawing board with winner or loser stamped on their blueprints. Someone has to decide to make additional investments in companies that appear to have good prospects, thereby putting more money at risk, or to shut down companies that no longer appear promising. Government is more likely to delay closing the failures and more likely to pump in additional money to cover mistakes or misjudgments."[437]

Even Silicon Valley entrepreneurs, who would presumably benefit the most from a greater involvement of government in the supply of venture capital, are not unanimously supporting these proposals. T.J. Rogers, the CEO of Cypress Semiconductor Corp. and a classic example of successful entrepreneurship in high technology, is an articulate critic of government intervention in this area. He has brilliantly synthesized the shortcomings of governmental action:

> Think for a moment about the realities of life at Cypress and then extrapolate them to the chip industry and Silicon Valley as a whole. Our company has 150 product designers. We have more than 70 technologists. We sell more than 1,500 products. We are working right now on 50 different new products - from high-speed computer memories to data communications chips. With my technical training and my managerial background, it takes me 16 hours a day to stay on top of this organization. Cypress is but one $250 million company in a $50 billion semiconductor industry. Thus, if you take the details I

> have just described and multiply them by 200, you have a sense of the complexity of the chip industry. If you take that level of complexity and multiply it by another factor of ten or more, you have the complexity of Silicon Valley. How can the government possibly hope to cope with the details of Silicon Valley? How could the government even know who the players are in any given week, let alone pick winners and losers?"[438]

The bottom line of this analysis is clear. The brief review of the evidence provided here suggests that government involvement in venture capital is not necessary, is not likely to succeed, and may divert government's scarce resources from other, far more effective and efficient uses. Given the intricate nature of the work of venture capital professionals, even if a venture capital shortage did come about, it would be irrational for government to et involved in the direct provision of venture capital. There are much more effective ways for government to affect capital flows, such as altering the tax rate on capital gains or liberalizing restrictions on private investors. The venture capital market works very well. It channels money to technologies and industries that offer high rates of return, and plays a crucial role in the capability of the American economy to develop new breakthrough technologies and entrepreneurial startup companies. In fact, the U.S. venture capital industry is frequently cited as a great strength of the U.S. financial system and is envied by other leading industrial nations. Government is not well suited to act as a supplier of venture capital. Our brief review of contemporary government venture capital programs shows that government is unable to perform the role of venture capitalist. In brief, the venture capital market does not need government's help, and the federal government is the wrong institution to play the role of venture capitalist.

Moreover, it is important to point out that the problems and difficulties associated with direct government intervention in venture capital markets during the 1980s and 1990s are reinforced by the experience of earlier efforts at government involvement in venture capital. As earlier chapters have shown, there has been a long tradition - at last since the Great Depression and New Deal period - to call for government intervention in venture capital markets. But, as our analysis has shown, efforts at direct government intervention in the supply of venture capital have tended to not be successful, or whose utility has been limited to functioning as temporary experiments which encouraged the formation of private venture capital mechanisms as with the early SBIC program. Government has been far more successful in its use of a series of indirect mechanisms, such as capital gains reductions or the reduction in restrictions on potential private investors, in stimulating the flow of private funds into venture capital.

LEARNING FROM THE CHALLENGES

Venture capital is considered by many analysts to be a source of competitive advantage for the U.S. economy, since it has played a crucial role in the emergence and development of new technologies, new firms and new industries, helping to set in motion Schumpeterian gales of creative destruction. Nonetheless, as this chapter has shown, venture capital is not a panacea for innovation and economic development and there are negative elements of venture capital financed innovation when viewed from the perspective of the economy of society as a whole. Here, it is important to point out that these negative aspects are not intrinsic to venture finance, but rather are largely associated with the modern institutionalized form of venture capital of the 1980s and 1990s. Many of these negative aspects of venture capital were not present in previous eras and are associated with the time-sensitive characteristics of the limited partnership form and the huge increase in the venture capital pool.

Our analysis does not support the view that foreign investment in venture capital and high-technology threatens U.S. interests. Basically, our review of the available evidence indicates that foreign investment in U.S. high-technology during the 1980s was not nearly as large as portrayed, and that it began to recede by the early 1990s. Moreover, there is evidence that the activity of foreign investors in the U.S. may have beneficial effects. Foreign corporate investors can provide U.S. startups with substantial advantages such as access to high-quality manufacturing facilities and to distribution networks in foreign markets. These new forms of cooperation go well beyond simplistic explanations that perceive the gains for one side in the deal as losses for the other. The emerging patterns of cooperation offer clear advantages to all parties involved. In fact, the mobilization foreign investment has been a useful feature of venture investing at least since the 19th century.

Finally, we have seen that attempts to provide involve the government in the direct provision of venture capital, while politically popular for obvious reasons, are fraught with problems. In fact, this book has shown that government efforts to indirectly stimulate the venture capital market through changes in tax policy or in restrictions governing investment by private institutions have a much larger effect on the venture capital market than do attempts at direct government provision of venture capital.

It is increasingly recognized that the problems confronting the U.S. and the advanced industrial nations more generally have little to do with venture finance and are more systemic in nature. It is indeed striking to us how frequently policy-makers seize upon simplistic solutions in the financial sphere, like government provision of venture capital, in attempts to solve what are deeper structural problems. We believe our analysis has shown that the supply of capital, in this case venture capital, is not the determining factor in economic development, but rather is a function of the effective demand for capital which is conditioned by the broad environment for investment.

Here, we simply note that the United States like all other technologically-advanced nations is caught up in a shift to a new age of capitalism, a shift to a knowledge-based economy, where the keys to success are harnessing the ideas and innovative capabilities of all workers, from the R&D lab to the factory floor, to turn out the high-quality, state-of-the-art products the world's consumers want to buy.[439] Government interventions in the venture capital market does little to address this underlying transformation. A systematic reshaping of government policy is required to support the new economy. Indeed, it is increasingly apparent that the existing mass-production policy environment of regulatory, tax, and fiscal policies which grew up to meet the requirements of the old, mass-production economy is ill-equipped to meet the requirements of the emerging, knowledge-based economy. Worse yet, it may even be an obstacle to the emergence of that new economic system. American firms and managers operate within a maze of economic and policy incentives which were well suited to a mass-production environment, but which frequently create disincentives for needed restructuring along high-performance lines. Bank lending policies, for example, typically require that small and medium-sized manufacturers put up their inventory as collateral for bank loans - a practice that impedes their ability to adopt the just-in-time inventory and delivery practices that are required of world-class, high-performance manufacturers. The critical task for government is not to provide venture capital but to help put in place the incentive structure, business climate, and economic infrastructure required for this new economy to take root and flourish.

CHAPTER 11

VENTURE CAPITAL, TECHNOLOGICAL CHANGE, AND INDUSTRIAL DEVELOPMENT

KEY THINGS TO HIGHLIGHT

- EVOLUTIONARY PROCESS OF VC

-MAJOR ORGANIZATIONAL INNOVATIONS

- ROLE IN INDUSTRIAL DEVELOPMENT

- ROLE IN HIGH-TECH - SSI

- WHAT WE CAN LEARN ABOUT NATURE OF GOVERNMENT INTERVENTION

The very phrase venture capital calls forth the image of new financiers of innovation who back cutting-edge high-technology concerns. These industrial enterprises are usually linked to some cutting-edge, industry-defining technology - biotechnology, advanced materials, computer software, and the like. Popular conventions aside, we tend to associate venture capitalism with the sweeping technological and economic revolution of the past two or three decades. But, venture capital has a much deeper and richer history than that. Indeed, the rise of new forms of finance to channel capital to new enterprise and new industries is a defining feature of the America's technological, industrial and economic development.

This chapter sheds important light on the central hypothesis advanced in this book - that new forms of finance, or more appropriately venture capital, are often required to finance the birth of new technologies and business organizations, and the more general process of technological and industrial development. In other words, we suggested that the rise of new forms of finance, or venture capital, correspond to the rise of new industries and technologies. We aimed to essentially draw upon, expand and test Schumpeter's seminal insights on the role of innovation in capitalist development. In Schumpeter's eyes, economic development is a process of discontinuous evolution which is driven by technological change. Major innovations, or clusters of innovations, set in motion strong gales of creative destruction which revolutionize industrial production and industrial organization. However, the risks associated with these major innovations are sufficient to deter average firms, so exceptional entrepreneurs are required to set such gales in motion. In our view, Schumpeter's risk-taking entrepreneurs require a symmetric counterpart in the financial system.

We believe that the historical record, at least for the American case, lends considerable support for this hypothesis. America's first industrial revolution of textile production in and around Boston both required and reinforced the rise of a new set of financial institutions that economic historians such as Lance Davis, Robert Dalzell, and Naomi Lamoreaux have variously referred to as relationship banking or equity-financed insider lending. New financiers of innovation similarly arose to finance the technology-based corporations and corporate complexes of the second industrial revolution: the activities of Andrew Mellon in financing Pittsburgh's industrial complex are illustrative of this process. During this epoch, a new and more complex system for banking and investment thus emerged as a vehicle for technological change and industrial development. The high-technology revolution of the mid-to-late twentieth century required yet another round of financial innovation and a new set of venture capitalists to bring to fruition. These new venture capitalists grew up alongside the high-technology innovation complexes of Silicon Valley and Route 128. By the 1980s, a new and highly institutionalized national system for venture capital had emerged to finance the latest wave of entrepreneurial, technology-based enterprise. Simply put, venture capital is a defining element of the American pattern of technological change and industrial development.

The venture capital system itself evolved alongside American industrialism, becoming increasingly formal and institutional in character over time. The early venture capital or insider lending of the New England textile industry was largely a regional system, built upon close personal ties between the region's financiers and industrialists. The new forms of venture capital that emerged to finance America's second industrial revolution took shape as more formal institutions, such as Andrew Mellon's Union Trust Company. The high-technology venture capital of the mid-to-late twentieth century evolved into a more fully-blown institutional system of formal, indeed legal, organizations such as the limited partnership and its own set of trade associations and research organizations. Furthermore, this institutional system of venture capital evolved into a well-articulated national system for mobilizing capital via coinvestment syndicates and other mechanisms.

Our historical excursus thus lends considerable support to the view that the processes of finance or capital formation, technological change and industrialization occur in tandem over time. They can be seen as different faces of an overall development process which grow up together, influence and shape one another, and are to some degree inseparable. This can be thought of as a cumulative process as industrial growth generates new sources of capital which are in turn invested into subsequent rounds of industrial expansion and growth. With every major technological step forward, corollary shifts in finance occur and new forms of venture finance are created. These new financial forms emerge in response to the of mismatch of capital and industrial needs, as older, more traditional forms of capital remain tied to older paradigms of industrial organization and growth. New mechanisms for providing capital - and new financiers of innovation- are required to support the rise of new technologies, new enterprises and new industries.

Furthermore, our findings suggest that place matters in the co-evolution of finance and industrial development. Here, we simply suggest that Schumpeter's fundamental insights have a considerable spatial or geographic dimension. As we have seen, major technological changes, or shifts in the organization of production tend to occur in specific places and diffuse unevenly across the industrial landscape. The growth and development of local industrial complexes in turns creates the expanding economic base, vibrant investment climate, and new opportunities for capital accumulation. The initial opportunities may well be filled by traditional financiers and investors in established financial centers especially given the well-developed financial structure of contemporary capitalism. Yet over time, the developmental trajectory of the new growth complex creates a momentum of its own, helping to create and indeed generate new sources of indigenous capital, finance, and investment articulated to the needs of its local industries. The new complex is now able to finance itself and embarks on a period of self-reinforcing growth while, at the same time, retaining connections to outside sources of capital and investment.

Our review of the historical record leads us to conclude that venture capital has played a rather fundamental role in innovation, industrial transformation and economic development. Capital and creative destruction thus go hand in hand in the process of technological change and industrial growth in American economic history.

Third, and related to this, our analysis of the evolution of venture capital and of its role in technological change and industrial development enables us to provide some insight on the role of government in this process. The evidence suggests that government plays is most important role indirectly, creating incentives for investment in vc - such as ERISA and capital gains - rather than direct stuff like SBA or Clinton shenanigans

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APPENDIX I:

RESEARCH DESIGN

MARTIN: YOU MAY WANT TO ADD OR REVISE BELOW

The research presented in this book was designed to shed light on the role of venture capital in the processes of technological change and economic development. It is informed by a wide range of literature, including work on technolgical innovation, organiational theory, the economics of technical change, geography and regional development. We used a combination of research methodologies to explore these questions and issues.

First, we conducted extensive field research. The field work was designed to shed light on the history and evolution of the venture capital industry, the nature of venture capital investment, and the role of venture capital in economic development. The field research consisted of extended field visits to Silicon valley, the Boston Route 128 area, and other areas with significant concentrations of venture capital and high-technology industry. We conducted over one hundred interviews with venture capitalists, entrepreneurs, research scientists and engineers, and government officials over the ten year period from 1986 to 1996 [Appendix table XX provides a listing of our interview subjects]. The main interviews with venture capitalists were conducted jointly by the authors in three major field research trips, including two rounds of interviews in Silicon Valley in December 1986 and March 1988 and one in the Greater Boston area in May 1987. These were supplemented by a wide range of additional interview conducted by the authors independently, with collaborators or by graduate students. The interviews on the biotechnology case study were conducted by martin Kenney during the period ??? to ???.

Richard Florida conducted an additional round of interviewa in Silicon Valley in March 1993, and jointly conducted the interview for the case study of flat panel displays with David Browdy in the period May through September of 1992. David Talento conducted the interview for the American Superconductor case during April 1989. The interviews on the computer networking industry were conducted by Martin Kenney and Urs von Berg during 1995 and 1996.

Second, we conducted historical and institutional analyses of the evolution of venture capital and high-technology industry. We conducted a range of archival research to obtain data on the historical evolution of the venture capital industry. This phase examined a wide range of documents relating to key events in the development of the venture capital industry - the creation of the Small Business Administration and its financing arm, the Small Business Investment Companies (SBICs), the early history of American Research and Development (ARD) in Boston, and the early development of the Silicon Valley venture capital complex. The archival research explored materials at the Harvard Business School Library and Stanford Business School library, the historical files of the Silicon Valley Research Center, and materials provided by venture capitalists themselves. This aspect of the research also reviewed all of the back issues of *Venture Capital Journal* beginning in the early 1960s, as well as other publications from Venture Economics which provide rich detail on the evolution, investment strategies, and development of the venture capital industry and its major firms. We used this information to develop infomation on the evolution of the venture capital industry overall and in major regional centers, constructing detialed geneaologies or "family-trees" for venture capital in Silicon Valley and the Boston-Route 128 area. Mark Samber conducted archival research on the venture capital activities of the Mellon interests while a doctoral student in Applied History at Carnegie Mellon

University.

Third, we compiled a data on the organizational structure and geography of venture capital. We used available industry sources, particularly data available from Venture Economics, to developed longitudinal data on the growth of the venture capital industry, the location of venture capital funds, and the patterns of investments. These data roughly cover the period from the late 1960s to 1995 and provide an overall picture of changes in the supply, location and investment of venture capital over time. We used these data to compile maps, tables, and descriptive statistics of changes in the location and investment of venture capital. We then built a detailed, micro-level database on venture capital location and investment for the period 1983-1987. The database provides detailed data on venture capital location, investment and coinvestment at the firm level. It is based upon information on venture capital activity, published in *Venture Capital Journal*, the monthly trade journal of the venture capital industry for the period January 1984 through December 1987. The data come from annual surveys of the entire population of venture capital funds conducted by Venture Economics which publishes *Venture Capital Journal*. The data cover a 40-45 percent sample of the population of venture capital funds, and according to Venture Economics, are comparable to data for the entire population of venture capital funds, and are not systematically biased by geography or investment type. These are the most comprehensive data available on the venture capital industry and include micro-level information on the venture capital firms, venture capital investments, venture capital coinvestments, and the companies that receive those investments. We used these data to compile maps, tables, and statistical analyses of trends in venture capital supply, investment, and coinvestment patterns at the national, state, and MSA (metropolitan statistical area) level. This aspect of the research represents a major extension and advance over previous research in that it moves the unit of analysis from the state to the MSA level. Donald Smith conducted the econometric analyses of these data reported in Appendix II, and Elizabeth Sechocka and Mark Clark, assisted in the compilation of the micro-level database during their tenure as students at Carnegie Mellon University.

APPENDIX TO CHAPTER 9

MODELLING VENTURE CAPITAL SUPPLY AND INVESTMENT[8]

This appendix presents formal models of venture capital location and investment developed by Donald Smith, our colleague and collaborator at Carnegie Mellon University's center for Economic Development. The models are based on that venture capital is a central component of an area's technological infrastructure - a special form of an agglomeration economy comprised of specialized economic, technological, and financial networks which support high technology industrial and technological development. From this general notion, flow two more specific hypotheses.

In terms of venture capital location, the hypothesis was that the location of venture capital is determined by both the concentration of high technology business and the concentration of financial resources. In terms of venture capital investment, the was that venture capital investment is primarily drawn to major concentrations of high technology business. The models were estimated at the MSA level to avoid the ambiguity or aggregation problems that might come from state or regional level data. Both models are cross-sectional and drawn across a two-year time series.

[8] This appendix draws from the work of Donald F. Smith, Jr. of the center for Economic development at Carnegie Mellon University and is a revised version of the techniucal section of Donlad Smith and Richard Florida, NEED TO COMPLETE THIS NOTE.

Venture Capital Location Model

The location model examined the factors which affect the location of venture capital funds. The dependent variable is number of venture capital offices in a MSA. While it would have been preferabble to run two models of venture capital location - one using offices, the other using the dollar volume of venture capital resources they control - it was impossible to obtain reliable data on venture capital resources at anything below the state level. There are four independent variables in the model: a measure of the size of the overall banking or financial sector (FINCAP), a measure of the presence of high technology industry (HTEMP), a measure of venture capital co-investment (NETWORK), and a measure of transportation access (TRANS). Descriptive statistics for the variables appear in Appendix Table 1.

[Appendix Table 1]

A measure of the high technology base (HTEMP) was used to explore the relationship between venture capital and high technology industry. This variable is measured as total high technology employment in an MSA for 1984 and 1986. High technology employment was defijned according to the U.S. Bureau of Labor Statistics hybrid definition, which combines two measures of high technology intensity: the ratio of R&D expenditures to sales and the percent of the labor-force who are scientists and engineers.[440] This variable is based on data collected by the U.S. Small Business Administration which is a revised version of the Dun and Bradstreet data for 1984-86. Much has been written about the limitations of the Dun and Bradstreet data, particularly with respect to inaccurate representation of firm births and firm deaths. The SBA data have been updated and revised to minimize these biases. These data are the best available at present, and there is no evidence that the errors in the data are geographically biased. Therefore, the effect of these errors on the geographic, econometric analyses is likely to be small, and appear in the form of noise, rather than any systematic bias.

A measure of the concentration of financial institutions (FINCAP) was used to test the hypothesis that venture capital concentrates in areas with established concentrations of financial institutions. Generally speaking, it is expected that a large base of financial institutions and assets provides the capital base required for venture capitalists to raise capital for a fund. In addition, proximity to financial institutions and to large concentrations of financial assets also facilitates connections to broader financial sources which allow venture capitalists to access later stage financing provided by banks and other institutional investors. This was operattioalized this by using as the amount of commercial bank deposits within an MSA. This data is reported by the Federal Deposit Insurance Corporation for the period 1984-1986 and covers the total population of commercial banks in the U.S. Data on financial assets held by other types of financial institutions are unavailable at the MSA level. The volume of commercial bank deposits covers roughly 70 percent of non-equity financial assets held in the U.S.

A measure of venture capital co-investment was used to explore the idea that co-investment increases venture capital investment by allowing venture capitalists to diversify their investment portfolios and pool risk. It was expected that venture capitalists who are well-connected to local and national venture capital networks to attract new venture capital offices either through new fund formation or spin-offs from established venture capital funds. The co-investment network variable (NETWORK) was measured as a cumulative count of venture capital co-investments engaged in by venture capitalists in a given MSA. This requires some additional clarification. For example, when venture capitalist x from MSA A participates in an investment with two other venture capitalists, venture capitalist y from MSA A and venture capitalist z from MSA B, this is counted as four co-investments for MSA A (1 between x and y, 1 between y and x, 1 between x and z, and 1 between y and z), and two for MSA B (1 between z and x, and 1 between z and y). These data were measured from 1981 to the year in question to minimize contemporaneous correlation between co-investment totals and the number of deals completed in a given year. It is important to note that this is a measure of the total number of co-investment decisions rather than a measure of investment decisions (which in the example above would count the relationship between x and y as 1 investment for MSA A); and further that it is measure of venture capital co-investment as opposed to the final destination of the investment itself. The co-investment variable is from our venture capital data base outlined above.

A measure of transportation access (TRANS) was used to look at how important access to investments is in determining the spatial distribution of venture capital supply. Generally speaking, this variable tests the transportation cost minimization hypothesis which lies at the heart of traditional location theory. More specifically, surveys of venture capitalists' found that access to investments is an important consideration in the location of venture capital funds.[441] Given the hands-on character and proximity requirements of venture capital investing, it is important to explore to what degree venture capitalists choose locations based upon transportation accessibility to outside investments. In other words, if a venture capitalist is based in a given MSA and invests elsewhere, that venture capitalists has to be able to visit those outside investments. Thus, the home base for all operations is likely to depend upon good air transportation to many potential investment sites. Reflecting this, the transportation variable is a measure of air accessibility represented by the number of commercial airport operations (takeoffs and landings) within an MSA. These data are from Federal Aviation Administration (FAA). These data were provided by the FAA for the period 1984-86. This measure represents an improvement over the hub airport variable employed by Ann Markusen and her collaborators in that it is continuous and that it includes non-hub airports.[442]

The location model views the spatial distribution of venture capital supply as a function of: (1) the high technology industrial base, (2) the size of the financial sector, (3) the existence of venture capital networks, and (4) transportation accessibility as measured by the volume of airport operations.

Our data on venture capital firms locations is characterized by a large number of zero observations as many MSA's do not have a venture capital firm. In this case, zero is the censoring point in the distribution of venture capital firms. An MSA cannot have fewer than zero firms. However, not all MSAs with zero venture capital firms can be assumed to be equally (un)attractive locations for a venture capital firm to locate. Attempting to estimate a model with data from a censored distribution using ordinary least squares regression would result in biased estimates for the parameters. However, the TOBIT method of estimation is designed to yield consistent estimates in the case of a censored regression. It does so by estimating a two-part likelihood function, taking into account the likelihood of being above zero and estimating the parameters in those cases.[443]

To better understand the nature of our limited dependent variable, envision a normal distribution. Then, place a lower limit of zero on the distribution, which slices all observations below that point and reports them as a zero observation. Hence, we have data on y, the observed data, and wish to make inference about y*, the unrevealed true distribution. It is observed that y = y* for y* > 0, and y = 0 for y* <= 0. Tobit estimates both the effect of a variable on the probability of being above the zero censoring point and the effect on the positive observations of y (in this case either the number of venture capital offices or investments). The likelihood function is as follows:

Install Equation Editor and double-
click here to view equation.

Limdep version 5.1 was used to perform the estimation. Limdep uses the iterative, Newton method of maximum likelihood estimation of the parameters. The model that was estimated is specified as follows:

1.1 $LOCATE = B_0 + B_1*FINCAP + B_2*HTEMP + B_3*NETWORK + B_4*TRANS + E_1$

where B's are coefficients to be estimated and E is the disturbance(or error) term.

Venture Capital Investment Model

A second model was used to explore the factors which affect the geographic distribution of venture capital investment. It examines venture capital investment in light of the underlying high technology base, the local supply of venture capital, and the presence of venture capital networks. This model also operates at the MSA level for the years 1984 and 1986. The model was set up as a recursive, simultaneous system with the location equation. This was done to separate out the direct effects of the independent variables on investment from the indirect effects that work through the location variable.

The dependent variable was the number of venture capital investments (INVEST). The investment data were compiled from information on venture capital investment published in *Venture Capital Journal*, the monthly trade journal of the venture capital industry. The venture capital data cover the period 1982-1987; however, limitations in the data used for the independent variables made it necessary to limit the analysis to the years 1984 and 1986. The venture capital data comprise a representative (40-45 percent), sample of all venture capital investments made by institutional venture capital intermediaries over the study period according to Venture Economics, the organization which collects the raw data.

While it would have been preferred to run two models, the first on the number of investments, and the second on the dollar volume of investments, the data were not available. There were a significant number of missing observations on the dollar volume of venture capital investments. Furthermore, using the number of investments avoids the bias imparted by a measure of the dollar volume of investments or dollar volume per transaction which may be skewed toward a small percentage of large-scale financing (e.g., leveraged buy-outs of existing companies), which are not representative of the start-up investments associated with venture capital. Ultimately, what we want to measure is the level of venture capital activity, not the size of the deals being financed. Thus, the number of investments is the most appropriate measure.

The investment model included the following independent variables. Three separate measures were used to capture the high technology base: high technology employment (HTEMP), high technology start-ups (HTSTART), and industry-funded R&D at universities (R&D). Together, these variables examine the flow of venture capital toward established concentrations of high technology industry. High technology employment provides an overall measure of the size of the high technology sector. High technology start-ups are a more specific measure of potential investment opportunities; it is expected that the number of actual investments will be a function of potential investment opportunities.

These two variables were adapted from the SBA data and, as such, suffer from some limitations. The limitations of the start-up data are more severe, given the under-reporting of new firms which are not captured in D&B's credit ratings and the over-counting of change of ownerships as new starts. However, both phenomenon are unlikely to be geographically correlated, and as such are not likely to impart systematic bias to the results. Basically, the limitations of the data amount to adding noise to the model.

Industry-funded R&D at universities was used to measure R&D to capture potential university-based spill-overs to commercial technology development.[444] In addition, such R&D expenditure contributes to the development of the underlying technological base and supply of scientific and technical labor power, and thus are part of the broader infrastructure for innovation and new technology development. This variable was based on data reported by the National Science Foundation on university R&D, and is the best available measure of R&D at the MSA level.

The location of venture capital offices (LOCATE) was included to test the hypothesis that venture capitalists invest locally. This was the same as the dependent variable in the location model. Venture capital co-investments were used to explore the relationship between venture capital networks and investment. It wsa expected that venture capital centers which have a high level of co-investment will be more active investors.

A measure of transportation access was included to test the hypothesis that accessibility influences venture capital investment. Survey research suggested that venture capitalists frequently visit their investments.[445] Furthermore, the need for access is heightened due to the information-intensive and interactive nature of venture capital investing, where financiers provide managerial assistance as well as capital. It is also expected that investments are less likely to be discovered in areas which have relatively poor transportation access and when discovered to pose significant opportunity and transaction costs for investors thereby reducing their attractiveness.

The investment model was specified as follows: venture capital investment (INVEST) is a function of (1) the size of the high technology employment base (HTEMP), (2) the number of high technology start-ups (HTSTART), (3) the amount of industry-funded R&D at universities (R&D), (4) the number of venture capital offices (LOCATE), (5) venture capital co-investments (NETWORK), and (6) transportation access (TRANS).

The model was specified in terms of recursive system of equations to account for the separate effects on location and investment. The model was estimated in its reduced form and solved for the structural coefficients in order to separate the direct effect of variables on investment from the indirect effect on investment that occurs through the variables that effect the location of venture capital supply. Thus, the model was specified in terms of the following recursive system of equations; where the B's and C's are parameters to be estimated, and the E's are disturbances:

1.1 $\text{LOCATE} = B_0 + B_1\text{*FINCAP} + B_2\text{*HTEMP} + B_3\text{*NETWORK} + B_4\text{*TRANS} + E_1$. AND

2.1 INVEST = $C_0 + C_1$*LOCATE + C_2*HTEMP + C_3*NETWORK + C_4*TRANS + C_5*R&D + C_6*HTSTART + E2.

In this system, each of the dependent variables is best treated as a (censored) limited dependent variable, due to a large mass of observations which are zeroes. As such, both equations are treated as censored regressions and utilize the type-1 Tobit procedure to estimate the parameters via maximum likelihood estimation. Since there is some reason to suspect that the error terms are correlated, and it is likely that some of the unobserved effects picked up by the disturbance terms are indeed coincident, the Tobit procedure is performed on the reduced forms of each equation, listed below:[446]

1.2 LOCATE= $B_0 + B_1$*FINCAP + B_2*HTEMP + B_3*NETWORK + B_4*TRANS + E_1.

2.2 INVEST = $C_0 + C_1$***[** $B_0 + B_1$*FINCAP + B_2*HTEMP + B_3*NETWORK + B_4*TRANS+ E_1 **]** + C_2*HTEMPLOY + C_3*NETWORK + C_4*TRANS + C_5*R&D + C_6*HTSTART + E_2.

This reduces to:

2.3 INVEST = $(C_0+(C_1B_0))$ + (C_1B_1)*FINCAP + $(C_1B_2+B_2)$*HTEMP + $(C_1B_3+C_3)$*NETWORK + $(C_1B_4+C_4)$*TRANS + C_5*R&D + C_6*HTSTART + $(C_1E_1 + E_2)$.

Using Gs for the reduced form parameters and V for the reduced form disturbance yields:

2.4 INVEST = $G_0 + G_1$*FINCAP + G_2*HTEMP + G_3*NETWORK + G_4*TRANS + G_5*R&D + G_6*HTSTART + V.

Statistical theory tells U.S. that consistent estimators of parameters that are continuous functions of other, consistently estimated parameters are obtainable from continuous functions of the estimators of those parameters. Estimates are obtained for the G coefficients. However, it is the C coefficients that are the parameters of interest. Noting that $G_1 = C_1 * B_1$ is a continuous function, and that we have consistent estimates of the parameters G_1 and B_1 from Tobit estimation applied to the first equation and the reduced form of the second equation, we obtain a consistent, asymptotically efficient estimator for C1 by dividing the estimator of G1 by the estimator of B1.

Similarly, we solve uniquely for each of the other parameters of interest, namely the structural parameters of the investment equation (the C's). Estimated standard errors for the structural coefficients in the investment equation are obtained using the Delta Theorem for continuous functions of consistent estimators.

Findings

The findings for the venture capital location model are summarized in Apendix Table 2. Overall, the model performed well, and the findings are robust. The results suggest that the geography of venture capital supply is driven by the following factors. First, the spatial distribution of venture capital supply is related to the size of the existing financial base, specifically by the volume of bank assets. This confirms the hypothesis that venture capital is concentrated near established financial centers: A large base of financial assets and institutions provide the capital base required to raise a venture capital fund. In addition, a significant number of venture capital funds in large financial centers like New York and Chicago are divisions of large financial institutions or spin-offs from those institutions.

Proximity to financial institutions and to large concentrations of financial assets also allows venture capitalists to access the sources of later stage financing provided by banks and other institutional investors.

[Appendix Table 2 here]

Second, and not surprisingly, the location of venture capital funds is positively related to high technology employment. The model thus confirms the hypothesis that venture capital is located near high technology industry. This is attributed to the specialized, information-intensive and transaction-intensive nature of venture capital activity, particularly the hands-on nature of venture capital investment in high technology industry. This further suggests that venture capital and high technology industry are mutually reinforcing.

Third, the spatial distribution of venture capital supply is strongly related to linkages to and networks with outside venture capitalists. Ties to outside venture capitalists matter in location decisions, as venture capital funds locate in proximity to others that are well-integrated in national networks or near other funds with which they have co-invested before.

Fourth, the transportation variable is not related to the spatial distribution of venture capital supply. This coefficient is insignificant and negative in the 1984 sample, and it is insignificant and positive in the 1986 sample. This implies that transportation access is not an important factor in venture capitalists' location decisions. However, we are cautious in interpreting this result. Our analysis indicates that there is some degree of correlation between the variables TRANS and HTEMP. This type of co-linearity can effect the statistical significance of the estimates. However, it does not affect the consistency of the estimates, and the coefficients have opposite signs in the two equations. Thus, co-linearity alone cannot explain the seemingly anomalous result. This result may reflect the limitations of our departures and arrivals data and are willing to entertain the notion that more robust metric, perhaps flight time weighted by MSA, might yield a different result. However, given our understanding of the venture capital industry and the previous analysis of venture capital co-investment patterns, we are led to conclude that transportation access is mitigated by the co-investment process. Simply put, the need for access is minimized because a share of venture capitalists who are located close to the investments act as lead investors, allowing the remainder to participate as long distance investors.

The findings of the venture capital investment model are summarized in Appendix Table 3. This model also performed well, and the findings are again robust. First, venture capital investment is positively related to the high technology industrial base. All three measures, high technology employment, high technology start-ups, and industry-funded R&D at universities, are positive and significant for both 1984 and 1986. This confirms the hypothesis that venture capital flows to specialized centers of high technology industry.

[Appendix Table 3 here]

Second, venture capital investment is positively related to the level of venture capital co-investments in an area. This suggests that venture capital investment is stimulated by a highly networked venture capital community which provides access to outside capital. This supports the idea that such networks help venture capitalists identify investments and obtain access to outside capital.

Third, transportation access is not significantly related with venture capital investment. It is negative and the estimated coefficient has a very small t-ratio. This indicates that access does not effect venture capitalists' investment decisions and that transportation access does not appear to effect the flow of venture capital across space. This apparently contradicts the findings of survey research which indicate that venture capitalists' have a preference for proximity. The lack of significance of this variable might also be explained, in part, by the significant degree of co-linearity between TRANS and the high technology variables HTEMP and HTSTART, as discussed previously.

However, given our understanding the venture capital industry, the lack of significance can be explained as the outcome of the co-investment process, where lead investors identify, monitor and provide hands-on assistance to new ventures, loosening the overall spatial constraint, while confirming the need for proximity. These lead investors are embedded within the local technological infrastructure, and as such can access tacit information and provide the face-to-face contact required to reduce investment risk for themselves and for other, external investors.

Fourth and perhaps most significantly, venture capital investment is not related to the distribution of venture capital supply. In fact, the coefficient for the location of venture capital offices is negative and significant in both samples. This indicates that venture capital investment is not determined by the location of venture capital funds, contradicting both the conventional wisdom and academic theory and the underlying rationale for public policy intervention - that local venture capital supply generates local venture capital investment, leading ultimately to high technology economic development. This reflects the venture capital network at work, as co-investment loosens the spatial constraint on venture capital investing. While we would expect this result to be statistically insignificant, the negative result is a bit surprising.

A number of factors appear to be driving this result. Part of the explanation lies in the high level of venture capital export venture capitalists in New York and Chicago. Furthermore, while Boston area and Silicon Valley venture capitalists do invest a higher percentage of their capital locally, venture capitalists in both areas, especially the Boston-Route 128 area, do export some of their capital. This result also reflects the fact that Silicon Valley is comprised of a series of separate MSAs. Here, the model may be picking up the local export of capital from San Francisco based venture capitalists to investments in the San Jose, Santa Clara and Santa Cruz MSAs.

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60. The Licensing Office had worked with American Research and Development before in the potential start-up of a bio-materials company. However, at that time the MIT polices, with regard to venture capitalists taking equity and what would and would not be allowed, had not been finalized. An earlier attempt to match MIT technology with private venture capital had fallen through. However, in the process of making the agreement ARD and MIT had developed a strong working relationship and a prototype model for a new university spinoff. George McKinney, a managing general partner at ARD, worked with the initial bio-materials deal, and during the developing relationship, took the opportunity to tell MIT of ARD's interests in developing upcoming biotechnology and materials technologies in the future. The development of this relationship would later become crucial in the discovery and start-up of ASC.

61. This policy of allowing faculty and the university to take equity is unusual for a university licensing office. Yet it is this very unique characteristic that has helped develop the university/industry environment at MIT into one of the most successful catalysts for start-up companies. The Licensing Office recognizes its unique status and has taken the initiative to insure that it remains one of the most successful licensing offices in the country. In addition, it has stipulated strict policies to deal with the unique university/faculty relationship involved in most start-ups. For example, MIT will not allow a mixing of sponsored research to continue at the university if there is any equity involvement. This includes equity held by faculty as well as the university. This rule is strongly adhered to because it is believed the potential conflict of interest is too great. A related policy declares that MIT will not have a seat on the board of directors of any of its start-ups. This policy was created to insure protection from liability. In addition, university involvement on a board of directors is believed to be a potential conflict of fiduciary responsibility in the event MIT must invoke due diligence clauses with regard to progress made on patents they have filed with faculty start-ups. Following the new policy guidelines, the Licensing Office had assisted in the start-up of a few biotechnology companies that tested a new model of university/industry relations. Previous to the development of ASC, six biotechnology companies had been developed and incubated through MIT and its venture capital relationships.

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80. See, Raymond Goldsmith, *A Study of Savings in the United States*, National Bureau of Economic Research Service, Princeton: Princeton University Press, 1955, 3 volumes.

81. See, Naomi Lamoreaux, *Insider Lending: Banks, Personal Connections, and Economic Development in Industrial New*

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82. Naomi Lamoreaux, *Insider Lending*, 1992, p. 13.

83. Lance Davis has argued that American economic and industrial development was punctuated by periods of "capital immobility." Davis suggests that capital immobility became acute in the post-bellum decades because firms required external finance (or access to greater resources) as a result of industry's westward migration, and technological innovations in manufacturing ushered in by mass production. While New England's textile industry gave rise to the most advanced capital markets in the nation, little of that capital moved to the South despite the South's intricate involvement in the existence of a textile industry in Boston. Impeded by communications and transportation systems ill-equipped to handle continental transactions, New England lenders could not efficiently tap into potential frontier markets, although they actively attempted to establish financial ties to the frontier. Southern and Western industry experienced a widespread shortage of capital, and local pooling of capital was necessary to help these industries finance their expansion. The inflexibility of financial markets comprised a major obstacle to industrial expansion for much of the later 19th century. See, Lance Davis, "Capital Immobilities and Finance Capitalism: A Study of Economic Evolution in the United States, 1820-1920," *Explorations in Entrepreneurial History*, 1, Fall 1963, pp. 88-105; Lance E. Davis, Douglass C. North, "International Capital Flows and the Development of the American West," *Journal of Economic History*, 16, December 1956, pp. 493-505. For a thorough account of Boston elite financing the western railroads, see, Arthur Johnson and Barry Supple, *Boston Capitalists and Western Railroads*, Cambridge, 1967.

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87. See, David Bieto, "Andrew Mellon, in the *Encyclopedia of American Business History and Biography*, New York, 1988, pp. 267-82. Also, Junius Edwards, *A Captain in Industry*, New York, 1957, pp. 40-41.

88. See, David T. Bieto, "Andrew Mellon," in *The Encyclopedia of American Business History and Biography,* pp. 267-282.

89. See, Burton Hersh, *The Mellon Family: A Fortune in History*, New York: William Morrow & Company, 1978. Mellon's tactics backfired and he would have to wait until the Westinghouse companies reeled under the financial panic of 1907 before another opportunity to gain financial leverage presented itself. Westinghouse came away from the deal empty handed, and with a bitter distaste for the Mellon's and the whole Pittsburgh financing scene. Westinghouse had been given a similar ultimatum in 1869 by Robert Pitcairn when he sought to start up the air brake company. Andrew Mellon vowed never to allow a Pittsburgh manufacturing firm slip away from his financial control, and to one day control the Westinghouse company.

90. See, Mark Samber, "Forging New Cultures: The Corporate Capital Networks of Pittsburgh's Industrialization, 1860-1919, Baltimore, Maryland: 18th Annual Social Science History Association conference, November 6, 1993.

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92. ADD NOTE ON MELLON INSTITUTE

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413. Personal interview with Vinod Khosla of Kleiner Perkins, by Richard Florida, March 22, 1993.

414. This section draws from personal interviews with William Coates, former Westinghouse executive, Peter Brody, founder of Magnascreen and Panelvision, Thomas Maloney of Magnascreen and panelvision, and others, by Richard Florida and David Browdy, May-September 1992.

415. Personal interview by Richard Florida, summer 1992.

416. Personal interview with William Coates, by Richard Florida, September 1, 1992.

417. Personal interview by Richard Florida, summer 1992.

418. The machine used a series of shadow masks which would deposit the various materials in a patterned array directly on the substrate, eliminating the need for the multiple photolithographic steps used in normal semiconductor technology. But the density requirements for the new displays the company was developing pushed the machine and the new mask technology beyond the state-of-the-art. Basically, the machine which had been used to produce less dense patterns or circuits of 30 lines per inch was now being used to try to produce circuits of higher density, 50 lines per inch or more. Panelvision's location in Pittsburgh also played a role in these difficulties. Its suppliers were all located far from the company, in Silicon Valley, Route 128, or even in Europe. This made communication and interaction in equipment design and implementation difficult. Personal interview with Peter Brody, May 1992, by Richard Florida and David Browdy.

419. Personal interview with William Coates, by Richard Florida, September 1, 1992.

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