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Venture Capital and Innovation in Energy

Josh Lerner

7.1 Introduction

The past two years have seen challenging times for venture capital activity. The fact that no companies went public in the second quarter of 2008—the first time in three decades that this happened—and the low realized returns for venture funds in the past decade more generally have raised alarms about the viability of the venture model. As Dixon Doll, cofounder of Menlo Park-based DCM and current National Venture Capital Association chairman remarked:

> While we clearly recognize that the IPO drought is being driven largely by a weak economy, there are other systemic factors that are making the IPO exit less attractive for high quality venture-backed companies. Our government and the private sector should be doing all that it can to encourage these innovative, high quality companies to enter the public markets and grow from there.[1]

As a result of these questions, the volume of funding raised by venture capital organizations and the amount disbursed to portfolio firms have both dropped. In few places has this drop been as dramatic as in alternative

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1. See http://www.nvca.org/pdf/Q2_08_Exits_Release.pdf.

energy. The amount disbursed to these firms fell from $1.3 billion in the second quarter of 2008 to just over $200 million in the first quarter of 2009, and while there was some recovery by 2010, the investment levels remained considerably below earlier heights.[2]

Already voices have been raised, expressing worry about the implications of this decline—and the associated shifts in venture capitalist behavior—for technological innovation. For instance, in an influential new volume, Judy Estrin (2008), the former chief technology officer of Cisco systems, argues that short-term thinking and a reluctance to take risks are causing a noticeable lag in innovation. She argues that venture capitalists that back entrepreneurial firms have been too cautious to make big bets, particularly after the costly failures experienced during the dot-com bust.

This chapter seeks to understand the implications of the difficulties in the venture market on innovation, with particular emphasis on alternative energy. It makes three arguments:

- Venture capital funding has an important role to play in stimulating innovation and economic growth.
- But venture funding has a tendency to be cyclical. This tends to reduce the private and social returns to these innovations.
- These dynamics have important implications for thinking both about the probable effectiveness of private-sector investments in energy and whether and how the government should play a role.

In particular, the final section makes two key claims. First, it argues that the situation may not be as grim as it initially appears. While there are many reasons for believing that, on average, venture capital has a powerful impact on innovation, the impact is far from uniform. In particular, during boom periods, the prevalence of overfunding of particular sectors can lead to a sharp decline in terms of the effectiveness of venture funds. While prolonged downturns may eventually lead to good companies going unfunded, many of the dire predictions seem overstated.

Second, we consider some of the implications for public policy. Our analysis suggests that, while the rise of venture capital has been an important contributor to technological innovation and economic prosperity, an effective policy agenda going forward will not simply seek to spur much venture financing. We highlight the fact that many of the steps that policymakers have pursued have had the consequence of throwing "gasoline on the fire": that is, they have exacerbated the cyclical nature of venture funding. Instead, the environment for venture capital investment can be substantially improved by government policies (both federal and state) that encourage private investment and address "gaps" in the private funding

2. See https://www.pwcmoneytree.com/MTPublic/ns/moneytree/filesource/exhibits/09Q1MTPressRelease.pdf.

process, such as industrial segments that have not historically captured the attention of venture financiers. In short, we argue that policymakers have to view efforts to assist young firms within the context of the changing private-sector environment.

7.2 Venture Capital and Innovation

It is helpful to begin by briefly considering the role venture capital investors play. The financing of young and growing companies is a risky business. Uncertainty and informational gaps often characterize these organizations. These information problems make it difficult to assess these companies and permit opportunistic behavior by entrepreneurs after the financing is received.

7.2.1 Conflicts in the Venture Process

To briefly review the types of conflicts that can emerge in these settings, conflicts between managers and investors can affect the willingness of institutional investors to provide capital. If the firm raises equity from outside investors, the manager has an incentive to engage in wasteful expenditures (e.g., lavish offices) because he or she may benefit disproportionately from these but does not bear their entire cost. Similarly, if the firm raises debt, the manager may increase risk to undesirable levels. Because providers of capital recognize these problems, outside investors demand a higher rate of return than would be the case if the funds were internally generated.

Additional problems may appear in the types of more mature companies in which venture capital firms specializing in growth equity invest. For instance, entrepreneurs might invest in strategies or projects that have high personal returns but low expected monetary payoffs to shareholders.

Even if the manager wants to maximize firm value, information gaps may make raising external capital more expensive or even preclude it entirely. Equity offerings of companies may be associated with a "lemons" problem: that is, if the manager is better informed about the company's investment opportunities and acts in the interest of current shareholders, then he or she will only issue new shares when the company's stock is overvalued. Indeed, numerous studies have documented that stock prices decline upon the announcement of equity issues, largely because of the negative signal sent to the market. This "lemons" problem leads investors to be less willing to invest at attractive valuations in young or restructuring companies, or even to invest at all.

Specialized intermediaries, such as venture capital organizations, can address these problems. By intensively scrutinizing companies before providing capital and then monitoring them afterward, they can alleviate some of the information gaps and reduce capital constraints. Thus, it is important to understand the tools that venture capital investors use in this difficult

environment, which enable companies ultimately to receive the financing that they cannot raise from other sources. It is the nonmonetary aspects of venture capital that are critical to its success: the screening of investments, the use of convertible securities, the syndication and staging of investments, and the provision of oversight and informal coaching.

7.2.2 The Tools of Venture Capital

Where, then, does the venture capital advantage come from? To address the information problems delineated in the preceding, venture capital investors employ a variety of mechanisms, which seem to be critical in boosting innovation.

The first of these is the screening process that venture capital investors use in selecting investment opportunities. This process is typically far more efficient than the process that other funders of high-risk projects, such as corporate research and development (R&D) laboratories and government grant makers, typically use. For instance, most large, mature corporations tend to look at their existing lines of business when choosing projects to fund. Technologies outside the firm's core market, or projects that raise internal political tensions, often get shelved. In fact, many successful venture-backed start-ups are launched by employees who leave when their companies decline to pursue what these employees see as a promising technology.

Numerous studies have documented that typical venture capital fund managers use an exhaustive process to assess the large number of business plans they receive each year. One of the pioneering studies (Wells 1974) described a typical process:

> 1) Conversations with venture capitalists that ask[ed firm] to look at company; 2) Checked personal references of controller, vice-president, and president; 3) Met with company's founders and controller; 4) Conversation with loan officer at major insurance company. The insurance company's loan committee had turned down company's request for financing even though the loan officer recommended it; 5) Conversation with company's accountant . . . ; 6) Conversation with local banker who slightly knew the company; 7) Conversation with banker who handles company's account; 8) Telephone conversation with director of company; 9) Talked to about 30 users; 10) Talked to two suppliers; 11) Talked to two competitors.

One sophisticated individual investor, who follows an approach similar to independent firms, suggests it is likely to take up to 160 hours to properly screen an opportunity (Amis and Stevenson 2001, 114). A leading venture capital group, Bessemer Venture Partners, prepared a "Due Diligence Booklet" that all potential investors were supposed to complete for each investment. This fifty-page publication raised a large variety of questions about the industry, the company, the people, and the transaction itself.

How do venture capital investors make sense of all the data they gather during this assessment process? Clearly, certain measures are more important than others. After interviewing a large number of funds about their investment criteria, Tyebjee and Bruno (1984) described the most common criteria as follows:

1. Market attractiveness (size, growth, and access to customers)
2. Product differentiation (uniqueness, patents, technical edge, profit margin)
3. Managerial capabilities (skills in marketing, management, finance, and the references of the entrepreneur)
4. Environmental threat resistance (technology life cycle, barriers to competitive entry, insensitivity to business cycles, and downside risk protection)
5. Cash-out potential (future opportunities to realize capital gains by merger, acquisition, or public offering)

Steve Kaplan and Per Strömberg (2004), who examined the actual analyses that the venture capital funds undertake when presenting potential transactions to their investment committees, identify a similar set of findings. They grouped the key decision-making criteria into three overall categories: (a) internal factors (quality of management, performance to date, funds at risk, influence of other investors, portfolio fit, and monitoring costs and valuation); (b) external factors (market size and growth, competition and barriers to entry, likelihood of customer adoption, and financial market and exit conditions); and (c) difficulty of execution (nature of the product or technology and the business strategy model).

Another way in which venture capital investors screen transactions is through financial analyses. They carefully analyze what the prospective returns from these investments will be, conditional on the firm being successful. They only invest if the expected return is suitably high. This requirement of a very high return, if the firm is successful, stems from the high failure rates associated with early-stage and restructuring investments. For instance, only approximately one-third of venture capital-backed firms complete initial public offerings, typically the most attractive route in which to exit investments. While some investments are exited successfully though acquisitions, in most cases, these investments generate far lower returns. Even in later-stage investing, the frequency with which things do not go according to plan leads to demands for high hurdle rates. Despite all the care and expertise of venture capital investors, disappointment is the rule rather than the exception.

In addition to the careful interviews and financial analysis, venture capitalists will often make investments with other investors. One firm will originate the deal and look to bring in other firms. Involving other venture capital firms provides a second opinion on the investment opportunity. There is

usually no clear-cut answer as to whether any of the investments that a venture capital organization undertakes will yield attractive returns. Having other investors approve the deal limits the danger that bad deals will get funded. This is particularly true when the company is early-stage or operating in an uncertain market. Syndication also allows the venture capital firm to diversify. If the venture capital investor had to invest alone into all the companies in his portfolio, then he or she could make far fewer investments. By syndicating investments, the venture capital investor can invest in more projects and largely diversify away firm-specific risk.

The result of this detailed analysis is, of course, a lot of rejections: studies suggest only 1/2 to 1 percent of business plans seem to be funded (Wells 1974; Fenn, Liang, and Prowse 1996). Inevitably, many good ideas are rejected as part of this process. Most venture capital investors are embarrassed to admit these goofs, but Bessemer cheerily posts their "antiportfolio" of great companies they passed on for various reasons.[3] And, of course, many companies are funded, which ultimately prove to be disappointments.

When venture capital investors invest, they typically hold not common stock, but rather preferred stock. The significance of this distinction is that if the company is liquidated or otherwise returns money to the shareholders, the preferred stock will get paid before the common stock that the entrepreneurs, as well as other, less-privileged investors, hold. Moreover, venture capital investors add numerous restrictive covenants and provisions to the preferred stock. They may be able, for instance, to block future financings if the valuation is not what they are comfortable with, replace the entrepreneur, and have a set number of representatives on (or even control of) the board of directors. In this way, if something unexpected happens (which is the rule rather than the exception with entrepreneurial and restructuring firms), the venture capital investor can assert control. These terms vary with the financing round, with the most onerous terms reserved for the earliest financing rounds.

In addition to the initial selection process, the advice that venture capital firms provide to entrepreneurs, as well as the post-investment monitoring and control, support top-quality innovation. Venture capital investors also tend to spot more potential future applications of technology and business models than larger, mature companies do, perhaps because older companies focus on narrower markets.

The staging of investments also improves the efficiency of venture capital funding. In large corporations, R&D budgets are typically set out at the beginning of a project, with few interim reviews planned. Even if projects do get reviewed midstream, few of them are terminated when signs suggest they're not working out.

These practices contrast with the venture capital and growth equity pro-

3. See http://www.bvp.com/Portfolio/AntiPortfolio.aspx.

cess: once the decision to invest is made, these venture capital investors frequently disburse funds in stages. The refinancing of these firms, termed "rounds" of financing, is made conditional on achieving certain technical or market milestones. Providing financing in this fashion allows the venture capital investor to gather more information before providing additional funding, thus helping investors begin to separate which investments are likely to be successful and which are likely to fail. Managers of the venture- and growth equity-backed firms have to return repeatedly to their financiers for additional capital, which allows the venture capitalists to ensure that the money is not squandered on unprofitable projects. Thus, an innovative idea only continues to be funded if its promoters are able to continue to execute, and, conversely, those projects that prove promising are able to access capital in a timely fashion.

Finally, venture capital investors also provide intensive oversight of the firms. Michael Gorman and Bill Sahlman (1989) found that venture capital investors who responded to their survey spent about half their time monitoring an average of nine portfolio investments and serving on the boards for five of those nine companies. They visited their companies relatively frequently and spent an average of eighty hours a year on site with the company on whose board they served. Frequent telephone conversations amounted to another thirty hours per year for each company. In addition, they worked on the company's behalf by attracting new investors, evaluating strategy against new conditions, and interviewing/recruiting new management candidates.

Interviews with venture capital investors and entrepreneurs suggest that the consequence of these tools is that venture capital investors play an important role in boosting the firms that they fund. Their assistance has several dimensions: accelerating growth, professionalizing and improving management practices, and ensuring long-run success (see, for instance, Gurung and Lerner 2008, 2009).

What prohibits other financial intermediaries (e.g., banks) from undertaking the same sort of monitoring? While it is easy to see why individual investors may not have the expertise to address these types of agency problems, it might be thought that bank credit officers could undertake this type of oversight. Yet even in countries with exceedingly well-developed banking systems, such as Germany and Japan, policymakers today are seeking to encourage the development of a venture capital industry to insure more adequate financing for risky entrepreneurial companies. The limitations of banks stem from several of their key institutional features, from regulations, skill sets, to compensation schemes.

7.2.3 Large-Sample Evidence

Clearly, venture capital exerts a major impact on the fates of individual companies. But does all this fundraising and investing influence the overall

economic landscape as well? How could it even be determined whether such an influence exists? And if it did exist, how would it be measured?

To assess this question, we can look at studies of the experience of the market with the most-developed and seasoned venture capital industry, the United States. Despite the fact that venture activity is particularly well developed in this nation, the reader might be skeptical as to whether this activity would noticeably impact innovation: for most of past three decades, investments made by the entire venture capital sector totaled less than the R&D and capital-expenditure budgets of large, individual companies such as IBM, General Motors, or Merck. On the face of it, this suggests the business press has exaggerated the importance of the venture capital industry. After all, high-tech start-ups make for interesting reporting, but do they really redefine the U.S. economy?

One way to explore this question is to examine the impact of venture investing on wealth, jobs, and other financial measures across a variety of industries. Though it would be useful to track the fate of *every* venture capital-financed company and find out where the innovation or technology ended up, in reality, only those companies that have gone public can be tracked. Consistent information on venture-backed firms that were acquired or went out of business simply doesn't exist. Moreover, investments in companies that eventually go public yield much higher returns than support given to firms that get acquired or remain privately held.

These firms have had an unmistakable effect on the U.S. economy. In September 2008, 895 firms were publicly traded on U.S. markets after receiving their private financing from venture capitalists (this does not include the firms that went public but were subsequently acquired or delisted). One way to assess the overall impact of the venture capital industry is to look at the economic "weight" of venture-backed companies in the context of the larger economy.[4] By late 2008, venture-backed firms that had gone public made up over 13 percent of the total number of public firms in existence in the United States at that time. And of the total market value of public firms ($28 trillion), venture-backed companies came in at $2.4 trillion—8.4 percent.

Venture-funded firms also made up over 4 percent (nearly one trillion dollars) of total sales ($22 trillion) of all U.S. public firms at the time. And contrary to the general perception that venture-supported companies are not profitable, operating income margins for these companies hit an average of 6.8 percent—close to the average public-company profit margin of 7.1 percent. Finally, those public firms supported by venture funding employed 6 percent of the total public-company workforce—most of these jobs high-salaried, skilled positions in the technology sector. Clearly, venture investing fuels a substantial portion of the U.S. economy.

4. This analysis is based on the author's tabulation of unpublished data from Securities Data Company (SDC) Venture Economics, with supplemental information from Compustat and the Center for Research into Securities Prices (CRSP) databases.

Venture investing not only supports a substantial fraction of the U.S. economy, but it also strengthens particular industries. To be sure, it has relatively little impact on industries dominated by mature companies—such as the manufacturing industries. That's because venture investors' mission is to capitalize on revolutionary changes in an industry, and the preceding sectors often have a relatively low propensity for radical innovation.

But contrast those industries with highly innovative ones, and the picture looks completely different. For example, companies in the computer software and hardware industry that received venture backing during their gestation as private firms represented more than 75 percent of the software industry's value. Venture-financed firms also play a central role in the biotechnology, computer services, and semiconductor industries. All of these industries have experienced tremendous innovation and upheaval in recent years. Venture capital has helped catalyze change in these industries, providing the resources for entrepreneurs to generate substantial return from their ideas. In recent years, the scope of venture groups' activity has been expanding rapidly in the critical energy and environmental field, though the impact of these investments remains to be seen.

As these statistics suggest, venture capitalists create whole new industries and seed fledgling companies that later dominate those industries. The message is clear: the venture capital revolution served as the driving force behind the transformation of the U.S. economy in recent decades.

It might be thought that it would be not difficult to address the question of the impact of venture capital on innovation. For instance, one could seek to explain across industries and time whether, controlling for R&D spending, venture capital funding has an impact on various measures of innovation. But even a simple model of the relationship between venture capital, R&D, and innovation suggests that this approach is likely to give misleading estimates.

This is because both venture funding and innovation could be positively related to a third unobserved factor, the arrival of technological opportunities. Thus, there could be more innovation at times that there was more venture capital, not because the venture capital caused the innovation, but rather because the venture capitalists reacted to some fundamental technological shock that was sure to lead to more innovation. To date, only two papers have attempted to address these challenging issues.

The first of these papers, by Thomas Hellmann and Manju Puri (2000), examines a sample of 170 recently formed firms in Silicon Valley, including both venture-backed and nonventure firms. Using questionnaire responses, they find evidence that venture capital financing is related to product market strategies and outcomes of start-ups. They find that firms that are pursuing what they term an innovator strategy (a classification based on the content analysis of survey responses) are significantly more likely and faster to obtain venture capital. The presence of a venture capitalist is also associated with a significant reduction in the time taken to bring a product to market,

especially for innovators (probably because these firms can focus more on innovating and less on raising money). Furthermore, firms are more likely to list obtaining venture capital as a significant milestone in the life cycle of the company as compared to other financing events.

The results suggest significant interrelations between investor type and product market dimensions and a role of venture capital in encouraging innovative companies. But this does not definitively answer the question of whether venture capitalists cause innovation. For instance, we might observe personal injury lawyers at accident sites, handing out business cards in the hopes of drumming up clients. But just because the lawyer is at the scene of the car crash does not mean that he caused the crash. In a similar vein, the possibility remains that more innovative firms choose to finance themselves with venture capital, rather than venture capital causing firms to be more innovative.

In my work with Sam Kortum, I visit the same question. Here, we look at the aggregate level: did the participation of venture capitalists in any given industry over the past few decades lead to more or less innovation? It might be thought that such an analysis would have the same problem as the preceding personal injury lawyer story. Put another way, even if we see an increase in venture funding and a boost in innovation, how can we be sure that one caused the other?

We address these concerns about causality by looking back over the industry's history. In particular, as we discussed in the preceding, a major discontinuity in the recent history of the venture capital industry was the U.S. Department of Labor's clarification of the Employee Retirement Income Security Act (ERISA) in the late 1970s, a policy shift that freed pensions to invest in venture capital. This shift led to a sharp increase in the funds committed to venture capital. This type of external change should allow us to figure out what the impact of venture capital was because it is unlikely to be related to how many or how few entrepreneurial opportunities there were to be funded.

Even after addressing these causality concerns, the results suggest that venture funding does have a strong positive impact on innovation. The estimated coefficients vary according to the techniques employed, but, on average, a dollar of venture capital appears to be *three to four* times more potent in stimulating patenting than a dollar of traditional corporate R&D. The estimates, therefore, suggest that venture capital, even though it averaged less than 3 percent of corporate R&D in the United States from 1983 to 1992, is responsible for a much greater share—perhaps 10 percent—of U.S. industrial innovations in this decade.

A natural worry with the preceding analysis is that it looks at the relationship between venture capital and patenting, not venture capital and innovation. One possible explanation is that such funding leads entrepreneurs to protect their intellectual property with patents rather than other mecha-

nisms such as trade secrets. For instance, it may be that the entrepreneurs can fool their venture investors by applying for large number of patents, even if the contributions of many of them are very modest. If this is true, it might be inferred that the patents of venture-backed firms would be lower quality than nonventure-backed patent filings.

How could this question of patent quality be investigated? One possibility is to check the number of patents that cite a particular patent.[5] Higher-quality patents, it has been shown, are cited by other innovators more often than lower-quality ones. Similarly, if venture-backed patents are lower quality, then companies receiving venture funding would be less likely to initiate patent-infringement litigation. (It makes no sense to pay money to engage in the costly process of patent litigation to defend low-quality patents.)

So what happens when patent quality is measured with these criteria? As it happens, the patents of venture-backed firms are more frequently cited by other patents and are more aggressively litigated—thus, it can be concluded that they are high quality. Furthermore, the venture-backed firms more frequently litigate trade secrets, suggesting that they are not simply patenting frantically in lieu of relying on trade-secret protection. These findings reinforce the notion that venture-supported firms are simply more innovative than their nonventure-supported counterparts.

Mollica and Zingales (2007), by way of contrast, focus on regional patterns: as a regional unit, they use the 179 Bureau of Economic Analysis economic areas, which are composed by counties surrounding metropolitan areas. They exploit the regional, cross-industry, and time series variability of venture investments in the United States to study the impact of venture capital activity on innovation and the creation of new businesses. Again, they grapple with causality issues by using an instrumental variable: as an instrument for the size of venture capital investments, they use the size of a state pension fund's assets. The idea is that state pension funds are subject to political pressure to invest some of their funds in new businesses in the states. Hence, the size of the state pension fund triggers a shift in the local supply of venture capital investment, which should help identify the effect of venture capital on patents.

Even with these controls, they find that venture capital investments have a significant positive effect both on the production of patents and on the creation of new businesses. A one standard deviation increase in the venture capital investment per capita generates an increase in the number of patents between 4 and 15 percent. An increase of 10 percent in the volume of venture capital investment increases the total number of new businesses by 2.5 percent.

5. Patent applicants and examiners at the patent office include references to other relevant patents. These serve a legal role similar to that of property markers at the edge of a land holding.

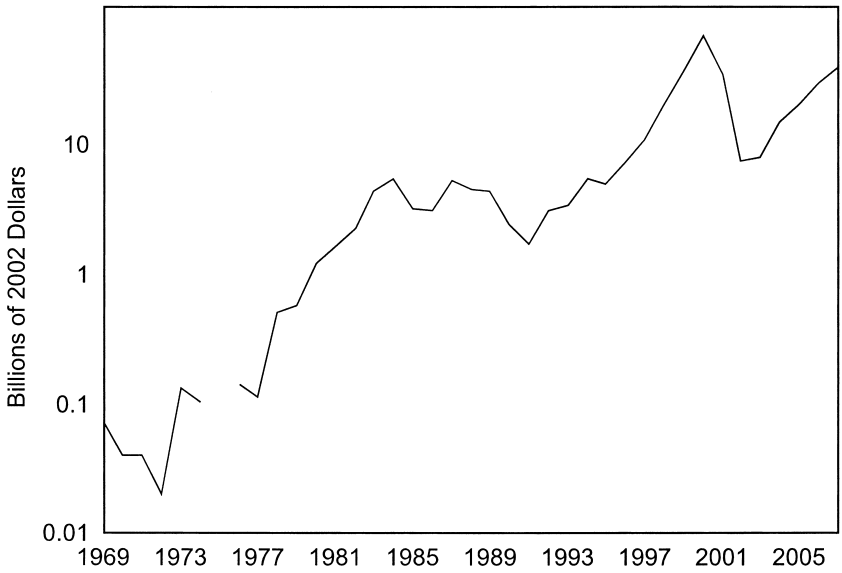

Fig. 7.1 Venture capital fundraising by year, 1969–2007

Source: The figure is based on unpublished Asset Alternatives and Venture Economics databases.

Note: There was no venture fundraising in 1975.

7.3 Cyclicality in the Venture Capital Industry

But venture capital also is far from a seamless and steady way to fund innovation, as our opening discussion suggested. The recent changes in the venture capital market are not the first such cycles in the venture market. Figures 7.1 and 7.2 depict the changing amount of venture capital funds raised and the returns from these funds. In this section, we will explore what accounts for such extreme variations.

7.3.1 A Simple Framework

To help understand the dynamics of the venture capital industry, it is helpful to employ a simple framework.[6] The two critical elements for understanding shifts in venture capital fundraising are straightforward: a demand curve and a supply curve. Just as in markets for commodities like oil and semiconductors, shifts in supply and demand shape the amount of capital raised by venture funds. These also drive the returns that investors earn in these markets.

The supply of venture capital is determined by the willingness of investors

6. The supply and demand framework for analyzing venture capital discussed here was introduced in Poterba (1989) and refined in Gompers and Lerner (1998).

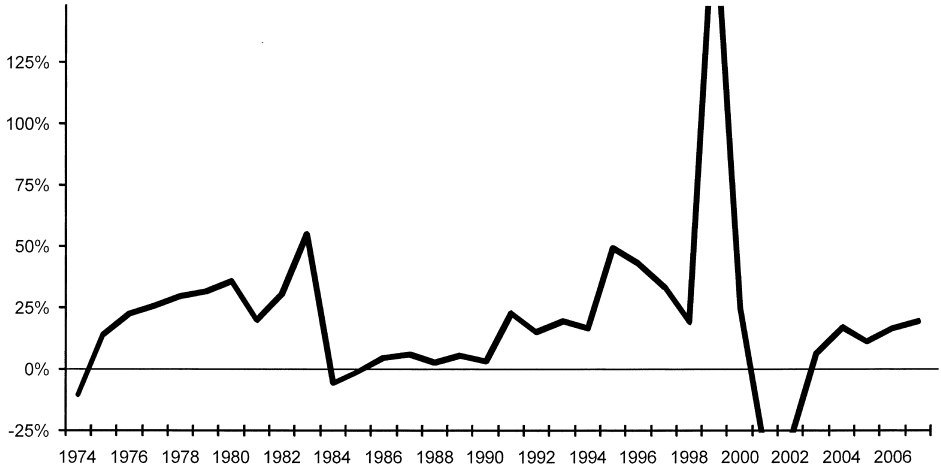

Fig. 7.2 Returns to venture capital investments, 1974–2007
Source: The figure is based on an unpublished Venture Economics database.

to provide funds to venture firms. The willingness of investors to commit money to venture capital funds, in turn, is dependent upon the expected rate of return from these investments relative to the return they expect to receive from other investments. Higher expected returns lead to a greater desire of investors to supply venture capital. As the return that investors expect to earn from their venture investments increases—that is, as we go up the vertical axis—the amount supplied by investors grows (we move further to the right column, the horizontal axis).

The number of entrepreneurial firms seeking venture capital determines the demand for capital. Demand is also likely to vary with the rate of return anticipated by investors. As the minimum rate of return sought by the investors increases, fewer entrepreneurial firms can meet that threshold. The demand schedule typically slopes downward: higher return expectations lead to fewer financeable firms because fewer entrepreneurial projects can meet the higher hurdle.

Together, supply and demand should determine the level of venture capital in the economy. This is illustrated in figure 7.3. The level of venture capital should be determined by where the two lines—the supply curve (S) and the demand curve (D)—meet. Put another way, we would expect a quantity Q of venture capital to be raised in the economy, while the funds to earn a return of R, on average.

It is natural to think of supply and demand curves as smooth lines. But this is not always the case. Consider, for instance, the venture capital market before Department of Labor's clarification of the "prudent man" rule of the ERISA in 1979. The willingness of investors to provide capital before the

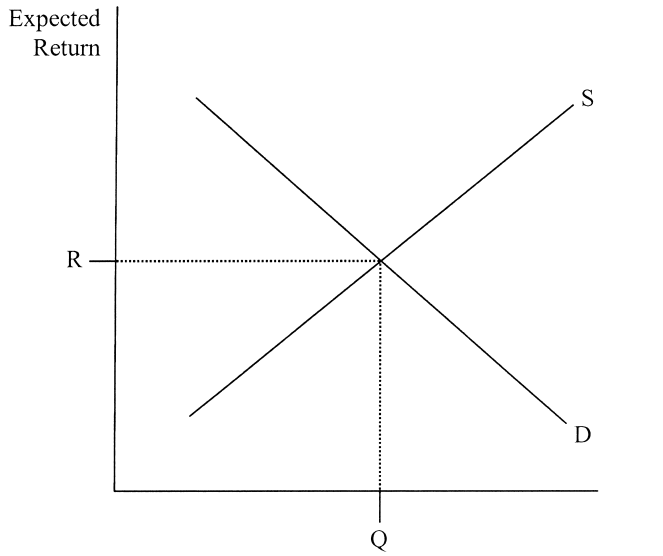

Fig. 7.3 Steady-state level of venture capital

clarification of ERISA policies looked like the supply curve may be been distinctly limited: no matter how high the expected rate of return for venture capital was, the supply would be limited to a set amount. The vertical segment of the supply curve resulted because pension funds, a segment of the U.S. financial market that controlled a substantial fraction of the long-term savings, were simply unable to invest in venture funds. Consequently, the supply of venture capital may have been limited at any expected rate of return.

7.3.2 The Impact of Shifts

These supply and demand curves are not fixed. For instance, the shift in ERISA policies led to the supply of funds moving outward. Similarly, major technological discoveries, such as the development of genetic engineering, led to an increase in the demand for venture capital.

But the quantity of venture capital raised and the returns it enjoys often do not adjust quickly and smoothly to the changes in supply and demand curves. We can illustrate this by comparing the venture capital market to that for snack foods. Companies like Frito-Lay and Nabisco closely monitor the shifting demand for their products, getting daily updates on the data collected in supermarket scanners. They restock the shelves every few days, adjusting the product offering in response to changing consumer tastes. They

can address any imbalances of supply and demand by offering coupons to consumers or making other special offers.

By way of contrast, in the venture market, the quantity of funds provided may not shift rapidly. The adjustment process is often quite slow and uneven, which can lead to substantial and persistent imbalances. When the quantity provided does react, the shift may "overshoot" the ideal amount and lead to yet further problems.

This can be illustrated again using our framework. It is important to distinguish here between short-and long-run curves. While in the long run, the curve may have a smooth upward slope, the short-run curve may be quite different. The long-run supply curve (*SL*) may have a smooth upward slope. But the supply in the short run may be essentially fixed if investors cannot or will not adjust their allocations to venture capital funds. Thus, the short-run curve may instead be a vertical line (*SS*).

This difference is illustrated figure 7.4, which explores the short- and long-run impact of a positive demand shock. The discovery of a new scientific approach, such as genetic engineering, or the diffusion of a new technology, such as the transistor or the Internet, may have a profound effect on the venture capital industry. As large companies struggle to adjust to these new technologies, numerous agile small companies may seek to exploit the opportunity. As a result, for any given level of return demanded by investors, there now may be many more attractive investment candidates.

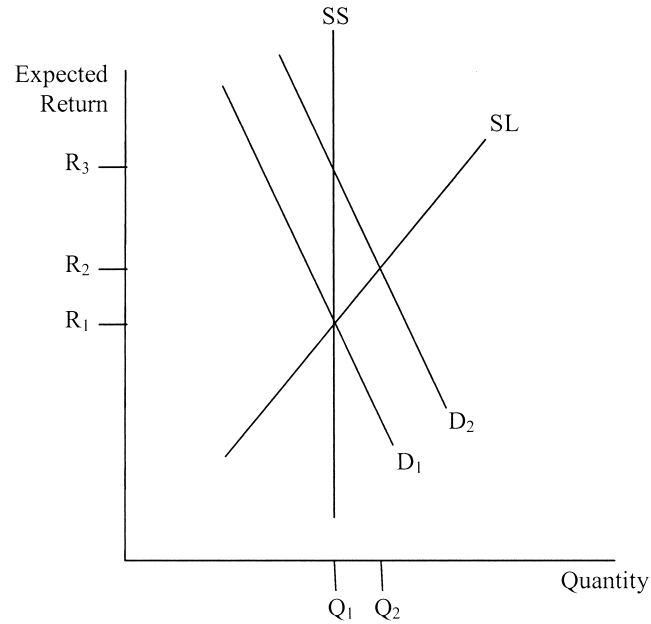

Fig. 7.4 Impact on quantity of a demand shock

In the long run, the quantity of venture capital provided will adjust upward from Q_1 to Q_2. Returns will also increase, from R_1 to R_2. In the months or even years after the shock, however, the amount of venture capital available may be essentially fixed. Instead of leading to more companies being funded, the return to the investors may climb dramatically, up to R_3. Only with time will the rate of return gradually subside as the supply of venture capital adjusts.

There are at least two factors that might lead to such short-run rigidities. These are the structure of the funds themselves and the slowness with which information on performance is reported back to investors. We will explore how each factor serves to dampen the speed with which the supply of venture capital adjusts to shifts in demand.

The Nature of Venture Funds

When investors wish to increase their allocation to public equities or bonds, this change is easily accomplished. These markets are "liquid": shares can be bought and sold easily, and adjustments in the level of holdings can be readily accomplished. The nature of venture capital funds, however, makes these kind of rapid adjustments much more difficult.

Consider an instance where a university endowment decides that venture capital is a particularly attractive investment class and decides to increase its allocation to these investments. From the time at which this new target is agreed upon, it is likely to be several years before the policy is fully implemented. Because venture funds only raise funds every two or three years, if the endowment simply wants to increase its commitment to existing funds, they will need to wait until the next fundraising cycle occurs for these funds. In many cases, they may be unable to invest as much in the new funds as they wish.

The reluctance of venture groups to accept their capital stems from the fact that the number of experienced venture capitalists often adjusts more slowly than the swings in capital. Many of the crucial skills of being an effective venture capitalist cannot be taught formally: rather, they need to be developed through a process of apprenticeship. Furthermore, the organizational challenges associated with rapidly increasing the size of a venture partnership are often wrenching ones. Thus, groups such as Kleiner Perkins and Greylock have resisted rapidly increasing their size even if investor demand is so great that they could easily raise many billions of dollars.

If, indeed, the endowment decides to undertake a strategy of investing in new funds, potential candidates for the university's funds will need to be exhaustively reviewed. Once the funds are chosen, the investments will not be made immediately. Rather, the capital that the university commits will only be drawn down in stages over a number of years.

The same logic works in reverse. If the endowment or pension officers decide to scale back their commitment to private equity, it is likely to take a

number of years to do so. An illustration of this stickiness was seen following the stock market correction of 1987. Many investors, noting the extent of equity market volatility and the poor performance of small high-technology stocks, sought to scale back their commitments to venture capital. Despite the correction, flows into venture capital funds continued to rise, not reaching their peak until the last quarter of 1989.[7]

Another contributing factor is self-liquidating nature of venture funds. When venture funds exit investments, they do not reinvest the funds but, rather, return the capital to their investors. These distributions are typically either in the form of stock in firms that have recently gone public or cash. The pace of distributions varies with the rate at which venture capitalists are liquidating their holdings.

Thus, during "hot" periods with large numbers of initial public offerings and acquisitions—which are likely to be the times when many investors desire to increase their exposure to venture capital—limited partners receive large outflows from venture funds. Even to maintain the same percentage allocation to venture funds during these peak periods, the institutions and individuals must accelerate their rate of investment. Increasing their exposure is consequently quite difficult. Conversely, during "cold" periods, when investors are likely to wish to reduce their allocation to this asset class, they receive few distributions. Thus, it is often difficult to achieve a desired exposure to venture capital during periods of rapid change in the market.

The Role of Information Lags

A second factor contributing to the stickiness of the supply of venture capital is the difficulty in discerning what the current status of the venture market is at any given time. While mutual and hedge funds holding public securities are "marked to market" on a daily basis, the delays between the inception of a venture investment and the discovery of its quality is long indeed.

The information lags can have profound effects. For instance, when the investment environment becomes far more attractive, it can take a number of years to fully realize the fact. While investments in Internet-related securities in the mid-1990s yielded extremely high returns, it took many years for the bulk of institutional investors to realize the size of the opportunity. Similarly, when the investment environment becomes substantially less attractive, as it did during the spring of 2000, investors often continue to plough money into funds. (see, for instance, the discussion in Kreutzer [2001].)

Some of these information problems stem from the firms themselves. The types of firms that attract venture capital are surrounded by substantial uncertainty and information gaps. But these inevitable difficulties are exacerbated by the manner in which the performance of funds is typically reported.

7. This claim is based on an analysis of an unpublished Venture Economics database.

The first of these is the conservatism of the valuations. Venture groups tend to be extremely conservative in reporting how much the firms they invest in are worth, at least until the firms are taken public or acquired. While this limits the danger that investors will be misled into thinking that the funds is doing better than it actually is, this practice minimizes the information flow about the current state of the market.[8]

This reporting practice, for instance, must lead us to be cautious in evaluating the returns depicted in figure 7.2. Because relatively few firms get taken public during "cold" markets and many do during "hot" ones, there are many more dramatic write-ups in firms during the years with active public markets. But the actual value-creation process in venture investments is quite different. In many cases, the value of a firm actually increases gradually over time, even as it is being held at cost. Thus, the low returns during cold periods understate the progress that is being made, just as the high returns during the peak periods overstate the success during those years. Thus, the signals that venture groups receive are quite limited.

An Illustration

The preceding discussion ignores many of the complex institutional realities that affect the ebbs and flows of venture capital fundraising. But even such simple tools can be quite helpful in understanding overall movements in the venture capital activity, as can be illustrated by considering the recent history of the venture capital industry.

As figure 7.1 illustrates, the supply of venture funding began growing rapidly in the mid-1990s. Many practitioners at the time viewed this event glumly, arguing that a boost in venture activity must inevitably lead to a deterioration of returns. Yet the investments during this period enjoyed extraordinary success, as figure 7.2 illustrates. How could these seasoned observers have been so wrong?

The reason is that these years saw a dramatic shift in the opportunities available to venture capital investors. The rapid diffusion of Internet access and the associated development of the World Wide Web ushered in an extraordinary period in the U.S. economy. The ability to transfer visual and text information in a rapid and interactive manner was a powerful tool, one that would transform both retail activities as well as the internal management of firms.

Such a change led to an increase in the demand for venture capital financing. Thus, for any given level of return that investors demanded, there should have been a considerably greater number of opportunities to fund. Far from declining, the rate of return that venture investments enjoyed actually rose. Much of this rise reflected the fact that the supply of effective and cred-

8. The problems with the accounting schemes used by venture capital groups are discussed in Cain (1997), Gompers and Lerner (1997), and Reyes (1990).

ible venture organizations adjusted only slowly. As a result, those groups who were active in the market during this period enjoyed extraordinary successes.

7.3.3 Why Does the Venture Market Overreact?

Another frequently discussed pathology in the venture market is the other side of the same coin. Once the markets do adjust to the changing demand conditions, they frequently go too far. The supply of venture capital ultimately will rise to meet the increased opportunities, but these shifts often are too large. Too much capital may be raised for the outstanding amount of opportunities. Instead of shifting to the new steady-state level, the short-term supply curve may shift to an excessively high level.

The same problem can occur in reverse. A downward shift in demand can trigger a wholesale withdrawal from venture capital financing. Returns rise dramatically as a result. While the supply of venture capital will ultimately adjust, in the interim, promising companies may not be able to attract funding. In this section, we explore two possible explanations for this phenomenon.

Do Public Markets Provide Misleading Information?

One possibility is that institutional investors and venture capitalists may overestimate the shifts that have occurred. They may believe that there are tremendous new opportunities and, consequentially, shift the supply of venture capital to meet that apparent demand.

This suggestion is captured in figure 7.5. A positive shock to the demand for venture capital occurs, moving the demand curve out from D_1 to D_2. Limited and general partners, however, mistakenly believe that the curve has shifted out to D_3. The short-run supply curve thus shifts from SS_1 to SS_3, leaving excessive investment and disappointing returns in its wake.

Such mistakes may arise because of misleading information from the public markets. Examples abound where venture capitalists have made substantial investments in new sectors, at least partially responding to the impetus provided by the high valuations in that sector. Understanding why public markets overvalue particular sectors is beyond the scope of this piece. Certainly, though, it seems in some cases that investors fail to take into account the impact of competitors: firms appear to be valued as if they are the sole firm active in a sector, and the impact of competitors on revenues and profit margins are not fully anticipated.

Whatever the causes of these misvalautions, historical illustrations are plentiful. One famous example was during the early 1980s, when nineteen disk drive companies received venture capital financing. (For detailed discussions, see Sahlman and Stevenson [1985] and Lerner [1997].) Two-thirds of these investments came in 1982 and 1983, as the valuation of publicly traded computer hardware firms soared. Many disk drive companies also

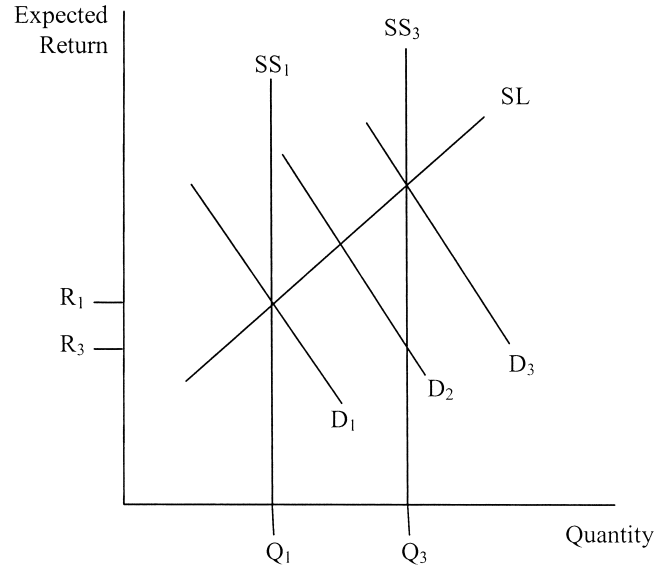

Fig. 7.5 Misleading public market signals

went public during this period. While industry growth was rapid during this period of time (sales increased from $27 million in 1978 to $1.3 billion in 1983), it was questioned at the time whether the scale of investment was rational given any reasonable expectations of industry growth and future economic trends. Indeed, between October 1983 and December 1984, the average public disk drive firm lost 68 percent of its value. Numerous disk drive manufacturers that had yet to go public were terminated, and venture capitalists became very reluctant to fund computer hardware firms.

Unreasonable swings in the public markets may also lead to over- and underinvestment in venture capital as a whole. Institutions typically try to keep a fixed percentage of their portfolio invested in each asset class. Thus, when public equity values climb, institutions are likely to want to allocate more to venture capital. If the high valuations are subsequently revealed to be without foundations, the level of venture capital will have once again overshot its target.

Do Venture Capitalists Underestimate the Cost of Change?

A second explanation for the "overshooting" phenomenon is venture capitalists' failure to consider the costly adjustments associated with the growth of their own investment activity. The very act of growing the pool of venture capital under management may cause distractions and introduce organizational tensions. Even if demand has expanded, the number of opportunities that a venture group—or the industry as a whole—can address may at first be limited.

Why might these adjustment costs come about? One possibility is that growth frequently leads to changes in the way in which venture groups invest their capital, which has a deleterious effect on returns. A second possibility is that growth introduces strains on the venture organization itself.

First, consider the types of pressures that rapid growth imposes on the venture investment process. Rather than making more investments, rapidly growing venture organizations frequently attempt to increase their average investment size. In this way, the same number of partners can manage a larger amount of capital without an increase in the number of firms that each needs to scrutinize. This shift to larger investments has frequently entailed making larger capital commitments to firms up-front. This has the potential cost of reducing the venture capitalist's ability to control the firm using staged capital commitments.

Similarly, venture firms syndicate less with their peers during these times. By not syndicating, venture groups can put more money to work. As the sole investor, the venture groups can allow each of its partners to manage more capital while keeping the number of companies that he or she is responsible for down to a manageable level. But this syndication can have a number of advantages, such as helping reduce the danger of costly investment mistakes.

Another set of explanation factors relates to organizational pressures. Limited and general partners may underestimate the consequences of expanding the scale (and the scope) of the fund. An essential characteristic of venture capital organizations has been the speed with which decisions can be made and the parallel incentives that motivate the parties. An expansion of the fund can lead to a fragmentation of the bonds that tie the partnership into a cohesive whole.

One dramatic illustration of these challenges is the experience of Schroder Ventures (Bingham, Ferguson, and Lerner 1996). Schroders' private equity effort began in 1985 with funds focused on British venture capital and buyout investments. Over time, however, they added funds focusing on other markets, such as France and Germany, and particular technologies, such as the life sciences. The venture capitalists—and the institutional investors backing them—realized that there were substantial opportunities in these other markets.

But as the venture organization grew, substantial management challenges emerged. In particular, it became increasingly difficult to monitor the investment activities of each of the groups, a real concern because the parent organization served as the general partner of each of the funds (and, thus, was ultimately liable for any losses). Each of the groups saw itself as an autonomous entity, and even in some cases resisted cooperating (and sharing the capital gains) with the others. While the organization eventually completed a restructuring that allowed it to raise a single fund for all of Europe, the process of change was a slow and painful one.

These tensions are by no means confined to international venture capital

organizations. Very similar tensions have appeared in U.S. rapidly growing groups between general partners specializing in life science and information technology and those located in different regions. In some instances, one of these groups has become convinced that the other is getting a disproportionate share of rewards in light of their relative investment performances. In others, it has become difficult to coordinate and oversee activities.

In some cases, these tensions have led to groups splitting apart. For instance, in August 1999, Institutional Venture Partners and Brentwood Venture Capital—venture funds that had each invested about one billion dollars over several decades—announced their intention to restructure (Barry and Toll 1999). The information technology and life sciences venture capitalists from the two firms indicated that they would join with each other to form two new venture capital firms. Pallidium Venture Capital would exclusively pursue health care transactions, while Redpoint Ventures would focus on Internet and broadband infrastructure investments. Press accounts suggested the decision was largely driven by the dissatisfaction of some of the information technology partners at the firms, who felt that their stellar performance had not been appropriately recognized.

In other cases, a key partner—often dissatisfied with his or her role or compensation—has departed a venture group, entailing a real disruption to the organization. For instance, Ernest Jacquet left to form Parthenon Ventures shortly after Summit Partners closed on a $1 billion buy-out fund ("Summit's Jacquet . . ." 1998). While it is very rare for investors to demand that their funds be returned—though, for instance, Foster Capital Management returned $200 million after the several junior partners departed in 1998—these defections can, nonetheless, affect the workings and continuity of these groups ("Foster Management . . ." 1998).

In short, rapid growth puts severe pressures on venture capital organizations. Even when the problems do not result in an extreme outcome such as a group dissolving, the demands on the partners' time in resolving these problems have often been substantial. Thus, during periods of rapid growth, venture capital groups may correctly observe that there are many more opportunities to fund. Rapidly expanding to address these opportunities may be counterproductive, however, and lead to disappointing returns.

7.4 Venture Capital and Alternative Energy

Before turning to the implications for policymakers, it is worth noting that in past few years, there has been a classic boom in venture investment in alternative energy. This has reflected the fact that the cost of energy has been very high. Despite earlier disappointments, in recent years, investment has surged in the sector, and the environment has become one that is more favorable for ventures in clean energy development.

From 2004 to 2007, investment in clean energy saw a huge surge, increas-

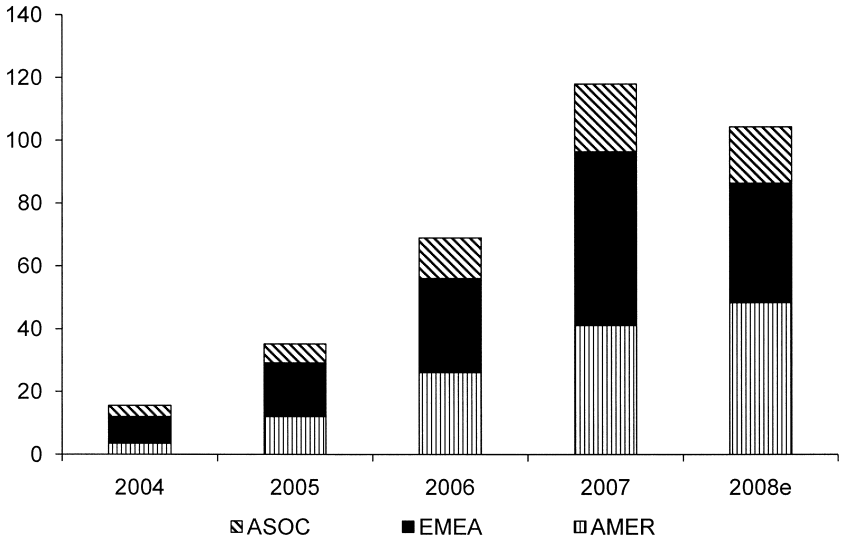

Fig. 7.6 Clean energy investment ($ in billions) by geography, 2004–2008

Source: World Economic Forum (2009).

Notes: Totals are extrapolated values based on disclosed deals from the New Energy Finance Industry Intelligence database. They do not include R&D or small projects, which is why the total in this chart is lower than the total new investment shown in other charts. ASOC-Asia Oceania region; EMEA-Europe Middle East Africa region; AMER-Americas region.

ing nearly fivefold. As recently as five years ago, venture investment in clean energy meant wind projects, mostly in Denmark, Germany, and Spain (see figure 7.6). The four-year surge in investment activity spanned all sectors, all geographies, and all asset classes, and as a result, the clean energy financing spectrum is well-developed, from very early stage investment in emerging technologies, right through to large established companies raising money on the public markets (figures 7.7 and 7.8). In the United States, investment in clean energy projects has grown dramatically in the past decade, surpassing the $13 billion mark in 2007.

This has been true not just for large firms, but also for new ventures. In 2007 alone, venture capital investment in clean energy technology companies was $2.5 billion, up from $30 million in 2001.[9]

It is important to note, however, that while the 2008 total is down only slightly from 2007 ($142 billion compared to the $148 billion in the previous year), a strong start may disguise a much weaker second half of the year due to the impact of the global financial crisis. In 2008, approximately 80 percent ($104 billion) of funding was provided by third-party investors such as venture capital and private equity, asset managers, and banks.

9. See U.S. Department of Energy (2008).

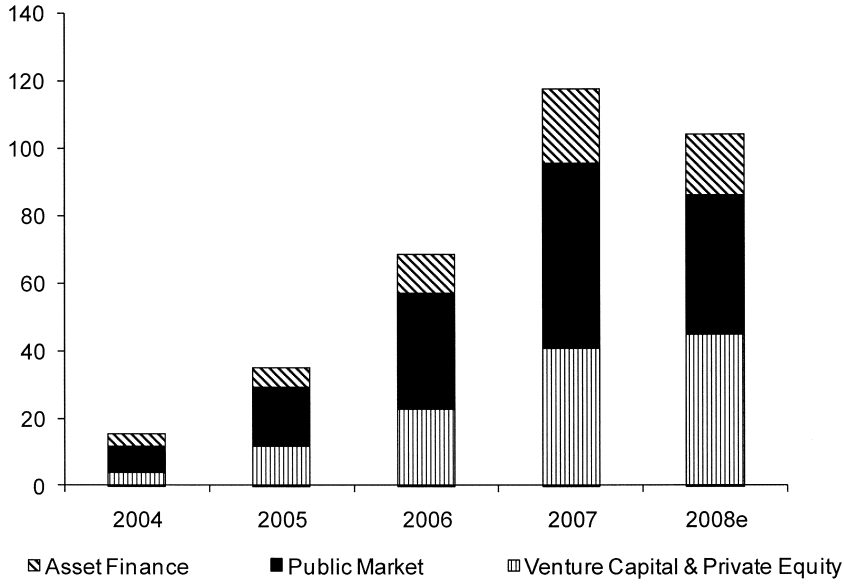

Fig. 7.7 Clean energy investment ($ in billions) by asset class, 2004–2008

Source: World Economic Forum (2009).

Notes: Totals are extrapolated values based on disclosed deals from the New Energy Finance Industry Intelligence database. They exclude R&D and small projects.

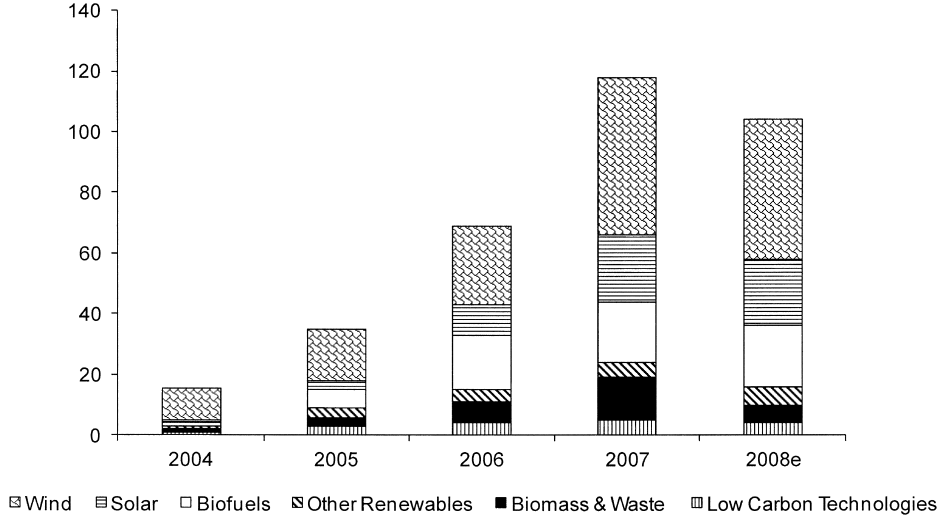

Fig. 7.8 Clean energy investment ($ in billions) by sector, 2004–2008

Source: World Economic Forum (2009).

Notes: Totals are extrapolated values based on disclosed deals from the New Energy Finance industry Intelligence database. They exclude R&D and small projects. Other Renewables includes geothermal and mini-hydro; Low Carbon Technologies includes energy efficiency fuels and power storage.

In 2005, wind was the dominant sector attracting venture capital investment. In 2006, biofuels attracted the highest venture capital investment, with the solar sector attracting the second highest amount. In 2007, 21 gigawatts of new wind capacity were added worldwide, an amount to half of new renewable energy capacity and over 11 percent of all new power generation capacity. Solar energy is now the fastest-growing sector and is a leader for venture capital investment. The development of large-scale solar projects in 2007 attracted $17.7 billion project financing, nearly a quarter of all new investment (up 250 percent from previous year). (See figure 7.9.)

The surge in investments has been reflected in the double-digit returns of these projects. In venture capital investments specifically, investors in clean technologies in Europe and the United States achieved excellent returns on their investments up to mid-2008, according to the third annual European Clean Energy Venture Returns Analysis (ECEVRA), completed by New Energy Finance in collaboration with the European Energy Venture Fair. The study is based on confidential returns by investors at the end of the first half of 2008 and covers 302 clean technology portfolio companies, representing €1.77 billion of venture capital invested in clean technology since 1997. Of these, 26 have so far resulted in public listings, and 32 have been exited or partially exited via trade sale. The success rate to date has been reasonably high with a pooled gross internal rate of return (IRR) (at the portfolio company level, not the fund level) for exited deals of over 60 percent, based on the limited number of exits and with only 23 companies being

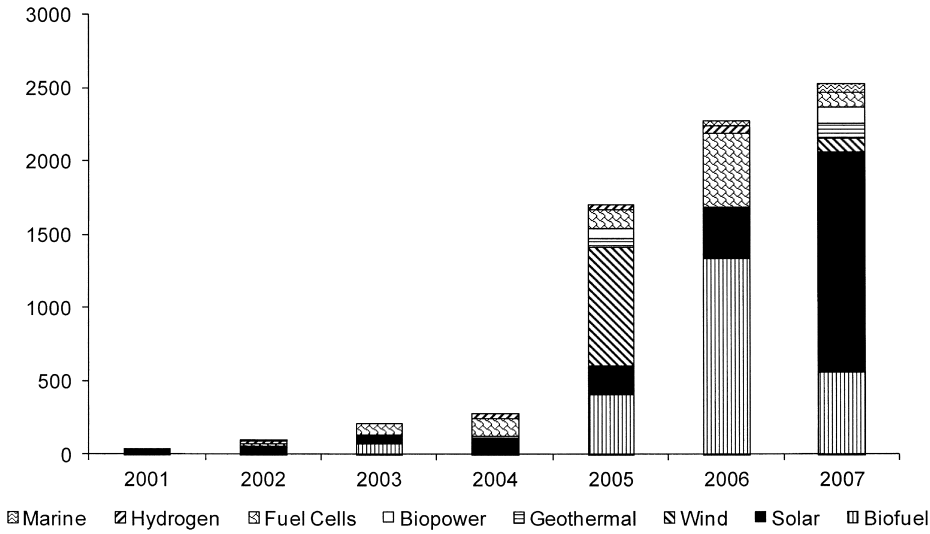

Fig. 7.9 Venture capital investment ($ in millions) in renewable energy technology companies, 2001–2007

Source: U.S. Department of Energy (2008).

Table 7.1 **Comparative IRR by year of study (%)**

	2006	2007	2008
Cumulative global overall IRR	49.3	43.9	61.1
Buy outs	n.d.	37.6	36.7
All venture	87.6	54.9	67.7
Europe	87.6	54.9	78.6
Europe excluding "Gorillas"	12.3	20.6	17.5
North America			7.5
All venture excluding "Gorillas"	12.3	20.6	14.5
All venture excluding "Gorillas" and recent investments held at book value	17.0	24.3	16.4

Source: New Energy Finance (2008).

Notes: n.d. = not disclosed. IRR = internal rate of return.

liquidated or written off at the time of the study. It is important to note that these exceptional returns were driven by the outstanding success of a small number of early investments in the solar sector—Q-Cells and REC in particular. Without these two particular investments, the pooled IRR was closer to 14 percent (see table 7.1). These patterns suggest some of the pattern of overfunding have been seen in this sector as well.

Looking ahead, one must consider the conditions that spawned such a surge in investment to understand the path that investment in the clean energy sector will take in the future. These extraordinary returns coincide with a new interest in all things green as well as historically cheap access to debt. The next few years will certainly be much harder for venture and private equity investors in the clean energy sector. The clean energy sector, like all other areas, has been affected by the financial crisis. Despite maintaining an estimated $14 billion of new investment thus far, excluding buy outs in 2008, and exceeding public market indices (S&P and NASDAQ), venture capital performance dropped sharply in the second quarter of 2008 (Thomson Reuters and the National Venture Capital Association [NVCA]). Venture exits in general have also fallen sharply.

Investment in the clean energy sector has suffered from three main causes. First, the industry suffered as a result of a 70 percent fall in energy prices. Second, the sector took a hit through the equity markets, as investors sold off stocks with any sort of technology or execution risk and went back to longer established businesses. Third, due to constrained credit, clean energy companies that require high capital were penalized.[10] The public markets which clean energy companies often used as a major source of fund raising, such as through initial public offerings (IPOs); secondary offerings, and convertible issues also dropped by 60 percent in 2008. (See table 7.2.)

10. See World Economic Forum (2009).

Table 7.2 Global clean energy investment, 2007–2008, US$ billion

Asset class	2007	2008 estimates	Change (%)
Venture capital/private equity	9.8	14.2	45
Public markets	23.4	9.4	60
Asset finance	84.5	80.6	5
Total	117.7	104.2	11

Source: World Economics Forum (2009).
Note: 2008 estimates are New Energy Finance preview figures published in October 2008.

The future of venture capital investment in the clean energy sector hinges upon two main conditions in the investing environment. The future of market conditions and the direction of government policy are two key factors in the future of clean energy sector.

Because of the nature of the higher up-front costs but lower fuel costs of clean energy projects, these projects are usually more sensitive to periods of higher interest rates or credit risk aversion. The present interest rates are a huge potential advantage for the clean energy sector. If credit markets ease—so far, banks are wary of lending capital in fear of default, and the Federal Reserve has not yet seen the results of its cheap debt—at some point, the clean energy projects could benefit tremendously, as cheap money flows into the system.

In addition, the McKinsey Global Institute notes that market and policy barriers such as lack of consumer education, fuel subsidies encouraging inefficient energy use, and asymmetrical benefits to tenants and landlords of investments in energy efficiency pose a threat.[11] As seen through the experience of Denmark and Japan, fully realizing energy efficiency opportunities requires a sustained supportive public policy. There is an opportunity to improve supply- and demand-side infrastructure. It can produce returns above cost of capital in major business. According to the report, $170 billion in energy efficient investment opportunities may have IRR of 17 percent or more.

The financial crisis also spawned changes in public policy toward the clean energy sector. For most policymakers, however, supporting the clean energy investment is seen as a way to combat the recession. In their policies of addressing urgent problems as well as long-term structural weaknesses in the economies, the clean energy sector will benefit.

If governments can lead by example, creating markets for clean energy through public procurement and mandating clean energy as well as enforcing energy efficiency standards, the investment in the clean energy sector will be bolstered and pose to be greatly profitable in the future. The suc-

11. See World Economic Forum (2009).

cess of venture investment in the clean energy sector depends heavily upon the kind of environment that governments develop for such investing. An entire ecosystem of supporting technology and service providers will be fundamental to the growth of a healthy clean energy sector—and this is inextricably linked to the ability of entrepreneurs and companies to create new businesses.[12]

7.5 The Consequences for Public Policy

While understanding the causes of cyclicality in the venture industry may be interesting, policymakers are much more likely to be interested in its consequences. In particular, to what extent do these changes affect the innovativeness of the U.S. economy?

In this section, we explore this question. We begin by considering the evidence regarding the cycles in the venture capital market on innovation. We highlight that while the overall relationship between venture capital and innovation is positive, the relationships across the cycles of venture activity may be quite different. We then consider the appropriate public policy response.

7.5.1 Innovation and Market Cycles

The evidence that venture capital has a powerful impact on innovation might lead us to be especially worried about market downturns. A dramatic fall in venture capital financing, it is natural to conclude, would lead to a sharp decline in innovation.

But this reasoning, while initially plausible, is somewhat misleading. For the impact of venture capital on innovation does not appear to be uniform. Rather, during periods when the intensity of investment is greatest, the impact of venture financing appears to decline. The uneven impact of venture on innovation can be illustrated with both case study and empirical evidence.

Field-Based Evidence

We have already discussed how in many instances the levels of funding during peak periods appear to "overshoot" the desired levels. Whether caused by the presence of misleading public market signals or the overoptimism on the part of the venture capitalists, funds appear to be deployed much less effectively during the boom period.

In particular, all too often these periods find venture capitalists funding firms that are too similar to one another.[13] The consequences of these exces-

12. See World Economic Forum (2009).

13. These results are also consistent with theoretical works in "herding" by investment managers. These models suggest that when, for instance, investment managers are assessed on the

sive duplication is frequently the same: highly duplicative research agendas, intense bidding wars for scientific and technical talent culminating with frequent defections from firm to firm, costly litigation alleging intellectual property and misappropriation of ideas across firms, and the sudden termination of funding for many of these concerns.

One example was the peak period of biotechnology investing in the early 1990s. While the potential of biotechnology to address human disease was doubtless substantial, the extent and nature of financing seemed to many observers at the time hard to justify. In some cases, dozens of firms pursuing similar approaches to the same disease target were funded. Moreover, the valuations of these firms often were exorbitant: for instance, between May and December 1992, the average valuation of the privately held biotechnology firms financed by venture capitalists was $70 million. These doubts were validated when biotechnology valuations fell precipitously in early 1993: by December 1993, only 42 of 262 *publicly traded* biotechnology firms had a valuation over $70 million.[14]

Most of the biotechnology firms financed during this period ultimately yielded very disappointing returns for their venture financiers and modest gains for society as a whole. In many cases, the firms were liquidated after further financing could not be arranged. In others, the firms shifted their efforts into other, less-competitive areas, largely abandoning the initial research efforts. In yet others, the companies remained mired with their peers for years in costly patent litigation.

The boom of 1998 to 2000 provides many additional illustrations. Funding during these years was concentrated in two areas: Internet and telecommunication investments, which, for instance, accounted for 39 percent and 17 percent of all venture disbursements in 1999. Once again, considerable sums were devoted to supporting highly similar firms—for example, the nine dueling Internet pet food suppliers—or else efforts that seemed fundamentally uneconomical and doomed to failure, such as companies that undertook the extremely capital-intensive process of building a second cable network in residential communities. Meanwhile, many apparently promising areas—for example, advanced materials, energy technologies, and micro manufacturing—languished unfunded as venture capitalists raced to focus on the most visible and popular investment areas. It is difficult to believe that the impact of a dollar of venture financing was as powerful in spurring innovation during these periods as in others.

basis of their performance relative to their peers (rather than against some absolute benchmark), they may end up making investments to similar to each other. For a review of these works, see Devenow and Welch (1996).

14. These figures are based on an analysis of an unpublished Venture Economics database.

Statistical Evidence

These suggestive accounts are borne out in a statistical analysis. Using the framework of Kortum and Lerner (2000), we show that the impact of venture capital on innovation was less pronounced during boom periods.

In this analysis, we analyze annual data for twenty manufacturing industries between 1965 and 1992. The dependent variable is U.S. patents issued to U.S. inventors by industry and date of application. Our main explanatory variables are measures of venture funding collected by Venture Economics and industrial R&D expenditures collected by the U.S. National Science Foundation (NSF).

To be sure, these measures are limited in their effectiveness. For instance, companies do not patent all commercially significant discoveries (though in the original paper, we show that the patterns appear to hold when we use other measures of innovation). Similarly, we are required to aggregate venture funding and patents into a twenty-industry scheme that is used by the NSF to measure R&D spending. Finally, our analysis must exclude the greatest boom period of all, the 1998 to 2000 surge (patent applications can only be observed with a considerable lag).

Table 7.3 presents our estimate of b, the influence of venture capital funding on patent applications, controlling for R&D spending, industry effects, and the year of the observation. Any number greater than 1 implies that venture capital is more powerful than traditional corporate R&D in spurring innovation. (This is a specification similar to regression [3.2] in that paper, with the addition of an added measure for the "hottest" periods.) We then show the implied coefficient when we estimate the impact of venture capital on innovation separately for those periods that had the great venture capital investments (defined here as the top 1 percent of industry-year observations). As the table reports, the impact of venture capital on innovation is

Table 7.3 Implied impact of venture capital on innovation

	Coefficient or p-value
Implied potency of venture financing, normal industry periods	13.57
Implied potency of venture financing, overheated industry periods	11.53
p-value, test of difference between normal and overheated industry periods	0.000

Source: Based on the linear patent production function estimated by Kortum and Lerner (2000).

Notes: The first row presents implied impact of venture financing on innovation for all manufacturing industries and years between 1965 and 1992 except where the levels of venture inflows are in the top 1 percent. The second row presents the implied coefficient during the industries and years where inflows are in the top 1 percent. The final row presents the *p*-value from a test that the two coefficients are identical.

some 15 percent lower during the boom periods, a difference that is strongly statistically significant.

As discussed in Kortum and Lerner (2000), the magnitude of the impact of venture capital on innovation diminishes—but remains positive and significant—when we control for reverse causality: the fact that technological breakthrough are likely to stimulate venture capital investments. When we repeat the analysis reported here using a number of these complex specifications, the magnitude of the difference between normal and boom periods remains similar, and the percentage difference widens. This statistical result corroborates the field study evidence suggesting that venture capital's impact on innovation is less pronounced during booms.

A Cautionary Note

These patterns may lead us to worry less about the short-run fluctuations in venture financing. While the impact on entrepreneurial activity is likely to be dramatic, the effects on innovation should be more modest.

This conclusion, however, must be tempered by the awareness of history: in some cases, surges in venture capital activity have been followed by pronounced and persistent downturns. As alluded to in the preceding, just as we can see "overshooting" by investors, so can we see prolonged "undershooting."

One sobering example was the 1970s. The late 1960s had seen record fundraising, both by independent venture groups and Small Business Investment Companies (SBICs), federally subsidized pools of risk capital. Many of the investments by the less-established venture groups failed in the subsequent recession, particularly those of the SBICs. (The selection process for these licenses appeared to emphasize political connections over investment acumen.) The poor returns generated a powerful reaction, leading both public and private market investors to be unwilling to contribute new capital.

Figure 7.10 depicts one consequence of the period of this reaction. The graph depicts the volume of initial and follow-on offerings in the sector that saw the greatest concentration of venture investments during this period: computer and computer-related firms. The amount of capital raised by these firms fell from $1.2 billion (in today's dollars) in 1968 to 1969 to just $201 million in the entire period from 1973 to mid-1978, with absolutely no financing being raised in many quarters. To be sure, many of the firms that raised capital during the boom years and then could not get refinanced had business plans that were poorly conceptualized or were in engaged in doomed battles with entrenched incumbents such as IBM. But many other firms seeking to commercialize many of the personal computing and networking technologies that would prove to have such a revolutionary impact in the 1980s and 1990s also struggled to raise the financing necessary to commercialize their ideas.

At the same time, it is important to note that while venture capital fund-

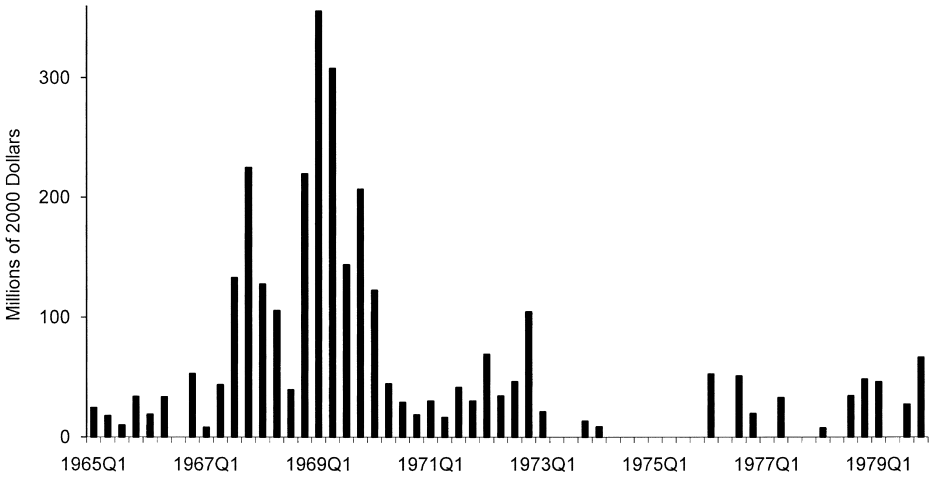

Fig. 7.10 Initial public offerings and seasoned equity offerings by computer and computer-related firms, by quarter, 1965–1979.
Sources: The authors compiled the information from *Investment Dealers' Digest,* the Securities Data Company database, and other sources.

raising and investment has cooled down considerably from the "white hot" days of 2000, the level of activity is still extremely high from a historical perspective. In fact, if we were to remove the 1999 to 2000 "bubble" period from figure 7.1, the venture industry has shown robust growth over the past decade. As a result, the rationale for government intervention to provide funding today seems slim, as we discuss in more detail in the following.

7.5.2 Implications for Government Officials

Government officials and policy advisors are naturally concerned about spurring innovation. Encouraging venture capital financing is an increasingly popular way to accomplish these ends: numerous efforts to spur such intermediaries have been launched in many nations in Asia, Europe, and the Americas. A comprehensive review of these programs, and the lessons that can be learned from them, is beyond the scope of this chapter.

Nonetheless, five lessons can be highlighted:[15]

- Governments around the world today are seeking to promote entrepreneurial and venture capital activity, employing a variety of "stage setting" and direct strategies.
- These steps are supported by the historical record and theoretical arguments regarding the importance of such interventions in the development of entrepreneurial regions and industries.

15. These lessons are drawn from Lerner (2009).

- But these efforts are challenging. Governments cannot dictate how a venture market will evolve, and top-down efforts are likely to be unsuccessful.
- The same common flaws doom far too many programs. These reflect both poor design—reflecting a lack of understanding of the entrepreneurial process—and problematic implementation.
- Government must play a careful balancing act, combining an understanding of the necessity of playing a catalytic role with an awareness of the limits of its ability to stimulate the entrepreneurial sector.

As we have highlighted, venture capital is an intensely cyclic industry, and the impact of venture capital on innovation is likely to differ in this cycle. Yet government programs have frequently been concentrated during the time periods when venture capital funds have been most active and often have targeted the very same sectors that are being aggressively funded by venture investors.

This type of behavior reflects the manner in which such policy initiatives are frequently evaluated and rewarded. Far too often, the appearance of a successful program is far more important than actual success in spurring innovation. For instance, many "public venture capital" programs, such as the Small Business Innovation Research (SBIR) and the Advanced Technology Program (ATP) initiatives, prepare glossy brochures full of "success stories" about particular firms. The prospect of such recognition may lead a program manager to decide to fund a firm in "hot" industry whose prospects of success may be brighter, even if the sector is already well funded by venture investors (and the impact of additional funding on innovation quite modest). To cite one example, the ATP launched major efforts to fund genomics and Internet tools companies during periods when venture funding was flooding into these sectors (Gompers and Lerner 1999).

By way of contrast, the Central Intelligence Agency's In-Q-Tel fund appears to have done a much better job of seeking to address gaps in traditional venture financing (Business Executives for National Security 2001). The SBIR program provides another contrasting example. Decisions as to whether finance firms are made not by centralized bodies but, rather, devolved in many agencies to program managers who are seeking to address very specific technical needs (e.g., an Air Force research administrator who is seeking to encourage the development of new composites). As a result, many off-beat technologies that are not of interest to traditional venture investors have been funded through this program.

A far more successful approach would be to address the gaps in the venture financing process. As noted in the preceding, venture investments tend to be very focused into a few areas of technology that are perceived to have great potential. Increases in venture fundraising—which are driven by factors such as shifts in capital gains tax rates—appear more likely to lead to

more intense competition for transactions within an existing set of technologies than to greater diversity in the types of companies funded. Policymakers may wish to respond to these industries' conditions by (a) focusing on technologies that are not currently popular among venture investors and (b) providing follow-on capital to firms already funded by venture capitalists during periods when venture inflows are falling.

More generally, the greatest assistance to venture capital may be provided by government programs that seek to enhance the demand for these funds, rather than the supply of capital. Examples would include efforts to facilitate the commercialization of early-stage technology, such as the Bayh-Dole Act of 1980 and the Federal Technology Transfer Act of 1986, both of which eased entrepreneurs' ability to access early-stage research. Similarly, efforts to make entrepreneurship more attractive through tax policy (e.g., by lowering tax rates on capital gains relative to those on ordinary income) may have a substantial impact on the amount of venture capital provided and the returns that these investments may yield. These less-direct measures may have the greatest success in ensuring that the venture industry will survive the recent upheavals.

In short, while government programs aimed at spurring venture capital and entrepreneurial innovation in alternative energy strive to produce a positive social rate of return, there are many challenges. The most effective programs and policies seem to be those which lay the foundations for effective private investment. Our analysis suggests that the market for venture capital may be subject to substantial "imperfections" and that these imperfections may substantially lower the total social gain achieved by venture finance. Given the extraordinary rate of growth (and now retrenchment) experienced by venture capital over the past decade, the most effective policies are likely those that focus on increasing the efficiency of private markets over the long term, rather than providing a short-term funding boost over a limited period.

References

Amis, David, and Howard Stevenson. 2001. *Winning angels.* New York: Pearson Education.

Barry, David G., and David M. Toll. 1999. Brentwood, IVP find health care, high tech don't mix. *Private Equity Analyst* 9 (1): 29–32.

Bingham, Kate, Nick Ferguson, and Josh Lerner. 1996. Schroder ventures: Launch of the Euro fund. Harvard Business School Case no. 9-297-026. Boston: Harvard Business School.

Business Executives for National Security. 2001. *Accelerating the acquisition and implementation of new technologies for intelligence: The report of the independent*

panel on the CIA In-Q-Tel venture. Washington, DC: Business Executives for National Security.
Cain, Walter M. 1997. LBO partnership valuations matter: A presentation to the LBO partnership valuation meeting. General Motors Investment Management Company. Mimeograph.
Devenow, Andrea, and Ivo Welch. 1996. Rational herding in financial economics. *European Economic Review* 40 (3–5): 603–15.
Estrin, Judy. 2008. *Closing the innovation gap: Reigniting the spark of creativity in a global economy.* New York: McGraw-Hill.
Fenn, George W., Nellie Liang, and Stephen Prowse. 1996. *The economics of the private equity market.* Washington, DC: Federal Reserve Board.
Foster management moves to dissolve consolidation fund. 1998. *Private Equity Analyst* 8 (December): 6.
Gompers, Paul, and Josh Lerner. 1997. Risk and reward in private equity investments: The challenge of performance assessment. *Journal of Private Equity* 1 (2): 5–12.
———. 1998. What drives venture capital fundraising? *Brookings Papers on Economic Activity, Microeconomics:* 49–192.
———. 1999. *Capital market imperfections in venture markets: A report to the Advanced Technology Program.* Washington, DC: Advanced Technology Program, U.S. Department of Commerce.
———. 2001. *The money of invention: How venture capital creates new wealth.* Boston: Harvard Business School Press.
Gorman, Michael, and William A. Sahlman. 1989. What do venture capitalists do? *Journal of Business Venturing* 4 (4): 231–48.
Gurung, Anuradha, and Josh Lerner. 2008. *The globalization of alternative investments.* Vol. 1. New York: World Economic Forum.
———. 2009. *The globalization of alternative investments.* Vol. 2. New York: World Economic Forum.
Hellmann, Thomas, and Manju Puri. 2000. The interaction between product market and financing strategy: The role of venture capital. *Review of Financial Studies* 13 (4): 959–84.
Kaplan, Steven N., and Per Strömberg. 2004. Characteristics, contracts, and actions: Evidence from venture capitalist analyses. *Journal of Finance* 59 (5): 2177–2210.
Kortum, Samuel, and Josh Lerner. 2000. Assessing the contribution of venture capital to innovation. *Rand Journal of Economics* 31 (4): 674–92.
Kreutzer, Laura. 2001. Many LPs expect to commit less to private equity. *Private Equity Analyst* 11 (1): 85–86.
Lerner, Josh. 1997. An empirical exploration of a technology race. *Rand Journal of Economics* 28 (2): 228–47.
———. 2009. *Boulevard of broken dreams: Why public efforts to boost entrepreneurship and venture capital have failed—and what to do about it.* Princeton, NJ: Princeton University Press.
Mollica, Marcos A., and Luigi Zingales. 2007. The impact of venture capital on innovation and the creation of new businesses. University of Chicago. Unpublished Manuscript.
New Energy Finance. 2008. *European and North American clean energy venture returns analysis.* London: New Energy Finance.
Poterba, James M. 1989. Venture capital and capital gains taxation. In *Tax policy and the economy.* Vol. 3, ed. Lawrence Summers, 47–68. Cambridge, MA: MIT Press.

Reyes, Jesse E. 1990. Industry struggling to forge tools for measuring risk. *Venture Capital Journal* 30 (September): 23–27.
Sahlman, William A., and Howard Stevenson. 1985. Capital Market Myopia." *Journal of Business Venturing* 1 (1): 7–30.
Summit's Jacquet departing to form own LBO firm. 1998. *Private Equity Analyst* 8 (May): 3–4.
Tyebjee, Tyzoon T., and Albert V. Bruno. 1984. A model of venture capitalist investment activity. *Management Science* 30 (9): 1051–66.
U.S. Department of Energy. 2008. *Renewable energy databook.* Washington, DC: GPO.
Wells, William A. 1974. Venture capital decision making. PhD diss., Carnegie-Mellon University.
World Economic Forum. 2009. Green investing towards a clean energy infrastructure. Project presented at the World Economic Forum Annual Meeting, Davos, Switzerland.