

Chapter 8: Venture Capital and Innovation in Energy

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Venture investments in alternative energy development has been booming over the past few years, reflecting the rising cost of energy. Clean energy has become particularly attractive for investment due to recent concerns about global warming. From 2004 to 2007, investment in clean energy saw an almost five-fold surge. The increase in investment activity spanned all geographies, all asset classes, and all sectors (Figures 1-3). The clean energy financing spectrum encompasses very early-stage investment in emerging technologies to large established companies raising money on the public markets. In the United States, investment in clean energy projects has grown dramatically over the past decade, surpassing \$13 billion in 2007.

This surge 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 2001.¹ 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.

However, the effects of the recent global financial crisis starting in 2008, coupled with the typically cyclic and uneven character of venture financing, have raised questions about the viability of the venture capital model. 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. Alarms have been sounded in particular about the implications of this decline for funding of technological innovation. For instance, in an influential new volume, Judy Estrin, 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 (Estrin 2008). She argues that venture capitalists who back entrepreneurial firms have been too cautious to make big bets, particularly after the costly failures experienced during the dot-com bust.

In few places has last year's drop in venture capital investment been as dramatic as in alternative energy innovation. The amount disbursed to entrepreneurial firms devoted to alternative energy fell from \$1.3 billion in the second quarter of 2008 to well under \$200 million in first quarter of 2009 (PricewaterhouseCoopers 2009).

Venture capital funding has an important role to play in stimulating innovation and economic growth, but it is perhaps not the silver bullet that many in the energy sector have been hoping. While infusions of venture funding into creative entrepreneurial pursuits can spur innovation, venture funding in any sector tends to be cyclical, rigid, and lagging in responsiveness, all of which can reduce the private and social returns to investments. Therefore, while there are many reasons for believing that *on average* venture capital has a powerful effect on innovation, the effect is far from uniform. In particular, during boom periods, the prevalence of over-funding of particular sectors can lead to a sharp decline in terms of the effectiveness of the venture funds. Likewise, prolonged downturns may eventually lead to good companies going unfunded.

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¹ US Department of Energy (2008). It is important to note, however, that while investment during 2008 was down only slightly from 2007 (\$142 billion compared with \$148 billion, respectively), a strong start may disguise a much weaker second half of the year due to the impact of the global financial crisis.

The cyclicity of venture capital funding has important implications for the effectiveness of this sort of private sector investments in energy and in addressing whether and how the government should play a role.

In this chapter, I explore the unique structure and workings of the venture capital process and its implications for innovation. In particular, I examine both the value and the challenges of the venture capital industry in addressing energy innovation, and I consider some of the implications of the venture capital process for public policy. While the rise of venture capital has been an important contributor to technological innovation and economic prosperity, it has been only one part of the solution. To date, many of the steps that policymakers have pursued have had the consequence of throwing gasoline on the fire—that is, they have exacerbated the cyclicity of venture funding.

[H1] A Venture Capital Primer

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 to determine their long run viability. Larger, more traditional institutional investors have therefore been traditionally unwilling to finance entrepreneurial businesses. By way of contrast, venture capital firms have specialized in backing risky businesses by employing both monetary and nonmonetary tools to understand and foster these kinds of businesses to increase their success. Indeed it is often the non-monetary aspects of venture capital funders that are critical to success: the screening of investments, the use of convertible securities, the syndication and staging of investments, and the provision of oversight and informal coaching.

For example 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 pioneering study describes a typical process, which involved both face to face meeting and other communications with the new company's founders, director, controller, banker, and accountant; a loan officer at a major insurance company that had turned down financing; a local bank that slightly knew the company; and multiple users, suppliers, and competitors of the business product (Wells 1974).

In addition, venture capital investors screen potential transactions through financial analyses. They carefully analyze what the prospective returns will be from these investments. It is not enough for a venture to be success—a venture capitalist will only invest if the expected rate of return is suitably high. A high expected return is needed because of the overall high failure rates associated with early-stage and restructuring investments. Only approximately one-third of venture capital-backed firms complete initial public offerings, typically the most attractive route for venture capital firms to exit investments. While some investments are exited successfully through acquisitions, these investments in most cases generate far lower returns. Even in later-stage investing, the frequency with which things do not go according to plan leads investors to only enter into projects in which they can expect a high minimum return if things go well. Despite the expertise and extensive analysis of venture capital investors, disappointment is the rule rather than the exception (see data in Gompers and Lerner 2004).

One sophisticated individual investor suggests it is likely to take up to 160 hours to properly screen one investment opportunity (Amis and Stevenson 2001). As part of this extensive process, investors must make sense of the abundance of data they gather by prioritizing certain investment criteria. Tyebjee and Bruno (1984) describe the most common criteria as the product's market attractiveness, its uniqueness, the managerial skills within the company, the environmental threat resistance (e.g., product life cycle, barriers to competitive entry), and the investment's cash-out potential. Similarly, Kaplan and Stromberg (2004) find that venture capital fund managers, group key decisionmaking criteria into three overall categories: internal factors (quality of management, performance to date, funds at risk, influence of other investors, portfolio fit and monitoring costs and valuation), external factors (market size and

growth, competition and barriers to entry, likelihood of customer adoption, and financial market and exit conditions), and difficulty of Execution (nature of the product or technology, and the business strategy model).

In addition to the careful interviews and financial analysis, venture capitalists will often syndicate investments—that is, make investments with other investors. Involving other venture capital firms provides a second opinion on the investment opportunity. In addition, having other investors approve the deal can limit the danger that bad deals may get funded. This is particularly true when the company is in an early stage or operating in an uncertain market. Syndication also allows the venture capital firm to diversify. If the venture capital firm had to invest alone into all the companies in its portfolio, then it could make far fewer investments. By syndicating investments, the firm can invest in a greater diversity of projects and reduce firm-specific risk.

The result of this detailed analysis is, of course, a lot of rejections: studies suggest only 0.5 to 1 percent of business plans may be funded (Wells 1974, Fenn et al. 1996). Inevitably as part of this process, many good ideas are rejected, and many companies are funded that ultimately prove to be disappointments.

Once the initial selection has been completed, venture capital firms usually become intensely involved with the firm in ways that sets them apart from traditional institutional lenders and government programs. Venture capital investors provide advice and intensive oversight of the companies they support. Gorman and Sahlman (1989) surveyed venture capital investors and found they spent about half their time monitoring an average of nine portfolio investments and serving on the boards of directors for five of those nine companies. The investors visited their companies relatively frequently, and spent an average of 80 hours a year on site with the companies on whose boards they served. Frequent telephone conversations amounted to another 30 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. This important role in boosting the companies venture capitalists fund accelerates growth, professionalizes and improves management practices, and assures long-run success (Gurung and Lerner 2008, 2009).

The staging of investment disbursement also improves the efficiency of venture capital funding. In the venture capital and growth equity process, investors frequently disburse funds in stages, rather than upfront and all at once. Once the decision to invest is made, a portion of the total funds is released to the company. The refinancing of these companies 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. The entrepreneurial company must return repeatedly to their financiers for additional capital, which allows the venture capitalists more oversight to ensure that the money is not squandered on unprofitable projects. Thus an innovative idea only continues to be funded if its promoters continue to succeed, and furthermore those projects that prove promising are able to access capital in a timely fashion. This staging contrasts with the funding process within large corporations, where research and development budgets are typically set at the beginning of a project, with few interim reviews planned. Even if projects do get reviewed mid-stream, few of them are terminated when signs suggest they're not working out.

[H1] Does VC Funding Increase Innovation?

For most of past three decades, investments made by the entire venture capital sector in the United States totaled less than the research-and-development (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 press has exaggerated the importance of the venture capital industry. After all, high-tech startups make for

interesting reporting, but do they really redefine the U.S. economy? And could they contribute significantly to energy solutions?

One way to explore these questions 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.

We do know, however, that those firms that do go public have an unmistakable effect on the U.S. economy. 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.² By late 2008, for example, venture-backed firms that had gone public made up more than 13 percent of the total number of public firms in existence in the United States at that time. The same companies represented 8.4 percent (\$2.4 trillion) of the total market value of public firms (\$28 trillion) and more than 4 percent (nearly \$1 trillion) of total sales (\$22 trillion) of all U.S. public firms. 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 companies 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. Therefore, venture investing fuels a substantial portion of the U.S. economy.

Venture investing also strengthens particular industries. To be sure, it has relatively little impact on industries dominated by mature companies, such as the manufacturing industries. This is because venture investors' mission is to capitalize on revolutionary changes in an industry, and the more mature sectors often have a relatively low propensity for radical innovation. By contrast, 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 have had a big role in new industries and in seeding fledgling companies that later dominate those industries. But the question of whether they cause these changes is not resolved by these statistics.

It might be thought that it would be a simple matter to tease out the effect of venture capital on innovation. However, determining causality can be difficult because both venture funding and innovation could be positively related to a third 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 which was sure to lead to more innovation. To date, only two papers address this question of causality.

Hellmann and Puri (2000) examined a sample of 170 recently formed firms in California's Silicon Valley. The survey included both venture-backed and non-venture companies. The study finds

² This analysis is based on the author's tabulation of unpublished data from SDC Venture Economics, with supplemental information from Compustat and the Center for Research into Securities Prices (CRSP) databases.

that firms that pursue an “innovator strategy” are significantly more likely and more quickly 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 lifecycle of the company as compared to other financing events. The results suggest a significant role of venture capital in encouraging innovative companies. But this does not definitively answer the question of whether venture capitalists cause innovation. For instance, the presence of personal injury lawyers handing out business cards at a crash site does not mean that the lawyers caused the crash. In a similar vein, the possibility remains that innovative firms are more likely to seek financing through venture capital, rather than venture capital causing firms to be more innovative.

In Kortum and Lerner (2000), we 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? And 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, 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 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 an examination of the impact of venture capital, because it is unlikely to be related to how many or how few entrepreneurial opportunities there were to be funded. The results of our study suggest that venture funding does have a strong positive impact on innovation. On average, a dollar of venture capital appears to be *three to four* times more potent in stimulating patenting (one indicator of innovation) 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.

Because we looked at patenting as a proxy for innovation, one possible alternative explanation is that venture funding leads to entrepreneurs to protect their intellectual property with patents, either as an alternative to other mechanisms such as trade secrets (e.g., they may be trying to fool their investors by applying for quantities of patents, even if the contributions of many of them are very modest). If this were true, it might be inferred that the patents of venture-backed firms would be of lower quality than non-venture-backed patent filings. However, we find the opposite to be true. We examined patent citations—higher-quality patents, it has been shown, are cited by other innovators more often than lower-quality ones. We also examined the quality of patents by looking at patent-infringement litigation, because it makes little sense to pay money to engage in the costly process of patent litigation to defend a low-quality patent. We found that 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 more innovative than their non-venture-supported counterparts.

Mollica and Zingales (2007), by way of contrast, focus regionally on the 179 Bureau of Economic Analysis economic areas, which are composed by counties surrounding metropolitan areas. The study exploits the regional, cross-industry, and time-series variability of venture investments in the United States to examine the effect of venture capital activity on innovation and the creation of new businesses. As an instrument for the size of venture capital investments, they use the size of a state pension fund’s assets. 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 investment, which should help identify the effect of venture capital investments on patents. The study finds 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 VC 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 VC investment increases the total number of new business by 2.5 percent.

[H1] Cyclicity in the Venture Capital Industry

As with markets for commodities like oil and semiconductors, shifts in supply and demand shape the amount of capital raised by venture funds. For example, the venture capital market expanded greatly after the Department of Labor's 1979 clarification of the "prudent man" rule of the Employee Retirement Income Security Act (the rule states that pension managers must invest with the same aims as would a prudent man). Prior to the labor department's clarification, pension fund managers avoided investment in venture funds because of concern that these investment choices were too risky to be considered prudent. After the clarification that portfolio diversification into a small amount of venture capital funds was not imprudent, demand increased for venture capital funds. Similarly, major technological discoveries, such as the development of genetic engineering, are followed by an increase in venture fund demand.

However, the quantity of venture capital raised and the returns it enjoys often do not adjust quickly and smoothly to the changes in demand. The often slow and uneven adjustment process can lead to substantial and persistent imbalances. In addition, when the quantity provided does finally react to demand, the responding shift may overshoot the ideal amount, and lead to yet further problems.

These shifts also drive the returns that investors earn in these markets. And as with other types of investment, the willingness of investors to commit money to venture capital funds depends upon the expected rate of return from these investments relative to the return they expect to receive from other investments. Over the past 40 years, both venture capital fundraising and returns on investment have swung dramatically (Figures 4 and 5).

A further difference can be seen between the long-run and short-run effects of changes in the demand for venture capital. A positive demand shock (e.g., 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 result in large companies at first struggling to adjust to the new opportunity, while numerous agile small companies may react quickly to exploit it. The entry of these new firms implies that for any given level of return demanded by investors, there now may be many more attractive investment candidates. In the long run, the quantity of venture capital provided will increase to a new level. Returns will also increase in the months or even years after the shock. However, the amount of venture capital available may become essentially fixed at that new level. Instead of leading to more companies entering into the market, the return to the investors may climb dramatically. 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.

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 rapidly accomplished. The nature of venture capital funds, however, makes these kind of rapid adjustments much more difficult.

One major bottleneck to the liquidity of venture funding is the venture capitalists themselves. Many of the crucial skills in effective capital investing are developed through time-consuming apprenticeship. Therefore, new venture capitalists do not appear overnight. Furthermore, the organizational challenges associated with rapidly increasing the size of a venture partnership are often wrenching ones. Thus, many venture capital groups resist rapidly increasing their size, even when investor demand is so great that they could easily raise many billions of dollars.

A second constraint is with the typical sources of venture funding, which are often large institutions such as university endowments or pension funds. These institutions may decide to increase their investment in venture funds, but several years may pass between the point the decision is made to implementation of the new policy. Additional time may go by while the endowment exhaustively reviews potential candidates for funding. Once the funds are chosen, the full investments will not be made immediately. Rather, the capital will be drawn down in stages over a number of years. Finally, further delays in funding may occur if the pension's decision to invest takes place out of sync with the venture fund's fundraising cycle (which generally occurs every two to three years).

The same delays work in reverse. If the endowment or pension officers decide to scale back commitment, it is likely to take a number of years to do so. An illustration of this stickiness followed 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 1989.³

Another contributing factor is the self-dissolving 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 cash or stock in firms that have recently gone public. 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 investment in venture capital—current investors receive large outflows from venture funds. Even to maintain the same percentage allocation to venture funds during these peak periods, the investors 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 since IPOs and acquisitions are few and far between. Thus it is often difficult to achieve a desired exposure to venture capital during periods of rapid change in the market.

Another important factor contributing to the cyclicity of the VC industry is the pervasive information lags that characterize the field. While mutual and hedge funds holding public securities are “marked to market”⁴ on a daily basis, the delays between the inception of any particular venture investment and the discovery of its quality is long indeed. Some of these information delays stem from the start-up companies themselves. The companies that attract venture capital are typically surrounded by substantial uncertainty and information gaps. Furthermore, venture groups tend to be extremely conservative in reporting how much the companies they invest in are worth, at least until the companies are taken public or acquired. While this limits the danger that investors will be misled into thinking that a company is doing better than it actually is, the practice minimizes the information flow about the current state of the overall market.⁵

Because relatively few firms get taken public during “cold” markets and many do during “hot” ones, during the years with active public markets it appears that the value of venture backed firms increases dramatically. But the actual value-creation process in venture investments is quite different. In many cases, the value of a new company actually increases gradually over time, even as it is being held at cost. Thus, the low returns during cold periods understate the progress being made, just as the high returns during the peak periods overstate the success.

³This claim is based on an analysis of an unpublished Venture Economics database.

⁴That is, priced at current market value.

⁵The problems with the accounting schemes used by venture capital groups are discussed in Cain (1997), Gompers and Lerner (1998a), and Reyes (1990).

Information lags can have profound effects. For instance, 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 investments became substantially less attractive, as it did during the spring of 2000, investors still continued to plough money into these funds.⁶

Information lags, combined with the rigidity of the venture fund structure, leads to inappropriate or lagged responses in the venture capital market. Furthermore, 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 existing opportunities. Instead of shifting to the new steady state level, the short-term supply curve may shift to an excessively high level. This can result in worthy companies receiving more funding than they can reliably absorb or unworthy companies receiving funds they don't deserve. During a downturn, a shift in demand can trigger a wholesale withdrawal from venture capital financing. While the supply of venture capital will ultimately adjust, in the interim, promising companies may not be able to attract funding.

[H2] Why Do Venture Markets Over-React?

One possible reason that venture markets over-react 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.

Such mistakes may arise because of misleading information from the public markets. In some cases, investors seem to 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 effect of competitors on revenues and profit margins is not fully anticipated. The consequences of excessive duplication is frequently the same: highly duplicative research agendas, intense bidding wars for scientific and technical talent culminating with frequent firm-to-firm defections, costly litigation alleging intellectual property and misappropriation of ideas across firms, and the sudden termination of funding for many of these concerns.

One famous example occurred during the early 1980s, when 19 disk drive companies received venture capital financing.⁷ Two-thirds of these investments came in 1982–1983, as the valuation of publicly traded computer hardware firms soared. Many disk drive companies also 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 then became very reluctant to fund computer hardware firms.

Another example was the peak period of biotechnology investing in the early 1990s. Reacting to the substantial potential of biotechnology to address human disease, the venture capital market funded dozens of firms pursuing similar approaches to the same disease target. 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. When biotechnology valuations fell precipitously just one year later, only 42 of the 262 publicly traded biotechnology firms had a valuation over \$70 million.⁸ Most of the biotechnology firms financed during this period ultimately yielded very disappointing returns for their venture financiers and only modest gains for society as a whole. In many cases,

⁶ For further discussion, see Kreutzer (2001).

⁷ For detailed discussions, see Sahlman and Stevenson (1986) and Lerner (1997).

⁸ These figures are based on an analysis of an unpublished Venture Economics database.

the firms were liquidated after further financing could not be arranged. In some cases, the firms shifted their efforts into other, less competitive areas, largely abandoning the initial research efforts. In other cases, the companies remained mired with their peers for years in costly patent litigation.

The venture capital boom of 1998–2000 provides many additional illustrations. Funding during these years was concentrated in two areas: Internet and telecommunication investments, which accounted for 39 percent and 17 percent, respectively, of all venture disbursements in 1999. Once again, considerable sums were devoted to supporting highly similar firms (e.g., the nine dueling Internet pet food suppliers) or to supporting 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 (e.g., advanced materials, energy technologies, and micro manufacturing) languished unfunded as venture capitalists raced to focus on the most visible and popular investment areas.

Unreasonable swings in the public markets may also lead to over- and under-investment 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 of their portfolio to venture capital. If the high valuations are subsequently revealed to be without foundations, the level of venture capital will have once again over-shot its target.

A second explanation for the market over-shooting in venture capital investment 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. Growth frequently leads to changes in the way in which venture groups invest their capital, which can have a deleterious effect on returns. Rapidly growing venture organizations frequently attempt to increase their average investment size, rather than investing in additional companies. In this way, the same number of partners can manage a larger amount of capital without increasing the number of companies that each needs to scrutinize. This shift to larger investments frequently entails making larger capital commitments to entrepreneurs up-front, which reduces the venture capitalist's control of the company through staged capital commitments. Similarly, venture firms syndicate less with their peers during these times. By not syndicating, the venture groups can allow to each of its partners to manage more capital while keeping the number of companies that he is responsible for down to a manageable level. But venture capital firms that are the sole funders of a company then lose the advantages of syndication, such as helping reduce the danger of costly investment mistakes.

Organizational tensions may arise when expansion of the venture capital firm's investments lead to a fragmentation of the bonds that tie the partnership into a cohesive whole. One poignant illustration is the experience of Schroder Ventures (Bingham et al. 1996). Schrodgers' private equity effort began in 1985 with funds focused on British venture capital and buyout investments. Over time, however, the firm added funds focusing on other markets, such as France and Germany, and particular technologies, such as the life sciences. But as the venture organization grew, substantial management challenges emerged. In particular, it became increasingly difficult for the parent organization to monitor the investment activities of each of the groups. Each group saw itself as an autonomous entity, and even in some cases resisted cooperating (and sharing the capital gains) with the others. The organization eventually restructured to raise a single fund for all of Europe, but the process of change was slow and painful.

In some cases, organizational tensions have led to groups splitting apart. In other cases, a key partner has departed a venture group, entailing a real disruption to the organization. In short, rapid growth puts severe pressures on venture capital organizations. Even when the problems do not result in an as extreme outcome as a group dissolving, the demands on the partners' time in resolving these problems are often substantial. Thus, firms that rapidly expand to address periods of rapid investment growth may be acting counterproductively and may find they garner disappointing returns.

[H2] Does Cyclicity Affect Innovation?

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, needs to be modulated by the knowledge that during periods when the intensity of investment is greatest, the impact of venture financing appears to decline.

In Kortum and Lerner (2000), for example, we analyzed annual data for 20 manufacturing industries between 1965 and 1992. We looked at the changing patterns of U.S. patents issued to U.S. inventors by their industry and their dates of application. We measured venture funding (collected by Venture Economics) and industrial R&D expenditures (collected by the National Science Foundation).⁹ We then estimated the influence of venture capital funding on patent applications, while controlling for R&D spending, industry effects, and the year of the observation. We found that during boom periods, the influence of venture capital on innovation is approximately 15 percent lower than during normal industry periods, a difference that is strongly statistically significant. The magnitude of the effect of venture capital on innovation diminishes—but remains positive and significant—when we control for reverse causality: the fact that technological breakthroughs are likely to stimulate venture capital investments. This statistical result corroborates field study evidence suggesting that the influence of venture capital on innovation is less pronounced during booms.

This result may alleviate some worry about the short-run fluctuations in venture financing, because it suggests that while the effects of these cycles 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 that in some cases, surges in venture capital activity have been followed by pronounced and persistent downturns. Just as we can see “overshooting” by investors, so can we see prolonged “undershooting.”

Undershooting in venture capital investment occurred in the 1970s. The late 1960s had seen record fundraising, both by independent venture groups and Small Business Investment Companies (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 Small Business Investment Companies. The poor returns generated a powerful reaction, leading both public and private market investors to be unwilling to contribute new capital.

Computer and computer-related companies were particularly hard hit, being the area of the greatest concentration of venture capital during that period. The amount of capital raised by these companies fell from \$1.2 billion (in 2000 dollars) in 1968–69 to just \$201 million during the entire period from 1973 to mid-1978, with absolutely no financing being raised in many quarters (Figure 6). To be sure, many of the companies that raised capital during the boom years and then could not get refinanced had business plans that were poorly conceptualized or were 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.

⁹ There were significant limits to our study. 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). Further, we were required to aggregate venture funding and patents into a 20-industry scheme that is used by the National Science Foundation to measure R&D spending. Finally, our analysis excluded the greatest boom period of all, the 1998–2000 surge, because patent applications can only be observed after a considerable time lag.

[H1] Venture Capital and Alternative Energy

The energy sector has become a classic example of the ups and downs of venture funding. The current decade has seen a classic boom in clean energy development, followed this past year with a strong downturn. Rising from less than \$20 billion in 2004 to almost \$120 billion in 2007, investment in clean energy is now projected to fall sharply in 2009.

Before the recent downturn, and as recently as five years ago, venture investment in clean energy meant wind projects, mostly in Denmark, Germany, and Spain. In 2005, wind was the dominant sector attracting venture capital investment. In 2006, biofuels development attracted the highest investment, with the solar sector attracting the second highest amount. In 2007, solar energy became 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 the previous year (Figure 7). On the ground, 21 Gigawatts of new wind capacity were added worldwide in 2007, amounting to half of all new renewable energy capacity and more than 11 percent of all new power generation capacity.

The surge in investment 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 through mid-2008, according to the third annual European Clean Energy Venture Returns Analysis, 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 \$2.52 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 rate of return (at the portfolio company level, not the fund level) for exited deals of more than 60 percent.¹⁰ 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 rate of return was closer to 14 percent (Table 1). These extraordinary returns coincide with a new interest in all things green, as well as historically cheap access to debt, which has allowed many companies to grow quickly.

The next few years will certainly be much harder for venture and private equity investors in the clean energy sector because the sector, like all other areas, has been weakened by the worldwide financial crisis. Despite maintaining an estimated \$14 billion of new investment thus far (excluding buyouts in 2008, and exceeding the S&P and NASDAQ public market indices), venture capital performance in clean energy dropped sharply in the second quarter of 2008. (Thomson Reuters and the National Venture Capital Association 2009).

Investment in the clean energy sector has suffered from three main problems in recent years. First, falling energy prices have taken the pressure and attention off the public's interest in alternative energy. Second, the sector took a hit through the equity markets, as investors sold stocks with any sort of technology or execution risk and went back to more conventional, longer established businesses. Third, due to the very constrained nature of the credit markets, clean energy companies that require large amounts of capital have been penalized.¹¹ The public markets that clean energy companies have used as a major source of fund raising—such as through initial public offerings, secondary offerings, and convertible issues—also dropped by 60 percent in 2008 (Figure 2).

¹⁰ The percentage is based on the limited number of exits and with only 23 companies being liquidated or written off at the time of the study.

¹¹ World Economic Forum (2009).

The future of venture capital investment in the clean energy sector hinges upon two key conditions in the investing environment: the future of the capital markets and the direction of government policy.

Because clean energy projects generally require higher up-front costs (incurred in the expectation of lower fuel costs), these projects are usually more sensitive to periods of higher interest rates or credit risk aversion. The present interest rates thus pose to be 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— but if credit returns and interest rates remain low, at some point clean energy projects pose to benefit tremendously.

In addition, the McKinsey Global Institute notes that if market and policy barriers such as lack of consumer education, fuel subsidies that encourage inefficient energy use, and asymmetrical benefits to tenants and landlords of investments in energy efficiency can be overcome,¹² there is a substantial opportunity to improve supply- and demand-side infrastructure and to produce returns above the cost of capital. According to the report, \$170 billion in energy-efficient investment opportunities may have rates of return of 17 percent or more, which should be attractive to outside investors.

The financial crisis has also spawned changes in public policy toward the clean energy sector, such as the Obama Administration’s subsidies of companies focusing on battery development. These short-run stimulus efforts, plus longer-run efforts to simulate the clean tech sector should benefit venture-backed firms in this sector.

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, investment in the clean energy sector will be bolstered and could become greatly profitable. The success 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.¹³

[H1] Public Policy and the Venture Capital Industry

While understanding the causes of cyclicity in the venture industry may be compelling, policymakers are much more likely to be interested in its consequences. In particular, to what extent do these cycles affect the innovativeness of the U.S. economy in general, and the energy sector in particular? While the overall relationship between venture capital and innovation is positive, the relationship across the cycles of venture activity may vary. An appropriate public policy response, if there is to be one, will take these cycles into serious consideration.

At the same time, it is important to note that the level of venture capital fundraising and investment activity over time is still extremely high. In fact, even if we were to remove the 1999–2000 “bubble” period from discussion, the venture industry would show robust growth over the past decade. Therefore, the rationale for government intervention to provide funding today seems slim.

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. These programs employ a variety of “stage setting” and direct strategies.

¹² Ibid.

¹³ Ibid.

However, as previously emphasized, venture capital is an intensely cyclic industry, and the influence of venture capital on innovation is likely to differ with this cycle. Yet government programs have frequently been concentrated during the time periods when venture capital funds have been most active, and the programs often have targeted the very same sectors that are being aggressively funded by venture investors. Government input can also exacerbate all the negative consequences of excessive duplication in funding. The same common flaws doom far too many programs. The flaws reflect both poor design—based on a lack of understanding of the entrepreneurial process—and problematic implementation.

Some of the programmatic difficulties are embodied in the manner in which government policy initiatives are frequently evaluated and rewarded. Frequently, 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 and the Advanced Technology Program 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 a “hot” industry where 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 Advanced Technology Program 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). In many effective programs, decisions as to whether to finance an entrepreneurial effort are made not by centralized bodies, but rather devolved in many agencies to program managers who seek to address very specific technical needs (e.g., a research administrator who seeks 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.

Another successful approach is to address the gaps in the venture financing process. As noted previously, venture investments have tended to focus on a few areas of technology that are perceived to have great potential for making both technological and financial leaps. History shows us that increases in venture fundraising 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 technologies funded. Policymakers have been more effective in spurring innovation if they (1) focus on technologies that are not currently popular among venture investors, and (2) provide 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 the venture 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 substantially benefit the amount of venture capital provided and the returns that these investments may yield. These less direct measures may have the greatest success in insuring 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. My 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 extraordinarily positive rate of growth (and recent retrenchment)

experienced by venture capital over the past decade, the most effective policies were those that focused on increasing the efficiency of private markets over the long term, rather than providing a short-term funding boost over a short period.

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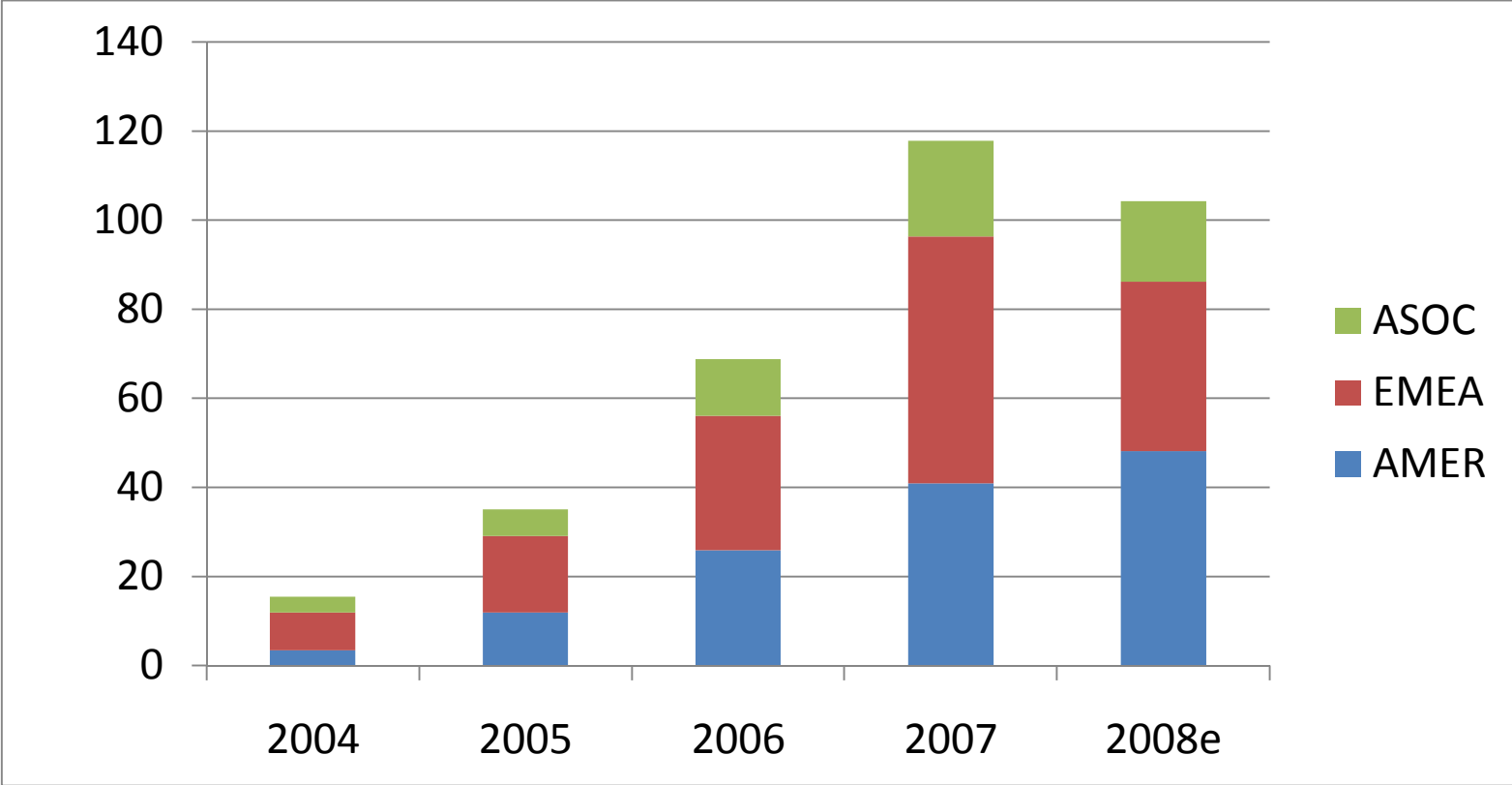
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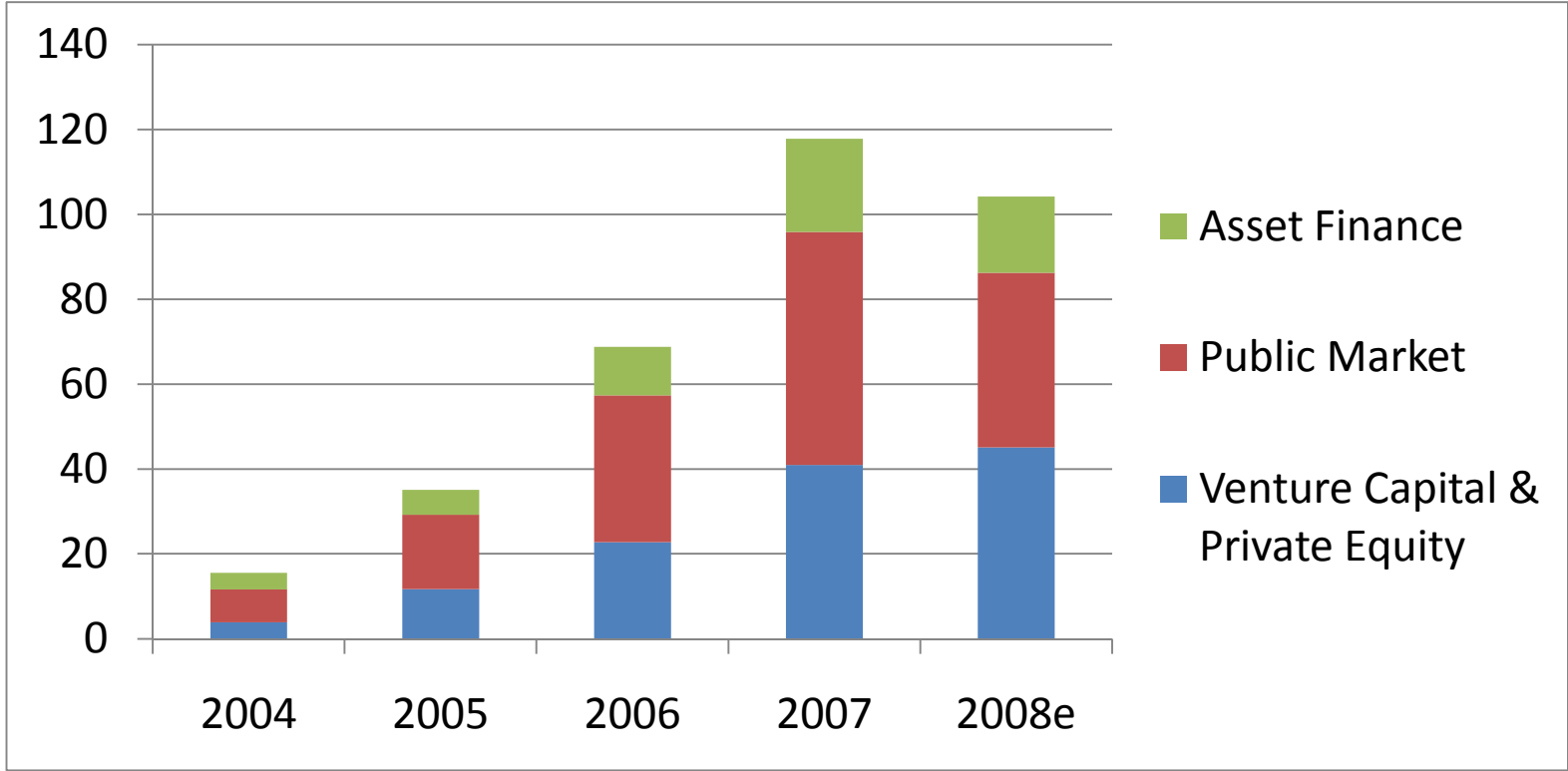
Figure 1: Clean Energy Investment (\$ in Billions) by Geography, 2004-2008.



Notes: Totals are extrapolated values based on disclosed deals from the New Energy Finance industry Intelligence Database. They do not include R&D or what the World Economic Forum defines as “ Small Projects.” ASOC = Asia Oceania region; EMEA = Europe Middle East Africa region; AMER = Americas region. 2008 figures are estimates only.

Source: World Economic Forum (2009)

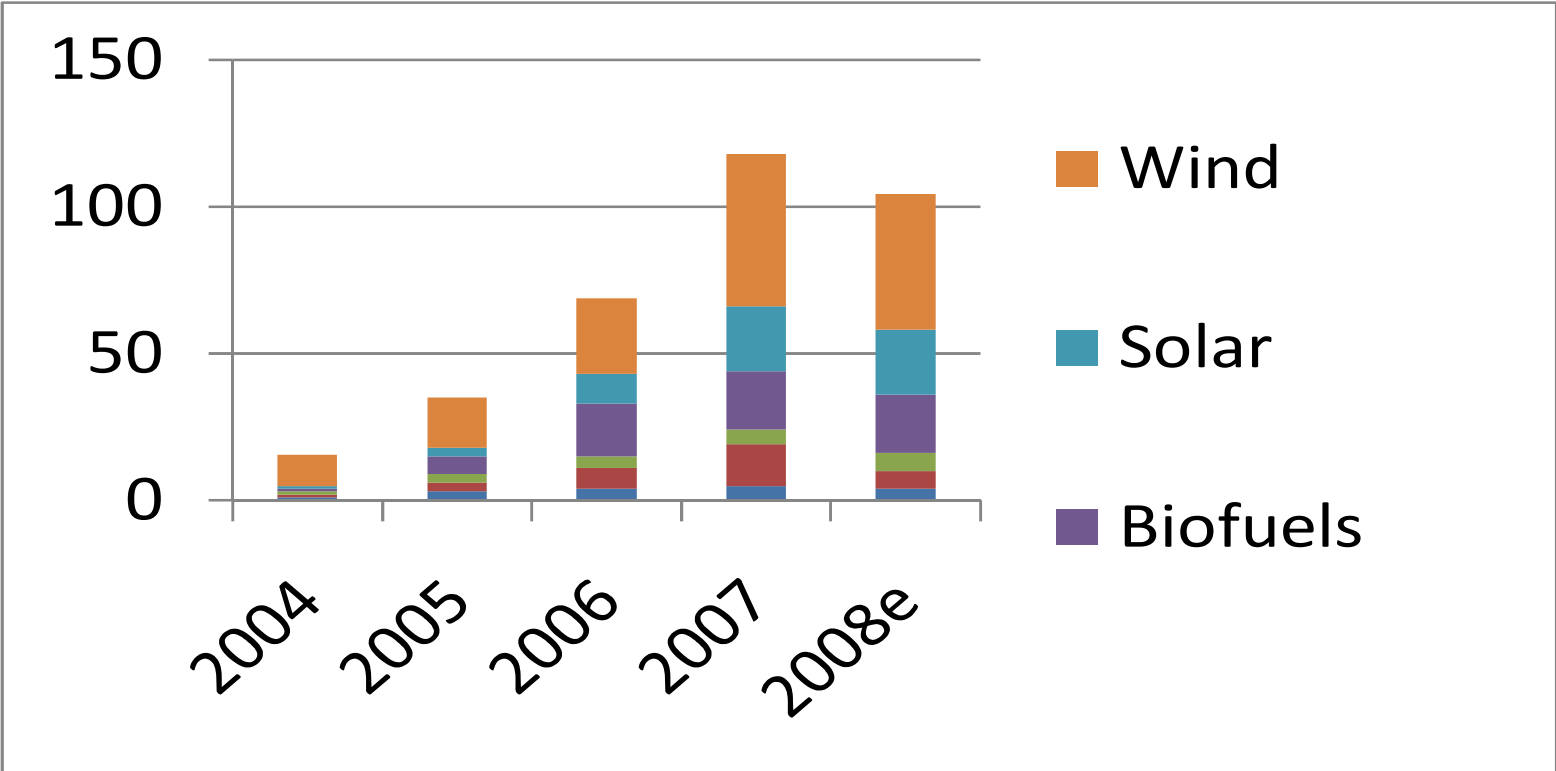
Figure 2: Clean energy Investment (in \$ Billions) by Asset Class, 2004–2008.



Note: Totals are extrapolated values based on disclosed deals from the New Energy Finance Industry Intelligence Database. They exclude R&D or what the World Economic Forum defines as “ Small Projects.” 2008 numbers are estimates only.

Source: World Economic Forum (2009).

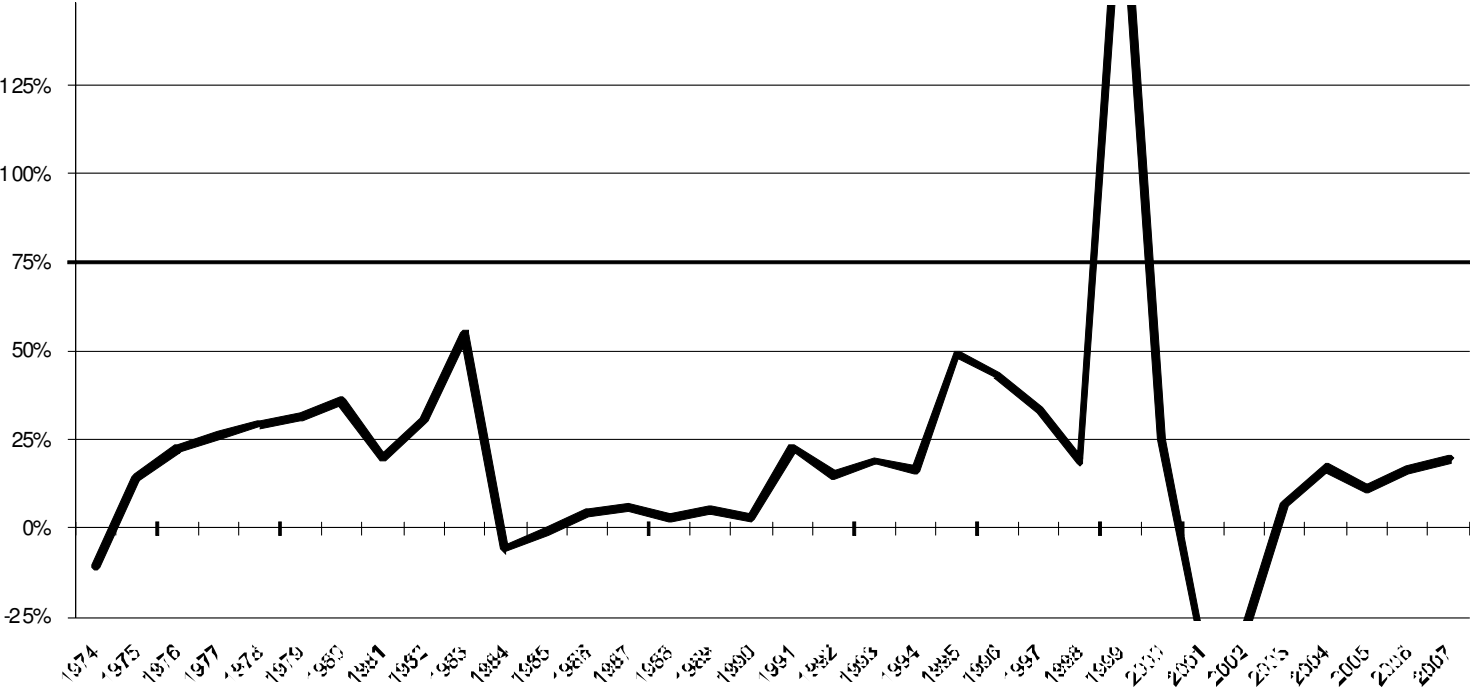
Figure 3: Clean Energy Investment (in \$ Billions) by Sector, 2004–2008.



Note: Totals are extrapolated values based on disclosed deals from the New Energy Finance industry Intelligence Database. They exclude R&D or what the World Economic Forum defines as “ Small Projects.” “Other Renewables” includes geothermal and mini-hydropower. Figures for 2008 are estimates only.

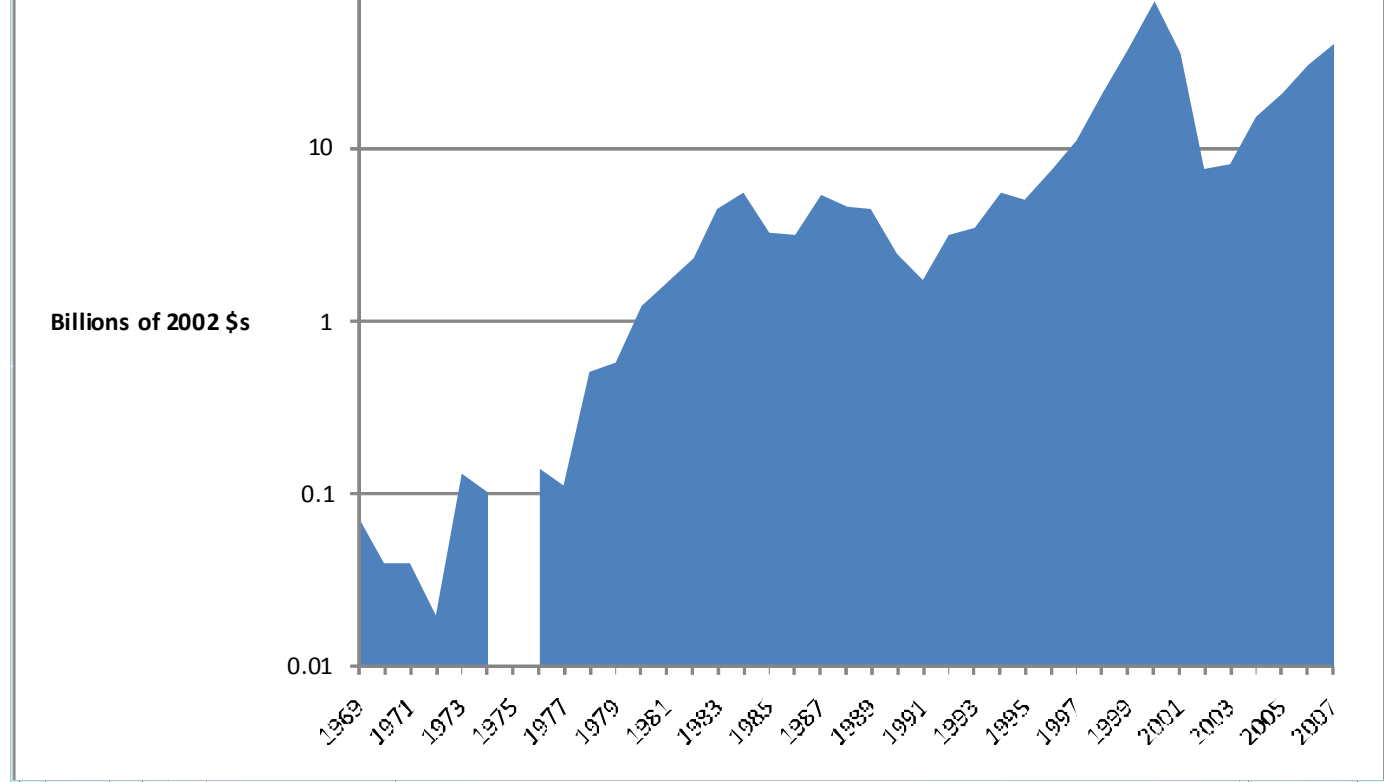
Source: World Economic Forum (2009).

Figure 4: Returns to venture capital investments, 1974–2007.



Source: The figure is based on an unpublished Venture Economics database.

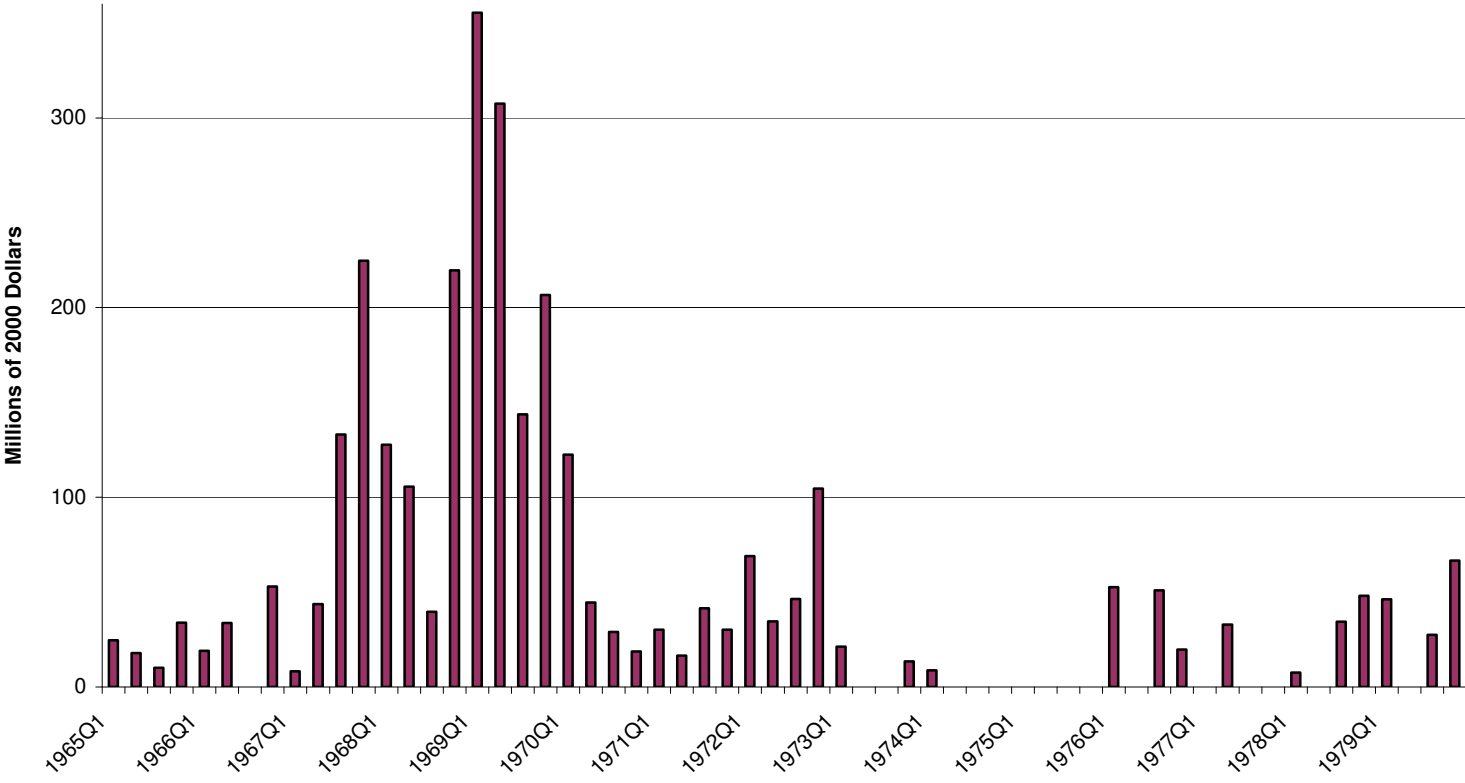
Figure 5: Venture capital fundraising in major nations by year, 1969–2007.



Note: . There was no venture fundraising in 1975.

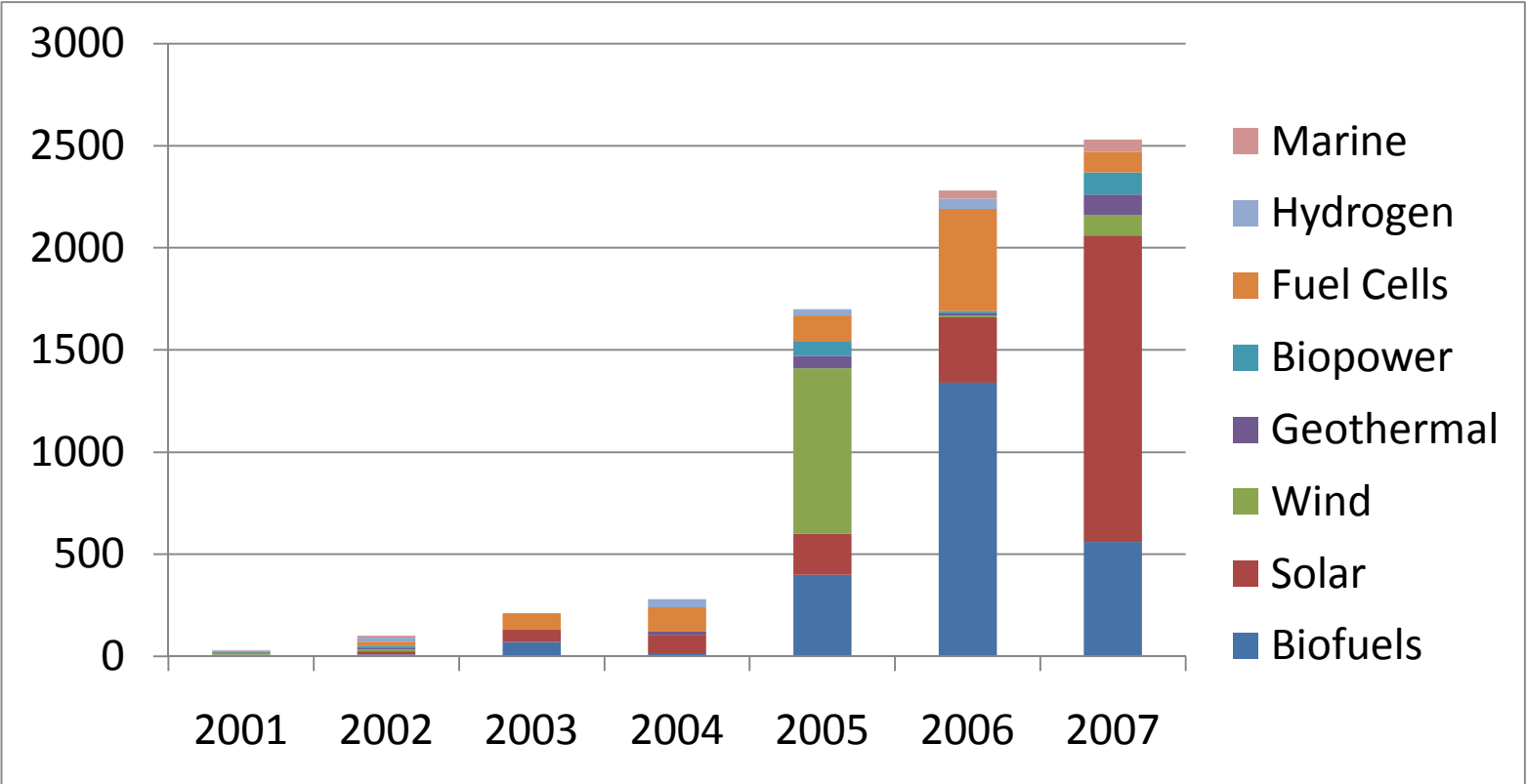
Source: The figure is based on unpublished Asset Alternatives and Venture Economics databases.

Figure 6: Initial public offerings and seasoned equity offerings by computer and computer-related firms, by quarter, 1965-1979.



Sources: Data were compiled by the authors compiled from Investment Dealers' Digest, the Securities Data Company database, and other sources.

Figure 7: Venture Capital Investment (\$ in Millions) in Renewable Energy Technology Companies, 2001-2007.



Source: US Department of Energy (2008).

Table 1: Comparative IRR by Year of Study.

Year of study	2006	2007	2008
Cumulative Global Overall IRR	49.3%	43.9%	61.1%
Buyouts	ND*	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).