
SUSTAINABLE DEVELOPMENT
AND BUSINESS
Markus Kallifatides and Lin Lerpold (eds.)

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This book is dedicated to Marie Ehrling for her long commitment to enabling studies of management practice conducted by researchers at the Stockholm School of Economics. Her commitment to research has also greatly contributed to our mission of science-based education and, thus, our students' education. Marie has also acted as an important executive within the sustainability field. She is deeply knowledgeable of the dynamic nature between business and society, encompassing both challenges and opportunities, some of which this book addresses.

Contents

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Stockholm, December 2016

Markus Kallifatides and Lin Lerpold

1 Up until 2009, the Annual Book was produced by Ekonomiska forskningsinstitutet (EFI), the predecessor to SIR.

CHAPTER 7

How do low-carbon industries emerge?

The evolution of solar photovoltaics in the United States and Japan, 1973–2005

MAX JERNECK

Introduction

Avoiding catastrophic climate change requires a rapid development of low-carbon industries. Our understanding of how that may occur can be informed by previous examples of low-carbon industry emergence. By comparing relatively successful and unsuccessful cases, it is possible to identify driving and blocking mechanisms. This chapter takes as its example a historical comparative case of one low-carbon technology, solar photovoltaics in the United States and Japan, from the period of the first oil crisis in 1973 until 2005. American producers dominated the industry initially but by the end of the period their share had dwindled to under ten per cent, while Japanese producers had captured 50 per cent (Jäger-Waldau 2006).

Explaining the different outcomes in the two countries can be done through a historical comparative case study. Since the divergence between them was undoubtedly caused by multiple interrelating factors, it will take close examination within each case, as well as across-case comparison to identify and untangle them. Central actors need to be identified, and their actions studied in context of situational structure, relations with each other, and the institutional arrangements regulating their interaction. By identifying and evaluating 'difference makers', it is possible to draw conclusions about which aspects of the low-carbon development process were amenable to human action, and therefore relevant to the task of devising a strategy for the future transition to a low-carbon economy. Knowing where to look requires a theory of both the mechanisms driving industrial change in general, and the particular institutional arrangements regulating them in the countries under study.

Theory

Since new technologies never emerge on a level playing field but are constrained by the existence of powerful incumbents, they need protected spaces to grow in. These can be provided by large private corporations, but since they rarely innovate in ways that would undermine their existing capabilities, we can expect truly radical low-carbon technologies to come from new upstarts. Protected spaces would therefore need to be provided by the state. State support is crucial for radical new technologies in general (Mazzucato 2013), but particularly for environmental technologies with little direct economic value. As Kenney and Hargadon (2013) demonstrate, private venture capital is not a viable model for most low-carbon technologies, which are capital-intensive and in direct competition with existing alternatives. States often provide protection for nascent industries, but this mainly occurs when it concerns their core activity, i.e., survival and expansion in the international state system. In other words, for the state to pursue industrial policy to develop low-carbon technology, they need to be pushed by outside actors.

Social movements are the primary initial actors, supporting transitions either by promoting new technologies directly or by blocking conventional technologies and thereby forcing policymakers to think creatively about technology policy. Social movements succeed when they manage to build alliances with other powerful groups, or act as a broker between them. They also need to frame their message in ways that are attractive to the public and that conform to accepted cultural norms (unless, which is more unusual, they manage to change those norms). Political pressure from social movements can lead the state to support low-carbon industries. Ultimately, however, the success of industrial policy depends upon the innovative capacity of enterprises. The analysis must therefore also include a theory of innovation.

The defining feature of innovation is its fundamental uncertainty. While regular investment decisions are decided by convention and from extrapolation of previous trends, innovation requires a vision of a future which is radically different from the present. Investment in innovation must be made on the basis of fictional constructions of the future (Beckert 2016). Collectively held expectations create the certitude necessary to commit resources to otherwise risky investments. As long as expectations do not stray too far from real technological constraints, they can be self-fulfilling. These are socially constructed, if only in the sense that they must be shared if they are to be

realized. Uncertainty thus compels economic actors to adopt a pro-social orientation; anonymous market transactions are avoided in favor of transactions through organizations or networks (Powell 1990).

The process of innovation requires various actors to cooperate fruitfully. To understand their roles, they can be analyzed as a set of ideal types. At the micro level, innovation is carried out by creative people with deep technological knowledge who are given the resources to develop their ideas until they can generate a return. Innovation begins with the *entrepreneur* who has a new idea, and the *financier* who is needed to finance the venture until it becomes profitable. If the venture is successful, the entrepreneur can hand over operations to the *manager* who supervises *workers*. There are potential tensions between these actors which must be resolved in order for the innovation process to proceed. Power configurations and institutional arrangements determine how, or whether, that occurs.

Since it takes time for the entrepreneur to assemble innovations before they can generate a profit, the initial stage must be financed by credit. As Schumpeter (Schumpeter 1934: 126) noted, this makes the financial system the 'headquarters of capitalism', determining which technologies are allowed to emerge. Before investing in the ideas of an entrepreneur, the financier must confront various forms of uncertainty. For new entrepreneurs, there is no history of income statements, no existing asset that can be used as collateral. There is only an intangible idea, which can only be evaluated on the basis of expected future profitability. Financiers who determine which projects to fund must do so on the basis of knowledge of the specific production process involved, as well as the character of the entrepreneur. This makes credit creation an inherently social process, 'embedded in relations of a strikingly personal sort', as Randall Collins (1986: 137) puts it. In an uncertain world where investment decisions are based upon faith and trust, creditworthiness and market opportunities are always 'socially constructed' (Dymski 1998: 251). An entrepreneur's network position determines his prospects for turning the venture into a going concern. Ideally, it combines close ties, transmitting the trust needed to maintain a credit line, with ties to more distant connections, enabling access to more remote information and market opportunities (Uzzi 1999). If one financier grants a loan to the entrepreneur, it sets off a 'sociological multiplier' which signals to other financiers that the venture is a sound

investment (Reisman 2004: 55). Conversely, if one financier rejects an investment, it signals to others that it might be wise to do the same.

Fruitful cooperation between entrepreneurs and financiers is not guaranteed, however. Bankers do not normally invest the time and effort it takes to evaluate the ideas of new entrepreneurs lacking collateral. Most new ventures are financed by the entrepreneurs themselves or by money from family and friends (Smith 2009). Entrepreneurs and financiers also have differing and potentially conflicting agendas. The entrepreneur wants to keep capital tied down in production, while the financier wants the production phase to conclude and output converted into money. To use Carlota Perez's (2002: 6) terminology, the entrepreneur represents *production capital* which is tied down in equipment, personnel, knowledge and routines, while the financier represents *financial capital* which is free to move. The underlying tensions tend to drive financial capital to decouple from production, as financiers constantly devise innovations in financial speculation.

Their differing logics create a tension at the heart of capitalism. If the agents of financial capital could, they would rather skip the production phase altogether and turn money directly into more money. Institutional arrangements determine whether this strategy is possible. Financial capital may aid creative destruction by redeploying resources from old to new industries. But it may lack the patient capital to sustain them. For innovation to proceed, production capital and financial capital must be made to operate in tandem. Whether this occurs is an empirical question which varies at different times and places, making it important to be attuned to historical and institutional analysis.

If the entrepreneur succeeds in turning the venture into a going concern, he or she can hand over operations to the manager, who supervises workers. This introduces another tension, that between the capital and labor. Production and finance capital both belong to the capitalist class. Their collective goal vis-à-vis workers is to extract as much effort as possible for the least cost. Conversely, workers can be viewed to have the opposite goal, to exert as little effort as possible for as much pay as possible. The effort-minimizing worker may predominantly apply to alienated labor, however. Innovation would not be possible if human beings did not have an inherent will to create, an activity that is rewarding in its own right. The task of the innovative enterprise is to harness this drive.

Innovation can be defined as an information creation process (Nonaka and Kenney 1991), and the actors with the most tacit knowledge about the production process are in the best position to contribute to it. Most innovation is incremental, consisting of individually minor but cumulatively major improvements to work processes and equipment. Workers, who have local, tacit knowledge to upgrade the work process and equipment are the major contributors to the process. In settings where workers are barred from participating, or where their tasks are narrowly defined and require few skills, their incentives and abilities to improve the work process are greatly diminished (Lazonick 1993: Part 1). Segmenting workers from management decisions impedes innovation while integrating workers into the work process advances it.

An innovative enterprise must resolve both the tension between production capital and financial capital, as well as that between capital and labor. The balance and relations between are determined within the firm by who controls it. It is also shaped by institutional context. The three nodes of innovation – financial capital, production capital, and labor – are regulated by different institutional arrangements in different countries. It takes conscious institutional bridging to connect them, often occurring during extraordinary political events such as economic depression or war. Path dependency then tends to reinforce them.

Beyond internal power dynamics, a firm's strategy is shaped by its position relative to other firms. Markets are populated by incumbent and challenger firms (Fligstein 1996). Incumbents seek to stabilize their position. Challengers normally have to operate within the confines set up by incumbents, although in certain circumstances they can upend the market and move into the incumbent position themselves. The main objective of both is to avoid direct competition (White 1981). This can be achieved by controlling inputs and outputs through vertical integration or by creating niches by diversifying into new lines of business. Power asymmetries between incumbents and challengers are also observed by third parties, most notably financiers, who determine whether they want to invest in a firm based on the competition they face. O'Sullivan (2005: 6) suggests that 'we could ask whether incumbent firms dominate because they are more innovative or because entrants are too financially constrained to compete with them'.

To sum up, studying the development of low-carbon technology requires attention to the strength of environmental social movements in the polity, the

capacity of the state and its relation to other power centers, and institutions connecting production capital, financial capital and labor among private enterprises. The analysis in each case will begin with political economy, i.e., the relation and balance forces between state and capital, and move on to the polity, i.e., the strength of citizen groups and ideological currents in civil society. It will then examine policy and the state's capacity to implement it, determined by the structure of the state bureaucracy. Finally, the analysis will center on private enterprises and their relations with each other and financiers.

Case One: the United States

The United States was the birthplace of the solar cell, and American firms dominated the industry in the 1970s. Beginning in the early 1980s, the American PV industry lost ground to foreign, and particularly Japanese, competitors. By 2005, the American share of the global market had declined to under ten per cent. This section will examine the causes behind this relative decline. The analysis begins with an overview of the American political economy in the 1970s and 1980s, before moving on to the polity, the state, and the private sector.

POLITICAL ECONOMY

The 1970s were marked by multiple crises which impacted the evolution of the PV industry. The decade began with environmental crisis, including a massive oil spill off the coast of southern California, leading to strong citizen pressure in favor of environmental regulation and the formation of the Environmental Protection Agency (EPA). Soon afterwards, the first oil crisis struck, putting the need for new energy sources on the public agenda. These two crises favored the development of photovoltaics. Other crises worked in the opposite direction. Stagflation was perceived to refute Keynesian economic policy and vindicate the monetarist theory of Milton Friedman. It de-legitimized regulation and the idea of state intervention, with policymakers 'picking winners'. While the first energy crisis had sparked policy experimentation with alternative technologies, the second energy crisis in 1979 led to a focus on more immediately available energy sources.

The 1970s also saw a shift in the power balance between social movements and business interests (Vogel 1989). When the decade began, American business was on the defensive. Social movements encroached on them, calling for

stronger regulation. Business mounted a counterattack, which bore fruit towards the end of the decade and culminated with the election of Ronald Reagan in 1980.

POLITY

The American environmental movement grew stronger in the 1970s, aiding the development of photovoltaics in several ways. A solar lobby was formed and even became involved in the policy process for a short while during the Carter years. The environmental movement consisted of two broad factions, old-school conservationists and a more radical branch associated with the 'deep ecology' movement (Mitchell 1980: 348). Solar activists affiliated with the former camp emphasized slow progress and avoiding over-optimism, while more radical solar activists saw the turn to solar as part of larger plan to remake society (Orr 1979). One of the most attractive features with solar energy, they thought, was the fact that it could bypass centralized power structures. Switching to solar was part of a greater shift to a more decentralized and democratic society, outside the reach of corporate and government power. 'Solar advocates saw their preferred technologies leading to their preferred social arrangements' (Laird 2001: 190).

Environmental concerns were shared broadly by the public. The message of the environmental movement was in tune with the general climate of opposition to concentrated political and economic power. But the movement had only a narrow social base, consisting mainly of upper-class citizens. There were no successful efforts to unite labor, environmental and consumer movements to promote solar energy (Etzkowitz 1984: 427). Neither did it succeed in presenting its ideology in a cultural frame attractive to the public. The environmental movement's reform strategy centered around state regulation (Buttel and Larson 1980: 326), which came under attack during the general anti-regulation sentiment of the late 1970s, spurred both by abject failures of regulations, and the resurgent business community's deregulatory counter-narrative.

The environmental movement did not lack organizational resources or public support. But it failed because its vision of progress was fundamentally at odds with that of both the public and the policymakers the movement sought to influence. While the actions of solar advocates in expanding the active support for solar energy was short-lived, they played an important role in blocking alternatives, particularly at the state level. Its main influence on

policy was indirect. By raising awareness of environmental issues among the public, legislators came to consider it a popular issue with voters (McFarland 1984: 520). The environmental movement made sure that energy policy after the 1973 was not entirely directed at conventional sources.

POLICY

State policy affected American PV firms in several ways. The late 1970s and early 1980s was a period of tight fiscal policy and extraordinary tight monetary policy. The turn to monetarism in 1979 sent interest rates soaring and caused a sharp appreciation of the dollar, factors identified as major obstacles to PV firms (Coyle and Hawley 1983: 12, US Congress 1985: 53). Other general policies which impacted the PV industry included a relaxation of antitrust enforcement, allowing large conglomerates to compete unhindered with small PV firms, and financial deregulation, making new financial instruments and practices legal, enabling corporate raiders to restructure firms in the 1980s.

Energy policy affected PV more directly. A federal research program to advance photovoltaics was launched in 1972, and given further attention by the oil price hikes in 1973. The federal government supported the industry through demonstration projects, laboratory testing, subsidies for R&D, tax credits for homeowners, and, towards the end of the 1970s, a commercialization program. Some of these measures were highly effective, and even crucial to the emergence of the industry. Federal spending on research and development exceeded private spending by more than 2 to 1 (Roessner 1982: 124). According to one study, testing at the Navy's Jet Propulsion Laboratory greatly increased reliability and reduced the failure rate of solar modules from 45 per cent to 0.1 per cent (Varadi 2014: 96–7). While several of these activities were vital to the growth of the industry, the program as a whole was hindered by the usual problems of American industrial policy in the civilian realm: bureaucratic weakness, capture by vested interests, political rivalry, and constant policy changes.

Before the 1973 oil crisis, energy policy was a fragmented field, composed of a multitude of different and competing interests (Laumann and Knoke 1987: 189). Policymakers struggled to centralize energy policy throughout the decade, culminating in the creation of the Department of Energy in 1977. Chalmers Johnson (1982: 21) likened the process to an attempt to experiment

with Japanese-style industrial policy. It was not successful, as it conflicted with underlying state structures and industrial policy paradigm, and was consequently politically contested from the start. As Ikenberry (1986: 121) notes, 'attempts were made in the 1970s to alter the state's structural capacity in the energy area, and they proved unsuccessful'.

Renewable energy policy during the decade following the first energy crisis had a 'remarkably stormy history' (Frankel 1986: 61). Programs to support new technologies went through a 'sharp series of twists and turns', as leading ideas, interest groups, and political factions changed. The sharpest line of difference can be found between the Carter and the Reagan presidencies, but even Carter was not more than reluctantly committed to developing renewable energy. Towards the end of his term, he was beset by more urgent problems, including recession and the Iranian hostage crisis. State action was confined to short-term measures to put out political fires rather than long-term strategies to develop new industries. Apart from a brief period of solar activism, energy policy never changed from its original focus on conventional sources and nuclear power. Public spending on energy R&D increased by a factor of 6 from the early to the late 1970s (Norberg-Bohm 2000: 128), but the vast majority of it went to fossil fuels and nuclear energy. Subsidies for renewable energy at their peak amounted to less than half the subsidies provided for coal, which in turn received less than half the subsidies for nuclear energy (Etzkowitz 1984). And subsidies to nuclear energy paled in comparison to subsidies to the oil industry. After the 1973 oil shock, they increased by 336 per cent, from $24 billion $120 billion (Etzkowitz 1984: 426–7).

As a new field, energy policy was constructed around existing power structures. Dominant sectors in the military, large corporations, and, in particular, the nuclear power industry directed energy policy to fit their purposes. The agency responsible for PV, the Energy Research and Development Agency (ERDA), had a strong orientation towards nuclear power, with 'virtually the entire staff' coming from the newly disbanded Atomic Energy Commission (Strum and Strum 1983: 137). Many of the same people, along with their pro-nuclear orientation, would later carry over to the Department of Energy.

There were two competing visions of how the PV industry should develop. The pioneering solar entrepreneurs envisioned an industry of small-scale energy production, off the grid (Perlin 1999: 57; Varadi 2014). Solar energy was too expensive to compete with conventional sources, but had the advantage of

being usable in remote locations or at sea. The pioneers saw a reasonably large potential in selling solar panels for such applications as roadside emergency phones, signaling systems for train crossings, electric fences, mountaintop communication centers, African villages, navigational aids and consumer electronics. These markets could be served by small firms, without much investment in research or large production facilities. Profits from these sales could then be plowed back into technical improvements, enabling a further and gradual expansion of the market to less remote locations until the technology was viable for widespread use. Modest policy measures such as mandating lights at remote train crossings were considered more helpful to spur the industry than lavish research grants (Perlin 1999: 78).

The other camp consisted of the energy policy bureaucracy and closely affiliated large manufacturing and energy corporations (Laird 2001). This camp was wedded to the idea of utility-scale photovoltaic generation, competing directly with conventional sources of energy. Proponents of this view favored a massive increase in research and development to improve the efficiency of solar cells in the laboratory until they could compete with centralized energy production. A rapid move towards large-scale mass production was considered necessary to bring down costs. Both activities were capital-intensive, which meant that they needed to be conducted by large corporations.

Representatives from small businesses and the Small Business Administration strongly expressed concern that small PV firms faced unfair competition from large corporations (US Congress 1979; 1983). The DOE's report on funding administered by research laboratories (SERI, Sandia and JPL) between the years 1979 to 1982 stated that small businesses received between 7 and 21 per cent, while big businesses received between 38 to 72 per cent (US Congress 1983: 118). Calls were made to invoke antitrust laws, but they were difficult to apply to, particularly in emerging industries (Wilcox 1981). Moreover, the ideology shaping antitrust legislation itself changed during the time of investigation. The trend during the 1970s was towards greater acceptance of oligopolistic competition when it led to lower product costs for the public (Wilcox 1981: 726). The DOE competition office maintained that there was no action needed; oligopolistic competition between large corporations was enough (Wilcox 1981: 725). It was also concluded that 'potential competition' existed in the form of electronics companies, whose considerations about possibly entering the industry had a disciplining effect on the participants

within it. It is true that American electronics companies potentially could have become major players in the PV industry – that was the case in Japan. Why this did not occur will be outlined further on in this chapter.

In 1977, the DOE proposed a procurement plan for PV modelled on the success of the semiconductor program of the 1950s and 1960s (Hart 1983; Etzkowitz 1984). It had significant differences, however, the most obvious being size. A second difference was that while transistors ordered for spacecraft and missiles had a clear purpose, solar cells ordered by federal agencies did not, and were not subjected to rigorous reliability tests. The semiconductor program was based on the premise that the military needed semiconductors and integrated circuits of high quality, no matter the cost, making it highly profitable to enter the business. The program for photovoltaics on the other hand, aimed at lowering cost. Manufacturers delayed investment in plants because they expected rapid cost reductions to make them obsolete in only a few years (Roessner 1982: 125–126). The program did not become very attractive, and in the long run, costs, and therefore profits, would decline. Unlike in the semiconductor program, where federal agencies announced a steady demand for the foreseeable future, the federal PV program could make no such promises.

The market-enhancing approach of the semiconductor program was not in effect towards the PV industry, because the DOE did not have the bureaucratic strength and connectedness to industry that would have enabled it. As a weak agency without much bureaucratic autonomy, the Department of Energy did not escape the fate of its predecessor of being controlled by existing vested interests surrounding it. With few resources, the DOE was dependent upon large corporations to facilitate this process. Reviewing hundreds of applications, many of them written without professional experience, and deciding how to distribute grants would have been an overwhelming burden for the department. Paul Maycock, the director of the DOE's program for solar electricity, admitted a bias towards large corporations, saying it was difficult to do business with small firms, as they lacked sizable staffs and skills in presenting proposals (Nag 1980). Even near the height of solar power optimism in the United States, he expected only the largest firms to survive. "In the end, we are going to have four companies, as in the automobile industry", he predicted.

Reagan entered office in 1981 with the intention of abolishing the Department of Energy altogether, although he did not succeed in breaking down

congressional resistance. The administration did succeed in cutting support for commercialization programs, which were deemed to be intervening in the realm of the market and left only early research, which was considered as a legitimate correction of market failure. Notably, energy sources with powerful constituencies, such nuclear and oil, did not have their funding cut.

In sum, energy policy greatly aided the photovoltaics industry by providing research, laboratory testing, reliability standards, loans, demand and legitimacy, but it concentrated the industry largely into the hands of large corporations. This would not necessarily have been a problem; in Japan, PV policy was also largely geared towards large corporations. But the organization and governance of large American corporations differed greatly from their Japanese counterparts, making them unsuitable developers of the technology.

PRIVATE ENTERPRISE

The terrestrial American solar photovoltaic industry was founded by a handful of entrepreneurs. Their main difficulty was finding willing investors who could provide *financial commitment*. They managed to gather enough money from family and friends and sometimes more distant investors to launch their enterprises (Berger 1998: 69, 76; Varadi 2014: 20), but they soon found it difficult to attain the needed funds to expand.

The first American PV firm to focus on the terrestrial market was Solar Power Corporation (SPC), founded in 1973 by Elliot Berman. He originally took his idea to a number of venture capitalists, but they 'weren't very venturesome', and declined the offer (Perlin 1999: 53). Instead he turned to the oil company Exxon, which made SPC a subsidiary. The second firm to emerge was Solarex, also founded in 1973, by Hungarian immigrants Joseph Lindmayer and Peter Varadi. They did not have any luck courting venture capitalists either, visiting 20 of them without success, and developing 'allergic reactions if somebody mentioned the word "venture capitalist"' in the process (Varadi 2014: 19, 192). Bill Yerkes, who founded the third major PV firm Solar Technology International (STI) in 1975, visited an estimated 75 venture capital firms (Johnstone 2011: 44) before selling his firm to the oil company Arco two years later.

Solar Power Corporation, Solarex, and Solar Technology International dominated the industry, holding around 80 per cent of the American market

into the 1980s (Richman 1983). If they had trouble securing venture capital, less prominent firms had no greater luck. Robert Willis, who founded Solenergy, was turned down by ten venture capitalists, reporting that they were not interested in risky ventures but rather in established but fast-growing concerns (Ellis 1979: 13). Paul Maycock, who managed the Department of Energy's photovoltaic program, assisted several small firms in their efforts to raise venture capital without being able to raise 'a penny'. He cited the fact that 'private sector-risk capital wants to have return in the next 2 to 3 years' and that '[t]hose things that are 3 or 4 years out are very difficult to get funded' (US Congress 1983: 5, 18).

Beyond a lack of information, small firms had difficulties securing finance because investors knew that huge conglomerates were in competition with them (Berger 1998: 80). Most independent entrepreneurs were compelled to sell their firms to large conglomerates, worsening the situation for the few independents that remained.

The American PV industry was greatly affected by changes in corporate structure and strategy from the late 1960s to the 1980s. In the late 1960s, a new clique of financially oriented managers came to dominate American corporate governance (Fligstein 1990). Their conception of control was to manage the corporation like an investment portfolio, buying and selling firms in other lines of business. As Espeland and Hirsch (1990: 78) describe them, '[t]hey were more financiers than managers, concerned with deal-making more than with the day-to-day operations of the companies they bought'. Consequently, most American corporations evolved into financial conglomerates, managing their subsidiaries from central headquarters with an arm's-length approach. Financial conglomerates 'tended to be "quite thin at the top", their administrative structure fashioned simply to watch over and allocate capital among a portfolio of businesses, there being no central research and development or central staff-coordinating offices' (Rumelt 1974). Tacit information about production was transposed to formal information as decision-making moved from the shop floor to managers relying on quantitative measures such as return on investment, a development that was not conducive to innovation (Lazonick 1992). As conglomerates expanded into ever more diverse product lines, *organizational integration* eroded and *strategic control* moved out of the hands of personnel with intimate knowledge about production into the hands of financial managers in central headquarters.

Bill Yerkes of STI described his firm's parent company Arco as a 'bumbling behemoth' with no knowledge of photovoltaics or even of manufacturing in general (Berger 1998: 80–4). Against Yerkes's protests, the company abandoned research in cadmium telluride and switched to amorphous silicon, resulting in a defective product that had to be withdrawn from the market, twice. Despite its $200 million investment, Arco did not manage to turn a profit. Anticipating an expiration of tax credits, Arco rushed to construct the world's largest PV plant without properly vetting the technology. Completed in 1985, it never went into operation. Similar problems plagued other conglomerates. RCA had pioneered thin film solar technology but lacked the managerial resources to commercialize it and sold it instead to competing Japanese firms (Johnstone 1999: 156–8). While conglomerates provided the PV industry with *financial commitment* through cross-subsidization, they lacked the other two social conditions of the innovative enterprise, *strategic control* and *organizational integration*. In the 1980s, financial commitment would erode as well.

When large corporations took over, so did the large-scale vision they favored. Elliot Berman's small-scale vision for Solar Power Corporation clashed with Exxon's, and when he left in 1975, the firm lost its leadership in building niche markets (Varadi 2014: 110, 129). Solarex had catered to niche markets during the 1970s, but after it became a subsidiary of Amoco, the focus began shifting more towards the 'big-picture' goal of reaching 'grid parity' with other forms of conventional energy production (Varadi 2014: 187). For oil majors to make a satisfactory return on their investment, they had to break through into the grid-connected utility electricity market. As one observer of Arco put it, 'building solar-powered water pumps for Egyptian farmers was not Arco's idea of a big market' (Richman 1983).

While the American financial conglomerates of the 1970s were inept at developing PV, the situation worsened during the 1980s when they were taken apart. The American corporation experienced a deep crisis in the 1970s, to a large extent because of Japanese competition. In the 1980s, the strategy of unrelated diversification was delegitimized and a new conception of control was instituted, continuing the trend towards increasing financialization. The rise of shareholder value and a concomitant restructuring of the American corporate landscape made corporations reverse their previous move towards diversification (Useem 1996; Fligstein and Shin 2007). Cross-subsidization of

diverse product lines was delegitimized and discontinued (Zuckerman 2000), causing a loss of *financial commitment* to PV technology. Deregulation and new debt instruments made it possible for corporate raiders to launch hostile takeovers or 'greenmail' companies for cash. The already vulnerable photovoltaics industry became a victim of the upheaval. In the 1980s, '[s]olar companies in the United States became pawns in the market for corporate control' (Jones and Bouamane 2012: 36).

In the 1980s, as the corporate landscape changed once again, large conglomerates came under pressure to divest and focus on their core competence. Exxon divested in 1982, signaling to investors that photovoltaics was a bad bet. General Electric divested from unrelated product lines to launch hostile takeovers. RCA became a target and divested. Standard Oil of Ohio and Phillips Petroleum divested under pressure from shareholders and corporate raiders, as did Arco in 1989, and its solar division was sold to the German company Siemens. Energy analyst Philip K. Verleger Jr. at Charles River Associates explained the move by saying that American firms were 'too tied up in short-term profits' to make the commitment necessary to make PV economically viable. As the *New York Times* summarized his argument: '[a] publically held company that invested heavily in solar technology would probably become the target of a corporate raider who would argue that shareholders' money would get quicker profits elsewhere' (Wald 1989).

Case Two: Japan

In the 1980s, when American PV firms were leaving the industry, Japanese firms built a new market for solar cells by integrating them with consumer electronics. When that market became saturated, they lobbied the Japanese government to create a new one in residential electricity generation (Kimura and Suzuki 2006). A rooftop solar program was launched in 1994 and further subsidies were added in 1997. These measures, coupled with foreign demand spurred by Germany's feed-in tariff law, passed in 2000, propelled the Japanese PV industry into a period of 22-fold growth between 1994 and 2003. During the first five years of the new millennium, almost half the world's solar cells were manufactured by Japanese firms, while the American share, standing at over 90 per cent in 1980, decreased to around 9 per cent (Jäger-Waldau 2006). Behind this rapid growth was a set of social forces and institutional arrangements uniquely conducive to long-range investments and incremental innovation.

POLITICAL ECONOMY

Modern Japan has been dominated by a conservative coalition of rural and urban elites, closely tied to a small yet pervasive state. In the postwar era, the ruling coalition was represented by the near-hegemonic Liberal Democratic Party (LDP), supported financially by big business and electorally by agricultural interests in a heavily gerrymandered countryside. Their core focus was industrial development. Initially, it had a military purpose, but was later pursued for its own sake. Organized labor has mostly been absent as a political force, but has had significant influence on the organization of work in large firms. Elites responded to the emergence of an organized labor movement with a combination of repression and cooptation, channeling discontent into vertical organization within enterprises to defuse horizontal class-based organization. An aristocracy of skilled workers were given a stake in the corporation, aligning their interests with management. Male blue-collar workers were given secure career paths and considerable autonomy. Issues of redistribution or environmentalist concerns were not political concerns except in extraordinary situations when outside groups forced them upon the establishment (Pempel 1982; Schreurs 2003).

POLITY

The single-minded focus on economic growth pursued by the state-business alliance showed not even minimal concern for environmental welfare. By the 1960s, it had turned Japan into the most polluted country on earth. Solar energy was put on the agenda partly as a response to a growing disaffection with this situation. Several environmental hazards caused death and deformities, sparking outrage and the growth of environmental activism. Unlike in the United States, the environmental movement encompassed various social classes (Reich 1984). One reason was that in Japan, the workers movement had effectively been removed from the political arena. Pollution became the dominant issue in the 1960s, attracting radicalized students and other opposition groups. By framing the issue as a direct threat to human health, caused by the ruling elites, the activists' definition fit other disparate opposition groups. Various small opposition parties, such as the communist party, the socialist party, and the clean government party incorporated environmental issues, aiding and organizing victims, and attacking the government.

Environmentalists had normally been excluded from the policymaking process, and had to act through the courts or the press. But in the late 1960s and 1970s, pollution became such a grievance that policymakers and bureaucrats had to pay attention. Unwilling to compromise with the overarching goal of economic growth, the preferred solution was the development of advanced environmental technology, such as solar cells. Once policymakers decided that environmental problems were a priority, state capacity allowed them to move quickly to implement changes – at least changes that were not in opposition to the general interests of big business.

Another period of crisis occurred in the early 1990s, when the ruling LDP party was challenged for the first time. Disaffection at the end of the bubble economy opened up a space for opposition movements. The opposition party won and enacted the Basic Environmental Law which included the promotion of environmental technology, laying the groundwork for the residential subsidy.

POLICY

The Japanese state played an active role in developing the industry, providing R & D subsidies, funding for demonstration projects, organizing cooperative research consortia, and ultimately creating a market for residential electricity generation. Industrial policy in the semiconductor sector also aided Japanese PV producers, which were originally involved in electronics, semiconductors and ceramics. State support for PV was more reliable in Japan than in the US, but financial support for R&D did not, apart from a slight exception in 1991, exceed that of the United States until 2001 (Knight 2011). Although the quantity of government support was lower in Japan, the quality was greater. Photovoltaics were developed within Japan's prestigious industrial Ministry of International Trade and Industry (MITI), in contrast with the United States, where it was handled erratically under the newly established and politically unstable Department of Energy.

The powers of MITI were born out of extraordinary historical circumstances. A post-war purge cleared away the military and the *zaibatsu* (family-owned conglomerates), allowing the economic bureaucracy, which was necessary for post-war reconstruction, to expand its powers. Pressure to liberalize the economy in the 1960s caused its methods of industrial restructuring to shift to 'administrative guidance' and the formation of research consortia. MITI's

power derived not from its ability to dominate private industry but rather to work with and through it. The networked economy of Japan provided many entry points for industrial policy, enabling it to influence the market without having to go through the political channels of the LDP or the Diet. Samuels (1987: 260) describes a situation of constant negotiation, where the state rarely if ever attained its initial goals.

The state has not been very successful in achieving broad sectoral shifts, but where the state can intersect at the junctures of established industries and new industries, it has been very effective. The state could strategically upgrade sectors where industrial support authorization already exists, and 'foster hybrid industries through technological fusion where administrative boundaries and legislative authorization permit' (Calder 1995: 248). In the 1980s, mixed public-private institutions such as the Key Technology Center and the New Energy and Industrial Development Organization (NEDO) operated successfully with the private sector developing new industries, including PV.

Major efforts to develop photovoltaics began with the government's Sunshine Program in 1974, a MITI-led effort designed to promote alternative energy after the oil crisis. It consisted mostly of support for conventional energy, particularly coal, but included a small sum for solar energy.

The program was expanded after the second oil shock in 1979. The Alternative Energy Law was enacted in 1980, preceded by intense struggle between MITI and other ministries and with private industry (Samuels 1981). The inter-bureaucratic struggle was shaped by two contradictory goals set up by Prime Minister Ohira in 1979, promotion of alternative energy and 'financial reconstruction'. MITI wanted increased funding to achieve the first goal, while the Administrative Management Agency and the Ministry of Finance wanted to control spending to achieve the second.

MITI's opening bid would grant it extensive powers of industry, allowing officials to set legally binding targets for industry's conversion from oil to alternative energy (Samuels 1981: 152). The agency also proposed to create special accounts and taxes for MITI to finance the energy conversion strategy, and to form an Alternative Energy Public Energy Corporation over which MITI would gain full supervisory control. None of these were ultimately implemented as originally proposed, however. Industry opposed them on grounds that they encroached on the private sector (Samuels 1981: 153). The AMA and MOF opposed them on grounds of cost. Instead of a public policy

corporation, a hybrid public-private form was chosen. From the private sector's perspective, it was a case of separating government funding from government control. The project is operated in conjunction with a number of private companies, including Toshiba, NEC, Mitsubishi, Sanyo, Sharp and Kyocera.

NEDO's program became focused on low-cost PV products, which had the most commercial potential (Newham 1986: 63). It sponsored a wide variety of projects through universities, research agencies, and private companies. The companies shared all results produced under NEDO sponsorship (Newham 1986: 64). The main concern in the mid-1980s was to scale the technology already used in gadgets for large-scale use.

A research consortium, PVTEC, was formed in 1990, consisting of 29 private manufacturers of PV cells, modules and systems. It created spillover effects among participants from various industries, including chemicals and textiles (Watanabe et al. 2002).

A second Sunshine Program was launched in 1993, coupled with a residential subsidy. The expanded role of PV in the 1990s was the result of intense lobbying from the PV firms, represented by the Japanese Solar Industry Association, and by climate change-conscious politicians within and outside the ruling Liberal Democratic Party (Kimura and Suzuki 2006). MITI opposed measures to reduce economic growth, making a massive expansion of solar energy and other low-carbon-technologies the default plan to reduce greenhouse gas emissions. The Japanese PV industry was set on a course of virtuous continuous expansion (Watanabe et al. 2002). The residential subsidy provided the long-term assured demand to set it in motion.

While the state was a necessary component in PV development, not only in PV but in other industries such as semiconductors and ceramics, it was not leading the effort. The big difference between the countries was in the organization of private enterprise. This difference, however, was largely caused by the way the Japanese state shaped the financial system after the war. It was specifically designed to encourage investment in productive instead of speculative activity, partly inspired by the economic theory of Joseph Schumpeter (Metzler 2013).

PRIVATE ENTERPRISE

In the 1970s, Japanese firms made inroads into industries related to photovoltaics, conquering almost half of the global semiconductor market and wiping out large parts of the American consumer electronics industry (Chandler et al. 2009). These firms viewed photovoltaics as a complementary investment to their existing capabilities, where they could plow some of their retained earnings (Kimura and Suzuki 2006). Japanese firms faced few of the constraints of their American counterparts, and kept on investing undisturbed by the turbulence of the American 1980s merger wave. Aggressive investment, even during downturns, was a defining feature of Japanese postwar capitalism. Levels of corporate investment exceeded those of any other industrial nation, giving Japanese firms 'the most impressive investment performance ever achieved in any peacetime, democratic, market economy' (Gerlach 1992: 253–254). It was especially pronounced in capital-intensive industries such as semiconductors and electronics, the parent industries of photovoltaics.

Japanese electronics firms' main competitive advantage was financial commitment, secured through close ties with banks (Flaherty and Itami 1984; Langlois and Steinmueller 1999). Banks provided firms with 'dedicated capital' available for 'long periods of time, without regard to short-term returns' (Calder 1995: 250). Although Japanese banks turned highly speculative in the 1980s, corporate finance was largely insulated from such pressures by blocs of stable shareholders (Goldstein 1997). Perhaps even more important than access to reliable credit was retained earnings, and Japanese managers' ability to exercise strategic control over them without regarding to shareholders' interests. Managers were freed from 'the restrictions of short-term perspectives' to set 'long-term goals' (Iwata 1992: 175). Large Japanese firms continued to cross-subsidize PV through sales in other lines of business, as US firms had done in the era of the M-form conglomerates in the 1970s, but their diversification strategies focused on related, rather than unrelated, diversification.

Due to the institutional arrangement of cross-shareholding, in which firms held each other's shares for the long term, Japan did not experience a 'shareholder revolution' as did the United States. Instead of managers being compelled to act like shareholders, shareholders in Japan were compelled to act like managers (Gerlach 1992: 227). Japanese photovoltaics producers were not subject to the 'market for corporate control'. Beyond protecting against hostile

takeovers, cross-shareholding meant that Japanese managers were 'under less compulsion to sustain high quarterly profits than their US counterparts, and therefore freer to focus on long-term expansion of market share' (Okimoto 1989: 44).

Thirdly, and partly relatedly, a key strength of Japanese firms was the organizational integration of workers in the innovation process. American firms were segmented between white-collar and blue-collar workers (Lazonick 1993: 43). In Japan, blue-collar workers were integrated into the innovation process. Iwata (1992) argues that the elimination of shareholder control after the Asia-Pacific War turned the Japanese enterprise into a 'unified body of employees'. Lifetime employment turned the worker from a 'an external seller of his labor', to a 'corporatist who shares the responsibilities of management' (Iwata 1992: 176). At Kyocera, one of the top Japanese PV producers, workers were organized in self-managing teams known as 'amoebas'. According to Florida and Kenney (1990: 158–159), this organization was a mechanism for 'generating internal, self-imposed discipline, devolving manager responsibility to the shop floor, and motivating workers to work harder' thereby 'harnessing workers' knowledge and collective problem-solving capabilities for the enterprise'.

In sum, Japanese institutional arrangements – bank-financing, cross-shareholding, enterprise unions and lifetime employment – aligned the interests of financial capital, production capital, and labor in a manner that allowed them to maintain the social conditions of innovation. Consequently, Japanese firms drove American competitors out of the PV market and related markets. They also avoided the corporate upheaval afflicted their American rivals – a restructuring which to a large extent was caused by Japanese competition in the first place.

Conclusion

The framework developed in the theoretical section directed attention to the weaknesses of the American approach towards developing photovoltaics. By focusing almost exclusively on creating a future market for centralized energy generation, American firms missed the opportunity to develop the small off-grid and consumer electronics markets that were already available. There was an alternative path that was not taken, towards decentralized solar energy which would not have to compete with conventional sources. We know

this because that is how the industry developed in Japan, where solar cells were applied mainly for off-grid use and consumer electronics, allowing the technology to mature gradually without much reliance on subsidies or record-level energy prices. The chapter demonstrates that the main reason this path was not taken in the United States was a disconnection between industry and finance. The entrepreneurs who had the deepest knowledge of the technology and the markets where it would be cost-effective lacked connections to the financial sphere. Consequentially, most of them succumbed to large financial conglomerates, which were inefficiently governed by arm's length relations from central headquarters at first and by even more distant financial markets later. This made entry possible for Japanese firms, whose institutional and financial arrangements insulated them from financial constraints and destructive conflicts between shareholders and managers, as well as providing greater integration of workers in the innovation process.

In Japan, technologically innovative PV firms had ample financing and were sheltered from the turbulence of financial markets. In the United States, the financial system was unwilling to finance small entrepreneurial firms, causing the industry to become concentrated among large corporations. This would not necessarily have impeded innovation, if not for the way financial markets influenced large corporations in this era, first by turning them into unwieldy and inefficient conglomerates in the 1960s and 1970s, and then by breaking them up in the takeover wave of the 1980s. The end result was a suboptimal outcome that arguably set back the American, and thereby global, solar energy industry for decades.

References

Beckert, Jens 2016. *Imagined futures: fictional expectations and capitalist dynamics*. Harvard University Press

Berger. John J. 1998. *Charging ahead: the business of renewable energy and what it means for America*. Berkeley: University of California Press

Buttel, Frederick. H. and Larson, Oscar W. 1980. 'Whither Environmentalism – The Future Political Path of the Environmental Movement', *Nat. Resources Journal* 20: 323

Calder, Kenneth. E. 1995. *Strategic capitalism: Private business and public purpose in Japanese industrial finance*. Princeton University Press

Chandler, Alfred D. 2009. *Inventing the Electronic Century: The Epic Story of the Consumer Electronics and Computer Industries*. Harvard University Press

Collins, Randall 1986. *Weberian sociological theory*. Cambridge University Press

Coyle, Eugene. P. and Hawley, James. P. 1983. *Photovoltaics: Technology for Energy Independence*. California Commission on Industrial Innovation

Dymski, Gary 1998. 'Disembodied risk or the social construction of creditworthiness?', *New Keynesian Economics/Post Keynesian Alternatives*: 241–261

Ellis, Phillip. A. 1979. *The availability of capital for developing photovoltaic markets*. MIT Energy Laboratory

Etzkowitz, Henry 1984. 'Solar versus nuclear energy: Autonomous or dependent technology?', *Social Problems* 31(4): 417–434

Flaherty, Therese, and Itami, Hiroyuki 1984. 'Finance', in Okimoto, Takuo, and Weinstein (eds.), *Competitive Edge: The Semiconductor Industry in the US and Japan*. Stanford University Press

Fligstein, Neil 1990. *The transformation of corporate control*. Harvard University Press

Fligstein, Neil 1996. 'Markets as politics: a political-cultural approach to market institutions', *American Sociological Review* 61: 656–673

Fligstein, Neil and Shin, Taekjin 2007. 'Shareholder Value and the Transformation of the US Economy, 1984–2001', *Sociological Forum* 22: 399–424

Florida, Richard L. and Kenney, Martin 1990. *The breakthrough illusion: Corporate America's failure to move from innovation to mass production*. New York: Basic Books

Frankel, Eugene 1986. 'Technology, politics and ideology: the vicissitudes of federal solar policy, 1974–1983', *Energy Policy Studies* 3: 61–87

Gerlach, Michael L. 1992. *Alliance capitalism: The social organization of Japanese business*. Berkeley: University of California Press

Goldstein, Don 1997. 'Financial Structure and Corporate Behavior in Japan and the US: insulation versus integration with speculative pressures', *International Review of Applied Economics* 11: 27–48

Hart, Stuart 1983. 'The Federal Photovoltaics Utilization Program: An evaluation and learning framework', *Policy Sciences* 15: 325–343

Ikenberry, John 1986. 'The irony of state strength: comparative responses to the oil shocks in the 1970s', *International Organization* 40: 105–137

Iwata, Ryushi 1992. 'The Japanese enterprise as a unified body of employees: origins and development', in Shumpei and Rosovsky (eds.) *The political economy of Japan, Cultural and Social Dynamics*, Vol 3: 170–197

Johnson, Chalmers 1982. *MITI and the Japanese miracle: the growth of industrial policy, 1925–1975*. Stanford University Press

Johnstone, Bob 1999. *We were burning: Japanese entrepreneurs and the forging of the electronic age*. New York: Basic books

Johnstone, Bob 2011. *Switching to Solar*. Amherst, NY: Prometheus Books

Jones, Geoffrey and Bouamane, Loubna 2012. '"Power from Sunshine": A Business History of Solar Energy', Harvard Business School Working Paper 12–105

Jäger-Waldau, Arnulf 2006. 'PV Status Report 2006', Office for Official Publications of the European Communities Luxembourg

Kenney, Martin and Hargadon, Andrew 2013. 'Venture Capital and Clean Technology', in J. Zysman and M. Huberty (eds.) *Can Green Sustain Growth?: From the Religion to the Reality of Sustainable Prosperity*, Stanford University Press: 59–78

Kimura, Osamu and Suzuki, Tatsujiro 2006. '30 years of solar energy development in Japan: co-evolution process of technology, policies, and the market'. Paper presented at the Berlin Conference on the Human Dimensions of Global Environmental Change: 'Resource Policies: Effectiveness, Efficiency, and Equity'

Knight, Chris 2011. 'Failure to Deploy: Solar Photovoltaic Policy in the United States', in Block and Keller (eds.), *State of Innovation: The US Government's Role in Technology Development*, Boulder, CO. Paradigm Publishers: 173–195

Laird, Frank N. 2001. *Solar energy, technology policy, and institutional values*. Cambridge University Press

Langlois, Richard and Steinmueller, Edward 1999. 'Strategy and circumstance: The response of American firms to Japanese competition in semiconductors, 1980–1995', *Strategic Management* 21: 1163–1173

Laumann, Edward and Knoke, David 1987. *The organizational state: Social choice in national policy domains*. University of Wisconsin Press

Lazonick, William 1992. 'Controlling the market for corporate control: the historical significance of managerial capitalism', *Industrial and Corporate Change* 1(3): 445–488

Lazonick, William 1993. *Business organization and the myth of the market economy*. Cambridge University Press

Mazzucato, Mariana 2013. *The entrepreneurial state: Debunking public vs. private sector myths*. London: Anthem Press

McFarland, Andrew 1984. 'Energy lobbies', *Annual Review of Energy* 9(1): 501–527

Metzler, Mark 2013. *Capital as Will and Imagination: Schumpeter's Guide to the Postwar Japanese Miracle*. Cornell University Press

Mitchell, Robert 1980. 'How Soft, Deep, or Left-Present Constituencies in the Environmental Movement for Certain World Views', *Nat. Resources Journal* 20: 345

Nag, Amal 1980, 8 December. 'Big Oil's Push Into Solar Irks Independents', *Wall Street Journal*

Nelson Espeland, Wendy and Hirsch, Paul M. 1990. 'Ownership changes, accounting practice and the redefinition of the corporation', *Accounting, Organizations and Society* 15(1): 77–96

Newham, Mark 1986. *Photovoltaics: The Sunrise Industry*. London: Financial Times Business Information Ltd.

Nonaka, Ikujiro and Kenney, Martin 1991. 'Towards a new theory of innovation management: A case study comparing Canon, Inc. and Apple Computer' *Journal of Engineering and Technology Management* 8: 67–83

Norberg-Bohm, Vicki 2000. 'Creating Incentives for Environmentally Enhancing Technological Change: Lessons From 30 Years of US Energy Technology Policy', *Technological Forecasting and Social Change* 65(2): 125–148

O'Sullivan, Mary 2005. 'Finance and innovation', in *The Oxford Handbook of Innovation*. New York: Oxford University Press, pp. 240–265

Okimoto, Daniel I. 1989. *Between MITI and the market: Japanese industrial policy for high technology*. Stanford University Press

Orr, David W. 1979. 'US energy policy and the political economy of participation', *The Journal of Politics*, 41(4): 1027–1056

Pempel, Theodore J. 1982. *Policy and politics in Japan: Creative conservatism*. Temple University Press

Perez, Carlota 2002. *Technological revolutions and financial capital: The dynamics of bubbles and golden ages*. Cheltenham, UK: Edward Elgar Publishing

Perlin, John 1999. *From space to earth: the story of solar electricity*. Harvard University Press

Powell, Walter 1990. 'Neither market nor hierarchy', *The sociology of organizations: classic, contemporary, and critical readings*, 315

Reich, Michael 1984. 'Mobilizing for Environmental Policy in Italy and Japan', *Comparative Politics* 379–402

Reisman, David 2004. *Schumpeter's market: enterprise and evolution*. Cheltenham, UK: Edward Elgar Publishing

Richman, Tom 1983. 'May 1. The Fight to Harness the Sun', *Inc. Magazine*

Roessner, David 1982. 'Government-industry relationships in technology commercialization: The case of photovoltaics', *Solar Cells* 5(2): 101–134

Rumelt, Richard 1974. *Strategy, Structure and Economic Performance*. Harvard University Press

Samuels, Richard J. 1981. 'The Politics of Alternative Energy Research and Development in Japan', in R. A. Morse (ed), *The Politics of Japan's Energy Strategy*. Berkeley, California: Institute of East Asian Studies

Samuels, Richard J. 1987. *The business of the Japanese state: Energy markets in comparative and historical perspective*. Cornell University Press

Schreurs, Miranda A. 2003. *Environmental Politics in Japan, Germany, and the United States*. Cambridge University Press

Schumpeter, Joseph A. 1983 [1934]. *The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle*. London: Transaction Publishers

Smith, David 2009. 'Financial bootstrapping and social capital: How technology-based start-ups fund innovation', *International Journal of Entrepreneurship and Innovation Management* 10(2): 199–209

Strum, Harvey and Strum, Fred 1983. 'American Solar Energy Policy, 1952–1982', *Environmental History Review* 7(2): 135–154

US Congress 1979. 'Role of government funding and its impact on small businesses in the solar energy industry Part 1', Washington D.C.: US Government Printing Office

US Congress 1983. 'Marketing opportunities in the photovoltaic industry', Washington, D.C.: US Government Printing Office

US Congress 1985. 'The current state and future prospects of the US photovoltaics industry', Washington, D.C.: US Government Printing Office

Useem, Michael 1996. *Investor capitalism: How money managers are changing the face of corporate America*. New York: Basic Books

Uzzi, Brian 1999. 'Embeddedness in the making of financial capital: How social relations and networks benefit firms seeking financing', *American Sociological Review* 64: 481–505

Wald, Matthew L. 1989, March 7. 'US Companies Losing Interest in Solar Energy', *New York Times*

Varadi, Peter 2014. *Sun Above the Horizon: Meteoric Rise of the Solar Industry*. Singapore: Pan Stanford Press

Watanabe, Chihiro, Griffy-Brown, Charla, Zhu, Bing, and Nagamatsu, Akira 2002. 'Inter-firm technology spillover and the "virtuous cycle" of photovoltaic development in Japan', *Technological Change and the Environment* 127–159

White, Harrison C. 1981. 'Where do markets come from?', *American Journal of Sociology* 87: 517–547

Wilcox, Ronald L. 1981. 'Oil Companies and Photovoltaics: A Potential Monopoly', *Solar Law. Rep.* 3: 703

Vogel, David 1989. *Fluctuating fortunes: The political power of business in America*. Washington, D.C.: Beard Books

Zuckerman, Ezra W. 2000. 'Focusing the corporate product: Securities analysts and de-diversification', *Administrative Science Quarterly* 45(3): 591–619