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OVERCOMING THE LIABILITY OF NEWNESS: ENTREPRENEURIAL ACTION AND THE EMERGENCE OF CHINA'S PRIVATE SOLAR PHOTOVOLTAIC FIRMS

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Abstract

This study explores how entrepreneurs introducing a new organizational form can build legitimacy and capabilities to overcome significant liabilities of newness, and how their actions and the institutional structure co-evolve. Our multiple case study design enabled us to explicate specific actions that entrepreneurs founding China's private solar photovoltaic (PV) firms took as they built organizational capabilities and established their legitimacy vis-à-vis resource holders and global markets. We identified three legitimacy-based strategies they used: *leveraging* their existing sources of legitimacy, *aligning* their actions with established institutional rules and norms, and *enacting* the institutional environment to change perceptions of what is legitimate. We also found a stark contrast between the early and late entrants. The early entrants had to build an effective organizational capability and establish their own firm's legitimacy, as well as establish the legitimacy of the private Chinese solar PV firm as a viable organizational form, both domestically and abroad. Later entrants could leverage the legitimacy established by the early entrants, enabling them to more easily and quickly access external resources and become competitive. Our findings also suggest an important role for government in promoting and supporting entrepreneurship that complements well-established approaches. Namely, through its policies and actions, the government can create an environment in which experimentation and exploration is legitimate, thereby making it easier for entrepreneurs, new ventures and new organizational forms to access critical resources and realize their potential.

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OVERCOMING THE LIABILITY OF NEWNESS: ENTREPRENEURIAL ACTION AND THE EMERGENCE OF CHINA'S PRIVATE SOLAR PHOTOVOLTAIC FIRMS

1. Introduction

In this paper, we integrate entrepreneurship and institutional perspectives to understand how entrepreneurs may overcome a significant "liability of newness" (Stinchcome, 1965; Singh et al, 1986; Aldrich and Fiol, 1994) in order to establish new firms and a new organizational form in an industry dominated by incumbents. For any entrepreneur, the challenge of overcoming that liability is two-fold. First, and representing the core definition of entrepreneurship, they must effectively integrate and transform resources to build an organizational capability that enables them to exploit an opportunity. Second, entrepreneurs must establish their own legitimacy as founders as well as the legitimacy of their new venture in order to access resources they lack, such as financing, employees, supplies, customer demand and government approvals.

When the venture represents a new organizational *form*, the entrepreneur faces an even greater liability of newness. To the extent that the new organizational form is at odds with the dominant formal and informal institutional features of its environment, including regulations and dominant norms, beliefs and values (Scott, 1995; Suchman, 1995; Tolbert & Zucker, 1996; Stuart et al, 1999; Greenwood & Suddaby, 2006), an entrepreneur may not be able to access critical resources from external actors who see the form as illegitimate. In that case, an entrepreneur may have to engage in "institutional entrepreneurship" to change those formal and informal "rules" that define what is legitimate (e.g. Battilana et al, 2009; Sine & Lee, 2009; Sine et al, 2007) in order to access those resources.

We use the emergence of the private Chinese solar photovoltaic (PV) firms as a context to understand the process by which new entrants in an existing industry build

legitimacy for their firms and the new organizational form they represent.[1] When they first entered, their access to many key resources was severely constrained by their lack of legitimacy—as both new firms and as a new form of competitor. Until 2002, the "private Chinese solar PV firm" as an organizational form did not exist. Within five years, however, this form would displace the incumbent form—represented by multinationals from Japan, Germany and the USA—to become the major source of solar PV cells globally (Zhao et al, 2008; Algieri et al, 2011; Rigter & Vidican, 2010).

Prior research on the rise of successful new firms and industries in China has primarily addressed the role of government support (Peng and Luo, 2000; Xin and Pearce, 1996) and factor advantages—especially low-cost labor, raw materials and financing—as well as successful technological learning (e.g., Zeng & Williamson, 2007; McNally, 2008; Simon and Goldman, 1989; Guan and Ma, 2003; Xie and White, 2004, 2006; Xie and Wu, 2003; Mu and Lee, 2005; Jefferson et al, 1993). In these predominantly economics- and strategy-based studies, resources such as technology, low-cost production factors and government support are "out there". Attention to the institutional environment is limited to that of specific actors and formal institutional features, such as the legal or regulatory regime and government support.

Echoing Tolbert et al (2011), we argue that such analyses are representative of an undersocialized view of the entrepreneurial process, and even more so in the context of new entrants representing a new organizational form in an industry dominated by multinational incumbents. The entrepreneurs who established the private Chinese solar PV firms had to overcome significant liabilities of newness to access resources and build the companies that

[1] In contrast to module production that is a relatively simple assembly process, cell production is much more technically complex and requires a high level of technological capability and was considered too challenging for developing countries (Bruce, 2007:12-13). The key breakthrough for the entrance of new private Chinese solar PV firms was their ability to make cells at international standards of efficiency and quality at a competitive price.

would eventually emerge as global competitors. Understanding how they were able to do that was the basic question motivating our study; namely, *How did these entrepreneurs establish the legitimacy of both their firms and a new organizational form?* We also extended this question longitudinally to explore co-evolutionary dynamics; namely, *How did the actions of the early entrants impact the institutional environment, and how did that in turn affect the actions of later entrants?*

We gathered data on the entrepreneurs and their actions as they established their firms, complemented by data on the institutional environment, up to 2007 when these firms had displaced multinational incumbents in terms of global market share. Based on this data, we developed a typology of legitimacy-focused strategies that these entrepreneurs used—*leveraging*, *aligning* and *enacting*—in the process of founding and building their firms. We then identified a distinct difference between the early and later entrepreneurs. Specifically, the early entrepreneurs had to build legitimacy for themselves as founders and their new ventures, as well as for the organizational form they represented. They had to undertake all three types of legitimacy-focused strategies to access the external resources that they lacked. Later entrepreneurs, in contrast, did not have to expend the effort to build legitimacy for their organizational *form* vis-à-vis investors, potential employees, suppliers or customers. Instead, they could leverage the legitimacy of the form established by the early entrepreneurs. This helped them acquire resources much more quickly and easily and, thereby, build their companies and enter the market much faster than the early entrepreneurs. Based on these insights, we propose that policymakers wishing to promote entrepreneurship and new industries may add the active management of informal institutional forces—i.e, manipulating perceptions of what means and ends are legitimate vis-a-vis potential entrepreneurs and resource-holders—to their more traditional policy approaches.

2. Entrepreneurial action and the liability of newness

The empirical setting in which entrepreneurs must overcome the liability of newness of both a new venture and a new organizational form represents an ideal context to respond to Tolbert et al's (2011) call to integrate the usually separate literatures on entrepreneurship and institutions. These two streams of research both address legitimacy, but with important micro and macro distinctions (Überbacher, 2014). Here we discuss these differences and how we integrate them in our empirical study.

Entrepreneurship scholars frame the question of what actions are required to overcome the liability of newness in terms of an entrepreneur's ability to discover and exploit opportunities, as proposed by Venkataraman (1997) and further developed by others (Shane, 2000; Shane & Venkataraman, 2000; Eckhardt & Shane, 2003). From this perspective, entrepreneurs must do two things. First, they must identify or create a promising market opportunity. Second, they must integrate and transform resources in a way that creates an organizational capability that enables them to pursue that opportunity. Entrepreneurship research that addresses the question of legitimacy typically focuses on the founders and their new ventures and their access to resources; see, for example, the work reviewed by Überbacher (2014) and conceptual treatments by Zimmerman and Zeitz (2002) and Bitektine (2011). Entrepreneurs build legitimacy in order to access the resources they need to found and grow their businesses.

A complementary but largely separate stream of sociology-based literature draws attention to the role of the institutional context in entrepreneurship (e.g., Aidis et al, 2008; Bowen and DeClerq, 2008; Busenitz et al, 2000; Manolova et al, 2008; Sobel, 2008; Spencer and Gomez, 2004). Research from this perspective highlights the impact of formal and informal institutional features (Aldrich and Fiol, 1994; Suchman, 1995; Stuart et al, 1999; Zuckerman, 1999; Dacin et al, 2007). In contrast to entrepreneurship researchers' attention

to the legitimacy of an individual founder or specific new venture, however, scholars from an institutional perspective address the challenge for entrepreneurs pioneering new organizational forms or new sub-organizational elements such as structures, practices or roles (e.g., Sine & Lee, 2009; Glynn & Navis, 2010; David et al, 2013). The central challenge for new entrants is to establish the legitimacy of the organizational form or element vis-à-vis the regulatory regime and broadly held norms and beliefs (Saxenian, 1991; Sine et al, 2005; Greenwood and Hinings, 1988; Sorenson and Audia, 2000; Kaplan & Murray, 2010; Zimmerman and Zeitz, 2002) and social values, priorities and assumptions (Meek et al, 2010; Sine and Lee, 2009; Lounsbury and Glynn, 2001 Zott and Huy, 2007). They find the challenge is even greater in established or mature industries with established institutional "rules" compared to new and emerging industries in which the institutional environment is still in flux (e.g., David et al, 2013) or in which there are institutional actors with contradictory interests and logics (Kaplan and Murray, 2010).

This stream of research has generated insights into the liability of newness by showing the interplay among legitimacy, institutional structure, and entrepreneurial action. However, at its root, institutions, societal-level actors and organizational forms and elements rather than founders or organizations are the focal concern. The founding of new ventures is simply another context to study related institutional processes. Even studies of institutional entrepreneurship (e.g., Battilana et al, 2009; Sine et al, 2007; Greenwood et al, 2002; Powell et al, 2005) are primarily concerned with entrepreneurs as drivers of institutional change and less so with the organizations that they create. This contrasts with the entrepreneurship field's primary interest in entrepreneurs and how they create new organizations.

Rather than frame our research according to one perspective or another—the "macro" and "micro" choice framed by Überbacher (2014)—we integrate them in our empirical study. Drawing on Suchman's (1995) seminal work, this integration can be defined based on

choices about a) the object of legitimacy, b) the "audiences" evaluating legitimacy, and c) the purpose of achieving legitimacy.

First, regarding the object of legitimacy, we include key constructs from both the entrepreneurship and institutional perspectives. Entrepreneurship scholars have focused on the perceived legitimacy of the individual founder and the new venture, and more recently on their social capital (e.g., Kim & Aldrich, 2005). Sine and David (2010) draw a clear distinction between this stream of research and that of institutional theory, arguing that "an institutional approach to entrepreneurship shifts attention away from the personal traits and backgrounds of individual entrepreneurs and toward how institutions shape entrepreneurial opportunities and actions…" (2010:2). Empirical work in this vein assesses the legitimacy of organizational forms and sub-organizational features (practice, activity, role or structure), not of specific actors (individuals, teams or ventures). For our study, a full treatment of legitimacy and the liability of newness requires an analysis of all of these objects of legitimacy: namely, the individual founders and new ventures, as well as the new organizational forms and elements that they are introducing.

Second, regarding the salient audiences that define and evaluate legitimacy, we focus on specific and micro-level "audiences" who are salient to the entrepreneurs due to their control over specific resources. The audience may be a relatively large collective such as a target customer group, a smaller one such as "social enterprise angel investors", or even a single actor such as a regulator or opinion leader. This is in contrast to institutional scholars who have tended to focus on very broad groups or even society at large as the "social group" defining what is legitimate (Überbacher, 2014).

Finally, regarding the entrepreneurs' objective in achieving legitimacy, we recognize that the outcomes emphasized in the two perspectives are distinct but not mutually exclusive. Most entrepreneurship scholars treat the management of legitimacy as instrumental

(Zimmerman & Zeitz, 2002). It enables the entrepreneur to secure resources needed for an organization to survive or "persist"—one role highlighted by Suchman (1995:574). Research from the institutional perspective, however, has emphasized the other role discussed by Suchman (1995); namely, legitimacy's role in making the organization meaningful, credible or trustworthy vis-à-vis the "observer". These two objectives—*resources* and *meaning*—are not mutually exclusive. Entrepreneurs may undertake both in the process of building their firms, as described by David et al (2013) in their study of the emergence of management consulting firms, and Glynn & Navis (2010) in their study of satellite radio. Given the social benefit that is ascribed to solar power, we believe that both objectives are salient in the empirical context of our study. However, we also believe that achieving "meaning" also enhances a venture's ability to attract resources, even if indirectly. For the purpose of our study, we focus on the more directly instrumental view of legitimacy building and identify the direct and tangible resource benefits that the entrepreneurs' actions generate.

In summary, our integration of the entrepreneurial and institutional approaches to studying entrepreneurial action to overcome the liability of newness can be defined by specific conceptual choices that we made in order to frame our study and guide our analysis. First, we explore what the entrepreneurs did in order to establish the legitimacy of themselves as founders, their new ventures, and the new organizational form that they represented. Second, we identify a range of specific and salient resource holders and examine how the entrepreneurs managed legitimacy vis-à-vis these different audiences. Third, we explore how they integrated internal and external resources in order to develop the organizational capability that enabled them to enter the global solar PV industry and quickly become its main supplier.

3. Methodology

The successful entry of the private Chinese solar PV firms into the global industry is an appropriate context to understand the actions by which entrepreneurs, introducing a new organizational form into an established industry, build legitimacy to access resources that enable them to pursue a market opportunity. It also provides the opportunity to study how the actions of subsequent entrants differ in response to an evolved institutional environment.

3.1 Setting

That private Chinese firms and, collectively, the Chinese solar PV industry would be so successful by 2007 was not obvious before 2004.[2] As relative latecomers, new Chinese entrants did have some advantages. Foreign incumbents had established a dominant design for the products, the technology was fairly well established (Green, 2000), and production equipment specifically for the solar PV industry was available on the international market. China also offered a number of generic advantages for low-cost manufacturing, including relatively low costs for labor, electricity and environmental regulation conformance. Moreover, local governments were offering various forms of support, such as tax breaks and training subsidies, to any firm bringing significant employment opportunities to their areas. Finally, several government-subsidized social development programs targeting rural electrification in the late 1990s and early 2000s created a new albeit limited market opportunity for new private firms who had no government backing to cover sustained financial losses.[3]

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[2] China's entry into solar PV can be traced to the late 1950s, when the objectives were to serve the government's needs and objectives related to space, military, remote communications infrastructure and rural development. A timeline of key policy, organization and industry developments is presented in Table S1 in the online supplement to this article: URL. Significantly, the original state-owned manufacturers (nicknamed the "Old Four") were displaced as the dominant organizational form in China's solar PV industry once the new private firms entered (from 2002).

[3] More detail on deployment support is provided in Section S1 of the supplement appended to this article.

However, a potential entrepreneur would not find China in the early 2000s to be an attractive environment to establish a commercial solar PV manufacturing firm. Domestically, China had essentially no local supply of polysilicon (the key raw material), very limited and relatively immobile industry-specific human capital, out-of-date technology, weak innovation capabilities (Dai et al, 1999: Yang et al, 2003; REDP, 2004), and little in the way of related or supporting industries (de la Tour et al, 2011; Bruce, 2007).[4]

Technology—both production know-how and equipment—was very difficult for a new private firm to acquire, a critical factor in this industry (Kapoor and Furr, 2015). Most of the key equipment was not available domestically, and a combination of export restrictions by potential supplier countries, high cost, and restrictions on foreign exchange and import licenses by the Chinese government made importation very difficult (Bruce, 2007; Dai et al, 1999; Yang et al, 2003; REDP, 2004; Zhengrong Shi, Author's interview). Only state-owned enterprises (SOEs) with government funding had imported equipment, and that was justified not on commercial grounds, but by the fact that they were supplying the government's needs (Dai et al, 1999; REDP, 2004; Zhao et al, 2006).

Moreover, a private firm could not expect the established "Old Four" SOEs to share their know-how, and state-owned research institutes are typically reluctant to license their know-how to an unproven start-up, as they are not part of the same state-owned "family" and usually have limited financial resources (Liu and White, 2001). In any case, the SOEs' technological level was far below international standards and would not enable a recipient to compete in the international market (Dai et al, 1999; Bruce, 2007; Zhengrong Shi, Author's interviews). The small amount of Chinese-made modules that had made their way into the international market were of poor quality and had created a bad reputation for Chinese solar PV products (Hug and Schachinger, 2006).

[4] Additional detail on the environment affecting the Chinese solar industry and potential new private PV firm entrants is provided in Section S2 of the supplement appended to this article.

In any case, most potential Chinese entrepreneurs did not consider the market opportunity for solar PV to be attractive. Domestic demand was small, limited to a few government uses (satellites and remote terrestrial communications) and government-funded regional development projects (the Brightness Program), and that was being met by the domestic "Old Four" SOEs (Dai et al, 1999; REDP, 2004). Internationally, they saw global demand as relatively small in absolute terms, even if growing by 20% or more, and it was being met by large, established global producers concentrated in Japan, the USA and Germany (Grau et al, 2012; Zhengrong Shi and Xiaohua Qu, Author's interviews). Moreover, like elsewhere, the relatively high cost of solar PV compared to other technologies for generating electricity severely limited its competitiveness and market prospects (Dai et al, 1999; REDP, 2004).

Another disadvantage for any potential new entrant was the tight supply of both the raw material and wafers in China, which met primarily by imports. Exacerbating the situation for solar PV firms, the Chinese government was actively promoting the development of the semiconductor industry, channeling high-grade silicon and investment to those firms (REDP, 2004; Marigo, 2007). Even Suntech's founder described the global solar PV industry at that time as a "parasite" for the semiconductor and related industries (Author's interview).

In contrast to suggestions by some reports (e.g., Liu & Goldstein, 2013; Goodrich et al, 2011), the industry did not benefit from significant state-subsidized promotion before 2008. The central government did not provide direct financial or political support to the private solar PV sector before 2009 (Marigo, 2007:146; Qi, 2013:254-255). In the early 2000s, neither local government-backed venture capital firms (White et al, 2005) nor other sources of private financing (emerging domestic corporate-backed VCs or foreign VCs) saw solar PV as an attractive investment opportunity (Vietor, 2012).

Before 2005, local governments had no specific interest in solar PV as a commercial industry. Suntech's founder made proposals to a number of local governments across the country before finding a receptive audience in Wuxi (Vietor, 2012:2; Author's interviews). Yingli's founder built on his existing relationships to convince the Baoding government to support his venture (Yu, 2008). Neither the Wuxi nor Baoding officials were interested in solar PV per se; rather, they were interested only as a means to bring "high-tech" manufacturing and employment to their locales. In both cases, their financial support was in the form of equity rather than debt or subsidy—an example of local government-backed venture capital firms that had emerged in China during this period (White et al, 2005; Zhang et al, 2008). Most importantly, the private entrepreneurs retained control of these firms and responded to strong market-oriented incentives when setting their strategies.

Not until after 2007, by which time the Chinese firms and industry were already successful internationally, did local governments begin to support the industry through various targeted subsidies and incentives and by establishing solar PV industrial parks (Annual Report on China's New Energy Industries, 2011). In 2009 the central government stimulated the industry by launching the Golden Sun Program, including RMB4.8 billion (US$700 million) in funding to subsidize installation by end-users, and by putting the solar industry on the priority list for policy loans. Only in October 2010 did the central government officially cite solar PV as one of a number of strategic emerging industries deserving of support (State Proclamation (2010) No.32).

3.2 Data and analysis

In line with our research question, the unit of analysis is the entrepreneurs' actions, with a focus on those used to access external resources in order to build an organizational capability to capture the opportunity they saw in solar PV. We chose a multiple-case study

research design (Yin, 2013; Eisenhardt, 1989; Bingham and Eisenhardt, 2011) that would enable us to identify a potentially wider range of legitimacy-building actions than would a single case, and to distinguish similarities and differences across them.

The focal firms are the group of China's 10 largest solar PV firms based on sales and output as of 2010. Table 1 presents background information on the case firms, and Figure 1 shows their founding point, time to initial production, and initial production scale. Given our focus on entrepreneurial action in the founding and early growth period, we bracketed our data gathering between each firm's founding period (ranging from 1997 to 2006) and the end of 2007. By this time, they were firmly established, and the global financial crisis was yet to exert its major impact on the industry.

We drew on a wide range of data sources to triangulate and develop case histories for each of the ten firms and the industry's institutional environment. Appendix A[5] provides a detailed description of these sources, including 1) founders and senior managers of the 10 firms, 2) archival data including corporate documents, initial public offering (IPO) prospectuses, annual reports, media reports and industry-specific data consolidators (e.g., SolarStar (Beijixing, http://guangfu.bjx.com.cn) and Baidu Baike (http://baike.baidu.com)), 3) interviews and on-site observations at firm headquarters and facilities, and 4) corporate documents and analyst reports on non-Chinese solar PV firms. Other key sources of data on the industry include reports by Chinese government agencies, the International Energy Agency (IEA), the United States' National Research Council and National Renewable Energy Laboratory (NREL), the European Photovoltaic Industry Association (EPIA), Photon International, SolarBuzz and the Chinese Economic Information Network. Academic studies also provided data and insights into the industry during this period, including Bruce (2007),

[5] Included in the supplement appended to this article.

Algieri et al (2011), Grau et al (2012), Rigter & Vidican (2010), de la Tour et al (2011), Dai et al (1999), Yang et al (2003), Hoppmann et al (2013), and Hoppmann et al (2014).

We integrated the data into case histories for each firm. Using the historical method of process tracing (George & Bennet, 2005), we identified cause-effect relationships between elements of the institutional environment and an entrepreneur's actions, as well as between the entrepreneurs' actions and specific resource holders.[6]

We used the company case histories for within-case and cross-case analyses. Within-case analysis focused on what each founder did over the period from founding to becoming an established firm. We then made cross-case comparisons to identify similarities and differences related to any of the key constructs (e.g., entrepreneur's characteristics, legitimacy-building activities, acquisition of key resources, organizational capability and performance). This was an on-going process of iterating between existing data and across cases, gathering additional data, and triangulating across the multiple data sources. We continued this process of developing and comparing company cases and gathering additional data until the marginal increase in insights was negligible (Eisenhardt, 1989).

It became clear very early in our research that both the institutional environment and entrepreneurs' actions were quite different before and after July 2004, when Germany's amendment to its feed-in-tariff (FIT) regulations created a demand spike in the global market (Jäger-Waldau, 2006; Grau et al, 2012; Hoppmann et al, 2013; Hoppmann et al, 2014). Hence, we divide the presentation of our study's results into two periods: 1997-2004 and 2004-2007.

4. Legitimacy and capability-building

The early private Chinese solar PV firm entrepreneurs who decided to enter this industry before 2004 had to overcome even greater "liabilities of newness"—both as

[6] The detailed case descriptions for the early entrants are provided in Section S3 of the supplement appended to this article.

individuals, firms and collectively as a new organizational form—than the later entrants or those in other Chinese industries that have become global competitors. As already described, the local environment offered few industry-specific resources that early entrants could draw on to build an organizational capability that would enable them to enter domestic or international markets. In any case, those markets were not attractive due to the dominance of large, established incumbents. Furthermore, solar PV manufacturing demanded high-quality production capabilities, for which Chinese firms were not known internationally.

In spite of these factors that would seem to make private Chinese firm entry and success unlikely, and considering the large number of more attractive opportunities in other industries in China at that time, these entrepreneurs persisted. While their firms—Suntech, Yingli, Trina and CSI—would eventually emerge as major global suppliers, they had to overcome significant challenges in order to establish their legitimacy, access critical resources, and build a competitive organizational capability.

The entrepreneurs who entered after mid-2004, when the market opportunities became clearer, also had to establish their legitimacy, access external resources, and build competitive capabilities. However, these later entrants benefited significantly from the legitimacy established by the early entrepreneurs, enabling them to enter the market more rapidly and at greater scale. The cumulative action of these early and later entrepreneurs would result in China's becoming the most important solar PV production hub in the global solar PV industry within just five years of the first private firm beginning cell production.

4.1 Early entrants (1997-2004)

In addition to establishing their personal legitimacy and that of their new ventures, the Chinese entrepreneurs who decided to enter the industry before 2004 also had to direct significant effort towards establishing the legitimacy of the private Chinese solar PV firm as

an organizational form vis-à-vis external resource holders—a form of institutional entrepreneurship as discussed by David et al (2013) and Glynn and Navis (2010). This represents an integration of the strategic focus on micro actors and the institutional focus on macro "audiences", an area Überbacher (2014) identified as deserving further research.

Based on our analysis of their actions, we developed a typology of legitimacy-based strategies that the early entrepreneurs used to access critical resources as the build their firms.[7] The typology includes 1) *leveraging* their existing legitimacy, 2) *aligning* choices and actions with the norms and values considered legitimate by particular resource holders, and 3) *enacting* the perceptions of what resource holders consider legitimate. Examples of each for the four early entrants are presented in Table 2. While all of these entrepreneurs had some resources useful for founding their firms—such as entrepreneurial experience and personal wealth (Trina, Yingli) or technical expertise and international experience (Suntech, CSI)—they all faced significant resource gaps. Legitimacy-based strategies were key to their overcoming those gaps.

Leveraging begins with an entrepreneur's initial attributes that a particular resource holder considers legitimate. For example, while Suntech's Shi had no entrepreneurial experience, his technical expertise in solar PV and experience working in Pacific Solar in Australia increased his legitimacy vis-à-vis his first investors. In contrast, Yingli's Miao had no relevant technical expertise, but could leverage his reputation as a successful businessman to attract a key technical expert and gain support from the Baoding government. The later "exploiter" entrepreneurs were all able to leverage the post-2004 legitimacy of the "private Chinese solar PV firm" as a form to attract financing, personnel, supplies and customers more quickly than the earlier "explorers" had at the time of their founding.

[7] See the detailed case descriptions in Section S3 of the supplement appended to this article.

Over time, as the entrepreneur accrues, integrates and transforms resources and the venture develops, they may also gain new sources of legitimacy that they can then leverage to access resources from other actors. For example, Trina's Gao was a highly visible and vocal proponent of solar energy in the media, especially after his team succeeded in developing an off-grid solar energy system prototype. Such actions led the central government to select him to be involved in drafting China's technical standards for off-grid solar energy systems, as well as for Trina to be the first private firm selected as a supplier to the Brightness Program. Later, Gao was chosen to participate in drafting China's first Renewable Energy Law, giving him valuable access to policymakers and non-public information. Similarly, CSI's Qu was able to leverage a project funded by VW as well as the Canadian nationality of his company to attract both Canadian and Chinese engineers with experience in solar PV and semiconductor technologies.

Aligning is a second strategy that entrepreneurs use to respond to the regulatory, normative and cognitive forces that are central to institutional theory. Framing this in terms of agency and instrumentality, the entrepreneurs choose to align their actions and choices to match what an external actor (or "audience") considers legitimate in order to access the resources that the actor controls. Suntech's Shi, for example, developed a business plan, underwent personal due diligence as expected by the Wuxi VC investors, and invested his own US$400,000 in order to obtain their investment. He also acquired the technical and quality certifications that international customers would expect of a supplier.

The third strategy—*enacting*—corresponds to the concept of institutional entrepreneurship in which an individual or collective actor changes the definition of what is legitimate (DiMaggio, 1988). In line with findings from prior research (e.g., Sine et al, 2005; Sine et al, 2007; Santos & Eisenhardt, 2009; Glynn & Navis, 2010), we find the early entrepreneurs were all acting to change the perceptions of a broad range of external resource

holders regarding solar energy's economic and social potential, as well as the opportunity for private Chinese solar PV firms to be competitive. All of these early founders were active in public forums and media promoting solar power as a viable clean energy option that could improve air quality and living standards for Chinese people in remote areas with limited or no access to electricity. They also used their success in developing applications and manufacturing at scale to enhance the legitimacy of private Chinese firms as potential competitors in an industry dominated by SOEs in China and sophisticated multinationals internationally. Later, when Suntech became the first private Chinese firm to list its shares on the NYSE, making Shi the richest man in China in 2006, the legitimacy of this new organizational form across a wide range of resource holders, including investors, technical and managerial talent, suppliers and government officials was solidified. It also attracted new entrepreneurs to the industry.

4.2. Late-stage entrepreneurial action (2004-2007)

Before 2004, none of the entrepreneurs who would found the six firms that would join China's top 10 solar PV suppliers considered solar energy an attractive opportunity (Dai et al, 1999; REDP, 2004; Author's interviews). The domestic market was small, especially as the government's Brightness Program had ended in 2003 (REDP, 2004; Qi, 2013), and multinational incumbents more than served international markets. Global demand for solar PV had been growing steadily since 2000 as developed country governments introduced incentives supporting solar energy production and equipment installation. Established producers, concentrated in Japan, the USA and Germany, had expanded production in response to this growth, and global capacity was able to meet demand.

Germany's Renewable Energy Resources Act Amendment of July 2004, however, significantly raised the feed-in tariff for solar-based electricity and removed the subsidy

ceiling, triggering a dramatic increase in demand for PV solar modules. Year-on-year global demand doubled to 1,121 MW, and would rise to nearly 3,000 MW by 2007 (EPIA, 2010). While such a demand curve should have been a blessing for the incumbent global producers in Germany, Japan and the United States, they were not prepared to increase their capacity at a rapid enough rate to capture all of it.[8] The two to three-year lag in their responding to this demand spike created a window of opportunity for entrepreneurs and aggressive Chinese firms (e.g., Hug and Schachinger, 2006). During that time, the early entrants—Suntech, Yingli, Trina, CSI—were positioned to leverage their existing capacity and operational and market experience.[9]

These developments attracted the attention of a new set of Chinese entrepreneurs. Moreover, the legitimacy of the Chinese private solar PV firm as a viable organizational form that Suntech in particular had established reduced the liability of newness for this new group of entrants. Suntech had proven that a Chinese firm could produce at international standards and sell into international markets. Suntech's success had also attracted foreign venture capital and private equity investors looking for similar opportunities and with expectations of listing on a foreign stock exchange. This possibility was particularly attractive to these new Chinese entrants—mostly serial entrepreneurs—who were looking for new and lucrative investment opportunities.

This initial motivation by these new entrants for entering the solar PV industry—a strategic calculation based on clear market demand and growth, and the possibility of a foreign stock listing—is very different from that of the earlier entrants. The founders of Suntech, Yingli and Trina were initially focused on the potential environmental and social benefits that solar could offer, and relied more on their conviction regarding solar's potential

[8] For more detail, see Section S4 of the supplement appended to this article.

[9] Development of the four early entrants during this period is described in Section S5 of the supplement appended to this article.

social benefit rather than strong evidence that solar demand would increase and their investment would generate a windfall return.

Financing the founding and growth of solar PV firms also changed significantly from the early- to later-stage entry period.[10] For the early entrants, the level of investment to begin production was less than US$10 million. This changed dramatically for the post-2004 new entrants as the minimum efficient scale in the solar PV industry increased rapidly with follow-on investments in capacity by all firms. Production-scale financing ranged from US$15 million (JA Solar) to US$75 million (LDK), and firms had to rapidly attract even greater growth capital to match the increasing minimum efficient scale (MES) of the industry.

Although start-up capital requirements were significantly greater for the later entrants, these founders also controlled or had access to greater sources of capital than the early entrants. Some of these founders were a hybrid of corporate and serial entrepreneurs, including those from Solarfun, Sunergy, JA Solar and LDK. As heads of existing companies in unrelated industries (with the exception of JA Solar), they used their existing companies to finance investments in new solar firms. For example, Xiaofeng Peng founded LDK with $45 million invested by Suzhou Liouxin, the protective clothing manufacturer he owned, along with a loan of $30 million from the Xinyu city government.

Other founders were pure serial entrepreneurs who used money from previous ventures to fund their entry into solar PV. The two brothers who founded Jinko, Xianhua and Xiande Li, had previously founded small firms in auto repair and firefighting equipment, and were also following the example of their brother, Li Xianshou, who had founded ReneSola. They used their own money as initial start-up capital, but were able to use customer pre-payment for expansion capital before attracting VC investment. All of these six firms

[10] Details on the financing and listings of these top 10 Chinese solar PV firms is presented in Table S2 of the supplement appended to this article.

attracted significant VC and private equity in a short period. Five of them listed on US exchanges before the global financial crisis of 2008, and the remaining one listed in 2010.

Besides the founders' motivations, timing and financing characteristics, these new entrants also differed from the early entrants by varying less in their choice of entry point in the industry value chain and degree of integration. As described above, each of the four early entrants chose a different point of entry and degree of integration, from nearly full-integration in the case of Yingli, to a narrower focus on cells and modules by Suntech, and an even narrower and downstream focus on applications and power systems by CSI and Trina. In contrast, the founding teams of the first group of new private entrants (Solarfun, Sunergy, JA Solar) were more narrowly focused on capital-intensive cell production and relatively more labor-intensive module production with higher variable costs. The second wave of new entrants (ReneSola, LDK, Jinko) focused on upstream opportunities—ingot and wafer production—that had relatively higher capital investment requirements.

These later entrants also had more options for sourcing raw material (silicon and ingots), technology and equipment, and key personnel. The Chinese government had already realized that limited domestic silicon production capacity made China's semiconductor and related industries (like solar PV) subject to international price fluctuations and potential supplier hold-up. It supported the development of new crystalline silicon production, including funding an R&D alliance between Luoyang Monosilicon (the first domestic SOE silicon manufacturer, founded in 1964) and the General Research Institute of Non-ferrous Metals. As a result of such efforts, domestic output rose from essentially nothing in 2004 to 1,156 MT by 2007 (Zhao et al, 2008).

The surge in market demand also spurred the entrance of local Chinese firms supplying consumables and downstream (mostly assembly) equipment specifically for this industry. Before 2004, several firms had adapted existing products to meet the needs of the

early solar PV firms (e.g., for Suntech), but they did not consider this to be a very promising market and did not invest significant resources in product development. The post-2004 influx of capital, however, as well as the founding of new China-based PV firms, represented a major new market that justified expansion. In a very short time, local suppliers focused R&D on the specific requirements of the solar PV industry. This not only served to overcome the shortage in supplies that followed the spike in demand, but also provided low-cost alternatives to expensive imports (Zhao et al, 2006; Zhao et al, 2008; Marigo, 2007; Author's interviews). As Chinese PV firms became major customers, leading global suppliers were also much more willing to adapt and co-develop equipment to match these firms' needs (Zhengrong Shi and Xiaohua Qu, Author's interviews; Bruce, 2007). This responsiveness was in stark contrast to the earlier period when Chinese customers were an insignificant market for these suppliers.

With significant financing, rapidly growing markets and the prospect of a foreign stock listing, the new entrants could more easily attract experienced talent domestically and internationally than could the four early entrants. More Chinese with relevant technical background, who had studied and worked abroad, became interested in following the example of Suntech's Shi and returning to China. Indeed, Shi's alma mater, the University of New South Wales, became a major source of key technical talent for the new entrants. Suntech itself became an important source of founders and top management teams for these later entrants, including Sunergy, Solarfun and JA Solar. The new entrants were also more successful in attracting top functional managers for R&D, operations and marketing from the closely related semiconductor and solar PV equipment industries. Finally, as in any rapidly growing industry, headhunting was rampant and experienced managers had many opportunities to move to other solar PV firms.[11]

[11] The movement of key personnel is presented in Figure S2 of the supplement appended to this article.

5. Entrepreneurial action and the emergence of a new organizational form

Our study was initially motivated by the simple question of how new entrants could overcome the liability of newness; specifically, the dual challenge of building an adequate organizational capability while lacking legitimacy that would help them acquire the resources to build that capability. The time period corresponding to the founding and emergence of China's major producers also included a policy-induced inflection point in demand that had a dramatic impact on the global industry. As a result, we were able to compare entrepreneurial action between two different groups of firms—the early and late entrants based on this market-related inflection point—that also corresponded to two different institutional environments. The following sections discuss our findings that answer our initial research question, and also present deeper insights emerging from the opportunity to compare entrepreneurial action under two very different institutional environments.

5.1. Legitimacy within the entrepreneurial process

Our empirical findings address two shortcomings that Überbacher (2014) identifies in institutional approaches to studying legitimacy and new ventures. First, we find significant variation in the sources and degree of legitimacy at the micro (entrepreneur and venture) level within a group of actors representing the same organizational form. This variation is typically not addressed in most institutional theory-based analyses. Second, we find that the entrepreneurs took different actions vis-à-vis different types of resource holders who had different criteria for evaluating legitimacy. Institutional approaches, in contrast, tend to assume shared views of legitimacy among a macro "audience", or focus on a single specific audience.

Our study of multiple cases enabled us to identify a wide range of actions that the entrepreneurs undertook as they sought to build legitimacy for themselves, their new ventures and the private Chinese solar PV firm as an organizational form in order to access external resources. We have proposed a typology of strategies that includes *leveraging* existing legitimacy, *aligning* with existing norms of legitimacy, and *enacting* the environment to change the definition of what is legitimate. Our findings complement those from research in other emerging industry environments that highlight the importance of entrepreneurs establishing legitimacy vis-à-vis their institutional environment (e.g., Ahlstrom et al, 2008; Saxenian, 1991; Kaplan and Murray, 2010; Sorenson and Audia, 2000; Sine et al, 2005). This explicitly instrumental focus on the role of legitimacy differs from most institutional-based studies of entrepreneurial legitimacy-building that are concerned with changes in meaning and the general acceptance of new organizations and new organizational forms as the outcome of interest (e.g., Glynn and Navis, 2010; David et al, 2013).

Because they lead to access to critical external resources, these legitimacy-based strategies represent critical activities within the entrepreneurial process, and we propose a general model of entrepreneurial action that explicitly integrates them (Figure 2). At the core of the model is the entrepreneurs' integration and transformation of resources to develop the capability to pursue an opportunity that they have identified or created. They also use legitimacy-based strategies vis-à-vis external actors—single or collective—to access the resources they lack.

In a feedback loop, the performance of the firm's capability vis-à-vis the opportunity will impact the venture's stock of available resources in two ways. One is direct; for example, revenues will bring cash that is a useful generic resource. The second is indirect, as demonstrated performance can contribute to the perceived legitimacy of the entrepreneur,

venture or new organizational form, which can then be leveraged vis-à-vis external resource holders.

While others have included legitimacy in models of the entrepreneurial process, it is primarily treated as a resource (e.g., Zimmerman & Zeitz, 2002). In contrast, we propose that a full model of entrepreneurial action must include not only legitimacy as a resource, but the actions by which entrepreneurs build and leverage legitimacy in order to acquire other resources.

5.2. Co-evolution of the institutional environment and entrepreneurial action

Tolbert et al (2011) cite research showing how changes in the institutional environment (specifically, social movements) have created new opportunities for entrepreneurs to exploit (e.g., Sine et al 2003; Hiatt et al, 2009), and how these entrepreneurs' actions in turn have an impact on the institutional environment (e.g., Sine et al, 2007). Our study extends the analysis to the next step; namely, how the new institutional environment impacts subsequent entrepreneurs and results in differences between early and late entrants.

Our proposed model of entrepreneurial action helps structure the description of this process and how it results in the distinct differences we found between the earlier and later entrepreneurs. All of the entrepreneurs founding the private firms we studied had to develop organizational capabilities and also establish their organization's legitimacy vis-à-vis external resource holders. Unlike the early entrants, however, the later entrants did not have to overcome the additional "liability of newness" attached to being a new organizational *form*. We find March's (1991) exploration-exploitation distinction useful to contrast these firms and their actions vis-à-vis the market and institutional environment in which they were founded, with the early entrants representing "explorers" and late entrants "exploiters".

Table 3 summarizes the key differences between the explorer and exploiter entrepreneurs emerging from our study. In the early stages of China's private, market-oriented solar PV industry (late 1990s to 2004), the "explorer" entrepreneurs could not point to a clear, major unmet market opportunity. Both domestic and foreign solar PV demand was more than met by incumbents. Moreover, these explorers had little to draw on from the domestic environment to develop the organizational capability needed to enter and compete in the market. As a result, they had to do more than simply assemble existing resources to found their firms. For many key resources, if they did not possess or develop it themselves, they had to adapt and improvise related resources from other industries.

The lack of legitimacy of both the new firms and this new organizational form compounded their challenge in accessing externally-held resources compared to the later exploiters. First, their legitimacy vis-à-vis suppliers, customers, financers and potential employees was not established. The only solar PV firms in China were SOEs serving essentially as suppliers to government users and projects. The global industry incumbents were large, established multinationals based in advanced countries. Second, the general perception of Chinese manufacturing for being cheap but also poor quality created a challenge for convincing international customers that they could meet demanding standards for technology and quality.

The later "exploiters" (founded after July 2004) also had to meet the challenge of accessing and integrating resources to develop the organizational capability to compete in the market. However, they faced a much more amenable market and institutional environment. First, market size and uncertainty moved in favorable directions. Triggered by the German tariff revision of July 2004, market demand was not only clear but far outstripped global incumbent capacity, and customers were more inclined to consider new sources of supply. Furthermore, bottlenecks in specific points in the value chain—ingots, wafers and cells—

became clear and made it easier to strategically target the most promising business opportunities within the solar industry.

Complementing developments in the market environment, by late 2004, key resource holders—suppliers, customers, managerial talent, investors and a few local governments in China—began to see the private Chinese solar PV firm as a promising and attractive form of competitor in the industry. The early private Chinese firms had demonstrated that they could meet the technical and quality demands of global customers. When global demand spiked after Germany and other countries adopted deployment support policies, these Chinese firms demonstrated that they were able to ramp up production more quickly than either domestic SOEs or multinational incumbents.

These developments conferred critical legitimacy on private Chinese solar PV firms as a group in the eyes of domestic and international suppliers of raw materials and equipment, investors, international customers, and top technical and managerial talent. This legitimacy enabled the later entrepreneurs to gather resources and build their organizational capability much faster than the explorers. For example, the early entrants had a much greater challenge in establishing their legitimacy vis-à-vis potential employees, and had to commit significant effort to doing so. In contrast, the late entrants could not only headhunt from the early entrants, but could attract top talent from multinational firms in the solar and the related semiconductor and electronics industries.[12] Similarly, the combination of proven production capabilities by the early entrants and the new market opportunity after the German policy change attracted both domestic and international VC and private equity. The later entrants enjoyed much greater initial funding, as well as much faster follow-on financing and stock market listing (Online supplement, Table S2). For example, Suntech's initial funding in January 2001 was US$6 million in cash from local government VC plus US$400,000 of the

[12] For a detailed overview of the movement of key personnel to and among these firms, see Figure S2 of the supplement appended to this article.

founder's own cash. The next investment was convertible debt four years later, and the company listed a year after that in December 2005. Later entrants were able to attract from US$13 million to US$53 million in initial financing and list on overseas stock exchanges in just one or two years.

The ability of the exploiters to access resources superior to those available to the explorers just a few years earlier was enhanced by their organizational form having become legitimate as a customer, supplier, employer and investee. Because of the success of the explorers in establishing both their individual legitimacy and the legitimacy of the private Chinese solar PV firm vis-à-vis key resource holders, the exploiters did not have to do the additional work to establish their legitimacy as an organizational form.

In summary, the market and institutional features of the industry environment were significantly different for the explorers and exploiters, and the nature of their entrepreneurial actions was similarly different. The explorers could not simply piece together existing and easily accessible resources to develop the requisite organizational capability to enter and succeed in the market. They had to do much more creating and adapting of resources specific to other industries. They also had to work harder to establish their legitimacy in order to access other critical resources, such as financing, customer credibility and interest, and managerial talent. The success of their actions significantly reduced the liabilities of newness faced by the later entrants, as the established legitimacy of the organizational form they adopted gave the later entrants greater and faster access to external resources.

5.3. Implications for policy: A role for legitimacy

Our findings have implications for policy and the debate about the proper role of the government in promoting entrepreneurship and targeting industries for growth. One implication is that identifying opportunities and building organizational capabilities can, and arguably should, be left to entrepreneurs. At most, as suggested by Hoppmann et al (2013),

the government's indirect support in stimulating market demand and thereby enhancing the market opportunity could be useful, especially when new firms need critical first sales to develop. Ideally, however, such support should last only long enough for the new firms to be viable on their own; i.e., to build the necessary organizational capability, compete and be economically viable. One danger of such support, however, is that the government may have incentives to continue or even increase support to achieve policy or social development objectives, regardless of the impact on the market competitiveness of the firms benefiting from such support. It could lead to a state of perpetual dependence, with the recipient firms never developing into independently sustainable, competitive firms. It could also reduce the opportunity for more efficient new entrants to replace such incumbents. Another danger identified by Hoppmann et al (2013) is that such stimulation could also create perverse incentives that skew investment and innovation in socially undesirable directions.

Our findings also reinforce the arguments that others (e.g., Blackburn and Shaper, 2012) have made for the government role in creating an environment that enables entrepreneurship. First, it can *allow* rather than *constrain* the options for new organizational forms and sub-organizational elements. Ideally, it would actively facilitate the administrative process by which entrepreneurs may establish new firms and new organizational forms. Second, the government should invest in supporting infrastructure and human capital domestically and create an environment that attracts human capital from abroad (whether returnees or foreigners). These indirect means may be both more effective and result in fewer market distortions than the government directly subsidizing new firms in targeted industries or stimulating demand in a targeted way.

Our findings on legitimacy's impact on access to external resources suggest another role for government in supporting entrepreneurial activity and complement the findings of Sine et al (2005) on the impact of institutions on new firm entry. The government has

significant influence in defining what is "legitimate" in the institutional environment, and through that can affect incentives and the ability of entrepreneurs—of new ventures and especially of new forms—to access resources, survive and grow. In the formal institutional domain, regulations that strictly define the different types of organizations and how they can undertake a particular business activity could essentially preclude an alternative organizational form from emerging. More open or flexible regulations, on the other hand, create a wider "legitimacy space" in which alternative forms could enter. To the extent that the government wishes to promote "creative destruction", it should allow enough space for new forms to emerge in order to challenge incumbents. Even in the informal institutional domains of norms and culture, the government has the power to shape the public's view of what is legitimate, even if it is only one of many other sources of influence regarding the perceptions of norms. For example, when government officials or politicians publicly praise entrepreneurs who attempt or succeed in challenging established forms of organizations, they are effectively conferring legitimacy that could help not only that particular entrepreneur and venture but also others of the same form. More generally, the government can work to increase the legitimacy of experimenting and challenging existing business norms in search of more effective and efficient organizations.

5.4 Directions for future research

Our study of the emergent leaders in China's solar PV industry allowed us to identify differences in entrepreneurial action depending on the relative legitimacy of the organizational form that a new entrant represents. A logical extension of this research would be to look at a larger sample of the population of Chinese solar PV firms that entered this industry in order to relate founding characteristics and development factors to firm survival and performance. We could test hypotheses regarding the founding characteristics,

development and performance of firms as related to entry timing. Extending the analysis period beyond 2007 to 2012 would also allow us to relate firm-level factors to differences in the impacts of two demand shocks—the "boom" of 2004-2008 and the relative "bust" following the global financial crisis—on these firms' performance. Complementing such a study would be a global comparison of solar PV firms over the same period to compare the responses to these shocks of firms based in different countries. We might see very different actions and outcomes when comparing private, listed and state-owned firms, or solar PV-focused firms and solar PV subsidiaries of diversified firms. This industry is also an excellent setting to study the implications for competitive dynamics when new entrants with significantly different resources, capabilities and strategies rise to challenge incumbents.

Our study also suggests an analogous empirical research question in the context of corporate entrepreneurship; namely, does the nature of entrepreneurial action by internal entrepreneurs differ significantly when the firm is pioneering new growth opportunities compared to moving into more established ("legitimate") areas? This could provide useful insights into the nature of challenges facing internal entrepreneurs and the legitimacy-based strategies that are effective for developing successful new corporate ventures.

6. Conclusions

Our study of how the founders of China's private solar PV firms overcame their "liabilities of newness" provided an excellent context to explore the role of legitimacy in entrepreneurial action and the co-evolution of entrepreneurial action and the institutional environment. We identified specific actions by which the entrepreneurs accessed resources from external actors in order to pursue the opportunity they saw in solar energy. This led to a model of entrepreneurial action that integrates the key concept of legitimacy and specific types of legitimacy-based strategies within the general process—an extension of the work

exploring the intersection of these two fields.

We also developed insights into the co-evolutionary dynamics that result in distinct differences between early and late entrants in the nature of their "liability of newness" and the implications for entrepreneurial action. The actions of the early entrants established the legitimacy of a new organizational form. That created a different institutional environment for the later entrants and significantly reduced their challenge of accessing external resources. As a result, the later entrepreneurs were able to enter and become competitive much faster than the early entrants.

Finally, our study suggests ways in which policymakers may use legitimacy as a means of promoting entrepreneurship, new forms of organizations, and the emergence of new industries. By adopting more proscriptive ("what is not allowed") rather than prescriptive ("what is allowed") regulations, for example, they may create a greater "legitimacy space" that allows for more alternatives to emerge. They can also influence the normative and cognitive perceptions of what is legitimate. For example, their positive response to actors' efforts to introduce new or alternative forms, firms, practices or other organizational elements can also help increase the legitimacy of those actors and such experimentation. This creates a social and cultural environment in which entrepreneurs, new firms and new industries are more likely to emerge.

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REFERENCES

Ahlstrom, D., Bruton, G., Yeh, K., 2008. Private firms in China: Building legitimacy in an emerging economy. Journal of World Business 43, 385-399.

Aidis, R., Estrin, S., Mickiewicz, T., 2008. Institutions and entrepreneurship development in Russia: A comparative perspective. Journal of Business Venturing 23, 656.

Aldrich, H. E., Fiol, C. M., 1994. Fools rush in? The institutional context of industry creation. Academy of Management Review 19, 645-670.

Algieri, B., Aquino, A., Succurro, M., 2011. Going "green": Trade specialization dynamics in the solar photovoltaic sector. Energy Policy 39, 7275-7283.

Balaguer, A. and Marinova, D., 2006. Sectoral transformation in the photovoltaics industry in Australia, Germany and Japan: Contrasting the co-evolution of actors, knowledge, institutions and markets, Prometheus, 24 (3).

Battilana, J, Leca, B., Boxenbaum, E. 2009. How actors change institutions: Towards a theory of institutional entrepreneurship. Academy of Management Annals 3:1, 65-107.

Bingham, C., Eisenhardt, K. 2011. Rational heuristics: The 'simple rules' that strategists learn from process experience. Strategic Management Journal 32, 1437-1464.

Blackburn, R., Schaper, M. (eds), 2012. Government, SMEs and Entrepreneurship Development: Policy, Practice and Challenges. Gower Publishing, Surrey.

Bowen, H., DeClercq, D., 2008. Institutional context and the allocation of entrepreneurial effort. Journal of International Business Studies 39, 747.

Bruce, A., 2007. Capability Building for the Manufacture of Photovoltaic System Components in Developing Countries. PhD Thesis. School of Photovoltaics and Renewable Energy Engineering, The University of New South Wales.

Busenitz, L. W., Gomez, C., Spencer, J. W., 2000. Country institutional profiles: Unlocking entrepreneurial phenomena. Academy of Management Journal 43, 994-1003.

Dacin, T., Oliver, C., Roy, J-P., 2007. The legitimacy of strategic alliances: An institutional perspective. Strategic Management Journal 28, 169-187.

Dai, Y., Shi, Z. and Xi, X., 1999. Technological innovation of the Chinese photovoltaic industry, Prepared for the Center for the Integrated Study of the Human Dimensions of Global Change, Carnegie Mellon University, Beijing, China.

David, R., Sine, W., Haveman, H., 2013. Seizing opportunity in emerging fields: How institutional entrepreneurs legitimated the professional form of management consulting. Organization Science 24, 356-377.

de la Tour, A., Glachant, M., Ménière, Y., 2011. Innovation and international technology transfer: The case of the Chinese photovoltaic industry. Energy Policy 39,761-770.

DiMaggio, P.J. 1988. Interest and agency in institutional theory. In L. Zucker (Ed.), Institutional Patterns and Organizations, 3-22. Ballinger, Cambridge, Massachusetts.

Eckhardt, J., Shane, S., 2003. Opportunities and entrepreneurship. Journal of Management 29, 333-349.

Eisenhardt, K. 1989. Building theories from case study research. Academy of Management Review 14, 532-550.

George, A., Bennett, A., 2005. Case Studies and Theory Development in the Social Sciences. MIT Press: Cambridge, Massachusetts.

Glynn, M., Navis, C. 2010. Entrepreneurship, institutional emergence, and organizational leadership: Tuning in to "the next big thing" in satellite radio. In Sine, W., David, R. (eds), Institutions and Entrepreneurship (Research in the Sociology of Work, Vol.21), 257-286.

Goodrich, A., James, T., Woodhouse, M., 2011. Solar PV manufacturing cost analysis: U.S. competitiveness in a global industry. National Renewable Energy Laboratory: PR-6A20-53938.

Grau, T., Huo, M., Neuhoff, K., 2012. Survey of photovoltaic industry and policy in Germany and China. Energy Policy 51, 20-37.

Green, M., 2000. Photovoltaics: Technology overview. Energy Policy, 28, 989-998.

Greenwood, R., Hinings, C., 1988. Design archetypes, tracks and the dynamics of strategic change. Organization Studies 9, 293-316.

Greenwood, R., Suddaby, R. 2006. Institutional entrepreneurship in mature fields: The big five accounting firms. Academy of Management Journal 49, 27-48.

Greenwood, R., Suddaby, R.,Hinings, C., 2002. Theorizing change: The role of professional associations in the transformation of institutionalized fields. Academy of management Journal 45, 58-80.

Guan, J., Ma, N., 2003. Innovative capability and export performance of Chinese firms. Technovation 23, 737-747.

Hiatt, S., Sine, W.,Tolbert, P. 2009. From Pabst to Pepsi: The deinstitutionalization of social practices and the creation of entrepreneurial opportunities. Administrative Science Quarterly 54, 635-667.

Hirshman, W.P., Hering, G., Schmela, M., 2007. Gigawatts - the measure of things to come: Market survey on global solar cell and module production in 2006, Photon International (March 2007), 136-166.

Hoppmann, J., Huenteler, J., Girod, B., 2014. Compulsive policy-making: The evolution of the German feed-in tariff for solar photovoltaic power. Research Policy, 43, 1422-1441.

Hoppmann, J., Peters, M., Schneienider, M., Hoffman, V. 2013. The two faces of market support—How deployment policies affect technological exploration and exploitation in the solar photovoltaic industry. Research Policy 42, 989-1003.

Hsueh, R., 2011. China's Regulatory State: A New Strategy for Globalization. Cornell University Press, Ithaca.

Hug, R., Schachinger, M., 2006. Chinese Solar Modules Penetrating the German Market, Solar Reports, Solarserver Forum for Solar Energy.

Jäger-Waldau, A., 2006. Research, Solar Cell Production and Market Implementation of Photovoltaics, PV Status Report, European Commission.

Jefferson, G, Rawski, T., Zheng, Y., 1993. Incentives, autonomy and factor allocation of innovation in Chinese industry. Research in Quantitative and Technical Economics 4, 35-47.

Kaplan, S., Murray, F., 2010. Entrepreneurship and the construction of value in biotechnology. In N. Phillips, G. Sewell & D. Griffiths (eds.), Technology and Organization: Essays in Honour of Joan Woodward (Research in the Sociology of Organizations) 29, 107-147.

Kapoor, R., Furr, N. 2015. Complementarities and competition: Unpacking the drivers of entrants' technology choices in the solar photovoltaic industry. Strategic Management Journal, 36, 416-436.

Kim, P., Aldrich, H. 2005. Social Capital in Entrepreneurship. New Publishing, Hanover, Massachusetts.

Liu, J., Goldstein, D., 2013. Understanding China's renewable energy exports. Energy Policy, 52, 417-428.

Liu, X., White, S., 2001. Comparing innovation systems: a framework and application to China's transitional context. Research Policy 30, 1091–1114.

Lounsbury, M., Glynn, M., 2001. Cultural entrepreneurship: Stories, legitimacy and the acquisition of resources. Strategic Management Journal 22, 545-564.

Manolova, T., Eunni, R., Gyoshev, B. S., 2008. Institutional environments for entrepreneurship: Evidence from emerging economies in Eastern Europe. Entrepreneurship Theory & Practice 32, 203-18.

March, J., 1991. Exploration and exploitation in organization learning. Organization Science, 2, 71-87.

Marigo, N., 2007. The Chinese silicon photovoltaic industry and market: a critical review of trends and outlook, Progress in Photovoltaics, 15(2), 143-62.

Marigo, N.; Foxon T. J.; Pearson, P., 2010. Chinese low-carbon innovation: Developing technological capabilities in the solar photovoltaic manufacturing industry . Journal of Knowledge-based Innovation in China, 2(3), 253-268.

McNally, C. (ed.), 2008.China's Capitalist Transition. Routledge, Boston

Meek, W., Pacheco, D., York, J. 2010. The impact of social norms on entrepreneurial action: Evidence from the environmental entrepreneurship context. Journal of Business Venturing 25, 493-509.

Mu, Q., Lee, K. 2005. Knowledge diffusion, market segmentation and technological catch-up: The case of the telecommunication industry in China. Research Policy 34, 759-783.

Peng, M., Luo, Y., 2000. Managerial ties and firm performance in a transition economy: The nature of a micro-macro link. Academy of Management Journal 43, 486-501.

Pfeffer, J., Salancik, G., 1978. The External Control of Organizations: A Resource Dependence Perspective. Harper and Row, New York.

Powell, W., White, D., Koput, K., Owen-Smith, J., 2005. Network dynamics and field evolution. American Journal of Sociology 110, 1132-1205.

Qi, Y., 2013. Annual Review of Low-carbon Development in China. Beijing: Social Science Academic Press.

Rigter, J., Vidican, G., 2010. Cost and optimal feed-in tariff for small scale photovoltaic systems in China. Energy Policy 38, 6989-7000.

REDP, 2004. China PV Industry Development Report, Wang, S. (ed), NDRC/GEF/The World Bank China Renewable Energy Development Project Management Office, Beijing.

Santos, F., Eisenhardt, K., 2009. Constructing markets and shaping boundaries: Entrepreneurial power in nascent fields. Academy of Management Journal 52, 643-671.

Saxenian, A., 1991. The origins and dynamics of production networks in Silicon Valley. Research Policy 20, 423-437.

Schmela, M., 2005. Super Sonic Solar Market - Worldwide Market Survey - cell & module production, Photon International. March, 66-82.

Schmela, M., 2006. Silicon Shortage - so what! Market survey on cell & module production 2005, Photon International. March, 100-124.

Scott, W. R., 1995. Institutions and organizations. Sage, Thousand Oaks, CA.

Selznick, P., 1949. TVA and the Grass Roots: A Study of Politics and Organization. University of California Press, Berkeley, California.

Shane, S., 2000. Prior knowledge and the discovery of entrepreneurial opportunities. Organization Science 11, 448-469.

Shane, S., Venkataraman, S., 2000. The promise of entrepreneurship as a field of research. Academy of Management Review 25, 217-226.

Simon, D., Goldman, M. (eds.), 1989. Science and Technology in Post-Mao China. Harvard University Press, Cambridge.

Sine, W. D., R. J. David. 2003. Environmental jolts, institutional change, and the creation of entrepreneurial opportunity in the U.S. electric power industry. Research Policy 32, 185–207.

Sine, W., David, R., 2010. Institutions and entrepreneurship. In Sine, W., David, R. (eds), Institutions and Entrepreneurship (Research in the Sociology of Work, Vol.21), 1-26.

Sine, W., David, R., Mitsuhashi, H.. 2007. From plan to plant: Effects of certification on operational start-up in the emergent independent power sector. Organization Science 18, 578–594.

Sine, W., Haveman, H., Tolbert, P., 2005. Risky business: Entrepreneurship in the new independent power sector. Administrative Science Quarterly 50, 200-232.

Sine,W., Lee, B., 2009. Tilting at windmills? The environmental movement and the emergence of the US wind energy sector. Administrative Science Quarterly 54, 123-155.

Singh, J., Tucker, D., House, R. 1986. Organizational legitimacy and the liability of newness. Administrative Science Quarterly 31, 171-193.

Sobel, R. 2008. Testing Baumol: Institutional quality and the productivity of entrepreneurship. Journal of Business Venturing 23, 641-655.

Solarbuzz, 2007. Solar Cell Manufacturing Plants; http://www.solarbuzz.com/Plants.htm.

Sorenson, O., Audia, P., 2000. The social structure of entrepreneurial activity: Geographic concentration of footwear production in the United States, 1940-1989. American Journal of Sociology 106, 424-462.

Spencer, J., Gomez, C., 2004. The relationship among national institutional structures, economic factors, and domestic entrepreneurial activity: A multicountry study. Journal of Business Research 57, 1098-107.

State Proclamation, No.32. 2010. China State Council's decision on cultivating and developing strategic emerging industries. www.gov.cn/zwgk/2010-10/18content_1724848.htm.

Stinchcome, A., 1965. Social structure and organization. In J. March (ed.), Handbook of Organizations. Rand McNally, Chicago.

Stuart, T., Hoang, H., Hybels, R., 1999. Interorganizational endorsements and the performance of entrepreneurial ventures. Administrative Science Quarterly 44, 315-349.

Suchman, M., 1995. Managing legitimacy: Strategic and institutional approaches. Academy of Management Review 20, 571-610.

Tolbert, P., David, R., Sine, W., 2011. Studying choice and change: The intersection of institutional theory and entrepreneurship research. Organization Science 22, 1332-1344.

Tolbert, P., Zucker, L., 1996. The institutionalization of institutional theory. In Clegg, S., Hardy, C. Nord, W. (eds.), Handbook of Organization Studies. Sage Publications, London, 175-190.

Überbacher, F., 2014. Legitimation of new ventures: A review and research programme. Journal of Management Studies 51, 667-698.

Venkataraman, S., 1997. The distinctive domain of entrepreneurship. In J. A. Katz (Ed.), Advances in Entrepreneurship: Firm Emergence and Growth 3, 119-138.

Vietor, R., 2012. Suntech Power, HBS Case 9-710-013. Boston: Harvard Business School Publishing.

White, S., Gao, J., Zhang, W., 2005. Financing new ventures in China: System antecedents and institutionalization. Research Policy 36, 894-913.

Xie, W., White, S., 2004. Sequential learning in a Chinese spin-off: The case of Lenovo Group Limited. R&D Management 34, 407-422

Xie, W., White, S., 2006. Windows of opportunity, learning strategies, and the rise of China's handset makers. International Journal of Technology Management 36, 230-248.

Xie, W., Wu, G. 2003. Differences between learning processes in small tigers and large dragons: Learning processes of two color TV (CTV) firms within China. Research Policy 32, 1463-1479.

Xin, K., Pearce, J., 1996. Guanxi: Connections as substitutes for formal institutional support. Academy of Management Journal 39, 1641-1658.

Yang, H., Wang, H., Yu, H., 2003. Status of the photovoltaic industry in China. Energy Policy 8, 703-707.

Yu, Q., 2008. Several thoughts based on the investigation of Yingli New Energy Company. Baoding Daily, 5 December 2008.

Yin, R., 2013. Case Study Research: Design and Methods. 5th edition. Sage, Thousand Oaks, CA.

Zeng, M., Williamson, P. 2007. Dragons at Your Door: How Chinese Cost Innovation is Disrupting Global Competition. Harvard Business Press, Cambridge, Massachusetts.

Zhang W., Gao J., White, S., Vega, P., 2008. "Venture Capital and the Financing of China's New Technology Firms". Chapter 4 in Chris McNally (eds.), The China Impact: Capitalism in the Dragon's Lair. Routledge Press, Boston.

Zhao, Y., Wang, S., Li, X., Wang, W., Liu, Z., Song, S., 2006. Report on the Development of the Photovoltaic Industry in China (2004-2005), China Renewable Energy Development Project Office.

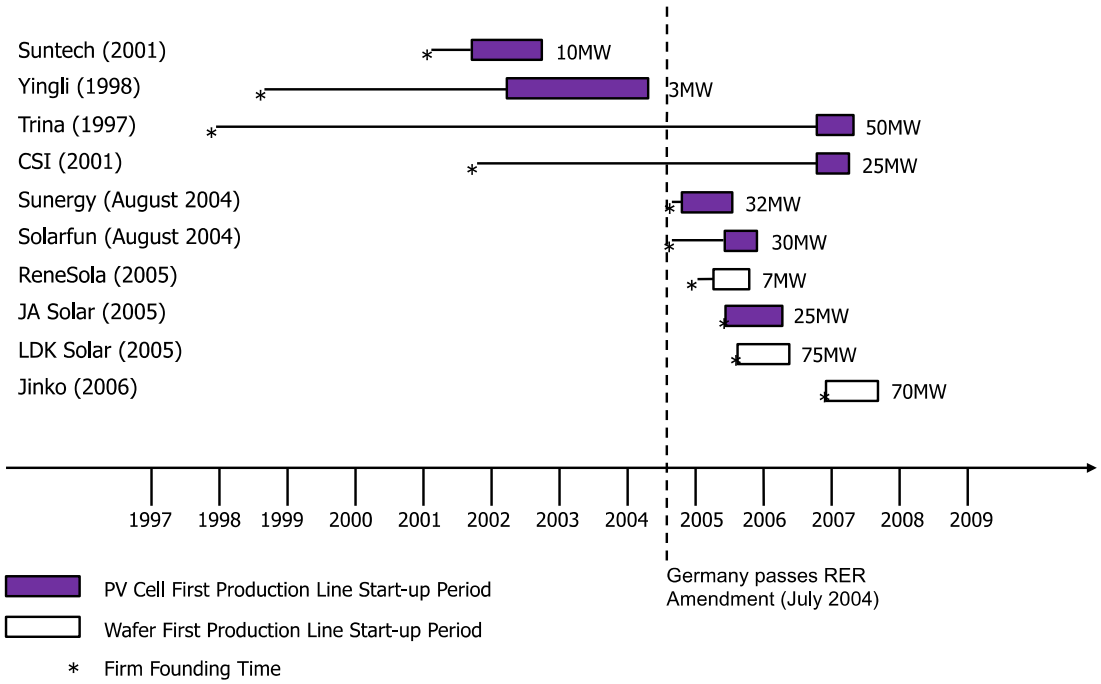
Zhao, Y., Wang, S., Wang, W., Li, X., Liu, Z., Qiu D., Song, S., 2008. Report on the Development of the Photovoltaic Industry in China (2006-2007). China Renewable Energy Development Project Office.

Zimmerman, M. A., Zeitz, G.J., 2002. Beyond survival: Achieving new venture growth by building legitimacy. Academy of Management Review 27, 414-431.

Zott, C., Huy, Q., 2007. How entrepreneurs use symbolic management to acquire resources. Administrative Science Quarterly, 52:70-105.

Zuckerman, E., 1999. The categorical imperative: Securities analysts and the illegitimacy discount. American Journal of Sociology 104, 1398-1438.

Figure 1
Milestones of China's top 10 solar PV firms



Sources: Compiled from company IPO prospectuses and annual reports, and author's interviews.

Figure 2

Integrated model of entrepreneurial action

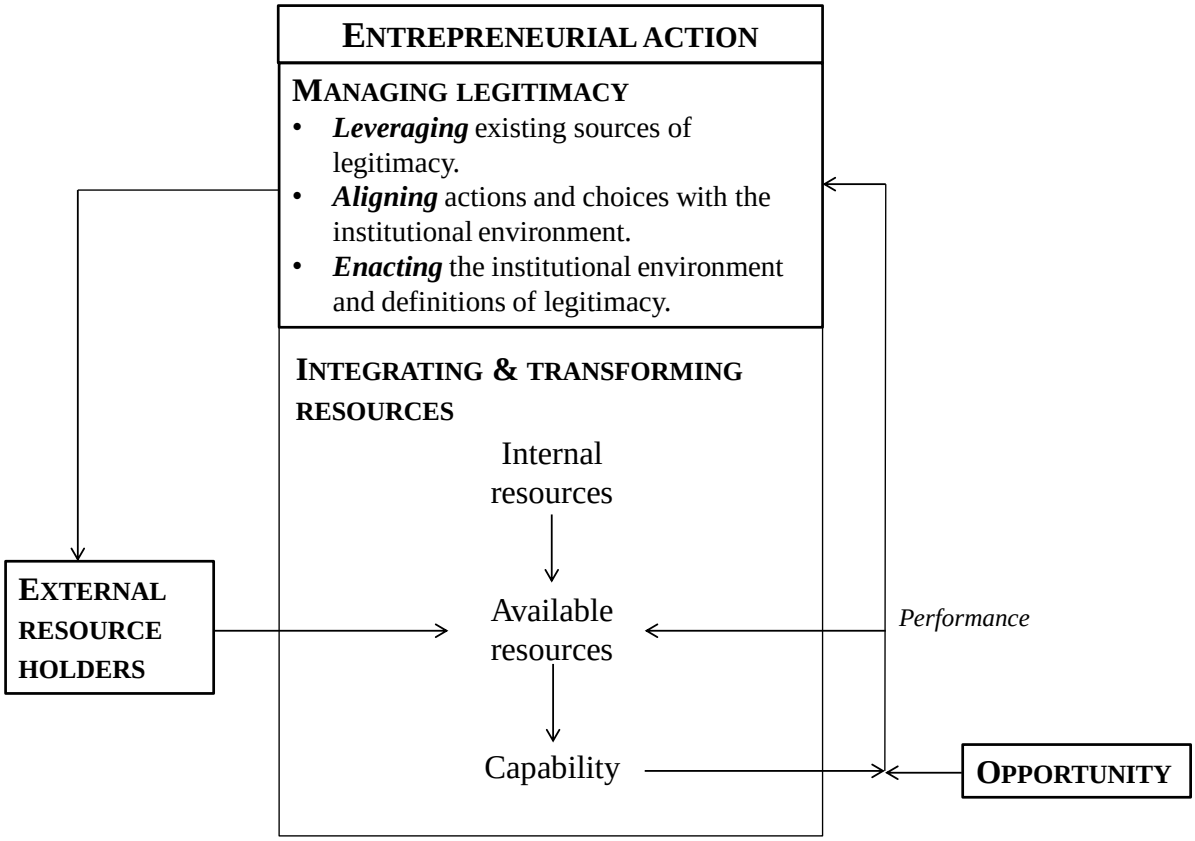


TABLE 1
Overview of case companies

	Trina	Yingli	Suntech	CSI	Solarfun	Sunergy	ReneSola	JA Solar	LDK	Jinko
Founding	Dec. 1997	Aug. 1998	Jan. 2001	Oct./Nov. 2001	Aug. 2004	Aug. 2004	Mar. 2005	May 2005	July 2005	June 2006
Location	Changzhou, Jiangsu	Baoding, Hebei	Wuxi, Jiangsu	Ontario, Canada and Changshu, Jiangsu	Nantong, Jiangsu	Nanjing, Jiangsu	Jiashan, Zhejiang	Ninglin, Hebei	Xinyu, Jiangxi	Shangrao, Jiangxi
Founder	Jifan Gao	Liansheng Miao	Zhengrong Shi	Xiaohua Qu	Yonghua Lu	Tingxiu Lu	Xianshou Li	Baofang Jing	Xiaofeng Peng	Xiande Li, Xianhua Li,
Founder background	MS in material science, entrepreneur (chemical additives).	Serial entrepreneur (cosmetics and water purification).	Returnee Ph.D (electrical engineering), Australian firm R&D director.	Returnee PhD (materials science), Canadian firm's technical VP (Asia Pacific).	Entrepreneur (electric meters).	Entrepreneur (electric transformers).	Entrepreneur (solar lawn lights), official in a county's cultural affairs bureau.	Entrepreneur (monosilicon mftg), director of a county electricity authority.	Entrepreneur (worker protective equipment).	Entrepreneur (fire-fighting equipment). Entrepreneur (automobile repair).
Motivation	"Clean energy is the way of the future."	"Solar power can bring electricity and improve the quality of life for millions of Chinese."	"I want to commercialize technology and help make China's solar PV industry become world-class."	"Solar power has a promising future, although it is still small and not profitable."	"Solar is a promising new investment opportunity."	"Solar is a promising new investment opportunity, and can complement my current business."	"This is a clear chance to enter a rapidly developing industry."	"Downstream integration is a promising opportunity."	"Developments in Europe are creating a great opportunity for me to move in a new direction, for which I could work all my life."	"Follow our elder brother, who founded ReneSolar."
Start-up funding	Founder	Founder	Founder, local govt. VC	Founder and friends	Founder	Founder	Founder and customer pre-payment	Founder	Founder, local government loan	Founder and customer pre-payment
Solar PV products	Off-grid solar systems, then modules, wafers, cells.	Modules, then ingots, wafers and cells.	Cells and modules.	Solar battery systems, then modules.	Modules, then monosilicon cells.	Polysilicon cells.	Monosilicon wafers from reclaimed silicon.	Monosilicon cells.	Polysilicon wafers.	Recovered silicon, then ingots, wafers, cells & modules.
IPO	Dec. 2006	June 2007	Dec. 2005	Nov. 2006	Dec. 2006	May 2007	Jan. 2008	Feb. 2007	June 2007	May 2010

Sources: Compiled from company IPO Prospectuses, annual reports, company websites, authors' interviews and media reports.

TABLE 2

Illustrations of legitimacy-based strategies for accessing external resources

Founder's initial personal resources (financial, human and social capital)			
Trina	**Yingli**	**Suntech**	**CSI**
Academic qualifications (MS in chemistry from Jilin University); reputation as a successful entrepreneur in unrelated businesses (detergent and energy-efficient building materials); personal wealth.	Reputation as successful entrepreneur in unrelated businesses (cosmetics trading and water purification); relationship with local government (Baoding); personal wealth.	Academic qualifications (Ph.D. in electrical engineering from UNSW in Australia); related technical expertise (research and 13 patents); 5 years experience as R&D director in Australian solar PV development company; English language ability; international experience.	Academic qualifications (Ph.D. in materials science from University of Toronto); leadership experience in R&D/engineering and business development in a Canadian firm; relationships with Chinese involved in China's early solar power field.
Legitimacy-based strategies			
Leveraging			
Used success in developing a demonstration off-grid solar energy system to gain recognition among government officials → Gao selected to help draft first national technical standards for off-grid solar power systems (2000). Used Brightness Program/village system project order, and success as first private firm to supply to the Brightness Program, to attract a senior manager and principal engineer from an SOE solar PV manufacturer (2002). Gao used visibility in media and	Used his entrepreneurial success and the prospect of bringing a central government demonstration project to the city to convince the local government to invest in Yingli (1998). Used the government demonstration project approval (1999) to a) attract a technical team, including a senior engineer from the Beijing Solar Research Institute and formerly in an SOE solar PV firm (2001), and b) convince the local government to reposition an existing industrial park from "old" to "new" energy businesses.	Used his technical qualifications and experience to gain interest of Wuxi government-backed VC firm to consider start-up funding for a solar PV firm. Used his personal reputation and Wuxi government VC funding to attract a top management team and technicians from both China and Australia, and a senior engineer from an SOE who had set up their PV cell line. Used success of second production line in terms of cost-effectiveness and international marketing strategy to gain Board approval for a third line.	Used Canadian nationality of the firm and VW project approval to attract both Canadians and Chinese engineers with experience in solar PV and semiconductor industries. Used CSI's Canadian nationality (HQ in Ontario) to a) receive tax incentives and other benefits from the local government for his Chinese operations and b) qualify for Canadian International Development Agency's (CIDA) solar energy projects in China.

successful deployment of village systems to be selected to working group developing China's first Renewable Energy Law and to serve as Vice Chairman of the Solar Power Construction Committee of China's Renewable Energy Society (2004).	Used success in supplying to the Brightness Program to attract US$5.3M investment from a local listed SOE to fund upstream integration to produce ingots, wafers and cells (2002).		
Aligning			
Founded a solar energy research center in 1999 to build his personal and Trina's legitimacy for technical capability. Gao cooperated with China's state media to help convince the visiting Organizing Committee of the Olympic Games (2001) of China's commitment to improving air quality in time for the 2008 Beijing Olympics. Donated 16 household solar power generation systems to the Changzhou Science and Technology Committee for Lhasa (2001) → aligned with government's Brightness Program objectives → chosen as supplier of 39 village systems for the Brightness Program (2002).	Hired a technical expert to develop a proposal to China's Central Planning Commission for a solar PV cell production demonstration project targeting polysilicon-based production, in line with the government's objectives under the Brightness Program. Bought Yingli's first turnkey production line for high-efficiency PV cells to satisfy conditions of the government's demonstration project (2002). Acquired ISO 9001, UL and TUV certifications to meet European customers' requirements (2004).	Developed a 200+ page business plan, accepted intense personal scrutiny as part of due diligence, and contributed his patents and US$400K cash to meet the demands of the Wuxi government VC firm. Initially supplied Chinese systems integrators, which matched the government's priority as they were supplying the Brightness Program, and also Suntech's domestic production capacity reduced the integrators reliance on imported cells. Acquired ISO 9001 and CE certifications and achieved technical and quality levels matching European customers' requirements (2002-2003).	Developed solar power generation equipment for rural areas of China to join with the Canadian International Development Agency and support the Chinese government's "Solar Electrification for Western China Project"; sold 2.2MW of solar module products.
Enacting			
Engaged in extensive media and other public relations activities to promote solar PV and its viability as a commercial industry with social benefits. Co-organized the first International Solar	Founded Yingli with his own money (US$600K) and developed a proposal to the Central Planning Commission to support his (and the first) private firm's plan to undertake production of solar PV cells.	Highly publicized launch ceremony for Suntech's first production line that had a capacity >double China's existing capacity showed potential of private firms vis-à-vis existing SOEs.	Participated in three solar energy forums in Beijing, Xining and Suzhou with the Chinese government and Canadian International Development Agency with the objective of promoting solar energy in China.

Power Generation Technology Forum in 2000 in Guangzhou to demonstrate Trina's prototype off-grid integrated solar energy system and market potential for such systems.	Successful completion of the demonstration project for vertically integrated production (ingot, wafer, cell, module) showed that a Chinese firm could implement the more advanced polysilicon-based process.	Exhibiting at international exhibitions (first in 2002) and offering cells and modules meeting international standards for technology and quality at competitive prices created awareness of Chinese firms as viable suppliers among foreign customers. Served as a beta test site for a Japanese equipment supplier to show that his firm could be a valuable customer. Successful listing on NYSE convinced wide range of resource holders (investors, technical and managerial talent, governments, etc.) of viability of private Chinese solar firms.

Sources: Compiled from company documents (IPO prospectuses, annual reports), company websites, author's interviews, media reports, and Solarbuzz reports.

Table 3

Private entrepreneurs and founding conditions: Early vs. late entrants

	Explorers **(enter 1997-2004)**	**Exploiters** **(enter 2004-2007)**
Founders	Private individuals; both first-time and serial entrepreneurs, some with deep technical expertise.	Private; mostly successful serial entrepreneurs.
Top management team	Chinese: either ~all local or ~overseas returnees, depending on founder's personal network; a few hired from SOEs in related industries.	Usually mixture of Chinese and non-Chinese; both solar PV firms (from SOEs and Explorers) and related industries.
Initial market/customer focus	Domestic and small-scale market; government development policy-driven projects.	International and large, rapidly growing commercial market.
Production technology	Limited choice; primarily from founder and through internal efforts, and embedded in equipment.	Primarily developed internally, some by technical agreements, and embedded in more advanced equipment.
Financing (pre-IPO)	Relatively small-scale, individuals/founder and local government-backed VC; major financing much later.	Medium-scale by corporate-serial entrepreneurs; quickly followed by major international and domestic VC/PE for rapid scale-up.
Raw materials and equipment	Sourced internationally (few/no Chinese domestic manufacturers); not considered important customers by suppliers.	Greater choice, both international and domestic; seen as key customers by suppliers.
Policy/government relations	Supports central government's social development objectives (rural electrification); government awards grants for technical projects. Local government provides some support under general policies promoting high-tech entrepreneurship and business development (not specifically targeting nor limited to solar PV).	Government actively promotes star entrepreneurs and ventures. After 2008, some local governments target solar PV for industrial parks and provide preferential conditions.

ONLINE SUPPLEMENT TO THE PUBLISHED ARTICLE

OVERCOMING THE LIABILITY OF NEWNESS: ENTREPRENEURIAL ACTION AND THE EMERGENCE OF CHINA'S PRIVATE SOLAR PHOTOVOLTAIC FIRMS

The sections below provide additional details regarding the context, case study entrepreneurs and firms, industry developments, and data sources. Sections are referenced in the main paper.

S1. Early role of Chinese government deployment support

The government played an important but indirect role in the late 1990s to early 2000s through its social development programs (e.g., the Brightness Program) targeting rural electrification (Table S1 in this supplement). This deployment support created a relatively small but critical domestic market for solar PV products for the new private firms who had no government backing to cover sustained financial losses. By late 2004 this was replaced by dramatic revenue growth driven by deployment support in Germany (Hirshman et al, 2007; Schmela, 2005, 2006). From that time, private financing, foreign demand and technology capability improvement and innovation, not Chinese government support, were critical to the Chinese firms' success in quickly increasing scale and output that, in turn, enabled them to capture most of the new global market demand (Marigo, 2007; Marigo et al, 2010; Bruce, 2007; Author's interviews).

S2. Context: Pre-2004 environment for solar PV in China

China in the early 2000s was far from an ideal environment in which to establish a commercial solar PV manufacturing firm or industry. Domestically, China had essentially no local supply of polysilicon (the key raw material); indeed, there was a worldwide shortage of silicon (Schmela, 2006). China also had very limited and relatively immobile industry-specific human capital, out-of-date technology, weak innovation capabilities (Dai et al, 1999: Yang et al, 2003; REDP, 2004), and little in the way of related or supporting industries (de la Tour et al, 2011; Bruce, 2007). These resources would have to be sourced internationally, at least until local sources developed. The cost for internationally available equipment, however, was prohibitive for most potential local entrepreneurs (Bruce, 2007; Zhengrong Shi,

Author's interviews), and difficulty in accessing technology is a critical strategic disadvantage in this industry (Kapoor & Furr, 2015). Only state-owned enterprises (SOEs) with government funding had imported equipment, and that was justified not on commercial grounds, but by the fact that they were supplying the government's needs (Dai et al, 1999; REDP, 2004; Zhao et al, 2006).

While the SOEs were able to supply enough for the government's purposes, they were not able to match international standards for conversion efficiency and quality. Although the basic technology had not changed since the 1970s, there were steady and, cumulatively, dramatic improvements in those performance parameters in the intervening period (Green, 2000). Chinese firms had weak innovation capabilities and were lagging further and further behind international standards (Dai et al, 1999). The small amount of Chinese-made modules that had made their way to the international market were of poor quality, creating a bad initial reputation for Chinese solar PV products (Hug and Schachinger, 2006).

Furthermore, potential Chinese entrepreneurs did not consider the market opportunity for solar PV to be attractive. While global demand was growing at 20% or more before 2004, it was still relatively small in absolute terms and could be met by the major incumbent producers in Japan, USA and Germany. (Figure S1 in this online supplement presents a timeline of major solar energy-related policy developments in the countries that were driving that demand growth.) Sharp, for example, first began commercial production of solar PV cells and modules in 1963, and was the largest producer globally with 324 MW of production capacity in 2004. Sanyo began production in 1980 and had a capacity of 68 MW in 2004 (Schmela, 2005; Jäger-Waldau, 2006). At the same time, domestic demand was small, limited to a few government uses (satellites and remote terrestrial communications) and government-funded regional development projects. Moreover, like elsewhere, the relatively high cost of solar PV compared to other technologies for generating electricity severely limited its competitiveness and market prospects (Dai et al, 1999; REDP, 2004).

Also at that time, neither China's central nor local governments saw solar PV as a commercially attractive industry. The central government's entire investment in the sector in the 1970s and 1980s was limited to a few manufacturing lines in five state-owned enterprises (SOEs), not for commercial or export objectives but to supply the Chinese government's needs regarding satellites, military and remote communications (REDP, 2004). Later, from the late 1990s to 2003, this temporarily expanded to include supplying villages with off-grid electrification under the Brightness Program. (See Table S1 for a chronology of key policy, industry and organizational events in China's early solar PV industry.) While this program

did create some domestic demand (a total of 20 MW), local entrepreneurs did not consider it to be a promising commercial opportunity for a Chinese firm. They believed that the cost structure would keep the price of solar-generated energy too high to expand demand in China, and that China offered no advantages vis-à-vis foreign incumbents in international markets (REDP, 2004; Bruce, 2007; Zhengrong Shi and Xiaohua Qu, Author's interviews).

In summary, private Chinese solar PV firm entrepreneurs had to overcome even greater "liabilities of newness"—both as individuals, firms and collectively as a new organizational form—than those in other Chinese industries that have become global competitors. The local environment offered few industry-specific resources that they could draw on to build an organizational capability that would enable them to enter domestic or international markets. In any case, those markets were not attractive due to the dominance of large, established incumbents. Furthermore, solar PV manufacturing demanded high-quality production capabilities, for which Chinese firms were not known internationally.

Potential entrepreneurs would have to build legitimacy vis-à-vis a wide range of external resource-holders, including buyers, suppliers, experienced technologists and managers, and financial markets. Internationally, Chinese firms had no reputation as solar PV manufacturers, and there was considerable doubt that they could meet the demanding technical and quality standards (Bruce, 2007; Hug and Schachinger, 2006). Domestically, while private firms and their owners were not restricted from operating in the industry, their legitimacy was hardly secure. The industry was open for private investment, but there was no precedent for a private firm in China, as all incumbents were SOEs. Even if they did emerge, government actors linked to the incumbent SOEs could perceive them as a threat and use their influence to hinder their growth, which is always a possibility in China's government-dominated economic and political system (Hsueh, 2011).

S3. Detailed case descriptions of the four early entrants

This section presents detailed descriptions of the backgrounds, founding and growth of the four early entrants—Trina, Yingli, CSI and Suntech. The specific challenges the early entrants faced varied depending on the background and characteristics of the founders, as well as on their common challenge of establishing the private Chinese solar PV firm as a legitimate organizational form vis-à-vis external resource holders. The following sections describe what these entrepreneurs did to access and integrate the resources needed to build

the organizational capability to capture what they saw as the opportunity for solar energy.[13] As their cases illustrate, each had to expend significant effort to establish their legitimacy vis-à-vis external actors holding key resources. This legitimacy building was not only for them individually and their firms, which is common for any new venture, but also for the new organizational form—a private Chinese solar PV firm—that they represented.

Although Suntech was the first private firm to produce PV solar cells using its own commercial production line, it was not the first to be founded (Figure 2). In 1997, the same year that the Kyoto Protocol was ratified, Jifan Gao founded what would become Trina. He was followed one year later by Liansheng Miao, who founded Yingli, and in late 2001 Xiaohua Qu founded CSI. All of them had to overcome significant challenges to establish their firms and sustain them in the face of a small domestic market and an international market dominated by incumbent, developed-country multinationals.

Trina

Jifan Gao, Trina's founder, held an MS in chemistry from Jilin University and had established his reputation as a successful entrepreneur in the detergent business. He had no direct contact with the solar industry, but describes how the ratification of the 1997 Kyoto Protocol had a profound impact on his view of energy and the future.[14]. He became obsessed with the prospects of clean energy, and began to search for promising new technologies. While he could fund a new start-up himself, however, he had no relevant technical or production experience, and no connections in the solar industry. Lacking such resources, he founded Trina in 1997 and initially targeted energy-efficient building materials. He had a short period of success in importing and producing a composite curtain wall, including some major government construction projects, until others entered the market and competition drove prices ruinously low.

At that point, he decided to shift to integrated solar energy systems for off-grid buildings. Lacking the technical expertise and reputation in this specific field, his first action was to establish a solar energy research center in 1999. In August 2000 his team became the first in China to develop a prototype off-grid household solar power system, which they demonstrated at the first International Solar Power Generation Technology Forum that Gao also co-organized. The following year he donated 16 of these systems to the Changzhou Science and Technology Committee to be installed in Lhasa, Tibet as part of the

[13] Data for these cases is drawn from the sources listed in Appendix A in this supplement.
[14] http://baike.baidu.com/view/2056977.htm#2; Trina website; http://www.trinasolar.com/cn/index.html

government's Brightness Program. Over this same period, he appeared frequently in the media and various forums, promoting both solar energy's benefits and Trina as a leader in developing working systems. These actions brought him and Trina recognition from the local and national government, which in turn brought several benefits. First, he was selected as a member of the committee drafting the National Technology Standards for Off-Grid Solar PV Systems. Second, in 2002 Trina became the first private firm to be chosen as a commercial supplier of village systems in Tibet under the Brightness Program (Trina IPO Prospectus; REDP, 2004).

These systems, however, needed to be much larger for villages, and Trina had neither the adequate technology nor the project management experience. However, the legitimacy Gao and Trina had developed vis-à-vis the government, in addition to the order for village solar power systems, helped him address this key resource gap. Specifically, it enabled him to attract Diming Qiu, the Deputy Manager and Principal Engineer of Yunnan Semiconductor, one of the "old four" SOE solar PV firms. Qiu had over 20 years experience in the solar PV industry and had overseen the construction of Yunnan's vertically integrated (ingot to module) PV manufacturing line. He had also been involved in Yunnan Semiconductor's installation of three solar power plants in Tibet in 1992 (Trina IPO Prospectus). After installing 39 power systems by late 2003, Qiu then led Trina's research project funded by the Ministry of Science and Technology for integrating solar power components with construction materials. Gao later decided to channel Trina's technical effort and financial resources to integrate upstream into module production, and in November 2004 launched Trina's first PV module production line.

Yingli

Like Trina's Gao, Liansheng Miao had established his personal reputation as a successful entrepreneur in industries unrelated to solar energy (cosmetics and water purification equipment). Also like Gao, Miao believed that solar energy had great potential, particularly for the hundreds of millions of Chinese living in remote areas with limited or no access to electricity.[15] His vision was closely aligned with the objectives of the Chinese government's Poverty Reduction Through Electrification Program, linked to the Brightness Program.

[15] http://baike.baidu.com/view/1218579.htm#1; Yingli website.

While Miao possessed the financial resources to found Yingli (US$600,000) in 1998, he lacked expertise in both solar PV and manufacturing. To close this gap, he hired a technical consultant to develop a proposal for a demonstration project grant funded by China's Central Planning Committee. In order to be considered, however, Yingli had to have greater registered capital. Miao was able to convince the local Baoding government to make an equity investment (cash and land), with the prospect of a prestigious project coming to this middle-level city (Yu, 2008).

Somewhat unexpectedly, Yingli's project application was approved in 1999. Miao was then able to convince the local government to reposition an existing industrial park from "old" to "new" energy businesses (Yu, 2008). The approval also gave him the legitimacy to attract a technical team and the financial support to acquire equipment. Critically, in 2001 he was able to persuade Yuting Wang to join as Chief Engineer. Wang came from the Beijing Solar Research Institute and, before that (1985-1996) had worked for Qinhuangdao, where he participated in the installation of the SOE's imported turnkey solar cell manufacturing line.[16]

Yingli acquired a turnkey production line in 2001 and produced its first modules in 2002. He leveraged that success to win an order to install nine solar power stations in Sichuan Province under the Brightness Program. With this order and the support of the Baoding officials, Miao then convinced Tianwei, a recently listed SOE in the power transmission industry based in Baoding, to invest US$5 million from its IPO proceeds. Part of this was used to buy out the local government's share. Miao used the rest to integrate upstream, producing ingots and wafers in 2003 and then PV cells from March 2004. At that time he also decided to target the international market, and acquired the ISO 90001, UL and TUV certifications demanded by European customers.

Suntech

Of the four early entrepreneurs, Zhengrong Shi's technical background was most closely related to solar PV, and he had extensive connections in the industry both in China and internationally. He had spent 13 years in Australia as a visiting scholar, PhD student, university research scientist and then research director for Pacific Solar, an Australian thin-film PV development company. In 2000 Shi decided to return to China, and in 2001 he moved his family to China and founded Suntech. He had been frustrated that Pacific Solar's CEO and board would not target commercial production of their solar PV technology out of

[16] Yingli IPO Prospectus.

fear of competition from major multinationals, such as BP Solar, Sharp, Kyocera and Siemens, that had dominated the industry since the 1970s. Shi believed that a long-term global move towards solar energy to counter environmental degradation would create an opportunity for new firms to compete (Author's interview).

Shi investigated a number of possible locations across China for his new firm. He finally decided on Wuxi, a major city in Shi's home province of Jiangsu. Shi's academic and research credentials impressed the local officials, and they were extremely interested in the prospect of increasing "high-tech" employment in their city. By coincidence, Shi's visit came soon after the Wuxi government, like many other local governments had formed a government-backed VC firm with funds from local SOEs (White et al, 2005). They were, however, particularly cautious about Shi as a founder and Suntech's prospects as an investment. Shi had always been involved in research, not commercial production. The scientist-as-entrepreneur was still relatively rare in China at that time. Scientists usually lacked their own start-up capital, and China's venture capital industry was still in its infancy. Even more importantly, they lacked a market mindset and management capability, according to Lenovo's co-founder and CEO.[17] Moreover, there was no precedent for a private solar PV firm in China, so Shi had no successful example to help him convince the Wuxi officials that the solar business had commercial prospects, nor a model on which he could base Suntech's business plan. More generally, neither foreign nor domestic VCs saw Chinese solar PV as having significant growth potential. Domestic VCs were particularly wary of investing in purely private ventures with unproven business models and no links to the government (Zhang et al, 2008).

To obtain financing from the Wuxi VC fund, Shi had to undergo a process that would seem relatively normal as part of any VC's due diligence process. First, they required that he present a detailed business plan, and he prepared one that would eventually reach over 200 pages in response to their follow-on questions and requests. They used the state-owned firm Changzhou Eging for technical and market due diligence. They also sent a five-person team to Australia to conduct personal due diligence on Shi, including an inspection of his home and interviews with his colleagues at Pacific Solar and his Ph.D. supervisor. Finally, they required Shi to contribute US$400,000 of his own money to the venture, as well as commit all of his patents and know-how, in return for a 25% share of the company and a performance bonus if Suntech met its profit targets. In return, they invested US$6 million in January 2001.

[17] Chuanzhi Liu, The critical challenge of VC investment in China, http://it.sohu.com/20041216/n223520052.shtml

This funding and Shi's personal reputation enabled him to attract a management team. This included two Chinese for marketing and administration and two key technical experts, one Chinese and one Yugoslav, who had also studied and worked in Australia (Figure 3). He was also able to recruit Yichuan Wang from Yunnan Semiconductor, where he had been a senior engineer involved in setting up that firm's PV cell production line.

With this combination of funding and expertise, Shi and his team were able to acquire equipment from different overseas suppliers and integrate them into a production line that they designed themselves (i.e., not a turn-key line). Simultaneously, Shi committed significant resources to establishing an internal R&D lab to drive subsequent innovations. For the shop floor he hired fresh graduates with no experience and trained them. To earn some revenues, they first began module assembly, sourcing cells from abroad and selling modules to integrators supplying the Brightness Program in 2002. They launched their own cell production line in September 2002 with a high-profile ceremony attended by local officials, Shi's Australian Ph.D. supervisor, and the founder of Pacific Solar, where Shi had been research director. Suntech's initial production capacity of 10 MW represented more than double China's domestic capacity at that time. Moreover, their technical level (measured by conversion efficiency) matched international standards, a condition that the Wuxi investors had required as part of their investment.

While Shi had proven that a private Chinese firm could undertake the mass production of solar PV cells, his founding team was having doubts about the commercial prospects for solar PV. They were not convinced that the domestic market represented a major commercial opportunity, and they thought the barriers to enter international markets were too great for a Chinese start-up firm. By the end of 2002, all four had left.

This spurred Shi to re-evaluate Suntech's strategy and shift his own primarily technical role to one promoting the firm's commercial growth (Author's interviews). To this end, in November 2002 he led a team to their first international PV exhibition to explore major overseas markets, specifically Europe, where he saw the most potential for a new firm like Suntech. At that time, Suntech was the first and only Chinese firm present at the industry trade shows, and also the only Asian firm at the key PV industry trade show in Berlin in 2002. Shi found that potential customers were surprised to see them, and he spent considerable time explaining his background in Australia and Suntech's achievements in Wuxi. Those he spoke to were open to Suntech's products, as long as they met requisite international standards for technical performance and quality, as well as being competitively priced (Bruce, 2007; Author's interviews). To speed progress towards meeting those

standards, he formed a technical cooperation agreement with the Photovoltaic Research Center of the University of New South Wales (UNSW) in December 2002. By March 2003 he had received CE certification for Europe. That same year, his orders were nearly equally split between customers in China and abroad. Suntech even achieved profitability in its first full year of production.

With that success, and believing in a potentially strong upward trend in the European market, Shi wanted to significantly increase production capacity by adding a second manufacturing line. The Suntech board, however, resisted, as the SOE investors did not want to make the necessary follow-on investment. Shi had to be extremely creative in working around this funding constraint. This included a combination of actions, such as sourcing some equipment locally as new Chinese suppliers had begun to enter the market, modifying the manufacturing process to eliminate the need for expensive PECVD equipment, buying second-hand equipment from Italy at 10% of the original cost, and carefully scheduling equipment orders and delivery to maximize working capital efficiency. Shi also collaborated with a Japanese supplier of screed printers—another expensive and critical machine in the production process. In return for serving as a beta site and contributing Shi's own technical expertise, the supplier gave Suntech a 50% discount (Author's interview; Bruce, 2007). In this way, Shi was able to set up the second production line of 15 MW capacity for just US$1.2 million. He also focused an engineering team on the first production line with the objective of increasing its capacity through process changes. By December 2003, Suntech had a total capacity of 30 MW (Suntech IPO Prospectus).

With this success in increasing capacity in an extremely cost-effective way (an example of Chinese "cost-innovation" (Zeng & Williamson, 2007)) and the promise of growing sales in the European market, Shi had a much easier time in persuading the Suntech board to add a third manufacturing line in early 2004. The third solar PV cell line commenced production in August 2004 with a capacity of 30 MW, bringing Suntech's total capacity to 60 MW and making it the 10th largest cell producer worldwide by 2004 (Suntech IPO Prospectus; Schmela, 2005).

CSI

Xiaohua Qu, another long-term expatriate, returned to China with relevant technical expertise and professional experience, as well as useful connections with what would be his first customer. He had worked for Canadian-based ATS and the research division of Ontario Power Generation Corporation after receiving his PhD in material science from the

University of Toronto in 1995. While at ATS, Qu had held leadership positions not only in R&D and engineering, but also procurement, business development and strategy. His last position took him to France to be the Technology VP for Asia Pacific for Photowatt International, which ATS had recently acquired. Here, he had the chance to travel to western China for business development, and formed relationships with people involved in China's early solar power field.

By that time, Qu had begun to feel he had reached a glass ceiling in ATS and Canada, and was searching for a way to start his own company (author's interviews; http://guangfu.bjx.com.cn/news/20110914/309348.shtml). Like the other early entrepreneurs, he felt that solar power had a promising future, in spite of the fact that ATS's solar power business was relatively small, losing money, and not considered important by the parent company. He began drafting a preliminary business plan in the summer of 2001, envisaging four possible directions for his start-up.

The project he ultimately chose—to develop a solar battery system for automobile applications—was one that he had helped review while at ATS but which ATS had decided to decline. He personally developed the concept design, and was himself surprised that it was the only project that Volkswagon (VW) approved (Author's interview; http://guangfu.bjx.com.cn/news/20110914/309348.shtml). In October 2001 he registered his company in Ontario and had an order from VW to deliver on the design. He saw this project as a promising opportunity, although he later admitted he was not sure how large the solar energy market would grow, or how quickly.

Qu resigned from ATS, which originally supported him in the hope that Qu would buy Photowatt's excess PV cell production (Author's interview). In November 2001 he set up his Chinese company in Changshu, near Shanghai, where VW has one of its major joint venture manufacturing facilities. Qu was a naturalized Canadian citizen and CSI's headquarters was registered in Canada, which he leveraged to receive various tax incentives and other benefits from the local government as a foreign-invested enterprise. The Canadian base and Qu's background also enabled him to recruit both Canadian and local engineers with experience in the semiconductor and solar PV industries to form R&D and management teams.

Within four months the team developed a prototype. Under VW China's supervision and guidance for quality control, Qu's company successfully delivered the first batch of products to VW in March 2002. He leveraged his success to expand his business, but kept the firm focused on design and module assembly for residential, commercial and industrial

product applications. Qu also leveraged his and CSI's Canadian nationality to cooperate with the Canadian International Development Agency and supply solar power generation equipment to rural areas of China under the government's "Solar Electrification for Western China Project" between 2002-2005. This contributed some revenues as well as giving CSI some useful exposure. As part of the project, CSI participated in three solar power forums held across China that were used to promote the industry. This raised Qu and CSI's profiles among high-level politicians and solar industry experts, and helped him to expand his business in the Chinese market and abroad. In 2004, CSI sold 2.2 MW of its solar module products, and by 2007 expanded upstream into PV cell production.

S4. Additional detail on the post-2004 market opportunity for Chinese entrants

July 2004 brought a major watershed policy event that changed the market and competitive dynamics of the global industry and ushered in a dramatically different market environment for solar PV. Global demand for solar PV had been growing steadily since 2000 as developed country governments introduced incentives supporting solar energy production and equipment installation. Established producers, concentrated in Japan, the USA and Germany, had expanded production in response to this growth, and global supply more than met demand.

Germany's Renewable Energy Resources Act Amendment in July 2004, however, significantly raised the feed-in tariff for solar-based electricity and removed the subsidy ceiling, triggering a dramatic increase in demand for PV solar modules. Year-on-year global demand doubled to 1,121 MW, with Germany's increase representing 83% of that growth. As other countries adopted similar incentives, global demand would rise to nearly 3,000 MW by 2007 (EPIA, 2010).

While such a demand curve should have been a blessing for the incumbent global producers in Germany, Japan and the United States, they were not prepared to increase their capacity at a rapid enough rate to capture all of it. These large firms, many of them subsidiaries of diversified electronics and energy firms (Balaguer and Marinova, 2006; Schmela, 2005, 2006; Hirshman et al, 2007), typically took 18-24 months to begin construction of new facilities once approved, and another 12 months for full-scale production to come on-line (Solarbuzz, 2007). Suntech's Shi also observed that the decision to allocate significant resources to increasing capacity could take a relatively long time in those firms (Author's interviews). For smaller PV-specialized firms, this was a major decision that was not to be taken quickly, given their relatively tight financial constraints. For other major PV

firms that were subsidiaries of large and diversified multinationals (e.g., BP Solar, Sharp, Kyocera, Sanyo, Shell), internal lobbying and formal approval processes were a major source of delay. Once approved, then the procurement process and delivery would add additional months (Bruce, 2007; Solarbuzz, 2007; Author's interviews).

S5. Development of early entrants in the post-2004 environment

Benefiting from Shi's earlier insistence on investments that had increased capacity from 10 MW to 30 MW in early 2004, and then to 60 MW just a month after the German policy was announced, Suntech was particularly well-positioned to exploit the new demand. Suntech's sales increased from 6.4 MW in 2003 to 29.5 MW in 2004 and 67.7 MW a year later. At the same time, Suntech saw a dramatic shift in its markets. In 2003, 46% of Suntech's US$13 million in sales were domestic, and South Africa was its largest international market (25%), followed by Germany (19%). In 2004, Suntech's revenues increased by more than 6 times to US$85 million, and China's share of that dropped to just 1.6%, while Germany's jumped to 72% to become Suntech's largest market, which it would remain for several more years (Suntech's IPO Prospectus and annual reports, 2005-2007).

Yingli and Trina were also able to benefit from this international demand spike and followed Suntech into the German market. Yingli found a market for all of the cells it could produce on its 3 MW line, along with 4.7 MW of modules. Trina soon followed in late 2004 with 6 MW of module capacity. CSI, focused downstream on the design and assembly of application-specific modules, was able to expand beyond its original customer base and sold 2.2 MW of module products in 2004. With this new focus on the European market, CSI, Trina and Yingli sought relevant certifications (e.g., ISO 9000, UL, IEC and TUV), as Suntech had done two years earlier. They all also followed with major investments in new capacity, with Yingli increasing its annual cell manufacturing capacity to 60 MW, module capacity to 100 MW, and both ingot and wafer capacity to 98 MW by 2006. By 2007 Trina had reached 200 MW and CSI 100 MW, including new capacity in cell manufacturing.

Suntech was also the pioneer among Chinese PV firms in listing on overseas stock markets to finance capacity expansion to a level that would give Suntech a competitive advantage over domestic and foreign rivals. A domestic listing was not possible, given China's strict listing requirements and low priority given to private firms compared to state-owned firms for the limited number of listings allowed. An overseas listing, however, represented another set of major challenges for a private Chinese firm. For example, Shi first

had to restructure the firm, which included convincing Suntech's state-owned investors (under the Wuxi government) to exit. Fortunately for his plans, the Wuxi government officials agreed to support this market-based initiative, and by January 2005 those investors left with an average 13-times return on their investment. This paved the way for a bridge loan to fund expansion, followed by an $80 million investment by Goldman Sachs and three other equity firms in May (Table 3).

In December 2005 Suntech became the first private Chinese firm to list on the New York Stock Exchange (NYSE) and raised US$400 million in its initial public offering. This watershed event marks a dramatic shift in the perceptions of the international investment community vis-à-vis private Chinese solar PV firms. The other early entrants, following Suntech's example, were able to quickly attract significant pre-IPO VC and private equity financing and then list on US exchanges (Table 4). This additional financing enabled them to rapidly increase production capacity to capture the new demand for PV products and, thereby, withstand competition from the flood of new entrants who had also been attracted by the demonstrated market size and potentially lucrative exit. Those early entrants who were not already vertically integrated also diversified upstream to better control supplies of what were becoming increasingly scarce inputs (cells, wafers and ingots).

Appendix A
Detailed list of data sources

CORPORATE	IPO Prospectus, 10-K , Annual Reports	Interviews, presentations and broadcasts
Trina Solar	2006-2011	*Founder/CEO* (presentation and Q&A session, 5th China New Energy International Forum, 2011), *VP for Public Affairs and International Market Development* and senior manager (author's interviews, 2~3 hours each, 2012)
Yingli	2007-2011	Senior manager for international relations (author's interview, 2 hours, recorded, 2012) , *VP for Operations, VP for International Division, CFO* (closed meeting presentations, 30~60mins. each, 2010), tour of HQ (manufacturing and R&D)
Suntech	2005-2011	*Founder/CEO* (author's interview, 2 hours, 2012; university presentation with Q&A, 1.5 hours, recorded, 2008; broadcast on CCTV-2's *Dialogue* program, 90 min., recorded, 2006), *VP for R&D, VP for Public Relations, Senior VP for Global Supply Chain* (author's interviews, 1.5-2.5 hours each, recorded, 2012), *Managers in manufacturing, quality control and public relations* (author's interviews, 30 min. each, 2012), tour of HQ (manufacturing and R&D)
CSI	2006-2011	*Founder/CEO* (author's interview, 2 hours, 2013), *Special Assistant to the President* (author's interview, 1 hour, 2013), manufacturing process manager (author's interviews,30 min., 2013), tour of HQ (manufacturing and R&D)
LDK	2007-2011	Founder/CEO: (university lecture with Q&A, 1.5 hours, transcribed)
Solarfun	2006-2011	*COO* (university lecture with Q&A, 1.5 hour, transcribed, 2007)
JA Solar	2007-2011	*CEO* (presentation, 5th China New Energy International Forum, 40 min., 2011)
Sunergy	2007-2011	
ReneSola	2007-2011	*VP* (presentation, 5th China New Energy International Forum, 40 min., 2011)
Jinko	2010-2011	*CEO* (presentation, 5th China New Energy International Forum, 40 min., 2011)

INDUSTRY	Years	Source
Chinese PV Industry Development Report	2003-2011	Office of China's Renewable Energy Development Project, National Development and Reform Commission of China
Annual Report on China's New Energy Industries	2011, 2013	New Energy Chapter, Chinese Federation of Commerce
United States Innovation Policy for the Global Economy	2012	United States National Research Council
Solar PV Manufacturing Cost Analysis: U.S. Competitiveness in a Global Industry	2011	United States Department of Energy, National Renewable Energy Laboratory (Publication: NREL/PR-6A20-53938)
Global Market Outlook for Photovoltaics to 2014	2010	European Photovoltaics Industry Association (EPIA)
*Solarbuzz (*Online service of a solar industry news and	2001-2014	URL: www.solarbuzz.com

analysis organization)		
Beijixing (SolarStar) (Chinese online solar PV industry news and analysis organization)	1999-2014	URL: http://guangfu.bjx.com.cn

Table S1

Major developments in China's state-owned solar PV sector

Government Policies	Enterprise developments	National developments
	1964. Kaifeng Solar Cell Factory and Emei Semiconductor Factory (polysilicon manufacturer) established.	
	1966. Luoyang Monosilicon Factory established.	
	1970 Kaifeng begins monosilicon production; begins solar PV cell R&D.	1971. First solar PV cells used in DongFangHong II (East Is Red II) satellite.
	1973. Yunnan Semiconductor Factory established (originally Kunming Transistor, est. 1967)	1973. First solar PV cells used on land (military and communications).
	1975. Kaifeng begins monosilicon solar PV production.	
	1977 Qinhuangdao Huamei Solar Cell Factory established.	
	1978. Ningbo Solar PV Factory established.	Pre-1980. Domestic demand ~0.1MW, all military and government use.
	1979. Yunnan Semiconductor begins production of solar PV cells; first sales to Yunnan TV broadcasting system.	
1980-85 (6th 5-Year Plan). Solar PV included as a target industry; >US$10M allocated to import 7 turn-key production lines.	Early 1980s. Kaifeng imports international-level monosilicon PV production line (0.3MW capacity).	
1980s (6th and 7th 5-Year Plans). Central and local governments allocate funds to the "Overcome Technical Challenges Program", which includes solar PV technology.	1984. Yunnan Semiconductor imports equipment from USA and Canada (0.5MW capacity).	
	1992. Yunnan Semiconductor installs 3 solar power stations in Tibet.	1998. Domestic market 0.9MW total; supplied by domestic production.
1997-2000. Brightness Program Pilot, based on 4 principles: government leads/user pays, multiple financing channels; reliance on market mechanisms. Village and household off-grid electricity to select villages in Tibet, Inner Mongolia, Qinghai.	1992-97. Yunnan Semiconductor improves/upgrades technology; leads domestic industry with 1.5MW capacity, 0.45MW sales (45% of domestic market). Some exports to SE Asia and developing countries.	1996-2000. >10 solar power stations installed.
		2002. 49 solar power stations installed in Tibet (by Yunnan Semiconductor).
	2003. Qinhuangdao Factory closed. Kaifeng Solar Cell Factory inactive.	Solar PV imports required to meet ~50% of increased domestic demand.
2000-2002. Brightness Program, Stage 1: RMB 40M (US$5M); in Tibet, Inner Mongolia, Gansu.	2004. Yunnan Semiconductor forms JV with Yunnan Provincial Government and China Military Hardware Group.	2003. Turning point in domestic supply/demand: 50MW production, 10MW demand, 80% exported.
2002-2003. Brightness Program, Stage 2: "Electrify the Western Regions"; total funds RMB 4.7B (US$ 570M), 34% for solar and solar/wind hybrid stations; for >700 villages without electricity in 7 provinces.	Ningbo Solar Cell factory restructured; management improved but no major improvement in operating results.	2005. 721 solar and solar/wind hybrid power stations; cumulative capacity of 16MW, >700 villages, 300k households, 13M people.

Compiled from the Chinese PV Industry Development Report (2003, 2004) and company websites.

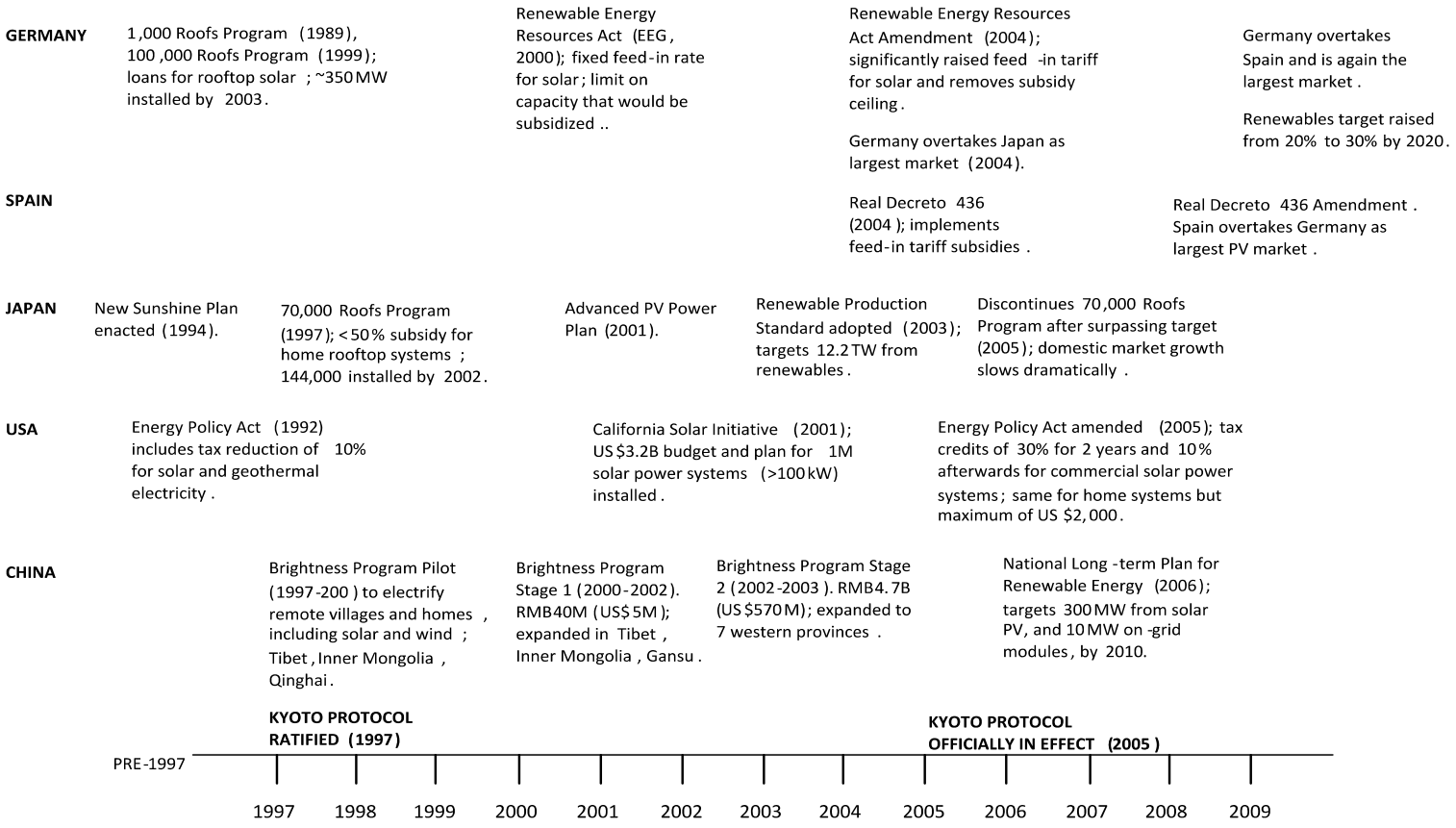
Table S2
Key investments in China's Top 10 solar PV firms

Firm	Date	Investment form	Amount	Investor/Exchange	Nationality
Suntech	2001.1	Equity Financing Equity Financing	$2M $6M	Zhengrong Shi (Founder) Wuxi's Municipal venture capital firm and seven Wuxi-based corporations	China China
	2005.1	Convertible Debt	$8.4M	Million Power Finance	HK
	2005.5	Equity Financing	$80M	Goldman Sachs, DragonTech Ventures, Actis Capital, Prax Capital, Natixis	USA, HK, UK, China, France
	2005.12	IPO	$400M	NYSE	USA
Yingli	1998.8	Equity Financing	$0.6M	Liansheng Miao (founder)	China
	2002.2	Equity Financing	$8.4M	Tianwei Baobian, Zhongxin Liye	China
	2006.11	Preferred stock (A)	$17M	Inspiration Partners	China
	2006.11	Convertible Debt	$85M	Deutsche Bank	Germany
	2007.1	Preferred stock (B)	$118M	Baytree Investments (under Temasek) JP Morgan& 12 other investment banks	Singapore USA
	2007.6	IPO	$391M	NYSE	USA
Trina	2006.5	Equity Financing	$40M	Milestone Capital , Merrill Lynch, Good Energies	USA
	2006.12	IPO	$98M	NYSE	USA
CSI	2002.1	Equity Financing	$0.4M	Individuals	Canada, China
	2005.12	Equity Financing	$7.8M	HSBC Pte Equity (Asia), JAFCO Asia	UK，Hong Kong
	2006.3	Equity Financing	$4M	HSBC Pte Equity (Asia), JAFCO Asia	UK，Hong Kong
	2006.11	IPO	$115M	NASDAQ	USA
LDK	2006.7	Equity Financing	$15M	Natixis, Brilliant Investment Limited, Decatur Overseas Corporation, Boundless Future Investment Limited	Hong Kong, France
	2006.9	Equity Financing	$48M	China Environment Fund 2004, CDH, China Harvest Fund, Natixis, JAFCO Asia, MUS Roosevelt China Pacific Fund	China，Hong Kong，Japan，USA, France
	2006.12	Equity Financing	$22.5M	Natixis, CDH, China Environment Fund 2004, MUS Roosevelt China Pacific Fund	China, Hong Kong, Japan, USA, France
	2007.6	IPO	$469M	NYSE	USA
ReneSola	2006.8	IPO	$50M	AIM of LSE	UK
	2008.1	IPO	$130M	NYSE	USA
JA Solar	2005.5	Equity Financing	$15M	Hebei Jinglong Industrial Group, Australia PV Science & Engineering, Australia Solar Energy Development	China Australia
	2006.8	Equity Financing	$10M $4M	Leeway Asia L.P, Mitsubishi Corporation	Cayman, Japan
	2007.2	IPO	$225M	NASDAQ	USA
Jinko	2008.5	Equity Financing	$24M	Flagship, Everbest International Capital	Singapore
	2008.9	Equity Financing	$35.2M	SCGC, CIVC Investment, or CIVC, Pitango Venture Capital Fund	China Israel
	2010.5	IPO	$100M	NYSE	USA
Solarfun	2006.8	Equity Financing	$53M	Citigroup Venture Capital Int'l Asia,	USA

				Legend Capital, Hony Capital, Good Energies, Individuals	HK, China, Switzerland
	2006.12	IPO	$150M	NASDAQ	USA
Sunergy	2006.1	Equity Financing	$13M	PraxCapital Fund	
	2007.5	IPO	$94M	NASDAQ	USA

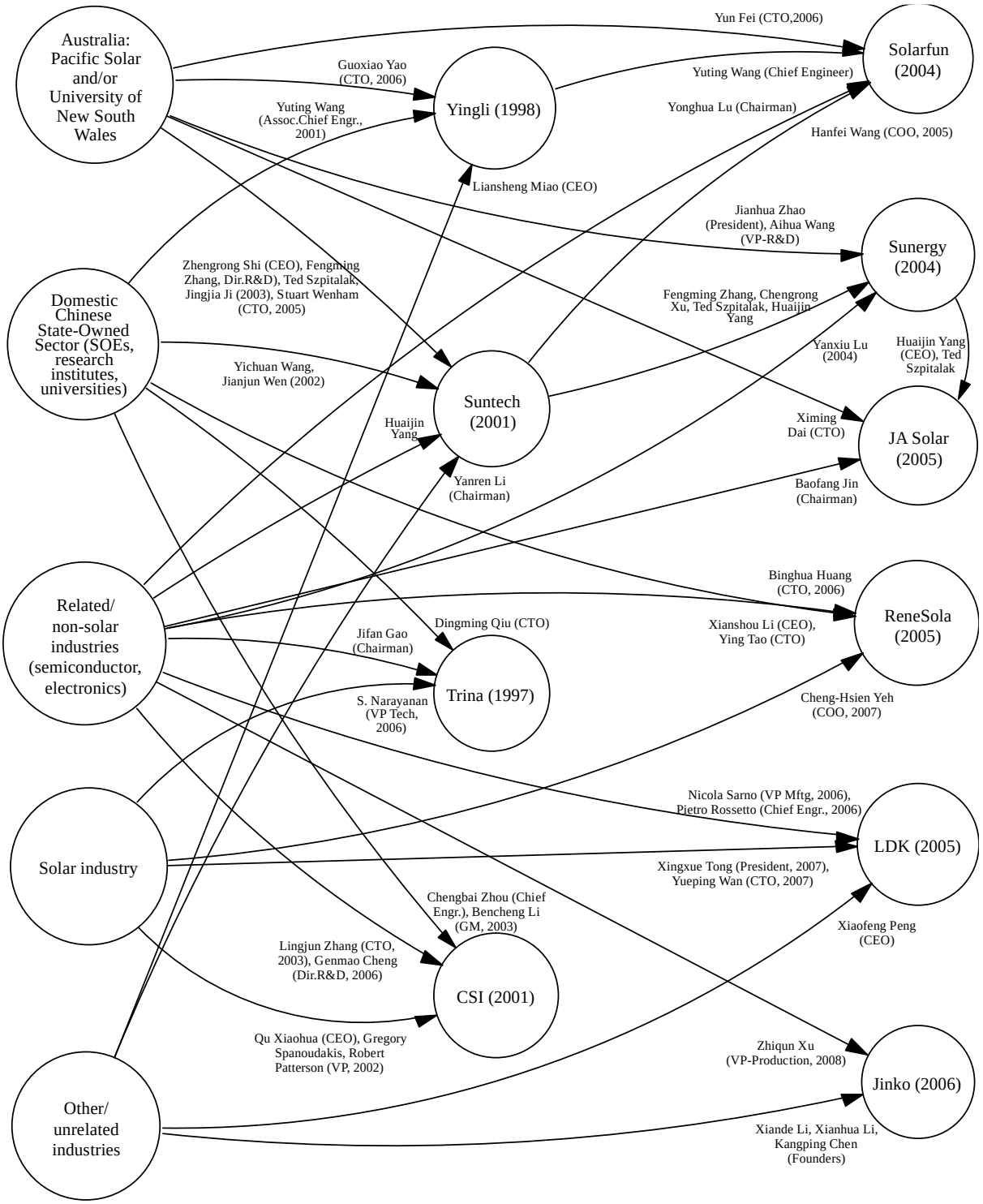
Sources: Compiled from company IPO prospectuses.

Figure S1
Significant policy events in major solar PV countries



Sources: Drawn from Chinese PV Industry Development Reports, 2003-2011; EPIA, 2010; Suntech IPO Prospectus; Suntech Annual Reports 2005-2010; SunPower Annual Reports 2005-2010; Q-cell Annual Reports 2006-2010; SolarWorld AG Annual Reports 2000-2010; Jäger-Waldau, 2006.

Figure S2
Movement of key personnel



Notes: Founding top management team and subsequent top managers and technical directors; joined in year noted, otherwise the founding year.

Sources: Company IPO prospectuses, annual and quarterly reports, and author's interviews.