Can a Fast-Expanding Market Sustain with Supply-Side Government Aid? An Investigation into the Chinese Solar Photovoltaics Industry

By
Pengji Wang
Lin Yuan
Adrian T. H. Kuah

The solar photovoltaics (PV) industry is a policy-driven business, in that political decisions considerably influence potential market takeoff or decline. This is particularly true for China. Between 2006 and 2010, the annual growth rate of solar panel output approached or exceeded 100%, with suppliers receiving financial aid from the government. Despite the prevalence of supply-side aid, its actual impact on the development of this fast-expanding market is debatable. We focus on 249 observations of 75 solar PV companies from 2005 to 2012, and investigate how government aid received in the form of bank loans

Correspondence to: Dr. Adrian Kuah, James Cook University Australia, Singapore Campus, 149 Sims Drive, Singapore 387380, (65) 6709-3718 (phone), (65) 6709-3889 (fax), Adrian.Kuah@jcu.edu.au

Published online in Wiley Online Library (wileyonlinelibrary.com)
 • DOI: 10.1002/tie.21771

and direct subsidies by these companies influenced their performance. Our empirical results show that supply-side government aid in China helps improve scale efficiency to a certain extent, but has a limited impact on technology efficiency. We find that supply-side aid leads to diseconomies of scale in the long run and, thus, to low efficiency and profitability.

Introduction

Fast-expanding markets (FEMs) are markets that expand by more than 15% per annum over a three- to five-year period (Tse, Esposito, & Soufani, 2013). Evolving concerns, trends, and the actual occurrence of an event can raise social awareness to create an FEM. Government actions or media influences can further influence these factors (Tse, Esposito, & Soufani, 2015). FEMs provide significant opportunities for firms to claim lucrative profit and build long-lasting competitive advantages. With great potential to develop new industry clusters, boost economic growth, and offer employment opportunities, an FEM represents a center of excellence for economies and thus is important for countries (Tse et al., 2015). This is particularly the case for countries suffering from a reduction in industrial output or a slowing of economic growth—for example, Japan, the United States, and some European countries, as well as emerging economies such as China, which have experienced such reduction in recent years. Despite its importance, an FEM may grow in either predictable or unpredictable ways, so the application of traditional market and economic theories is often inappropriate (Tse et al., 2015). As a result, the identification and development of FEMs deserves attention from both scholars and policymakers.

The solar photovoltaics (PV) industry is one such FEM that has recently received attention from many national governments. As global energy shortages and environmental pollution become increasingly prominent (Du et al., 2014), solar power generation has received worldwide attention and has become a key emerging industry because it is clean, safe, convenient, and highly efficient. However, awareness of this FEM was limited, and the PV market was only a niche market until the early 2000s. Triggered by government incentives for renewable energy offered by Europe (e.g., Germany, Spain) and the United States, the global solar PV industry has grown rapidly in recent years.

According to the Global Market Outlook for Solar Power 2014–2018 by the European Photovoltaic Industry Association (EPIA, 2014), global PV installation increased by 54% annually from 2000 to 2012 (see Table 1). The 2015 report (for 2015–2019) estimates the global PV installation will grow between 41 gigawatts and 60 gigawatts (EPIA, 2015). The United States, Europe, Japan, and China took on key roles in the manufacturing of PV products. As the global industry expanded, product costs declined. For example, the prices of components dropped from $4.5 per watt in 2000 to $1.7 per watt in 2010 (Puttaswamy & Ali, 2015). Such price declines led to the bankruptcy of several companies. From 2009 to 2014, 112 solar energy companies in the United States and the European Union declared bankruptcy, shuttered operations, or were acquired by competitors under suboptimal conditions (Wesoff, 2014).

When evaluating the dynamics of the solar PV market, government actions play an important role. As the EPIA (2014) highlights, PV remains a policy-driven business, in that political decisions considerably influence potential market takeoff or decline. According to McGinn (2013), at least 138 countries had formulated renewable energy

TABLE 1 Global Annual PV Installation (2000–2012) (Megawatts)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
China	19	5	19	10	10	8	10	20	40	160	500	2,500	3,500
United States	2	3	30	48	61	82	110	166	306	500	1,082	2,181	3,774
Europe	58	133	134	202	705	985	997	2,023	5,708	5,833	13,651	22,259	17,726
Global	293	324	454	566	1,088	1,389	1,547	2,524	6,661	7,340	17,151	30,133	30,011
Global growth rate		11%	40%	25%	92%	28%	11%	63%	164%	10%	134%	76%	0%

Source: EPIA.

targets by the end of 2012. Renewable energy support policies were identified in 127 countries in early 2012, more than two-thirds of which were in developing or emerging economies. As the sector matures, revisions to existing policies have become increasingly common.

The Chinese solar PV industry has attained exponential growth with the Chinese government's active involvement. Confirming the high importance of the solar PV industry to China's industrial transformation and energy conservation, the China State Council (n.d.) has included the industry as a strategic industry for development in the future. From 2006 to 2010, the annual growth rate of the solar panel output in China approached or exceeded 100%, a rate made possible by financial aid from central and local governments to suppliers. Such supply-side aid takes the form of free or low-cost loans; artificially cheap raw materials, components, energy, and land; and support for research and development (R&D) and technology acquisitions (Haley & Haley, 2013). Despite the prevalence of supply-side aid, the actual impact of such government support on industry development is most debatable.

In this study, we focus on 75 solar PV companies listed on the Chinese stock market between 2006 and 2012 and investigate how the financial aid received by these firms in the form of bank loans and direct subsidies influenced their performance. The empirical results suggest that supply-side financial aid can help improve scale efficiency to some extent but may not help with technology efficiency. In the long run, too much supply-side financial aid leads to diseconomies of scale and, thus, to low efficiency and profitability.

The Importance of Government Policy

During the past decade, institutional economists, most notably North (1990), argued that institutions, or "the rules of the game," prescribe the taken-for-granted assumptions, beliefs, and values underlying organizational characteristics and practices (DiMaggio & Powell, 1983; Zucker, 1977). Management scholars have widely accepted that institutional environments shape firm behaviors and strategies and, thus, performance (Oliver, 1992; Wan & Hoskisson, 2003). Indeed, prior research has emphasized the important role of government policy in promoting innovation, shaping managerial incentives, affecting transaction and agency costs, and making selective resource allocations across and within industries (e.g., Iyer, LaPlaca, & Sharma, 2006; Park, Li, & Tse, 2006; Sheng, Zhou, & Lessassy, 2013). Given that firms in developing countries such as China are typically under the control of different levels of governmental jurisdiction (Park et al., 2006), government policy plays an important role in shaping firms' investment decisions and performance in developing countries (Cull & Xu, 2005; Prabowo & Soegiono, 2010).

Government policies can be divided into supply-side policies, which are instruments providing additional inputs for firms' production, and demand-side policies, which are instruments influencing firm outputs (Aschhoff & Sofka, 2009). The former is associated with the public provision of resources, both tangible (e.g., funding) and intangible (e.g., scientific knowledge) in nature, while the latter influences markets for products or services (e.g., public procurement, mandatory standards) (Aschhoff & Sofka, 2009; Edler & Georghiou, 2007). Both types of policy instruments have the potential to promote firm performance and industry growth (Zhi, Sun, Li, Xu, & Su, 2014).

Doris and Krasko (2012) conclude that approximately 70% of the variation in newly installed PV capacity comes from policy differences. The solar energy demand-side policy covers a wide range of instruments, including demonstration projects, feed-in tariffs, net metering, green tags, renewable energy portfolios, public investment, tax preferences, government mandates, and regulatory provision (Sovacool & Gilbert, 2013; Sun, Zhi, Wang, Yao, & Su, 2014; Timilsina, Kurdgelashvili, & Narbel, 2012). The main goal of these policy instruments is to foster greater solar energy use. With the majority of the policy tools used in solar industry being on the demand side, several studies have examined the effectiveness of such demand-side policy tools. For example, Burr (2012) provides evidence that demand-side incentives (up-front subsidies, tax credits, and production revenues) helped the solar installations in California, and Hughes and Podolefsky (2013) show that demand-side policy (up-front rebates in California's solar initiative) had a large effect on residential solar installations.

By contrast, supply-side policies are less diversified and have received little attention in the literature (Taylor, 2008). These policies support the creation of firms in the solar supply chain, especially manufacturers. Such policies take the form of R&D and demonstration grants, low-cost loans for manufacturing, tax concessions, subsidies, financial support, and subsidized support infrastructure. However, empirical research investigating the effectiveness of supply-side policies is limited and inconclusive. For example, Deshmukh, Bharvirkar, Gambhir, and Phadke (2012) argue that R&D investment could promote the learning process and reduce the cost of solar. Using dummy variables to code the demand- and supply-side policies in the United States, Poneman (2015) finds that demand-side policies were more effective than supply-side policies in increasing the PV production as a percentage of total electricity production between 2000 and 2014. However, during the 2007–2014 period, supply-side policies were found to be more effective.

Supply-Side Government Aid in China

The Chinese government has embraced the solar PV industry by providing supply-side aid. In the initial investment stage before 2004, growth was slow as a result of limited domestic demand and a small world market. Chinese products were also of too low quality to compete in the markets effectively (Dunford, Liu, Liu, & Yeung, 2013). The Chinese government's intervention in the solar PV industry increased in 2004, when the German government began creating solar projects in Germany (Bloomberg, 2013). At the time, the Chinese government indicated strong support for the solar PV industry, which it considered a strategic sector for the country. To speed up industry growth, China adopted various supply-side policies to help firms build up their production capacities. Such supply-side government aid, at both central and local levels, provided solar PV manufacturers along the industry chain with free or low-cost loans, tax rebates, research grants, cheap land, energy subsidies, and technological, infrastructure, and personnel support (Chen, 2015).

The Central Chinese Government brought attention to solar energy and other renewable energy in the Tenth Five-Year Plan (2001–2005) (People's Daily, 2001, March 15). It stated that China would "actively develop new energy and renewable energy such as wind, solar, and geothermal power and promote energy saving and comprehensive utilization of technologies." In 2006, the Ministry of Finance issued "interim measures" and dictated that special funds would be allocated in the form of grants and soft loans to support R&D, promulgation of standards, demonstration projects, and promotion of "localized production of equipment for the development and utilization of renewable energy," with special emphasis on wind, solar, and tidal power (Howell, Noellert, Hume, & Wolff, 2010). In March 2008, the National Development and Reform Commission released the Eleventh Five-Year Plan for Renewable Energy (2006–2010). Government agencies put aside a special fund for renewable energy development and utilization, for example, by arranging financial funding and supporting the localization of renewable energy equipment (Howell et al., 2010, p. 33).

The local Chinese government also offered assistance to large companies. Such assistance included providing local government loan guarantees to secure bank loans and further state-owned enterprise investments. Large companies under local government jurisdictions are important because they are the main contributors to local tax revenues and economic growth (Arrighi, 2007). Consider, for example, Suntech Power Holdings Co. Ltd., once China's largest PV manufacturer. Despite objections from most senior executive officers and major stockholders (due to their concerns about the uncertainty in PV markets and slim profit margins), the CEO of Suntech, Mr. Zengrong Shi, convinced the Wuxi City government and local state-owned companies to invest in the firm, thus enabling Suntech to expand production capacity from a 20- to a 30-megawatt peak (MWp) in 2003 (Dunford et al., 2013).

One of the most common supply-side government aids comes from state-owned banks, which issue free or low-cost loans to solar PV firms. For example, between 2005 and 2012, the local bank loans given to Suntech Power Holdings jumped from US$56 million to US$3.7 billion. This was largely due to a municipal government's mandate on local state-owned banks to provide low-interest loans to Suntech. According to Mercom Capital Group (2011), banks loaned US$40 billion to 10 domestic manufacturers, including Suntech, LDK Solar, and Yingli Green Energy from January 2010 to September 2011 (see Table 2).

TABLE 2 Loans and Credit Agreement Involving Banks to Solar Companies in China

Company	Amount (US$ milllion)	Bank
China Synergy	160	China Development Bank
Daqo New Energy	154	Bank of China
Hanwa SolarOne	1,000	Bank of China
Hanwa SolarOne	885	Bank of Shanghai
JA Solar	4,400	China Development Bank
Jinko Solar	7,600	Bank of China
LDK Solar	8,900	China Development Bank
Suntech	7,330	China Development Bank
Trina Solar	4,400	China Development Bank
Yingli Green Energy	179	China Citic Bank, Bank of China
Yingli Green Energy	5,300	China Development Bank
Yingli Green Energy	144	Bank of Communications
Yingli Green Energy	257	Bank of Communications
Total	40,709	

Source: Mercom Capital Group (as of September 2011).

Another important form of supply-side government aid is direct subsidy, which comes under the forms of R&D subsidy, a special fund for renewable energy development, subsidy funds for utilizing stalk energy, Golden Sun Demonstration Project, a special fund for construction with renewable energy, a subsidy for a PV-building application demonstration project, biomass energy fiscal tax support policy, a subsidy for Green Energy Demonstration County, and so on (Shi, 2012). For example, the government of Yunnan Province issued a measure establishing a special fund and allocated its budget for renewable energy development in 2007. In 2009, three Chinese ministries jointly announced the Golden Sun Demonstration Program, which provided investment subsidies equal to 50% of the investment cost for grid-connected solar power systems (Howell, et al., 2010).

With supply-side government aid, solar PV manufacturers in China could operate and sell their products at lower price than foreign competitors. For example, it is estimated that the cost of setting up a 25-MWp production line with mixed local and foreign equipment is about half the costs of foreign companies (Dunford et al., 2013). With lower operation costs aided by the government, the PV industry experienced a dramatic expansion in China. According to the China Renewable Energy Society in Beijing, China's backing of the solar PV industry has left at least one factory producing PV products in half the country's 600 cities (Bloomberg, 2013). From 2004 to 2012, the average annual growth rate of China's solar cell production exceeded 100% in some instances (Table 3).

While China experienced expansion in its solar PV production capacity, some problems emerged. One challenge was the industry's heavy reliance on the world market rather than the domestic market. As Table 4 shows, China's share of PV installation was much smaller than global installation before 2010 (Zhang, Zhao, Andrews-Speed, & He, 2013). The overreliance on the world market was aggravated when the global PV market shrank following the European debt crisis in July 2011. Moreover, many European and U.S. solar enterprises, such as Solyndra, Spectra Watt, and Evergreen Solar, went into bankruptcy, attributing their collapse to the excessively fierce competition, especially from their Chinese counterparts. In response, the United States and the European Union launched an "anti-dumping and anti-bribery investigation" in China, focusing on its PV industry policies (Zhi, et al., 2014).

As a result, Chinese PV firms received fewer orders than expected, and most companies were forced to significantly reduce or even stop production. The excess supply caused prices to tumble. By 2011, wafer prices had dropped by approximately 70%, solar cells by 60%, and module prices by half (Solar Cell Central, n.d.). The low price drove 300 solar PV firms in China out of business from 2011 to 2012. Even the major players, such as LDK, Suntech, and Yingli, went into or near bankruptcy because the reduced profit margins due to the price collapse made it impossible to manage the high debt loads (Jordan, 2013).

TABLE 3 Solar Cell Production and Installation in China

Year	Solar Cell Production (MWp)	Domestic Solar Cell Installation (MWp)	Ratio of Installation to Production (%)	Growth Rate of Solar Cell Production (%)
2004	50	10	20	—
2005	200	8	4	300
2006	400	10	2.5	100
2007	1,088	20	1.8	172
2008	2,600	40	1.5	138.97
2009	4,000	144	3.6	53.85
2010	8,000	579	7.2	100
2011	13,000	2,048	15.8	62.5
2012	23,000	8,000	34.8	76.92

Source: Renewable Energy Research Institute, Hehai University (2013).

TABLE 4 Annual PV Installation Worldwide and in China, 2006–2010 (Megawatts)

	2006	2007	2008	2009	2010
World total	1,603	2,932	5,950	7,380	16,000
China	10	20	40	160	400
China as % of world total	0.6%	0.7%	0.7%	2.2%	2.5%

Source: National Development and Reform Commission, Semiconductor Equipment and Materials International (SEMI).

Although the Chinese government hoped to use supply-side aid to bail out underperforming solar PV manufacturers, the effectiveness of this aid was debatable. In the next section, we examine the impact of supply-side government aid on solar PV firms' performance using the sample of listed solar PV firms in China to evaluate the effectiveness of the policies.

Methodology

Sample

We examined 75 listed firms involved in the solar energy industry from 2005 to 2012. The data on performance, firm age, size, and ownership structure came from China

Stock Market & Accounting Research. Subsidy data came from SinoFin Information Technology Co. Ltd. As some of the listed firms entered our observation windows later than others (e.g., some firms refocused their business into solar PV), we had 249 observations in the 2005–2012 period.

Measures

First, we adopted several performance measures, including profitability (return on assets [ROA]), market performance (market-to-book value), and efficiency (pure technical efficiency and scale efficiency are based on data envelope analysis [DEA]; the Appendix explains the calculation of efficiency). Second, we focused on two main types of aid: low-cost loans and direct subsidy received by the listed firms. With regard to debt finance, there is no substantial corporate bond market in China. Debt financing mainly comes from state-owned bank loans, except for temporary financing from enterprise arrears or trade credits (Tian & Estrin, 2007). We used the total debt to proxy the low-cost loans obtained by the firms. Because direct subsidy may have a time-lag effect on firms, we examined the long-term effect of the subsidy measured by the accumulative three years' subsidy. We used the natural logarithmic function of the total debt and subsidy. Finally, we controlled for other variables that may influence performance, including firm age, state ownership, size, and past-year performance.

Statistical Approach

We used a fixed-effects model for the imbalanced panel data. The results of Hausman tests confirmed that a fixed-effects model would be appropriate, given the statistically significant differences in coefficients between the fixed- and random-effects models.

Results

Descriptive Statistics

From 2004 to 2012, there were 26 (firm-year) observations that did not receive any subsidy. As Figure 1 shows, the average annual subsidy that the solar PV firms received increased over the years. Similarly, the total debt these firms incurred also increased over the years, as Figure 2 shows.

Regarding the performance of the solar PV firms (see Table 5), we find that both size and output increased over the years (except in 2010) but profitability decreased. To explore the reasons for lower-than-expected profitability, we further examined firms' efficiency. We find that scale efficiency and pure technical efficiency improved only from 2005 to 2008, after which it remained static.

FIGURE 1 Annual Subsidy (RMB million) Received by Solar Firms (2005–2012)

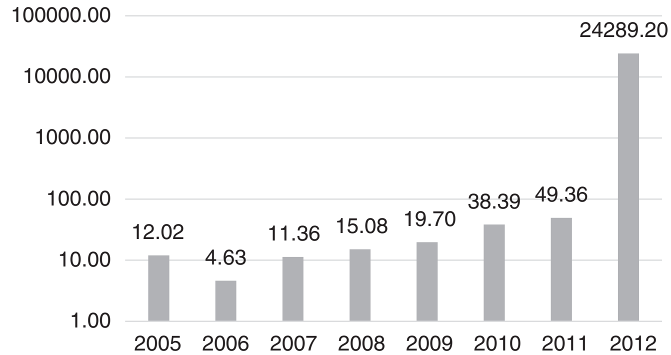
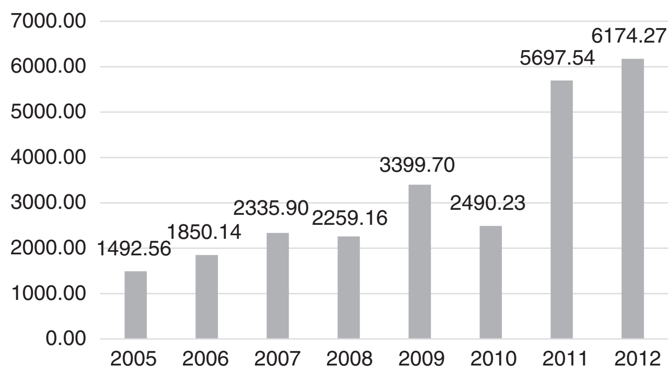


FIGURE 2 Total Debt (RMB million) of Solar Firms (2005–2012)



We further examined the reasons for the plateau of the scale efficiency among the listed solar PV firms. Of the 75 firms, 35 suffered from perpetual decreasing economies of scale within our observational time frame. Figure 3 shows that as time went by, increasingly more solar firms experienced decreasing returns to scale.

Regression Analysis

We examine the effect of subsidy and total debt on return on assets (ROA) in Table 6. In Model 1, we enter the control variables into the regression. In Model 2, we include in the main effect of subsidy and its squared term. In Model 3, we add the main effect of total debt. Finally, in Model 4, we add both subsidy and total debt.

Model 2 shows that the main effect of subsidy was significantly positive, while the squared term of subsidy was significantly negative. Thus, subsidy had an inverted U-shaped relationship to ROA. These results suggest that subsidy helps improve profitability to a certain extent while too much subsidy reduces profitability. Model 3

TABLE 5 Performance of Listed Solar Firms over the Years (2005–2012)

Year	2005	2006	2007	2008	2009	2010	2011	2012
Sales (RMB million)	1444.59	2207.64	2765.74	2845.00	3622.69	3098.57	4730.37	4530.63
Total asset (RMB million)	2601.51	3641.71	4714.58	4064.49	5953.70	4612.42	9289.34	9962.72
Return on assets	2.95%	2.70%	1.88%	1.07%	2.99%	3.19%	2.58%	–0.39%
Market to book value	2.05	2.61	6.07	2.86	4.00	7.62	2.25	2.52
Scale efficiency	97.62%	97.58%	97.89%	98.07%	97.85%	97.89%	97.39%	97.75%
Pure technical efficiency	88.39%	89.42%	90.13%	90.27%	89.49%	90.66%	89.92%	89.07%

FIGURE 3 Ratio of Firms with Decreasing Returns to Scale

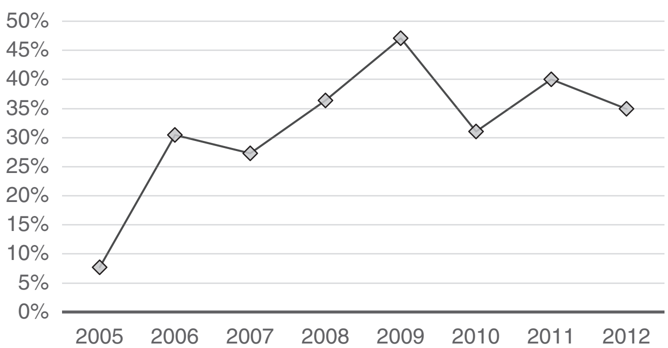


TABLE 6 Effect of Subsidy and Bank Loans on ROA (N = 249)

	Model 1	Model 2	Model 3	Model 4
Subsidy		0.052** (0.017)		0.051** (0.017)
Subsidy squared		–0.046* (0.018)		–0.046* (0.018)
Total debt			–0.174+ (0.105)	–0.145 (0.103)
Age	–0.011** (0.003)	–0.013** (0.004)	–0.012*** (0.003)	–0.013** (0.004)
State ownership	–0.044 (0.034)	–0.039 (0.034)	–0.051 (0.034)	–0.044 (0.034)
Liability	–0.263*** (0.051)	–0.261*** (0.049)	0.047 (0.194)	–0.002 (0.191)
Size	0.035* (0.015)	0.049** (0.016)	0.214+ (0.109)	0.198+ (0.107)
ROA in year $t-1$	–0.309** (0.095)	–0.271** (0.094)	–0.327** (0.095)	–0.287** (0.094)
Constant	–0.446 (0.314)	–0.733* (0.322)	–0.826* (0.387)	–1.045** (0.39)
R^2: within	0.24	0.11	0.03	0.10
Between	0.07	0.003	0.002	0.02
Overall	0.001	0.001	0.001	0.01
F	10.61*** (5,169)	4.35*** (7,167)	0.87 (6,168)	3.58** (8,166)

***Significant at 0.001 level; **significant at 0.01 level; *significant at 0.05 level; +significant at 0.1 level; all two-tailed tests.

shows that total debt was significantly negative at the marginal level, suggesting that more loans actually hurt firm profitability.

To probe why the subsidy and bank loans hurt profitability, we further examined their impact on firms' pure technical efficiency in Table 7. Model 5 includes only the control variables, while Model 6 includes the main effect of subsidy and its squared term. Model 7 tests the main effect of total debt and its squared term, and in Model 8, we test both subsidy and total debt.

In Model 8, neither the main effect nor the squared term of subsidy shows any level of significance. These results suggest that though the government provides subsidies to encourage solar firms' R&D activities, firms may not use them to boost R&D capability. However, the main effect of total debt was negatively significant, while the squared term of total debt was positively significant. These results suggest that small, low-cost loans are not sufficient to support any substantial R&D activity. Such loans may only firms allow to alleviate market uncertainty, while lessening their incentives to invest in R&D. However, sizable low-cost loans encourage firms to invest in R&D and, thus, to improve their pure technical efficiency.

Table 8 examines the impact of the subsidy and bank loans on firms' scale efficiency. Model 9 includes only the control variables. We add the main effect of subsidy and its squared term in Model 10, and in Model 11 we include the main effect of total debt and its squared term. We test the full model containing both the subsidy and total debt in Model 12.

TABLE 7 Effect of Subsidy and Bank Loans on Pure Technical Efficiency (*N* = 249)

	Model 5	Model 6	Model 7	Model 8
Subsidy		0.005 (0.006)		0.007 (0.006)
Subsidy squared		–0.007 (0.006)		–0.009 (0.006)
Total debt			–0.226* (0.096)	–0.252* (0.098)
Total debt squared			0.004+ (0.002)	0.005* (0.002)
Age	0.003** (0.001)	0.004** (0.001)	0.003* (0.001)	0.003* (0.001)
State ownership	0.03* (0.012)	0.031** (0.012)	0.028* (0.012)	0.03* (0.012)
Liability	–0.023 (0.017)	–0.023 (0.017)	0.083 (0.066)	0.083 (0.066)
Size	–0.012* (0.005)	–0.01+ (0.005)	0.045 (0.037)	0.046 (0.037)
ROA in year *t* – 1	0.054+ (0.032)	0.059+ (0.033)	0.04 (0.032)	0.047 (0.033)
Constant	1.12*** (0.107)	1.085*** (0.113)	2.828** (1.019)	3.071** (1.042)
R^2: within	0.096	0.103	0.130	0.142
Between	0.023	0.020	0.052	0.053
Overall	0.006	0.004	0.032	0.028
F	3.58** (5,169)	2.73* (7,167)	3.56** (7,167)	3.03** (9,165)

***Significant at 0.001 level; **significant at 0.01 level; *significant at 0.05 level; +significant at 0.1 level; all two-tailed tests.

TABLE 8 Effect of Subsidy and Bank Loans on Scale Efficiency (*N* = 249)

	Model 9	Model 10	Model 11	Model 12
Subsidy		0.012** (0.004)		0.004 (0.003)
Subsidy squared		–0.008+ (0.004)		–0.001 (0.004)
Total debt			0.538*** (0.056)	0.531*** (0.056)
Total debt squared			–0.013*** (0.001)	–0.013*** (0.001)
Age	0 (0.001)	–0.001 (0.001)	0 (0.001)	–0.001 (0.001)
State ownership	0.01 (0.009)	0.011 (0.008)	0.007 (0.007)	0.006 (0.007)
Liability	0.013 (0.013)	0.013 (0.012)	0.047 (0.038)	0.033 (0.038)
Size	0.001 (0.004)	0.005 (0.004)	0.034 (0.022)	0.027 (0.021)
ROA in year *t* – 1	–0.034 (0.024)	–0.027 (0.023)	–0.012 (0.019)	–0.012 (0.019)
Constant	0.944*** (0.079)	0.887*** (0.081)	–5.243*** (0.595)	–5.073*** (0.597)
R^2: within	0.025	0.096	0.411	0.441
Between	0.002	0.010	0.452	0.436
Overall	0.001	0.002	0.430	0. 428
F	0.87 (5,169)	2.53* (7,167)	16.67*** (7,167)	14.47*** (9,165)

***Significant at 0.001 level; **significant at 0.01 level; *significant at 0.05 level; +significant at 0.1 level; all two-tailed tests.

Model 10 shows that the main effect of subsidy was positively significant while the squared term of subsidy was negatively significant. Model 11 shows that the main effect of total debt was positively significant while the squared term of total debt was negatively significant. These results suggest that both the subsidy and bank loans had an inverted U-shaped effect on scale efficiency, implying that supply-side government aid does help firms' scale efficiency initially. However, too much subsidy may lead to diseconomies of scale.

To verify which firms benefited the most from supply-side government aid to improve their scale efficiency, we include the interaction between the status of economy of scale in the previous year and government aid and the interaction between firm size and government aid. Tables 9 and 10, respectively, report the results.

Model 14 shows that the interaction between subsidy and increasing economies of scale is positively significant while the main effect of subsidy is not significant. The interaction between total debt and increasing economies of scale is also positively significant, while the main effect of total debt is negatively significant at the marginal level. These results suggest that subsidy and bank loans help improve scale efficiency only when the solar firms are still in the stage of increasing returns to scale. By contrast, subsidy and bank loans do not help with scale efficiency (subsidy) and can even hurt scale efficiency (loans) when the firms have constant or decreasing economies of scale.

We obtain similar conclusions from Table 10. Model 16 shows that the interaction between subsidy and firm size is negatively significant and the main effect of subsidy is positively significant; the interaction between bank loans and firm size is negatively significant, while the main effect of bank loans is positively significant. These results suggest that subsidy and bank loans help scale efficiency more for smaller firms than larger firms.

TABLE 9 Firms that Benefited in Scale Efficiency from Government Aid: Moderation Effect on Economy of Scale

	Model 13	Model 14
Subsidy × increasing returns to scale		0.011*** (0.003)
Total debt × increasing returns to scale		0.039*** (0.004)
Increasing returns to scale	0.002 (0.004)	−0.838*** (0.095)
Subsidy	0.006** (0.002)	−0.004 (0.003)
Total debt	0.007 (0.028)	−0.041+ (0.022)
Age	−0.002 (0.001)	−0.001 (0.001)
State ownership	0.009 (0.009)	0.018* (0.007)
Liability	0.001 (0.051)	0.012 (0.039)
Size	−0.004 (0.029)	0.02 (0.022)
ROA in year *t*	−0.036 (0.025)	−0.007 (0.019)
Constant	0.944*** (0.102)	1.442*** (0.096)
R^2: within	0.083	0.488
Between	0.001	0.340
Overall	0.006	0.406
F	1.75+	14.48***

***Significant at 0.001 level; **significant at 0.01 level; *significant at 0.05 level; +significant at 0.1 level; all two-tailed tests.

TABLE 10 Firms that Benefited in Scale and Technical Efficiencies from Government Aid: Moderation Effect on Firm Size

	Scale Efficiency		Pure Technical Efficiency	
	Model 15	Model 16	Model 17	Model 18
Subsidy × size *t* − 1		−0.004** (0.001)		−0.001 (0.002)
Total debt × size *t* − 1		−0.011*** (0.001)		0.005+ (0.003)
Size *t* − 1	−0.004 (0.005)	0.235*** (0.031)	−0.016* (0.006)	−0.124* (0.057)
Subsidy	0.005** (0.002)	0.097** (0.028)	−0.001 (0.002)	0.012 (0.051)
Total debt	0.006 (0.005)	0.236*** (0.032)	−0.002 (0.007)	−0.11+ (0.058)
Age	−0.002 (0.001)	−0.001 (0.001)	0.004** (0.001)	0.004** (0.001)
State ownership	0.01 (0.008)	0.002 (0.006)	0.031** (0.012)	0.033** (0.012)
Liability	0.005 (0.014)	−0.01 (0.011)	−0.012 (0.019)	−0.008 (0.019)
ROA in year *t* − 1	−0.03 (0.024)	−0.02 (0.018)	0.065* (0.032)	0.061+ (0.032)
Constant	0.968*** (0.076)	−4.167*** (0.682)	1.226*** (0.104)	3.577** (1.23)
R^2: within	0.082	0.486	0.134	0.156
Between	0.001	0.519	0.041	0.119
Overall	0.007	0.512	0.011	0.050
F	2.15*	17.32***	3.68**	3.4***

***Significant at 0.001 level; **significant at 0.01 level; *significant at 0.05 level; +significant at 0.1 level; all two-tailed tests.

Finally, we investigate which firms benefited in technical efficiency with supply-side government aid in Models 17 and 18, by including the interactive effect of government aid and firm size on pure technical efficiency. The results in Model 18 show that the interaction between bank loans and firm size is positively significant while the main effect of bank loans is negatively significant. Neither the main effect of subsidy nor the interaction between subsidy and firm size is significant. These results suggest that only large firms benefited in their pure technical efficiency from more bank loans. The findings are quite reasonable given that R&D requires significant investments, which can only be undertaken by large firms. Direct subsidy that is too small does not help firms' R&D activities. Sizable loans seem to be more effective in supporting the large investment in R&D. These results further confirm our previous findings in Table 7.

Discussion and Conclusion

FEM

The importance and effectiveness of supply-side policies in the Chinese solar PV industry have been widely discussed (e.g., Zhang & He, 2013; Zhang et al., 2013; Zhi et al., 2014), but limited empirical evidence exists on the effect of supply-side policies. Our empirical study employed two key policy instruments used in the Chinese solar PV industry: government subsidy and low-interest bank loans. We found that both were ineffective in promoting firm performance. Although government subsidies improved firm profitability at a low level, firm profitability decreased profitability at higher levels. Bank loans hurt firm profitability rather than facilitated its increase. Only sizable bank loans improved the technical efficiency of solar firms. However, high levels of either government subsidy or bank loans hurt scale efficiency.

From the perspective of policymakers, our findings confirm the effectiveness of supply-side government policies in building up production capacity and driving down costs during the emergence stage of an FEM, particularly when firms are infant and operating below optimal scale. However, as the FEM matures and firms are established, overemphasizing supply-side policies does not help firms improve their profitability and efficiency. This might be because supply-side government support tends to bail out poor performers, in turn allowing them to be less responsive to market changes. For example, although Suntech experienced weak sales and was on the brink of bankruptcy in 2012, the Wuxi municipal government still gave directives to the local subsidiary of Bank of China to disregard the risk of default and grant emergency loans of RMB 200 million to the company. When incumbents' poor performance is buttressed by the injection of government aid, entrepreneurs will be misled by the overall market performance. For example, from 2011 to 2012, although 300 solar PV firms went out of business, 100 new firms were still being created. Thus, too much supply-side government aid may lead to misallocation of resources in the economy.

Practical Implications

In light of our findings, we argue that as an FEM matures, a policy mix comprising both supply-side and demand-side assistance would be most feasible. Demand-side support helps absorb excessive supply and drives firms to improve their pure technical efficiency and to direct their supply according to demand. Thus, our study provides a good rationale for China's move to offer more demand-side government initiatives since 2006 (Zhi et al., 2014).

Another implication to policymakers stemming from our results is that larger PV firms benefit more from supply-side government aid than small firms in terms of pure technical efficiency. Sizable bank loans are effective in helping firms' pure technical efficiency, while small direct subsidies are not. This result can be attributed to the large investment needed for and the high risks associated with R&D. Therefore, the size of supply-side government aid is critical if the government wants to improve firms' technology competence.

Our findings should also alarm business practitioners who are keen on investing in and managing FEM businesses. When an FEM is noticed by society and embraced through government actions, unarguably firms can benefit from supply-side government aid. However, it is dangerous if firms are blinded by such aid, losing sight of the potential market risks and becoming unadaptable in developing differentiation and diversification strategies. In the case of the Chinese solar PV industry, although Chinese firms have been able to dramatically increase their production capacity with the aid of central and local governments, overreliance on these supply-side policies has had negative effects on their profitability and efficiency. Instead of relying on government support to produce and sell similar products targeted to the global market, managers should fully utilize the government support to boost internal resources and capabilities to prepare themselves for the mature stage in FEMs, which calls for diversification.

Pengji Wang is senior lecturer at James Cook University Australia, Singapore Campus. She obtained her PhD from the National University of Singapore, and her research interests include corporate governance, strategy, and performance of firms from emerging economies. She has published in journals such as *Corporate Governance: An International Review, Journal of Business Ethics,* and *Singapore Management Review.*

Lin Yuan is assistant professor in management at the University of Macau. She received her PhD degree from the National University of Singapore. Her research interests include internationalization and financing strategies of emerging-market multinational corporations and entrepreneurial firms, innovation strategy, and business ethics. She has published in journals such as *Industrial Marketing Management, International Marketing Review,* and *Multinational Business Review.*

Adrian T. H. Kuah is Associate Professor of Business at James Cook University Australia, Singapore Campus. Previously, he was a faculty member and the MBA Director at Nottingham Business School and director of UG Business Studies at Bradford University. He received his PhD degree from the Manchester Business School, and his research focuses on services and national competitiveness. His work has appeared in the *European Journal of Marketing, European Business Review, R&D Management,* and *Singapore Management Review.*

References

Arrighi, G. (2007). Adam Smith in Beijing. London, England: Verso.

Aschhoff, B., & Sofka, W. (2009). Innovation on demand—Can public procurement drive market success of innovations? Research Policy, 38, 1235–1247.

Bloomberg (2013, September 9). Chinese zombies emerging after years of solar subsidies. Bloomberg. Retrieved from http://www.bloomberg.com/news/articles/2013-09-08/chinese-zombies-emerging-after-years-of-solar-subsidies

Burr, C. (2012). Subsidies, tariffs and investment in the solar power market. Retrieved August 1, 2015, from http://econ.arizona.edu/docs/JobMarket/burr_jobmarket12.pdf

Chen, G. (2015). From mercantile strategy to domestic demand stimulation: Changes in China's solar PV subsidies. Asia Pacific Business Review, 21(1), 96–112.

China State Council (n.d.). 12th Five-Year Plan for the Solar Photovoltaic in China. Retrieved from http://www.americansolarmanufacturing.org/news-releases/chinas-five-year-plan-for-solar-translation.pdf

Coelli, T. J. (1996). A guide to DEAP version 2.1: A data envelopment analysis (computer) program. Retrieved from http://www.owlnet.rice.edu/~econ380/DEAP.PDF

Cull, R., & Xu, L. C. (2005). Institutions, ownership, and finance: The determinants of profit reinvestment among Chinese firms. Journal of Financial Economics, 77(1), 117–146.

Deshmukh, R., Bharvirkar, R., Gambhir, A., & Phadke, A. (2012). Changing sunshine: Analysing the dynamics of solar electricity policies in the global context. Renew Sustain Energy Review, 16, 5188–5198.

DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. American Sociological Review, 48(2), 147–160.

Doris, E., & Krasko, V. A. (2012). Strategic sequencing for state distributed PV policies: A quantitative analysis of policy impacts and interactions. NREL/TP-7A30-56428. Golden, CO: National Renewable Energy Laboratory. Retrieved from http://www.nrel.gov/docs/fy13osti/56428.pdf

Du, X., Zhang, Y., Dai, Z., Liu, H., Wei, S., & Li, J. (2014). Power distribution strategy considering active power loss for DFIGs wind farm. Journal of Power and Energy Engineering, 2, 213–219.

Dunford, M., Lee, K.H., Liu, W, & Yeung, G. (2013). Geographical interdependence, international trade and economic dynamics: The Chinese and German solar energy industries. European Urban and Regional Studies, 20(1), 14–36. doi:10.1177/0969776412448093

Edler, J., & Georghiou, L. (2007). Public procurement and innovation—Resurrecting the demand side. Research Policy, 36, 949–963.

European Photovoltaic Industry Association (EPIA). (2014). Global market outlook for solar power 2014–2018. Brussels, Belgium: Author.

European Photovoltaic Industry Association (EPIA). (2015). Global market outlook for solar power 2015–2019. Brussels, Belgium: Author.

Haley, U. C. V., & Haley, G. T. (2013). How Chinese subsidies changed the world. Harvard Business Review Blog. Retrieved from https://hbr.org/2013/04/how-chinese-subsidies-changed

Howell, T. R., Noellert, W. A., Hume, G., & Wolff, A. W. (2010). China's promotion of the renewable electric power equipment industry. Dewey & LeBoeuf LLP. Retrieved from http://www.nftc.org/default/Press%20Release/2010/China%20Renewable%20Energy.pdf

Hughes, J. E., & Podolefsky, M., (2013). Getting green with solar subsidies: Evidence from the California solar initiative. Retrieved from http://spot.colorado.edu/~jonathug/Jonathan_E._Hughes/Main_files/PV_Subsidies.pdf

Iyer, G. R., LaPlaca, P. J., & Sharma, A. (2006). Innovation and new product introductions in emerging markets: Strategic recommendations for the Indian market. Industrial Marketing Management, 35, 373–382.

Jordan, P.G. (2013). Solar energy markets: An analysis of the global solar industry. London, England: Academic Press.

Mercom Capital Group. (2011). Loans and credit agreements involving Chinese banks to Chinese solar companies since Jan 2010. Retrieved from http://mercomcapital.com/loans-and-credit-agreements-involving-chinese-banks-to-chinese-solar-companies-since-jan-2010

McGinn, D. (2013). Renewables 2013 Global Status Report. Retrieved from http://www.ren21.net/Portals/0/documents/Resources/GSR/2013/GSR2013_lowres.pdf

North, D. C. (1990). Institutions, institutional change, and economic performance. Cambridge, England: Cambridge University Press.

Oliver, C. (1992). The antecedents of deinstitutionalization. Organization Studies, 13(4), 563–588.

Park, S. H., Li, S., & Tse, D. K. (2006). Market liberalization and firm performance during China's economic transition. Journal of International Business Studies, 37(1), 127–147.

People's Daily (http://www.people.com.cn/). (2001, March 15). China's Tenth Five-Year Plan for National Economic and Social Development (2001–2005), Chapter 7, Retrieved from http://www.people.com.cn/GB/historic/0315/5920.html

Poneman, M. (2015). Sunny side up? Analysing the effectiveness of policy support for solar energy on a state level. Retrieved from http://dacc.coalliance.org/fedora/repository/coccc%3A11231/MichaelPoneman2015EconomicsThesis_A1b.pdf/Michael%20Poneman%202015%20Economics%20Thesis%20_A1b.pdf

Prabowo, R., & Soegiono, L. (2010). Intellectual capital performance and government ownership: An analysis of Indonesian banks. Proceedings of the International Conference on Intellectual Capital, Knowledge Management & Organizational Learning (pp. 373–380). Hong Kong: Academic Publishing Limited.

Puttaswamy, N., & Ali, M. S. (2015). How did China become the largest solar PV manufacturing country? Retrieved from http://www.cstep.in/uploads/default/files/publications/stuff/dc6ff09f580c30a0a6fc-0d1a90ed813f.pdf

Renewable Energy Research Institute, Hehai University. (2013, June). Study on promoting PV industry in Jiangsu Province (in Chinese). The China Sustainable Energy Program. Retrieved from http://www.efchina.org/Attachments/Report/reports-20130601-zh/reports-20130601-zh

Sheng, S., Zhou, K. Z., & Lessassy, L. (2013). NPD speed vs. innovativeness: The contingent impact of institutional and market environments. Journal of Business Research, 66, 2355–2362.

Shi, D. (2012). China's renewable energy subsidy and its impact analysis. Retrieved from http://www.esi.nus.edu.sg/docs/event/shi-dan.pdf?sfvrsn=2

Solar Cell Central. (n.d.). Solar markets: PV solar growth. Retrieved from http://solarcellcentral.com/markets_page.html

Sovacool, B. K., & Gilbert, A. (2013). Feed-in tariffs and other support mechanisms for solar PV promotion. In reference module in earth systems and environmental sciences (online). Elsevier.

Sun, H., Zhi, Q., Wang, Y., Yao, Q., & Su, J. (2014). China's solar photovoltaic industry development: The status quo, problems and approaches. Applied Energy, 118, 221–230.

Taylor, M. (2008). Beyond technology-push and demand-pull: Lessons from California's solar policy. Energy Economics, 30(6), 2829–2854.

Tian, L., & Estrin, S. (2007). Debt financing, soft budget constraints, and government ownership: Evidence from China. Economics of Transition, 15, 461–481.

Timilsina, G. R., Kurdgelashvili, L., & Narbel, P. A. (2012). Solar energy: Markets, economics and policies. Renew Sustain Energy Review, 16(1), 449–465.

Tse, T., Esposito, M., & Soufani, K. (2013). Fast-expanding markets: Where new growth can be found? European Business Review, 2, 11–14.

Tse, T., Esposito, M., & Soufani, K. (2015). Fast-expanding markets: The revolution of the microeconomy. Thunderbird International Business Review. doi:10.1002/tie.21738

Wan, W. P., & Hoskisson, R. E. (2003). Home country environments, corporate diversification strategies, and firm performance. Academy of Management Journal, 46(1), 27–45.

Wesoff, E. (2014). Rest in peace: The fallen solar companies of 2014. Retrieved from http://www.theenergycollective.com/eric-wesoff/2165821/rest-peace-fallen-solar-companies-2014

Zhang, S., & He, Y. (2013). Analysis on the development and policy of solar PV power in China. Renewable and Sustainable Energy Reviews, 21, 393–401.

Zhang, S., Zhao, X., Andrews-Speed, P., & He, Y. (2013). The development trajectories of wind power and solar PV power in China: A comparison and policy recommendations. Renewable and Sustainable Energy Reviews, 26, 322–331.

Zheka, V. (2005). Corporate governance, ownership structure and corporate efficiency: The case of Ukraine. Managerial and Decision Economics, 26, 451–460.

Zhi, Q., Sun, H., Li, Y., Xu, Y., & Su, J. (2014). China's solar photovoltaic policy: An analysis based on policy Instruments. Applied Energy, 129, 308–319.

Zucker, L. G. (1977). The role of institutionalization in cultural persistence. American Sociological Review, 42, 726–743.

Appendix

We use data envelope analysis (DEA) to compute efficiency scores, including the technical efficiency score, the pure technical efficiency score, and the scale efficiency score. DEA can be roughly defined as a nonparametric method of measuring the efficiency of a decision-making unit (DMU) with multiple inputs and/or outputs. In DEA, there are n DMUs to be evaluated, each of which uses different amounts of m inputs to produce s different outputs. The purpose of DEA is to identify which of the n DMUs can be used to determine an envelopment surface. This envelopment surface is called the "empirical production function" or the "efficient frontier." By comparing each DMU with the envelopment surface, we can calculate their relative efficiency scores. Units that lie on the surface are efficient, whereas those that lie underneath the surface are inefficient. Under the DEA method, a firm with an efficiency score of unity (100%) is located on the efficient frontier in the sense that its inputs cannot be further reduced without decreasing its output. A firm with an efficiency score of below 100% is relatively inefficient.

Similar to the approach Zheka (2005) takes, we adopt an input-oriented DEA. We use DEAP version 2.1 to run the standard constant returns to scale (CRS) and variable returns to scale (VRS) models. Use of the CRS specification when not all DMUs are operating at the optimal scale will result in technical efficiency measures that are confounded by scale efficiencies (SE). The use of the VRS specification permits the calculation of technical efficiency absent these SE effects. Many studies have decomposed technical efficiency scores obtained from a CRS DEA into two components: one due to scale inefficiency and one due to "pure" technical inefficiency. This can be done by conducting both a CRS and a VRS DEA with the same data. If there is a difference in the two TE scores for a particular DMU, this indicates that the DMU has scale inefficiency and that this inefficiency can be calculated from the difference between the VRS technical efficiency score and the CRS technical efficiency score. This calculation is incorporated into DEAP 2.1. It was developed by the Centre for Efficiency and Productivity Analysis and can be downloaded freely from the Internet. Coelli (1996) provides a more detailed introduction to the calculation method. Ideally, output should be measured in physical units. Because the sample includes different subindustries, using physical units would make it difficult to compare firm outputs across subindustries. Therefore, following previous studies (Zheka, 2005), we measure output as sales revenue (adjusted by change in final product inventory) using log values. We compute labor as the log of the number of employees in the firm and capital stock as the log value of fixed assets in RMB. All the input and output data come from the China Stock Market & Accounting Research database.