Chapter 8

The Impacts and Interaction of Upstream and Downstream Policies for the Solar Photovoltaic Industries of China

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Chapter 8

The Impacts and Interaction of Upstream and Downstream Policies for the Solar Photovoltaic Industries of China

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Abstract

In this chapter, we provide a research framework on the industrial structure of solar photovoltaic (PV) industry in China and aim to study the incentive correlation and interaction between upstream and downstream firms. We first draw a picture of Chinese solar PV industry and go through the literature to lay out the history and existing policies of the industry and current issues that companies in different positions in the industry chain have to face. Secondly, we use industry data and apply unit root test, Johansen co-integration analysis, Granger causal test, and Directed Acyclic Graph test. With these econometric methods, we study the long-term relationship between the polysilicon price, government subsidies on polysilicon plants, the solar cell price, the solar power price, and government subsidies on solar power. Our analysis shows that the policy-conducting effects from upstream PV firms to the downstream products are smaller than that coming from the downstream PV firms to the upstream products. Policy implications are discussed. We recommend that the Chinese government should issue policies to facilitate coordination between the central government and local governments on the development of PV industry in China. The government should encourage indigenous innovations in the PV industry and improve its competitiveness. Policies on electricity pricing and cost allocation should also be improved to ensure the steady growth of the solar PV industry in China.

Key words: Upstream and downstream policies, solar photovoltaic industries, interaction, China.

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1. Background

China has issued a series of policies to support the development of the solar photovoltaic (PV) industry and to help domestic solar PV enterprises. The fiscal subsidy, financial support, and research and development support policies for the polysilicon and solar cells enterprises (the upstream) help expand the scale of manufacturing and speed up the technological progress of the downstream industry and reduce the costs and change the structures of end-products. Electricity subsidies, trade remedies, and financial support policies for the Solar Roof Plan and the Golden Sun Demonstration Project (the downstream) will help expand market demand and size, that should conduct to upstream industry, and strengthen competition, promote economy of scale, and technological progress of front-products. We use the model of demand price elasticity of producer and user to study the impact and interaction of upstream and downstream policies for solar PV industries. This study further calculates the shadow demand and predicts possible development scale of solar PV industry in China under different scenarios in the future. Based on this, we put forward sound policy improvement suggestions for the solar PV industry including technical support, tax preferential policies, fiscal and financial support policies, access policies, and electricity price subsidies for the upstream and downstream industries.

Shenghong Ma (2010) and Molin Huo (2012) explore the current technological level of PV industry in China and the cost competitiveness of PV power generation. They find that even though the cost of PV power generation is gradually declining, it is still far from realising the cost-effective power generation of traditional fossil energy. Junfeng Li (2011), Semiconductor Equipment and Materials International (SEMI) and China Photovoltaic Industry Alliance (CPIA) (2012), and Lifang Guo (2012) make a comprehensive analysis of the flagging situation of China's PV development, and its favourable and unfavourable prospects. Chuanggui Wang (2010), Zhou Deng (2012), and Li Ju (2012) probe into the underlying causes of the difficulties facing China's PV industry under the new situation. Sicheng Wang (2011), Qingzhen Li (2011), Lifang Guo (2011), Yuyang Li(2013), Guoxing Xie (2013), and Xiaolan Wang (2013) suggest that it is imperative to accelerate activation of domestic PV market, concentrate on the development of rural and urban distributed PV power generation, and work out a clear development plan for the PV industry.

Lei Li (2011), Zhou Deng (2012), and Jinwei Zhu (2012) analyse relevant policies set by the Energy Administration of the National Development and Reform Commission and their roles in PV development. They also put forward future policies and recommendations to promote the healthy development of the PV industry.

Section 2 reviews the history of China’s PV industry. Section 3 and 4 identify the main issues and challenges facing this industry. Sections 5 and 6 review the policies for this industry. Sections 7 and 8 analyse the impacts of these policies and Section 9 conducts a quantitative analysis on this issue. Section 10 concludes and draws policy implications.

2. The development of China's photovoltaic industry

The PV industry’s upstream produces high-purity silicon of the highest technology, the greatest profits, and the highest price and cost proportion. The industry’s midstream produces batteries, cell components, and related products. The downstream is an integration of the PV installation system.

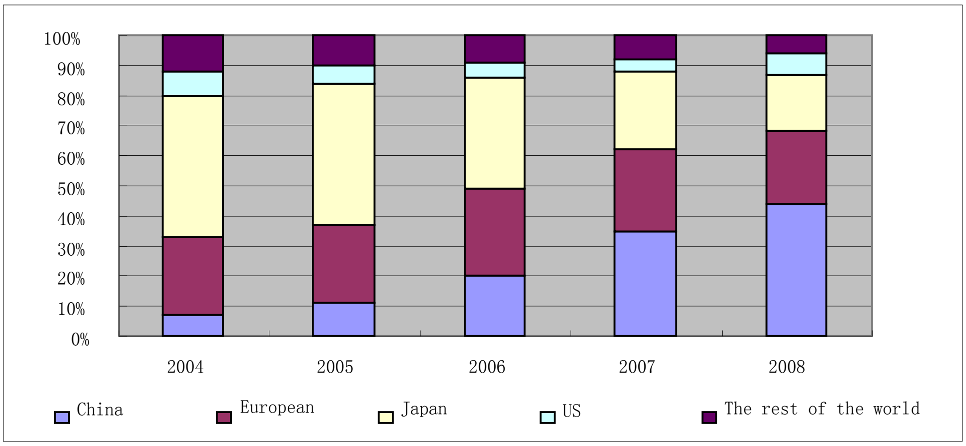
China's PV industry that produces silicon of high purity relies on foreign countries for raw materials, key technology and equipment, and market demand. The industry chain is not balanced; China's PV industries are mainly concentrated in the midstream with lower value, such as piece-cutting of silicon, production of batteries and cell components, and systems-supporting industries. The production in the upstream of polysilicon of high purity is mainly done in the US, Japan, Europe, and other developed countries.

(1) There has been a dramatic growth in the production of high-purity silica.

This is a result of the spurt in polysilicon prices around the world in early 2008 and the policy support of the National Development and Reform Commission.

China produced 20,000 tonnes of polysilicon in 2009, and 82,000 tonnes in 2011. In 2012, however, China's production of polysilicon was reduced to about 69,000 tonnes. Because of the great technological gap between China and the more advanced countries, high production costs, and predatory pricing of the United States (US), South Korea, and Europe, more than 90% of Chinese polysilicon companies had to stop production or cut output.

Figure 8.1: Global Market Shares of Cells



US = United States.
Source: China Merchants Securities.

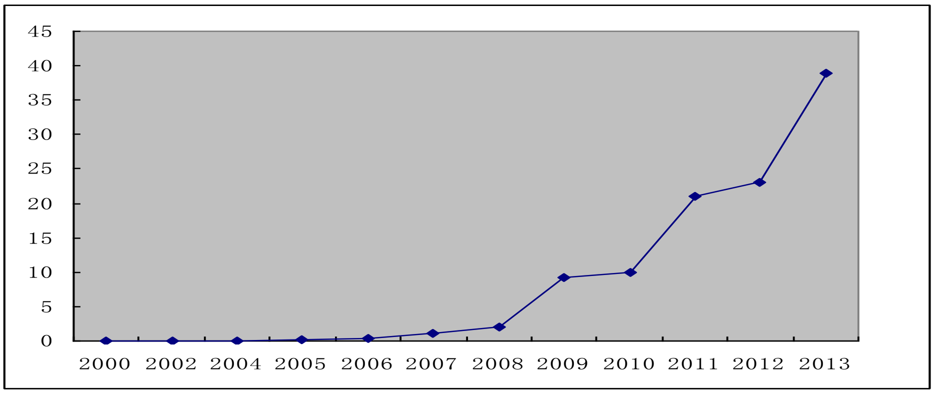
(2) China's solar cell production is growing rapidly and has ranked top in the world (Figure 8.1).

Since 2002, China's production capacity of PV cells has improved rapidly and has made significant achievements. As a result, a large number of assembling and packaging companies have emerged. China is rapidly moving as an international manufacturing power in the PV industry in terms of production scale of batteries and components.

In 2002, China's production of cells and cell components ranked seventh in the world. In 2005, its manufacture of PV cells and components ranked seventh in the world. In 2008, China became the world's largest producer of solar cells, with total capacity of about 3.3 gigawatts (GW), total output of more than 2 GW, and market share of over 30%. In 2009, China's production of solar cells reached 4.3 GW or 40% of the global outputs. In 2010, China's production of solar cells reached 9 GW, or more than 50% of the global outputs. In 2013, China's production of solar cells was up to 40 GW (Figure 8.2).[33]

[33] The upstream of photovoltaic industry produces high-purity silicon is characterized with the highest technology and the greatest profits. The prices are accountable for more than 70% of the costs; the midstream produces batteries, cell components and other related products; the downstream is an integration of photovoltaic installation system.

Figure 8.2: China's Production of Cells, 2000–2013 (in GW)



GW = gigawatt.

Sources: European Photovoltaic Industry Association; BP Statistical Review of World Energy (2012).

(3) China's total installed capacity of PV power generation now accounts for a small part of global output and its new installed capacity is rising markedly.

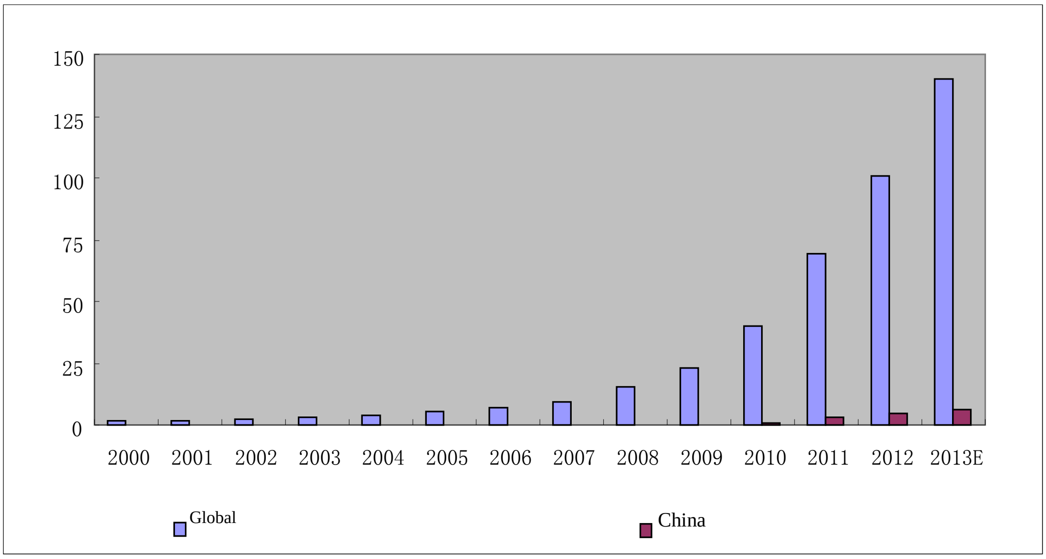
In 2007, China's PV installed capacity was only 0.1 GW. In July 2009, the Golden Sun Demonstration Project was officially launched and China's PV market has since then sustained high growth with an average annual growth rate of over 200% (Table 8.1). In 2013, its new installed capacity was 11.3 million kilowatts or three times higher than in 2012. Thirty percent of the world's new capacity is now concentrated in China and its total is more than that of the whole Europe (10.25 million kilowatts).

Table 8.1: China's Installed Capacity of Photovoltaic Power Generation from 2002 (MW, %)

Year	Installed Capacity	Increase Over the Previous Year	Accumulated Installed Capacity
2002	20	250	45
2003	10	-50	55
2004	10	0	65
2005	5	-50	70
2006	10	100	80
2007	20	100	100
2008	40	102	140
2009	160	297	297
2010	500	212	797
2011	2900	480	3697
2012	1190	-59	4887

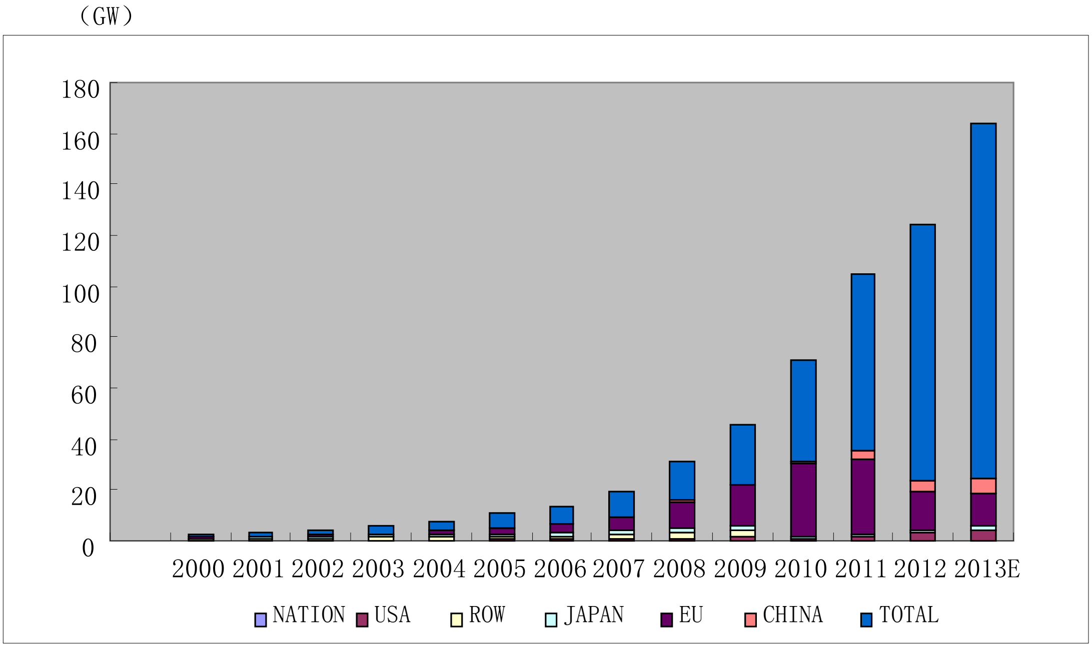
MW = megawatt.
Sources: National Energy Administration; Silicon Industry of China; Nonferrous Metals Industry Association.

Figure 8.3: Accumulated Installed Capacity, Global and China



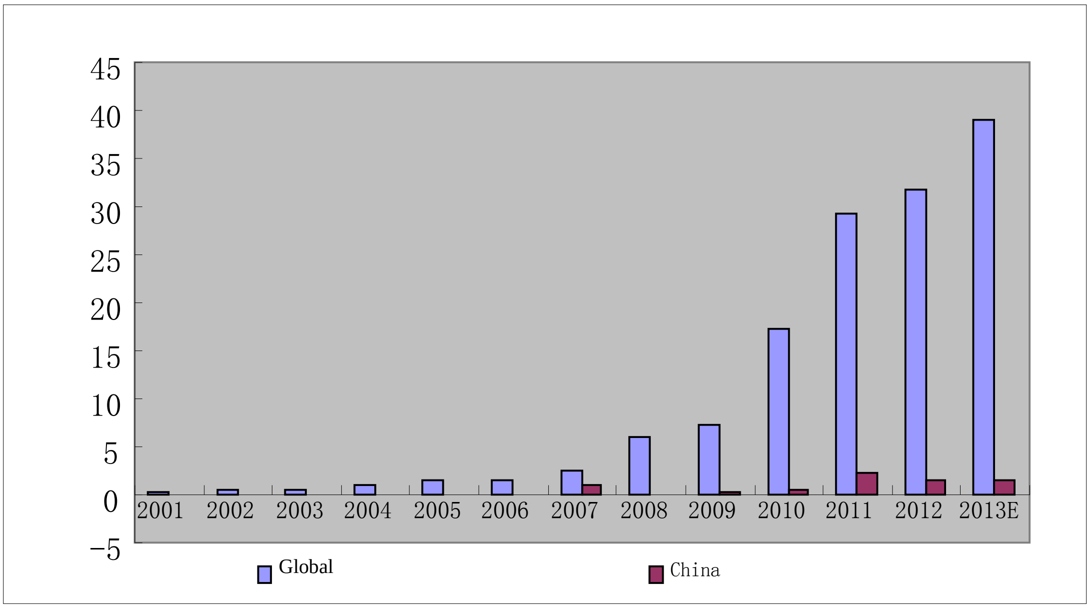
Sources: European Photovoltaic Industry Association; BP Statistical Review of World Energy (2012).

Figure 8.4: Global Accumulated Installed Capacity of Photovoltaic Power Generation



EU = European Union; ROW = Rest of the World; USA = United States of America .
Sources：(European Photovoltaic Industry Association; BP Statistical Review of World Energy (2012).

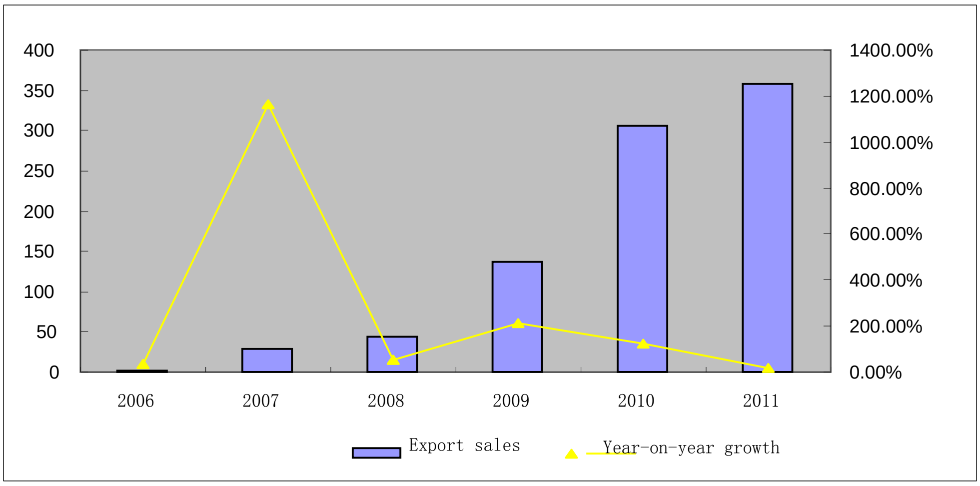
Figure 8.5: New Installed Capacity of Photovoltaic Power Generation, Global and China



(4) China's solar PV industry depends heavily on foreign markets.

Since China’s domestic PV market started late and small in scale, its PV industry relies heavily on foreign markets (Table 8.2).

Figure 8.6: China's Exports of Photovoltaic Products, 2006–2011 (10,000 billion, %)



Source: Report of Global Photovoltaic Industry (2012).

Table 8.2: China's Photovoltaic Industry's Independence from Foreign Markets

	2006	2007	2009	2010（predicated）
Output /MW	400	1088	4011	8000
Export /MW	390	1068	3851	7600
Domestic Installs/MW	10	20	160	400
Export Percentage %	97.5	98.2	96.0	95.0

MW = megawatt.

Sources: Wang Sicheng. Speed – up development of PV to ensure sustainable energy supply in China. Engineering Sciences, 2011(9), 51–61.

(5) Despite a short-term downturn, China's solar PV industry has a promising prospect in the long run.

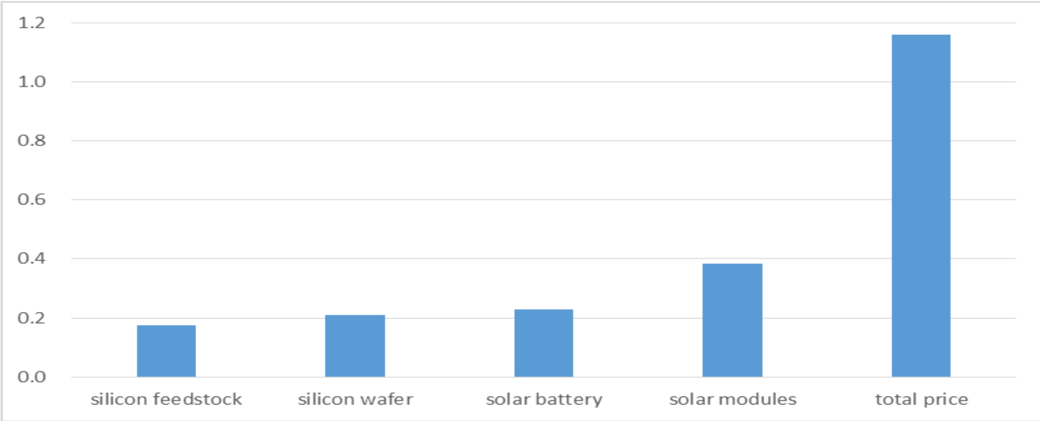
At present, the PV market is facing weak demand, with the double strikes of domestic overcapacity and under-expectation demands greatly aggravating the rapid price decrease of every chain in the PV industry. At present, the PV industry chains, (e.g., raw materials of polysilicon, silicon, cells, and modules) are earning small profits and some are even suffering losses.

Still, China's PV industry has enormous potential in the long run. The continuous improvement of PV industry is a prerequisite for the great development of the domestic market; the growing contradiction between energy supply and energy demand, and the changes in the energy structure point to the development of PV application market.

The relative cost ratio of module production and processing technology is quite high, while slicing techniques are faced with price cuts. Improvements in the conversion efficiency of PV products can directly reduce system-balancing costs. A 1% increase in the efficiency of components decreases the system-balancing costs by 5% to 7%. But for the price, a one-level increase in the conversion efficiency of components its price can go up by CNY0.1974/W. A one-level increase in cell efficiency raises its price by 3% to 5%.

Promoting technological progress and technological innovation of domestically produced equipment are the potential and decisive factors to lower costs.

Figure 8.7: Cost Structure of Polycrystalline Solar Cells



Sources: Semiconductor Equipment and Materials International's reports.

3. Main problems of China's solar photovoltaic industry

3.1. Low industry-chain concentration and lack of obvious scale effects

China leads in total output of solar products. However, some links in the industry chain have low industrial concentration and suffer from lack of obvious scale effects. Especially in the low sections of the industrial chain that have low entry barriers, the largest number of firms concentrate, which greatly impact the industrial concentration and scale benefits. As a result, their products have low added value, lack competitiveness, and earn weak profits.

3.2. Obvious technological gap in the entire industry

Although China has become a global manufacturing country in PV industry, it is far from being a great manufacturing power. To begin with, its basic research is weak and it lacks key technology and equipment.

Secondly, technological advances mainly take place in the manufacturing process, which lacks innovation and invention.

Thirdly, China's research institutes work inefficiently and the industry-academia-research collaboration has yet to take effect. The main innovating bodies of the solar PV industry are private firms. Research institutes show low R&D efficiency and week applicability.

Fourthly, although the PV industry has low technological barriers and high liquidity, its intellectual property protection is quite weak.

3.3. The development of photovoltaic application market greatly lags behind the development of the photovoltaic industry

The domestic PV market shows slow development and low application levels of PV products. Although China has become the world's largest manufacturer of PV products, the prices of its products and market spaces are greatly limited.

3.4. Serious overcapacity and heavy dependence on the international markets

In 2012, the domestic PV trade was greatly limited by the decline in market demand, overcapacity, and anti-dumping and anti-subsidy strategies of Europe and the US. Profits of domestic PV industry fell sharply and the whole industry faced operational difficulties. Many small and medium firms stopped production. In 2012, the operating rate of China's PV firms was less than 70%. Suntech, once an industry leader, declared bankruptcy in 2013.

3.5. Lack of industry standards and the need for government regulations

At present, China has no uniform standard in its PV industry and PV firms differ a lot in their manufacturing standards. It is thus necessary to speed up the establishment of technical standards and quality certification system for PV products and power generation system, change the standards of industry leaders into national mandatory standards, and actively participate in setting relevant international standards.

3.6. Industrial development disorder and serious blind investments

Currently, a lot of investors poured capital into the PV market due to low entry barriers in some of the links in the industry chain and local government’s support, resulting in serious blind investments, redundant construction, overcapacity, unhealthy competition, waste of resources, and environmental pollution.

4. Critical obstacles to the development of the domestic photovoltaic application market

Despite the decline in exports, industrial policies and corporate strategies have shifted focus to the domestic PV market and, as a result, its application market starts to rise rapidly. However, problems remain: small quantities, large obstacles, slow development, indefinite directions, and unclear policies. The domestic market shows different short-term and long-term trends.

(1) Regarding government guidance, not enough strategic emphasis is laid on the PV industry, and long-term development planning is lacking. Once faced with growth spurt, the government merely supported the expansion of production scale and took few effective measures to promote market development.

(2) Regarding economic benefits, the costs of PV applications remain very high and, as a result, limit market competitiveness. Economic efficiency is a deceptive factor, whether in centralised large-scale PV power plants or in distributed roof power plants. In China, PV power generation can only take 1,300 hours on the average. In areas with enough sunshine (1,500 hours the whole year), the PV cost is around one yuan per kWh, which is higher than the on-grid price of thermal power and wind power, both of which have hindered the development of centralised PV power plants. Small distributed power plants have to deal with the problem of high initial investment.

(3) Regarding the system, it is difficult to coordinate the interests of all stakeholders. The main stakeholders in constructing and using PV power stations are roof owners and grid companies. The first obstacles to the installation of power plants are the roof owners. Property owners and property companies are unwilling to install PV solar power plants because of costs, safety, aesthetics, and other considerations.

There are also difficulties in determining property rights, identifying the one responsible for the operation and management of power plants, and distributing benefits after completion. The second obstacles are the grid companies. The generating capacity of distributed PV power stations is limited and most of the generated power is used by the owners, so there is little impact on the grid system and small profit for grid companies after connection. So far, there have been some relevant requirements that grid companies need to follow, such as providing appropriate ports and devices for distributed power plants. However, due to lack of technical standards covering grid systems and subsidies, grid companies are unwilling to accept PV electricity.

(4) Regarding supporting policies, these lack implementation details and their supporting effects are limited. The main policies supporting domestic PV application markets are the Golden Sun Project and subsidies for distributed power generation plants from the National Energy Administration.

(5) Excessive growth leads to serious production backlog, and price wars result in the abnormal development of the market. On the one hand, since 2000, the wealth effect of domestic PV industry has stimulated a large number of private capitals to invest in the PV industry. On the other hand, under pressure to contribute to GDP growth and because of structural adjustment assessment, the solar PV industry or related industries were to be developed as key directions of strategic emerging industries in almost all provinces, municipalities, and autonomous regions. In 2011, because of the excessive concentration of private capital and government resources, China's PV manufacturing suffered industry-wide losses. Small-scale companies and those with weaker risk tolerance started clearing inventory and reclaiming funds, resulting in a disastrous decline of prices of PV products. Vicious price competitions not only deteriorated further the development of domestic PV enterprises but also affected the healthy development of the applications market.

5. Background of industry policies for solar PV

When cost per kWh is higher than price of local electricity, mere reliance on the market is not cost-effective and government subsidies are needed. Thus, PV demands are greatly influenced by adjustments of government subsidy policies at this stage. When cost per kWh is lower than price of local electricity, or the consumers' grid parity is realised, the market will drive the demand of PV power generation.

At present, the cost of PV power generation is still higher than the power generation cost of conventional energy. Thus, the end demand for PV industry is still not fully market-oriented. The demand fluctuates depending on the changes in the nation's industry policies.

Germany, Spain, Italy and other countries have launched feed-in tariff, a subsidy policy that has stimulated the rapid growth of installed capacity in the European market. In 2004, Germany modified the Renewable Energy Laws so that the on-grid prices of different application types and scales, and the yearly decrease of on-grid price were clarified, which contributed to a dramatic increase in PV installed capacity in the country. In 2005, Spain launched its fit-in tariff policy, which greatly promoted the development of its PV market, with new installed capacity reaching 2.5 GW in 2008. The drop in polysilicon's prices in 2009–2010 caused the cost of PV installation to fall sharply. In Germany and Italy, a short-term 'predatory' phenomenon appeared in the market under expectations of subsidy cuts. The PV manufacturing chain started a new round of capacity expansion. Influenced by the European debt crisis, a sharp fall in component prices, and other factors in 2010–2012, the countries with great growth of installation quantity, such as Germany, United Kingdom, France, Australia, etc., gradually reduced feed-in tariffs to curb excessive investment.

Because of subsidy cuts, Europe's new installed capacity in 2012 fell by 22 % to 17.58 GW for the first time in nearly a decade and further declined by 42% to 10.25 GW in 2013. Falling demand and excess capacity of the whole manufacturing chain led to the industry bottoming in 2011–2012.

Benefiting from direct subsidies on investment, tax relief, accelerated depreciation, green power certificate, and other policy supports, the US photovoltaic market has grown rapidly. In 2013, the country's new PV installed capacity increased by 41% compared to the previous years and reached 4.75 GW. In 2013, solar energy became America's second largest new power source, accounting for 29% of the total new installed electricity capacity and only behind the new installed capacity of gas (46%).

The vigorous development of Japan's PV market is also due to policy incentives. After the Fukushima Daiichi nuclear disaster in 2011, Japan has implemented renewable energy subsidies starting July 2012 and that would last for 20 years. It was the most generous subsidy in the world. In 2013, Japan's new PV installed capacity was 6.9 GW, second only to China's installed capacity.

5.1. Background and goals of China's policies

（1）The laws and policies issued from 2006 to 2008 to encourage the development of renewable energy. These policies set the supporting rules of cost allocation, full acquisition, and cap-and-trade. The solar PV power generation also benefited from them.

（2）The policies launched between 2007 to 2011 to solve the solar PV industry's prominent problem of overdependence on foreign markets. These preferential policies played positive roles in starting the domestic PV market and other aspects.

（3）The policies to solve the problems of serious overcapacity of the solar PV industry, overdependence of domestic market on external demands, and the common operational difficulties facing firms since 2012. China launched a number of emergency policies and tried to expand domestic demands of PV products by starting domestic distributed PV market. These emergency measures brought in hopes to the domestic PV industry.

6. Industry policies for solar photovoltaic industries

Since 2005, China has successfully issued a series of policies and strategies to support the development of the PV industry and help domestic PV firms freed themselves of difficulties （Table 8.3). These policies can be divided into five types: fiscal subsidy, electricity price subsidies, research and development support, industry entry, and trade remedy.

Table 8.3: China's Policies for Solar PV, 2005–2014

Policy	Time	Main Content
Renewable Energy Law	February 2005	Encourages and supports grid-connected power generation of new energies, such as solar energy. Sets corresponding policies on incentive price and cost allocation. Sets up special funds for renewable energy development. Supports technology research and development, system construction and demonstration projects, etc.
Interim Measures for the Management of Pricing and Cost Sharing of Electric Power from Renewable Energies	January 2006	Project pricing: reasonable cost + reasonable profits
Measures for the Control of Renewable Energy Fund	August 2006	A special fund to support the spread and application of solar energy in architecture, and solar power. Formulates rules for application and approval process of the fund. Special funds include unpaid subsidies and preferential loans.
Mid and Long-Term Development Plan for Renewable Energy	September 2007	Objectives for planned PV installed capacity are 300 MW for 2010 and 1800 MW for 2020. The Planning gives priority to the development of strategic reserves of solar technology and the construction of several PV power generation demonstration plants and solar heat power generation demonstration plants
The 11th Five-Year Plan for the Renewable Energy Development	March 2008	A plan for key areas of PV solar power to carry out power construction in areas without electricity, start application projects in PV cities, and support PV power station pilots. It also plans to conduct R&D work, equipment-manufacturing work, and to construct PV industry system.
Implementing Opinions on Expediting the Application of Photovoltaic Energy in Buildings	March 2009	Supports demonstration projects of PV application in buildings, implements 'Solar Power Rooftop Initiative', and encourages the combination between PV modules and buildings; implements fiscal support policy and develops the mechanism and model of government guidance and market-based implementation; enhances policy support in construction areas.
*I*nterim Measures for the Management of Fiscal Subsidy Fund for the Application of Photovoltaic Energy in Buildings	March 2009	Prescribes the scope and qualification requirements for the use of subsidy fund; encourages local governments to issue and implement supporting policies for PV development; sets the subsidy standard in 2009 to be in principle CNY20/Wp, with specific standards to be determined according to the level of integration with buildings and technology sophistication of PV products.
Provisional Rules on the Financial Subsidy Management of the Golden Sun Demonstration Project	July 2009	Specifies the key supporting objects of the Golden Sun Demonstration Project and the subsidy standards. Those listed in the grid-connected PV power generation projects of the Golden Sun Demonstration Project can get 50 % of the total investment in PV

		power generation systems and supporting projects from government as subsidies. In remote areas without electricity, independent PV power generation systems can get subsidies as high as 70% of the total investment.
Amendment to the Renewable Energy Law	December 2009	The state guarantees the purchase of electricity generated by using renewable energy resources.
Notice on Strengthening the Management of Golden Sun Demonstration Project and the Building Integrated Photovoltaic Application Demonstration Project	October 2010	Central finance proportionally provides price subsidies on key equipment of the demonstration projects per bidding agreement. Quota subsidies are used for other fees of the demonstration project construction.
Polysilicon Industry Access Requirements	December 2010	Specifies construction conditions, production layout, production scale, technical equipment, resources recycling, energy consumption, environmental protection, product quality, safety, health, and social responsibility of polysilicon projects.
Circular on the Implementation of the Golden Sun Demonstration Project in 2012	January 2012,	The total capital is not less than 30% of the project investment. The demonstrative projects about centred application of PV power generation should apply as a whole. The total installed capacity is not less than 10 MW. The installed capacity of scattered constructed users' power generating project that is not less than 2 MW.
The 12th Five-Year Plan for the Solar Photovoltaic Industry	February 2012	By 2015, the costs of PV components will decrease to CNY7,000/kW, system costs to CNY0.8//kWh, the average comprehensive power consumption of polysilicon production is lower than 120 kWh/km. The efficiency of monocrystalline silicon solar cells and polycrystalline silicon solar cells will reach 21% and 19%, respectively.
Circular on the Application for the Large-Scale Demonstration Areas of Distributed PV Power Generation	Septembe r 2012	The government will introduce a quota subsidy policy for power generation from PV projects in the demonstration areas and implement unified subsidy standards for the self-use of power generation and grid connection of redundant power generation.
Circular on the Implementation of Grid Connection Services for Distributed Photovoltaic Power Generation	October 2012	Provide grid connection for power generation of voltage less than 10kV with the total installed capacity of each grid connection node no more than 6MW; system backup fee is exempted for distributed PV and wind projects; grid connection authority is delegated to local prefecture-level companies with the cycle of grid connection procedures roughly 45 working days; all costs related to public power grid renovation arising from the connection of distributed PV and connection into public power grid shall be borne by the State Grid.
Circular on the Implementation of Grid Connection Services for Distributed Photovoltaic Power Generation	October 2012	Provide grid connection for power generation of voltage less than 10kV with the total installed capacity of each grid connection node no more than 6MW; system backup fee is exempted for distributed PV and wind projects; grid connection authority is delegated to local prefecture-level companies with the cycle of grid connection procedures roughly 45 working days; all costs related to public power grid renovation arising from the connection of distributed PV and connection into public power grid shall be borne by the State Grid.
Notice of Implanting Subsidy Policy Based on the Power in the Distributed Photovoltaic Power Generation and Other Related Problems	July 2013	Specifies the subsidy based on power.
Notice of National Development and Reform Commission that Makes Best of Price Lever to Promote the Healthy Development of Photovoltaic Industry	August 2013	Identified benchmark tariffs and their timeline, benchmark feed-in-tariffs for distributed PV subsidies (three types of solar energy resource regions to respectively follow the standards of CNY0.9/kWh, CNY0.95/kWh and CNY1/kWh for a duration of 20 years; for distributed PV power generation, tariff subsidy standard is CNY0.42/kWh according to the policy of full power generation subsidy.

Notice on Constructing Demonstration Areas of Distributed Photovoltaic Power Generation Application	August, 2013	According to the implementing scheme for demonstration areas submitted by relevant provinces (municipalities and autonomous regions), 18 industrial parks have been identified as the first batch distributed PV application demonstration areas, including Zhongguancun Haidian Industrial Park in Beijing.
Announced the First Demonstration Areas of the Distributed Photovoltaic Power Generation	August 2013	Clarifies that distributed PV power generation adapts the mode of 'use own power generating, excessive power are on grid and power regulation'.
Comments on the Financial Services of Supporting the Development	August 2013	Financial innovation. Establishes local investment and financing institutions. Unified-borrowing and Unified-lending Model.
Notice on the Issues About Adjusting the Additional Criteria of Renewable Energy Power Prices and the Green Prices	August 2013	Additional tariff for renewable energies is increased from 0.8 cents to 1.5 cents for each kilowatt hour.
Guides Further Supporting the Development of Photovoltaic and Other New Energies	August 2013	Fully supports the orderly and coordinated development of new energies by grid-connected services, power purchase services, grid-connected dispatch management, etc.
Soliciting Opinion on Manufacturing Specifications of Photovoltaic Industry	Septembe r 2013	Sets up industry rules and guides the transformation and upgrading of the industry.
Notice on the Value-added Tax Policy of Photovoltaic Power Generation	Septembe r 2013	Adopts drawback policy of value-added tax (50%) to PV power generation.
Circular and the Promotion of Banking Sector Support to the Healthy Development of PV Industry	October 2013	Encourages banks to support the development of PV industry.
Letter for Soliciting Public Opinions on the Scale of PV Construction in 2013 and 2014	October 2013	In 2014, installed capacity is planned to increase by 12GW, including 8GW of distributed PV.
Announcement of the First Batch of Compliant PV Enterprises	November 2013	Outputs and product quality are strictly required. Enterprises excluded in the list cannot enjoy bank credit and export rebates.
Provisional Measures for the Management of Distributed Photovoltaic Power Generation Projects; Provisional Measures for Operation Regulation of Distributed Photovoltaic Power Generation	November 2013	General provisions of distributed PV, capacity management, project record filing, construction conditions, power grid connection and operation, metering and settlement.
Notice on Exemption from Government Funds to the Distributed Photovoltaic Power that Used its Generators	November 2013	Self-generation and self-use of distributed PV are exempted from the payment of renewable energy tariff surcharge, national major water conservancy project construction fund, mid-and large reservoir resettlement support fund and rural power grid loan repayment fund.
Detailed Regulations on the Business Services of Distributed PV Power Generation (for Trial Operation)	February 2014	Prescribed detailed regulations on the grid connection of distributed PV power generation.
Credit Policy of 2014	February 2014	Requires banking and financial institutions to support the development of emerging strategic industries, such as information consumption, integrated circuit, new energy vehicles, and PV industry, etc.
Notice on Recommending Key Projects of Photovoltaic Industry of 2014	February 2014	The Ministry of Industry and Information Technology sets the recommended key projects of the photovoltaic industry. The China Development Bank will provide comprehensive financial services to projects that are elected and conform with the relevant

		conditions of the China Development Bank.
Circular on the Implementation of Grid Connection Services for Distributed Photovoltaic Power Generation	October 2012	Provide grid connection for power generation of voltage less than 10kV with the total installed capacity of each grid connection node no more than 6MW; system backup fee is exempted for distributed PV and wind projects; grid connection authority is delegated to local prefecture-level companies with the cycle of grid connection procedures roughly 45 working days; all costs related to public power grid renovation arising from the connection of distributed PV and connection into public power grid shall be borne by the State Grid.
Announcement of the Second Batch of Compliant PV Enterprises	April 2014	Further strengthens the management of PV manufacturing industry, keeps the industrial orders, raises the levels of industry development, accelerates the transformation and upgrading of the PV industry.
Suggestions of the National Energy Administration (NEA) on the Implementation of Relevant PV Power Generation Policies	April 2014	Vigorously promotes the diversified development of PV industry and expedited the expansion of PV market.
Circular of the National Energy Administration (NEA) on Accelerating the Fostering of Distributed PV Application Demonstration Areas	April 2014	Fosters a series of distributed PV power generation demonstration areas on the existing basis.

Source: Prepared by the authors.

(1) Fiscal subsidy policies

At present, there are six types of fiscal subsidies on PV industry in China: special fund for renewable energy development, special fund for renewable energy constructing application, fiscal subsidy fund for PV constructing application, fiscal subsidy fund for demonstration cities of renewable energy constructing application, fiscal subsidy fund for countryside of renewable energy constructing application, fiscal subsidy fund for the Golden Sun Demonstration Project.

(2) Electricity price subsidies

To speed up the application of PV industry in the power generation terminal, China created, in 2012, network subsidy tariff that established service work pinions on distributed PV power generation and network, and allowed distributed PV dispersive access to low-voltage distribution network .

In August 2014, the National Development and Reform Commission specified CNY0.42/kWh as the national subsidy standard for the PV industry. It was the first time the on-grid electricity price was categorised into three levels according to regions: CNY0.9/kWh, CNY0.95/kWh, and CNY1.0/kWh (Table 8.4 and Table 8.5).

Table 8.4: National PV Power Plant Network Power Price

Resources Regional Division	Network Power Price	Regions
Class Ⅰ Resource Area	CNY0.9 /kWh	Ningxia; Haixi; Jiayuguan; Weiwu, Zhangye, Jiuquan, Dunhang and Jinchang of Qinghai; Hami, Tacheng, Alatai, Kelamayi of Xinjiang; Except Chifeng, Tongliao, Xinganmeng, Hulunbeier of Inner Mongolia Autonomous Region
Class Ⅱ Resource Area	CNY0.95/kWh	Beijing; Tianjin; Heilongjiang; Jilin; Liaoning; Sichuan; Yunnan; Chifeng, Tongliao; Xinganmeng, Hulunbeier of Inner Mongolia Autonomous Region; Chengde, Zhangjiakou, Tangshan and Qinghangdao of Shanxi; Datong, Suozhou, and Xinzhou of Shanxi; Yulin and Yanan of Shanxi; Qinghai; Gansu; Except class I resource area of Xinjiang
Class Ⅲ Resource Area	CNY1.0/kWh	Except class I, Ⅱ resource area

kWh = kilowatt-hour.
Source: State Development and Reform Commission.

Table 8.5: Price of National Residents Distributed Photovoltaic Electricity

	Resident Electricity Price	Price of National Residents Distributed Photovoltaic Electricity
Guangdong	0.61 yuan/kWh	1.01 yuan/kWh
Shanghai	0.62 yuan/kWh	1.01 yuan/kWh
Hainan	0.61 yuan/kWh	1.00 yuan/kWh
Jiangxi	0.60 yuan/kWh	1.00 yuan/kWh
Hunan	0.59 yuan/kWh	0.99 yuan/kWh
Hubei	0.57 yuan/kWh	0.97 yuan/kWh
Anhui	0.57 yuan/kWh	0.96 yuan/kWh
Henan	0.56 yuan/kWh	0.96 yuan/kWh
Shandong	0.55 yuan/kWh	0.95 yuan/kWh
Zhejiang	0.54 yuan/kWh	0..95 yuan/kWh
Guangxi	0.53 yuan/kWh	0.94 yuan/kWh
Jiangsu	0.53 yuan/kWh	0.93 yuan/kWh
Sichuan	0.52 yuan/kWh	0.93 yuan/kWh
Chongqing	0.52 yuan/kWh	0.93 yuan/kWh
Hebei	0.52 yuan/kWh	0.92 yuan/kWh
Jilin	0.53 yuan/kWh	0.92 yuan/kWh
Xinjiang	0.55 yuan/kWh	0.91 yuan/kWh
Heilongjiang	0.51 yuan/kWh	0.91 yuan/kWh
Liaoning	0.50 yuan/kWh	0.90 yuan/kWh
Shanxi	0.50 yuan/kWh	0.90 yuan/kWh
Gansu	0.51 yuan/kWh	0.89 yuan/kWh
Tianjin	0.49 yuan/kWh	0.89 yuan/kWh
Beijing	0.49 yuan/kWh	0.89 yuan/kWh
Shanxi	0.48 yuan/kWh	0.88 yuan/kWh
Yunnan	0.48 yuan/kWh	0.88 yuan/kWh
Fujian	0.45 yuan/kWh	0.87 yuan/kWh
Guizhou	0.46 yuan/kWh	0.86 yuan/kWh
Neimeng	0.47 yuan/kWh	0.85 yuan/kWh
Ningxia	0.45 yuan/kWh	0.84 yuan/kWh
Qinghai	0.43 yuan/kWh	0.83 yuan/kWh

kWh = kilowatt-hour.
Source: http://guangfu.bjx.com.cn/news/20140313/496645.shtml

(3) Support policies on research and development

These include basic R&D support programmes that cover solar power generation technology in the future, and technical R&D support programmes which support the industrialisation of solar power generation technology.

(4) Industry entry policies

By the end of 2010, the Polysilicon Industry Entry Requirements put forward clear demands for technology, environmental protection, investment, and other aspects as access requirements into the polysilicon industry.

(5) Trade remedy policies

Regarding the dumping behaviours of foreign polysilicon enterprises, China's Ministry of Commerce decided, since November 2012, to determine whether to impose anti-dumping duty on imported solar-grade polycrystalline silicon coming from the US, South Korea, and the EU, or impose countervailing duty on imported solar-grade polycrystalline silicon originating in the US and the EU.

After implementing a series of industrial policies, China’s domestic PV application market has been rapidly expanding and has progressed in solving its overdependence on external demand. Also, in 2013, the Chinese government greatly improved its policy support to the PV industry. In 2014, as the domestic PV application market was seeing signs of increase in growth, some companies began working again, and the operations of a few firms markedly improved.

7. Problems with existing policies

There are some obvious problems with existing policies in promoting the development of photovoltaic industry.

1. More emphasis on the subsidies of subsidising end-product application than the supporting R&D support for the front-end industrial technology.

Subsidising PV industry is necessary at its present stage. However, almost all subsidies are concentrated in end-product applications, which may be conducive to the rapid expansion of the domestic PV market in the short term, but of little importance in reducing PV product costs and application costs. In fact, the biggest obstacles to China's producing PV products and reducing application costs are the key technology gaps, such as purification of silicon materials. Because advanced planning and support for the R&D of industrial technology are lacking, intrinsic and stable cost-reducing mechanism has yet to be formed.

2. More emphasis on subsidising projects' initial investments than electricity regulations after completion of projects

The electricity subsidies for 'settlement after electricity generation' are more reliable. The Solar Roof Plan and the Golden Sun Demonstration Project use initial investment subsidies. However, due to the lack of electricity regulations after completion of projects, some areas take advantage of government subsidies without these funds being utilised in full.

3. More emphasis on the construction of large-scale power plants than distributed local development and utilisation

Although the total solar energy is huge, its energy density is quite low, and thus, its scale development needs a great deal of land resources. From the perspective of construction costs of commercialising PV projects and management efficiency, it is difficult to adopt the ways of 'decentralised grids, local consumption'. Instead, the 'large scale–highly concentrated–long distance–high voltage delivery' pattern is preferred.

Investments in multiplex power transmission and annual utilisation hours are relatively low, leading to low efficiency in power transmission system, line losses, and long distance wheeling costs. It also weakens the economic benefits of PV power generation, which is aimed to replace fossil energy.

4. More emphasis on the cleanliness of every power-generating stage than control of energy consumption and pollution in the production processes

From the perspective of power generation, PV power generations are characterised as 'zero consumption, zero emissions', resource-saving, and environment-friendly. However, from the perspective of a full life cycle, the greenhouse gas emissions of PV power generation are less than the traditional fossil fuels, but larger than the major sources of renewable energy. In other words, the energy consumption during production process of PV products is not low, and in some stages even poses risks of environmental pollution. Based on this, China has not laid enough emphasis on the PV industry.

It is necessary to set up clear long-term development plans and development policies especially addressing the insufficient fiscal funds support, for China's PV industry, so as to create a favourable condition and build up a super platform for domestic PV firms to be internationally competitive.

5. Financing Situation

(1) The Main Financing Modes of Photovoltaic Industry in China and Scale of Financing

The capital-intensive and technology-intensive photovoltaic industry demands huge funds. The present financing modes for new energy industries in China include bank loans, stocks, corporate bonds, venture capital, etc.

1) Bank Loans. As a policy bank, the National Development Bank is the main force supporting the development of the PV industry in China. Sixty percent of bank loans for PV power plants and distributed PV power generation projects come from this bank. By the end of August 2013, the total loan to PV industry was CNY41.05 billion.

Although credit funds of state-owned commercial banks have taken shape, various market changes have forced commercial banks, since 2009, to impose tight and strict credit policies on PV firms and wind-power equipment manufacturers.

2) Capital Markets (mainly based on stock and bond markets). China's stock market is subject to high listing threshold, complex listing process, long approval procedure of financing proposals, and other policy barriers. Compared with equity financing, China's bond market has lagged behind, restricting bond financing scale of some firms to some extent.

3) Venture Capital. As most international venture capitalists keep a wait-and-see attitude, their investments in China's renewable energy projects are still at the trial stage, i.e. very limited. The main reasons are technical barriers, historical failures, undeveloped capital markets, and rough exit mechanism.

(2) The Main Financing Problems of the PV Industry in China

1) Due to high industrial, technology, and market risks, the PV industry’s financing scales are negatively restricted as it is considered a high investment risk.

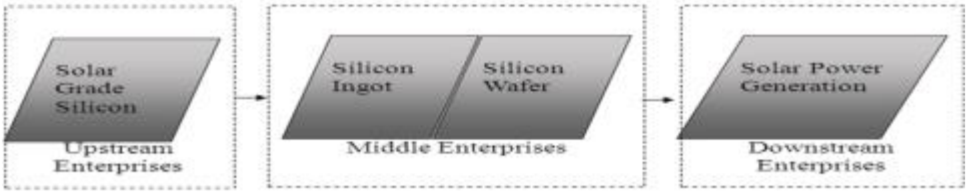
2) Financing channels are simple and credit scales of traditional banks are limited. Direct financing accounts for a relatively low 10% of total industrial funds.

3) Low degree of specialisation in venture investment.

8. Conduction Mechanism of China’s Photovoltaic Upstream and Downstream Industry Policies

The solar PV industry is an industry chain that develops and utilises silicon materials. This chain generally includes upstream firms that mainly produce solar-grade silicon, middle firms that mainly produce solar battery components such as silicon ingot, silicon wafer, etc., and downstream firms that mainly conduct grid-connected and off-grid solar power generation (Figure 8.8).

Figure 8.8: Solar Energy Photovoltaic Industry Chain



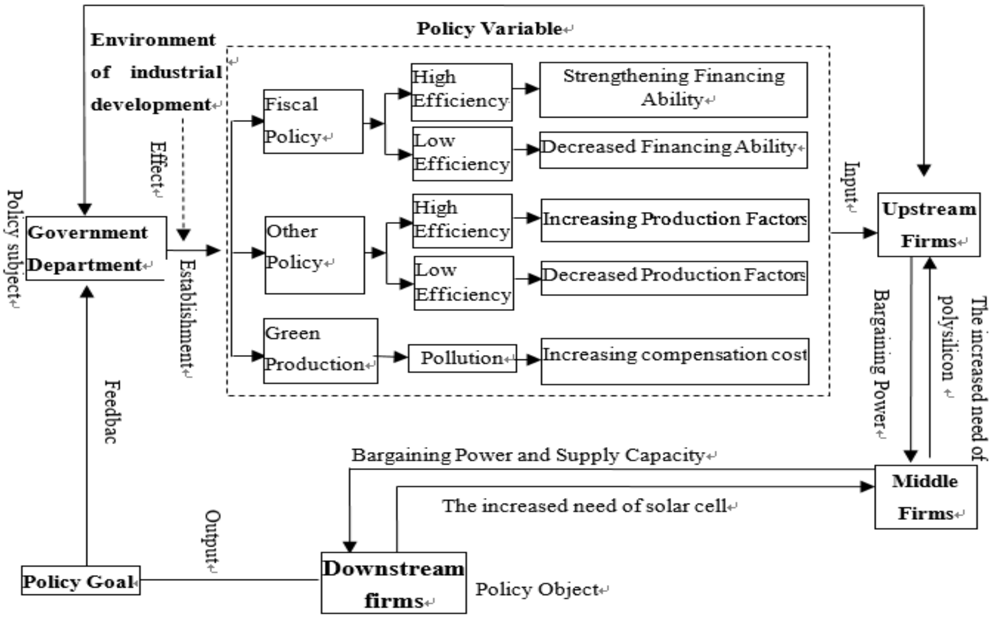
Source: Compiled by the authors.

To meet the requirements of low-carbon economy, developing its solar PV industry—referred to as an important industry providing clean energy in the future—is of great practical and strategic significance to China’s energy security. The central government and local governments have issued a series of solar PV industry policies in recent years to promote the development of the solar PV industry. Continuous good policies have become one of the main driving forces of the development of China’s solar PV industry, covering upstream firms, middle firms, and downstream firms. How would these policies promote the development of the PV industry, or how would the policies for upstream firms affect the development of downstream firms and vice versa? The following aspects will be considered in a study.

8.1. Conduction mechanism of China’s photovoltaic industry policies: from upstream to downstream

The main objects involved in policy-conducting path from upstream firms to downstream firms in the solar PV industry are government, policy variables, upstream firms, middle firms, and downstream firms (Figure 8.9).

Figure 8.9: Conduction Mechanism of China's Photovoltaic Industry Policies: From Upstream Firms to Middle Firms to Downstream Firms



Source: Compiled by the authors.

According to Figure 8.9, the main policy subject of China's solar PV upstream enterprises is the government, which sets fiscal policies, tax policies, and other policies (technical research and development, input and pollution compensation, etc.) based on the developing environment and trends. These policies take effect on the upstream firms, then through the middle firms and to the downstream firms. This policy-conducting process is not only influenced by the macro environment of the PV industry and by the development of the middle enterprises, whose feedback influences the development of the downstream enterprises. In the end, the task of realising the whole policy goal goes back to the government, which continues to modify and formulate corresponding policies to realise the industry goal. During the policy conduction process, the government and the enterprises act as subjects and objects, respectively, in a game. The goal of the government is to promote the development of the PV industry and guarantee the future supply of clean energy. The goal of the enterprises is to maximise their interests. Clearly, the government must ensure energy security while, at the same time, playing a game with the enterprises.

During this process, the government issues a series of industrial policies favouring the development of upstream firms according to the external macro environment of the industry (if the upstream firms can produce high-quality polysilicon products or the efficiency of polysilicon is quite high). For fiscal policies, the government first helps related upstream firms smooth financing channels by implementing more proactive fiscal policies and increasing their subsidies. Secondly, for the other policies, the government further intensifies efforts of developing and upgrading the polysilicon technology, optimising the investment environment, and implementing trade remedy policies, which eventually help the upstream polysilicon plants gain good advantages in international competitiveness. These policies further enlarge the production scale of upstream firms, and stimulate increase in production; enable the upstream firms to provide cheaper and high-quality supply of goods to the middle firms that assemble solar panels, thus promoting the development of middle business and improving product quality. In return, the development of middle firms and improvement of product quality provide a solid foundation and reliable supply for the development of the downstream firms.

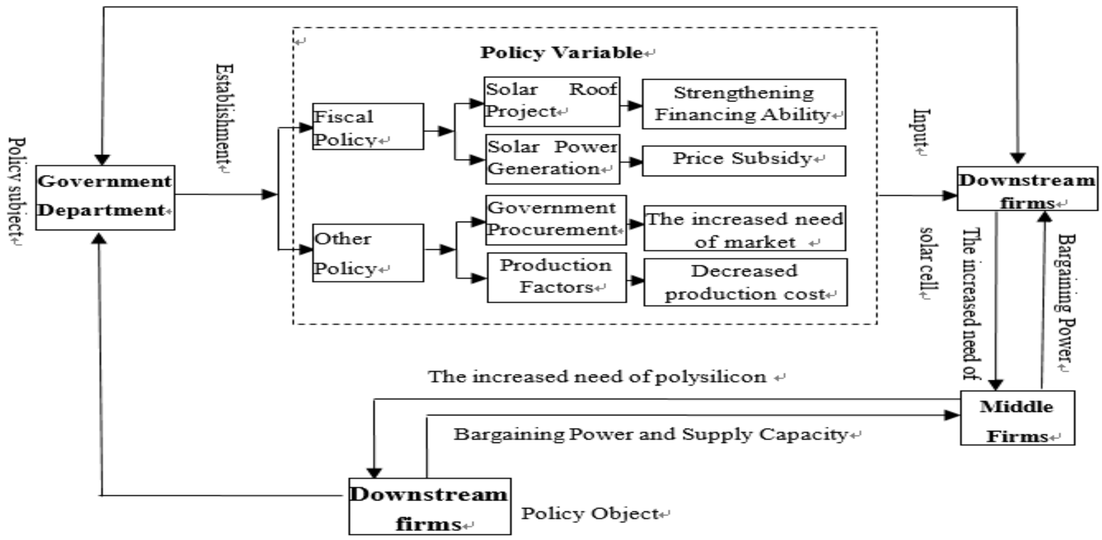
Conversely, if the government reduces its financial inputs to the upstream solar PV firms, cancels tax subsidies, and decreases R&D investments, etc., the production costs of the upstream firms will greatly increase and their advantages in the international market may be gradually lost. Then the middle firms that assemble solar panels will be faced with high-priced supplies with relatively low quality. As a result, the middle firms would not be able to provide sufficient resources for the downstream firms.

8.2. Conduction mechanism of China's photovoltaic industry policies: from downstream to upstream

The policies for the downstream firms that take a large proportion of the total policies of the solar PV industry affect the whole PV industry the most. For example, the Solar Rooftop Program, jointly implemented by the Ministry of Finance and the Ministry of Housing and Urban-rural Development in 2009 with CNY1.27 billion central budget, contributed to a nine-month continuous growth of price for polysilicon from CNY338.475 to CNY609.255 in 2010.

Policies for the downstream firms greatly promote the development of the upstream firms (Figure 8.10).

Figure 8.10: Conduction Mechanism of China's Photovoltaic Industry Policies: from Downstream Firms to Middle Firms and Upstream Firms

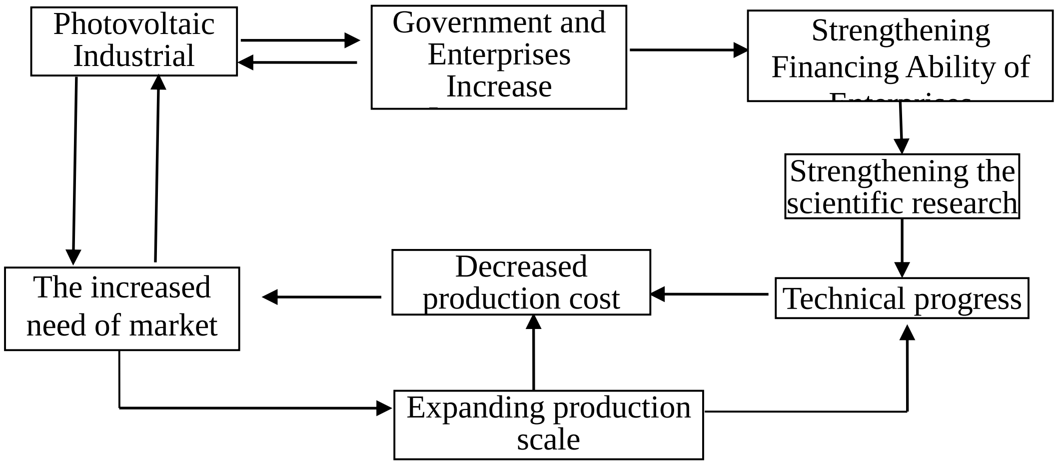


Source: Prepared by the authors.

According to Figure 8.10, the main body of the policy-conducting process from the downstream firms to the upstream firms is still the government. To begin with, the government effectively expands the market demand of downstream firms by implementing the Solar Rooftop Program, the Golden Sun Demonstration Project, and the government purchases. The downstream firms benefit from government subsidies that promote their development to some extent. Secondly, the feed-in tariff on solar power reduces the enterprises' production costs. These policies can greatly promote the development of the solar PV downstream firms, which, as a result, will further effectively increase the product needs of upstream-middle firms by expanding product market and reducing prices.

In conclusion, there are three main paths to promote the development of PV enterprises based on the impacts of the policies for upstream firms on the downstream firms and vice versa (Figure 8.11). Firstly, improve the investment environment of PV firms and enhance their financing ability; secondly, increase the openness of the PV market and raise the R&D and innovation level of PV firms; thirdly, expand the market demand for PV products, provide price subsidies, and reduce the enterprise's production and operating costs.

Figure 8.11: Conduction Mechanism of China's Photovoltaic Industry Policies



Source: Prepared by the authors.

9. Conduction effects of China's photovoltaic upstream and downstream industry policies

9.1. The introduction to the policy-conducting structure of solar photovoltaic industry chain

The solar energy industry chain covers upstream firms that mainly produce solar-grade silicon, middle firms that mainly produce solar energy battery components such as silicon ingot, silicon wafer, etc., and downstream firms that mainly conduct grid-connected or off-grid solar power generation. There are factors that influence the development of the solar PV industry chain. This paper only selects five indicators: price of polysilicon, government subsidies on polysilicon plants, price of solar cell, price of solar power, and the government's price subsidies on solar power.

9.2. Data

To reflect the relationships among these five indicators, data from China's PV industry, China environment, websites, and databases of renewable energy from January 2005 to December 2014 were processed. The selected data were used as sample data and processed separately. Given the non-stationary characteristics of most time series, statistical analysis was conducted on the data of price of polysilicon, government subsidies on polysilicon plants, the price of solar cell, the price of solar power, and the government's price subsidies on solar power. Eviews7.0 was used to analyse the correlation between variables.

Table 8.6 shows that the correlation coefficient between the price of polysilicon and government subsidies on polysilicon plants is 0.92896, between the price of polysilicon and the price of solar cell is 0.81236, between the price of polysilicon and the price of solar power is 0.52466, between the price of solar cell and solar power price is 0.82365, between the price of solar power and government subsidies on solar power is 0.96358. The data above reflect the high correlation between the price of polysilicon and government subsidies on polysilicon manufactures, that is, changes in government subsidies on polysilicon plants will lead to changes in the price of polysilicon, and this effect is relatively significant. Similarly, the impacts of government subsidies for solar power on the price of solar power are also significant. The correlation coefficient between polysilicon prices and government subsidies on solar power is 0.01235; between government subsidies on polysilicon plants and the government's price subsidies on solar power is 0.00235. It indicates some correlation between the price of polysilicon and government subsidies on solar power, as well as government subsidies on polysilicon plants and on solar power, but it is weak. The correlation coefficients between them are small.

Table 8.6: Correlation Coefficient Between Variables

	Price of Polysilicon	Government Subsidies on Polysilicon Plants	Price of Solar Cells	Price of Solar Power	Government Price Subsidies on Solar Power
Price of Polysilicon	1				
Government Subsidies on Polysilicon Plants	0.92896	1			
Price of Solar Cells	0.81236	0.02356	1		
Price of Solar Power	0.52466	0.61356	0.82365	1	
Government Price Subsidies on Solar Power	0.01235	0.00235	0.56951	0.96358	1

Source: Prepared by the authors.

9.3. Methodology

The unit root test, Johansen co-integration analysis, Granger causal test, and the more recently developed technique of directed acyclic graphs (DAG) were used in this study. Most scholars have applied DAG to conduct various effective analyses. The data of the five indicators (the price of polysilicon, government subsidies on polysilicon plants, the price of solar cell, the price of solar power and the government's price subsidies on solar power) of the solar PV industry chain are all time series. If the linear combination of them is stable, their long-term equilibrium relationship can be reflected by their linear combination. If the five indicators are co-integrated, there are unbiased estimators between them; however, it cannot indicate where the strongest correlation exists and which one plays the leading role in their causal relationship. Therefore, a Granger causal test is needed among the five indicators of the solar PV industry chain. Granger causality is based on the short-run causal relationships between variables and is used here to study whether there is a causal relationship between the five indicators of the solar PV industry chain, that is, a relationship of 'cause and effect' between them. Granger causal test proves to be relatively accurate in testing the causal relationship of prices and has been widely used as a result.

Based on the research ideas above, Granger clearly defined the causal relationship in 1969, which not x_{t-n} only can be accurately tested, but also can be used to quantitatively analyse x_t the causal relationship y_t between variables. Granger causality test is a technique for determining whether one time series is useful in forecasting another. For two time serious x_t and y_t, if y_t can be explained by its past of y_{t-1}; and if the lagged value is added at the same time and significantly improves the explanatory power, the x_t is the Granger reason of y_t . This part will give a brief introduction to the Ganger causality test.

(1). Unit Root Test

An important prerequisite to Granger causality is all the time series must be stationary, and this testing process is called unit root test. There are several unit root test techniques and Aggregation-Diffusion-Fractal is the most common. The ADF unit root test is based on the following three regression forms:

1）： $$\Delta y_t = \beta y_{t-1} + \sum_{i=1}^{p} y_i * \Delta y_{t-i} + \varepsilon_t$$

2）： $$\Delta y_t = c + \beta y_{t-1} + \sum_{i=1}^{p} y_i * \Delta y_{t-i} + \varepsilon_t$$

3）： $$\Delta y_t = c + \alpha t + \beta y_{t-1} + \sum_{i=1}^{p} y_i * \Delta y_{t-i} + \varepsilon_t$$

The null hypothesis, for all of them, is: Ho: β =0, that is, the unit root exists. The difference between model 1) and the other regressions is whether the drift and time trend are included. The constant c makes no impact on the asymptotic distribution of β in regression 3), but the trend α affects it indeed. So it should be considered whether the time trend is needed when model 3) accepts the null hypothesis (β =0) according to the ADF critical value, namely, considering whether α =0 while testing β =0. If the testing result shows that the null hypothesis α = β =0 can be accepted, the model 2) should be tested. In the same way, the constant c of the model 2) impacts the asymptotic distribution of β . So it should be tested whether c=0 when β =0. If null hypothesis c= β =0 can be accepted, the model 1) should be tested. The three models will be tested one by one, starting from model 3) to model 1). The test doesn't stop until the null hypothesis is rejected, namely the unit root doesn't exist and the series is stationary.

(2). Granger Causal Test

After the unit root test, Granger causal test can be conducted if the x_t and y_t are both stationary series. Granger causal test can be expressed as the following regressions:

1）: $$y_t = \sum_{i=1}^{m} \alpha_i x_{t-i} + \sum_{j=1}^{m} \beta_j y_{t-j} + u_t$$

2）: $$x_t = \sum_{i=1}^{m} \lambda_i x_{t-i} + \sum_{j=1}^{m} \delta_j y_{t-j} + v_t$$

Where the error terms u_t and v_t are assumed to be uncorrelated the null hypothesis of Granger causality is "X does not Granger-causes Y" or "Y does not Granger-causes X". The testing process can be discussed as follows:

1） If the coefficients of lagged x in model 1) are significantly different from zero ($\sum \alpha_i \neq 0$), and coefficients of lagged y in model 2) are not significantly different from zero ($\sum \delta_i = 0$), there is a unidirectional causality from x to y, namely x→y.

2）If the coefficients of lagged x in model 1) are not significantly different from zero ($\sum \alpha_i = 0$), and coefficients of lagged y in model 2) are significantly different from zero ($\sum \delta_i \neq 0$), there is a unidirectional causality from y to x, namely y→x.

3）If both the coefficients of lagged x in model 1) and the coefficients of lagged y in model 2) are significantly different from zero ($\sum \alpha_i \neq 0$ & $\sum \delta_i \neq 0$), there is a causal relationship between x and y, namely $y \leftrightarrow x$.

4）If both the coefficients of lagged x in model 1) and the coefficients of lagged y in model 2) are not significantly different from zero, there is no causal relationship between x and y, namely x and y are independent on each other.

(3). Directed Acyclic Graph

The Directed Acyclic Graph (DAG) is at present a widely-used analytic method. It mainly uses graphics to explore causal relationship that has nothing to do with the time sequences between variables. This method determines the causal relationship between variables mainly through calculating the conditional correlation coefficient and correlation coefficient, and mainly makes use of statistics to test the significance of the causal relationship between variables. The following three hypotheses are used to prove and determine whether the causal relationship exists between variables: sufficiency of causal relationship, confidence of causal relationship, and Markov Conditions. Sufficiency of causal relationship: All of the influencing factors of causal relationships can be found based on the premise that there is no missing data and the variables are complete, so the results of DAG by PC algorithm are accurate. Regarding confidence of causal relationship (with the relationship between correlation coefficient and the variables of directed edge and undirected edge), if both the conditional correlation coefficient and the correlation coefficient are zero, there is no undirected and directed link between these two variables. Markov Conditions: Change the probability distribution of variables in DAG into only probability distribution of the parent node and variables analysed. The PC algorithm mainly uses the Fisher's Z-statistics, mainly to test whether the partial correlation coefficient is significantly different from zero. The formula is as follows:

$$z[p(i, j|k)n] = 1/2\,(n - |k| - 3)^{1/2} \times \ln\left[\frac{|1 + p(i, j|k)|}{|1 - p(i, j|k)|}\right]$$

Where n is the number of observation samples used to estimate the correlation coefficients , $p(i, j|k)$ is the $z[p(i, j|k)n]\_z[p(i, j|k)n]$ partial correlation coefficient of variables of i and j with k conditional variable ; $|k|$ is the number of conditional variables. If $r(i, j|k)$ is the partial correlation coefficient of observation samples and if variables i, j and k are distributed normally, the bears a standard normal distribution.

(4). State Space Model

The linearised state-space model is conducted in this research, mainly including two equations: the state equation and the signal equation. The state equation can be expressed as:

$$P_t = \alpha_t X_t + R_t I + \chi L + \varepsilon T + B_t$$

where, P is the product price of China's PV firms; L is the government's supporting policy for the PV labours and expressed as the total employment of PV firms; T is the government's R&D supporting policy for the PV enterprise and expressed as the government's R&D investments in the PV enterprise; I is the price subsidy of country or enterprises on their products and expressed as the total price subsidies of ten representative firms in PV chains; X is industrial policy and acts as a virtual variable, which is 0 before implementing the industrial policies and is 1 after the implementation. The signal equation is:

$$X_t = T_1 X_{t-1} + \Phi_t V_t$$

Where, I, L and T are exogenous variable matrices, and B and V are white noise matrices. Suppose that X and P have joint normal distribution, and $X|P$ is conditional probability distribution, so the state equation and the signal equation are interrelated. Pt is constructed by the state vector X_t, exogenous variables It, Lt, Tt and residual item BT; State vector X_t is by its lag form X_t - 1 and residual Vt.

According to the theoretical analysis in this paper, the policies for the upstream (downstream) PV industry can greatly influence the development of the downstream (upstream) enterprises. These influences are not fixed; on the contrary, they will continually change with the changes of domestic and international economic environments as well as the characters of the PV industry itself. In order to accurately describe the dynamic relationship that how the policies for the upstream (downstream) PV industry impact the development of the downstream (upstream) enterprise, the time-varying parameter model of the state space model will be conducted in this paper, which can be expressed as:

$$@signal\ c11 = c(1) + sv1 * jy + sv2 * js + sv3 * zc + sv4 * cz + [var = exp(c(2))]$$
$$@state\ sv1 = c(3) + sv1(-1)$$
$$@state\ sv2 = c(4) + sv2(-1)$$
$$@state\ sv3 = c(5) + sv3(-1)$$
$$@state\ sv4 = sv4(-1)$$

9.4. Empirical results and discussion

The conducting direction and conduction pathway should be clearly specified when analysing the policy conduction process of the solar PV industry chain, that is, analyse what relationship exists between these two influencing factors of the industrial chain. Generally, there is a co-integration relationship between some time series, which can be divided into two cases: one-way relationship and two-way relationship. But there are some special cases where they influence each other but there is no co-integration relationship between them.

According to the Eviews7.0, all the variables are stationary after second differencing at 5% significance level (Table 8.7) and meet the necessary conditions of building co-integration equation.

Table 8.7: Unit Root Test

Variable	Silicon	S-subsidy	Solar	Power	P-power
Testing Form	(c,t,1)	(c,t,1)	(c,0,0)	(c,0,1)	(c,t,1)
t-ADF	-3.14	-1.26	--2.36	-0.42	-0.56
Critical Value	-3.56**	-3.56**	-2.96**	-2.94**	-3.56**
Conclusion	Non- stationary	Non- stationary	Non- stationary	Non- stationary	Non- stationary
Variable	Δsilicon	Δs-subsidy	Δsolar	Δpower	Δp-power
Testing Form	(c,0,1)	(c,t,1)	(c,t,0)	(c,t,1)	(0,0,2)
t-ADF	-3.12	-4.53	-6.13	-4.25	-1.89
Critical Value	-2.96**	-4.36**	-4.36**	-3.62**	-1.52*
Conclusion	Stationary	Stationary	Stationary	Stationary	Stationary

ADF = Aggregation-Diffusion-Fractal.
Notes: Testing form (c,t,k) means the constant, time trend and lag length included in the unit root test.**and* implies stationary at 5% level and 10% level.
Source: Prepared by the authors.

Table 8.7 provides the unit root test results. The T-ADF of five variables are all larger than the critical values at 5% significance level, implying these five variables are non-stationary; but they are stationary after first differencing, suggesting these five indicators are I(1) series. There is a long-run and stable co-integration relationship between solar PV industry chains.

The results above reveal the price system of the solar PV industry chain bears a long-term equilibrium relationship with each other; but the causal relationship between prices of the solar PV industry has not been determined, which need further testing by Granger causality test. As shown in Table 8.8, the prices of polycrystalline silicon, solar cell, and solar power Granger cause each other. Government subsidies on polysilicon plants is the Granger cause of the price of polysilicon, and government subsidies on solar power generation is the Granger cause of the price of solar power; but the price of polycrystalline is not the Granger cause of government subsidies on polysilicon plants, and the price of solar power is not the Granger cause of government subsidies on the solar power. There is a co-integration relationship between solar PV industry chains. The influences of government subsidies for polysilicon plants on the price of polysilicon, and government subsidies for solar power on the price of solar power are relatively significant.

Table 8.8: Granger Causality Test

Null Hypothesis	F-Statistic	P-Statistic	Accept/ Reject the Null Hypothesis
The price of polysilicon does not Granger cause government subsidies on polysilicon plants	1.04532	0.4126	Accept
Government subsidies on polysilicon plants does not Granger cause the price of polysilicon	5.62381	1.E-26	Refuse
The price of polysilicon does not Granger cause the prices of solar cell	2.31256	0.02589	Refuse
The prices of solar cellos does not Granger cause the price of polysilicon	4.58963	0.12356	Refuse
The price of polysilicon does not Granger cause the prices of solar power	2.38965	0.09632	Refuse
The price of solar power does not Granger cause the price of polysilicon	3.34569	0.19865	Refuse
The price of polysilicon does not Granger cause the government's price subsidies on solar power	0.79968	0.58694	Accept
The government's price subsidies on solar power does not Granger cause the price of polysilicon	2.36986	0.08965	Refuse
The prices of solar power do not Granger cause the prices of solar cell	3.18653	0.13256	Refuse
The prices of solar cell do not Granger cause the prices of solar power	2.89564	0.46531	Refuse
The prices of solar power do not Granger cause the government's price subsidies on solar power	1.56897	0.09865	Accept
The government's price subsidies on solar power do not Granger cause the prices of solar power	3.65891	1.56234	Refuse

Source: Prepared by the authors.

The Vector Error Correction (VEC) model can be considered according to the results above. The VEC model is often used for non-stationary time series and the variables in it should be co-integrated. The vector auto regression can be expressed as:

$$\Delta Y_t = \alpha\beta Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i Y_{t-i} + \varepsilon_t$$

The error term of each equation is stationary. But the co-integration can be expressed in many forms. In Error Correction Model, it can be expressed as:

$$\Delta Y_t = \alpha vecm_{t-1} + \sum_{i=1}^{p-1} \Gamma_i Y_{t-i} + \varepsilon_t$$

Each equation is an Error Correction Model. $vecm_{t-1} = \beta Y_{t-1}$ is an error correction that implies the long-term equilibrium relationship between variables, α indicates the speed of adjusting the variables to the equilibrium.

By accurately estimating parameters of ECM, a Correlation Matrix of these five indicators (the price of polysilicon, government subsidies on polysilicon plants, the price of solar cell, the price of solar power and the government subsidies on solar power) is worked out (Figure 8.12).

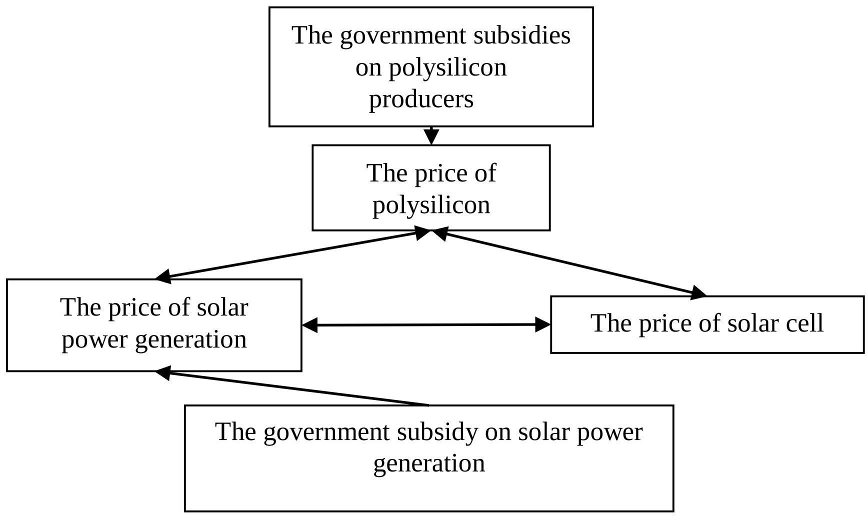
Figure 8.12: Correlation Matrix of Variables

$$\begin{bmatrix} 1 & & & & \\ 0.568956332 & 1 & & & \\ 0.163569732 & 0.045689324 & 1 & & \\ 0.412356871 & 0.423568793 & 0.235686369 & 1 & \\ 0.562368742 & 0.259657364 & 0.162368027 & 0.089563242 & 1 \end{bmatrix}$$

Source: Prepared by the authors.

Based on this Correlation Matrix of these five indicators, a study of their contemporaneous causal relationship is conducted by Directed Acyclic Graph (Figure 8.13). According to the results, the price of polysilicon, the price of solar cell, and the price of solar power affect each other; the changes of the prices of solar cells can also cause the changes of polysilicon's price, so do the price of solar power and the price of solar cell. It should be noted that government subsidies on polysilicon plants can cause the changes of polysilicon's prices, and then affect the price of solar power through middle enterprise's products. Similarly, government subsidies on solar power can affect the polysilicon's price fluctuations in the same way.

Figure 8.13: Contemporaneous Granger Causality Analysis Between Variables



Source: Prepared by the authors.

9.5. Empirical Results and Discussion

This part constructs the state space model so as to empirically analyse the policy-conducting effects at China's PV industry level (taking impact on price as example). The empirical results are also deeply studied.

(1) Unit Root Test. The variables of state model should be stationary. According to the principles of unit root test, two groups of variables are selected at first. One group is the products' price in the downstream PV industry P1, the government's supporting policy for the upstream PV labours L1, the government's R&D supporting policy for the upstream PV enterprise T1, the price subsidy on upstream PV enterprises I1. The other group is the products' price in the upstream PV industry P2, the government's supporting policy for the downstream PV labours L2, the government's R&D supporting policy for the downstream PV enterprise T2, the price subsidy on downstream PV enterprises I2. Next, ADF text is conducted for these two groups of variables. According to the testing results, the T-ADF is larger than the critical value at 10% significance level, implying these two groups of variables are stationary.

(2) The impact of upstream industry policy on the prices of downstream products. Considering the impacts of upstream PV industry policy on downstream products, this study covers 10-year data from 2005 to 2014 and uses the fixed average method for the regression analysis (Table 8.9 and Table 8.10).

Table 8.9: Impacts of Explanation Variables on the Prices of Downstream Photovoltaic Products

	Coefficient	**Std.Error**	**z-Statistic**	**Prob.**
C(1)	3.2098	0.00439	616.6895	0
C(2)	-3.9886	1.99E-09	-152.3657	0
C(3)	0.2015	0.00058	1223.006	0
C(4)	0.1985	1.23E-02	15612.58	0
C(5)	0.1135	4.65E-02	254.8596	0
	Final State	Root MSE	z-Statistic	Prob.
SV1	-0.1686	0.0248	-4685.009	0
SV2	26.6896	0.0475	5639.326	0
SV3	0.2986	3.39E-04	9189.26	0
SV4	0.0161	0.0456	28956.89	0
Log likelihood	-2.58E+06	Akaike info criterion		49869597
Parameters	4	Schwarz criterion		49869598
Diffuse priors	3	Hann an-Quinn criter		49869597

Source: Prepared by the authors.

Table 8.10: Dynamic Impacts of Explanation Variables on the Prices of Downstream Photovoltaic Products

Obs	**SV1F**	**SV2F**	**SV3F**	**SV4F**
2005	0.000	0.000	0.000	0.000
2006	0.1983	0.2894	0.5984	0.000
2007	0.3865	4.5896	-0.108	0.000
2008	-19.233	4.3981	0.098	0.000
2009	96.325	1.798	0.019	0.000
2010	-97.026	1.986	0.156	-368.887
2011	-152.364	5.986	-0.102	309.653
2012	-568.056	-10.365	-0.268	54.562
2013	-319.356	32.892	0.385	1496.356
2014	-509.365	41.236	0.568	2008.369

Source: Prepared by the authors.

As shown in Table 8.9 and Table 8.10, the coefficients of variables are all significant at 1% significance level. In general, (1) For the impacts of upstream PV industrial policies on the downstream products, the policy-conducting effects are not obvious, that is, one unit of price drop due to the subsidy for the upstream PV enterprises leads to 0.016-unit price drop of downstream products, which is mainly due to the nature of the PV industry in China. First, the impacts of polysilicon imports ： Generally, China's polysilicon production technology is poor and, as a result, the costs are higher than the costs abroad and competitive advantages are lost. Relevant data show that the spot prices of polysilicon imports are generally CNY0.5–10,000/tonne lower than the domestic products at the same grade. The domestic polysilicon firms are definitely shocked by these low prices and have to reduce their prices to compete with polysilicon imports for the limited market share. For example, due to the government policies, subsidies, and many other factors, the spot price of domestic polysilicon dropped from CNY165,000/tonne to CNY125,000/tonne, decreasing by 24.24%, from April 2014 to April 2015. The electricity-generating price of downstream PV industry only dropped from CNY1.2/kwh in 2014 to CNY1.15/kWh, only by 4.17%, which was small.

Second, the large impacts of demand for downstream products. For the same kinds of polysilicon products abroad, China is not competitive and has less export demands. On the contrary, the polysilicon imports greatly influence China's polysilicon enterprises. According to the silicon industry branches, China's polysilicon enterprises had about 8500 tonnes of internal inventory by the end of April 2015, which means most domestic firms suffered more than one month of inventory, which was much more than the normal range of one-week inventory and caused considerable pressure on firms' sale and capital operation. Faced with the double pressure of dumped imports and weak demand, domestic polysilicon's price had to continuously decrease, from CNY166,000/tonne in early April 2014 to CNY120,000/tonne at the end of April 2015. So, the impact of policy and subsidy for the upstream enterprises on the product price of downstream enterprises are weak. (2) For the analysis of the dynamic coefficients, the upstream industry policy had great influence on the downstream products in 2006, 2013, and 2014. In 2006, polysilicon firms were at the early stage of development, and the government introduced the Measures for The Control of Renewable Energy Fund, both of which made the price changes of upstream products produce large influence on the prices of downstream products. In 2013 and 2014, Chin's solar cells saw sustainable production growth. For example, China produced 26.2 million kW solar cells in 2013, with year-on-year growth of more than 20% and accounting for 65% of global production, which greatly promoted the development of the polysilicon enterprises and further increased the influences of the polysilicon price on that of downstream products. (3) The impact of downstream industry policy on upstream product prices. The method is the same as (2), using 10-year data from 2005 to 2014 and conducting regression analysis by fixed average method. See Table 8.11 and Table 8.12 for results.

Table 8.11: Impacts of Explanation Variables on the Prices of Downstream Photovoltaic Products

	Coefficient	**Std.Error**	**z-Statistic**	**Prob.**
C(1)	2.1986	0.00256	589.3651	0
C(2)	-2.6589	0.98E-12	-123.3645	0
C(3)	0.1956	0.0127	563.986	0
C(4)	0.2032	0.98E-19	9883.23	0
C(5)	0.1025	3.96E-09	243.368	0
	Final State	Root MSE	z-Statistic	Prob.
SV1	0.2358	0.0566	-456.156	0
SV2	9.3651	0.0759	2356.234	0
SV3	0.2866	2.99E-08	8563.45	0
SV4	2.3564	0.0563	12368.58	0
Log likelihood	-1.49E+06	A kai ke info criterion		38978447
Parameters	4	Schwarz criterion		38978448
Diffuse priors	3	Hann an-Quinn criter		38978447

Source: Prepared by the authors.

Table 8.12: Dynamic Impacts of Explanation Variables on the Prices of Upstream Photovoltaic Products

Obs	**SV1F**	**SV2F**	**SV3F**	**SV4F**
2005	0.000	0.000	0.000	0.000
2006	0.4563	0.5637	0.1235	0.000
2007	0.5632	5.4563	-0.068	0.000
2008	18.3642	6.4521	0.098	0.000
2009	56.325	0.5621	0.063	0.000
2010	32.376	5.7531	0.638	-125.456
2011	12.452	6.4573	-0.174	234.653
2012	45.237	9.457	-0.453	65.123
2013	23.54	13.653	1.478	2356.568
2014	63.365	23.647	1.037	2145.368

Source: Prepared by the authors.

According to Table 8.11 and Table 8.12, the coefficients of variables are all significant at 1% significance level. In general, (1) for the impacts of downstream PV industrial policies on the upstream products, the policy-conducting effects are relatively obvious, that is, one unit of price drop due to the subsidy for the downstream PV enterprises led to 2.356-unit price rise of upstream products, which is mainly because the demand of upstream products are greatly influenced by the downstream product demand. As mentioned before, China’s polysilicon suffers from poor production technology, high costs, and weak competitiveness. As a result, little changes take place in polysilicon exports but are greatly affected by the domestic demand. For example, the National Development and Reform Commission issued National Development and Reform Commission’s Notice of Promoting Healthy

Development of the Photovoltaic Industry by Price Leverage Function in 2013, which set whole power subsidy for the distributed PV power and the feed-in tariff was CNY0.42/kWh. In the same year, the polysilicon price rose from CNY122,500/tonne to CNY132,800/tonne, increasing by 8.4%. Obviously, the upstream product demand can be greatly influenced by the downstream product markets. (2) For the analysis of the dynamic coefficients, the downstream industry policies had relatively large influence on the upstream products from 2007 to 2012. During this period, China's polysilicon industry at rising stage gradually went into the product-accumulating stage. In addition, the decreasing demand for downstream products and poor subsidy policy led to downstream inventory backlog, which seriously affected the upstream product sales and decreased the prices. According to the silicon industry association, China produced 23,700 tonnes of polysilicon in the first two months of 2015, 11,900 tonnes in January, and 11,800 tonnes in February. However, the domestic demand is far less than the production. At the same time, the US and South Korea exported a large number of polysilicon to China by processing trade last year, which also caused downstream inventory backlog, especially the inventory of last year.

The above analysis implies that the policy-conducting effect from upstream PV enterprises to the downstream products is smaller than that from the downstream PV enterprises to the upstream products.

10. Conclusion and policy implications

The solar PV industry in China has faced many challenges as we have discussed in the previous sessions. Therefore, the government needs to carefully design its policies to encourage healthy growth of the industry. Based on the economic analysis we have conducted above, we would like to recommend the following policy implications:

First, the government should focus on the coordinative implementation of the policy plan and promote the healthy and coordinated development of the solar PV industry. The central government should coordinate with local governments to provide macroeconomic guidance. For example, the central government should set the solar PV generation plan and annual guidance. Local governments should optimise their annual power generation plans and enforcement projects subject to local resource, electric grid construction, and national quota control. Solar PV generation plants should be built with planned and unplanned investments, as well as generation restrictions led by such unplanned investments should be discouraged. Meanwhile, local governments should improve market transparency and avoid local protection.

Second, the government should increase technology standards for market entry. Some standards should be raised to international levels. Moreover relevant technology regulations should be implemented to enhance technology requirements to ensure that firms with more advanced technology will have better growth potential. More complete and strict standards and authorisation systems should be built up. After sale service standards should also be improved and products that could not reach the standards or overdue projects that could not be restructured should be eliminated from the market. Market should play more important role. Mergers and acquisitions should be encouraged and social resources should be allocated to the firms that meet regulation standards, which indirectly lead underdeveloped firms to exit the market.

Third, the government needs to support indigenous innovations and help solar PV firms enhance their competitiveness. There are many problems in technology economy issues, solar PV grid-connection, storage equipment manufacture and system integration, and electric system adaptation, among others. China should increase research funding to achieve technology breakthrough from materials to system industrial chain integration and local manufacture of high-end equipment. Through construction of research centres or technology upgrade, policymakers should support indigenous innovations and leading firms that have indigenous technologies. With these, the industry will benefit from increased competitiveness and accelerated commercialisation of research outputs.

Fourth, policymakers should improve electricity pricing and cost allocation policies to offer a stable market growth expectations. As there are several lessons to be learned from government subsidies to solar PV power generation projects, policymakers should make further complete policies to provide growth expectations to investment parties. Such a way will make it possible for higher capacity solar PV power generation.

Multilevel solar PV generation markets should be established. On-grid generation and off-grid applications should be integrated. Centralised development and localised application should be coordinated. Policymakers should release the enforcement rules for solar PV grid-connection and cost allocation in electricity pricing. More research should be carried out to find the mechanism to decrease solar PV on-grid prices. Government subsidies should be coordinated with market competition to encourage firms to cut costs and increase technology innovations.

Fifth, fiscal support and tax incentive policies should be applied to eliminate market obstacles. Tax incentives should be provided to solar PV firms and more complete subsidy policies should be established. If resources allow, multi-level subsidies would be the optimal policy choice, i.e. different fiscal subsidies will be given to companies with different technologies and products on different development stages. For firms with less developed technologies, subsidies should focus on technology R&D and demonstration projects. For those with more developed technologies, subsidies should focus on PV generation products. For those with mature technologies, subsidies should be added to electricity consumption, i.e., to end consumers. Market mechanism should lead the development of the PV industry.

Sixth, financial systems should be improved and social capital investments should be encouraged. Policy financing institutions should provide credit support to commercialisation of technology innovation and acquisition of foreign firms with industry-leading technology. The government should also lead various commercial finance institutions on innovative loan products to support indigenous innovations and commercialisation of the PV industry. PV firms that passed the requirements could issue enterprise bonds, corporate bonds, short-term financing bills, and mid-term notes, etc.

Seventh, policymakers should implement strategies that integrate technology, market, and policy. Experience in developed countries has proved that strategies that integrate technology, market, and policy are necessary conditions to secure commercial competition of the PV industry. In China, technology, market, and policy are disconnected from each other, which lacks scale-up effect. The government should give relevant guidance to encourage industry mergers and acquisitions and restructure. It should support those firms with essential technology and strong indigenous innovation potentials. By this way, those PV firms could extend industrial chain, grow large and strong, and then increase risk resistance ability.

References

‘Domestic Photovoltaic Market Began to Crack and Break Through’, *Solar Energy,* (1), 9–10.

China’s Industrial Information Network, June 18, (2014) *Review of the Global Photovoltaic Industry Development and Outlook of China’s Photovoltaic Industry in 2014.*

De La Tour, A., M. Glachant, and Y. Ménière (2011), ‘Innovation and International Technology Transfer: The Case of Chinese Photovoltaic Industry’, *Energy Policy*, 39(2), pp.761–770.

Deng, Z. (2013), ‘The Problems, Obstacles and Development Outlook of China’s PV Application Market’, *Energy of China,* 35(1), pp.12–16.

Dusonchet, L. and T. Entice (2010), ‘Economic Analysis by Solar of Different Supporting Policies for the Production of Electrical Energy Photovoltaics in Eastern European Union Countries’, *Energy Policy*, 38(8), pp.4011–4020.

Energy Bureau of National Development and Reform Commission (2011), *The Twelfth Five Year Plan for Renewable Energy Development*.

European Photovoltaic Industry Association (EPIA). 2011. *Global Market Outlook for Photovoltaics until 2015.*

Greenpeace. (2012), *Clean Production of Solar PV in China.*

Guo, L. (2012), ‘The Domestic Photovoltaic Market to Enter the Comprehensive Ice-breaking Period’, *China Securities Journal,* 23 October.

Guo, Y. (2013), ‘The Photovoltaic Enterprises under the Shadow of Double Anti-dumping’, *Wenhui Daily,* 8 March.

Huo, M. (2012), ‘Cost Reduction Potential of Photovoltaic Power Generation in China’, *Energy Technology and Economics,* 24(5), pp.7–11.

Li, J. .*2005–2014 China Solar PV Report*. Beijing: China Environmental Science Press.

Li, J. et al. (2011), *Annual Review and Outlook for China Solar PV Industry 2011.* Beijing: China Environmental Science Press.

Li, L. and C. Yang (2011), ‘Some Thoughts on the Development Strategy of China’s Photovoltaic Industry’, *Sino-global Energy,* 16(7), pp.30–36.

Li, Q. (2012), ‘The Domestic Photovoltaic Market May Prosper’, *China Electric Power News*, 25 October.

Li, Y. and Y. Wang (2013), ‘Photovoltaic “Personal Power Plant” Full of Promise’, *Economic Daily,* 27 May.

Ma, S. et al. (2010), ‘Analysis on the Cost, Price and Technical Progress of Photovoltaic Power in China’, *Solar Energy,* (4), pp.6–13.

McDonald, N.C. and J.M. Pearce (2010), ‘Producer Responsibility and Recycling Solar Photovoltaic Modules’, *Energy Policy*, 38(11), pp.7041–7047.

Photovoltaic Inverter Market Suffered Slight Setback in 2011. Available at: http://video.eccn.com/news_2012020208104218.

Semiconductor Equipment and Materials International (SEMI) and China Photovoltaic Industry Alliance (CPIA) (2012), *Annual Review and Outlook for China Solar PV Industry 2012.*

Shao, L. (2014), ‘Research on the Development Policies of New Energy Industry of China, Japan and South Korea’, *Contemporary Economy of Japan*, (3), pp.88–94.

Shen Y. (2014), ‘The impact of Supporting Policies on China PV Industry’, *Business and Management*, (3), pp.15–22.

State Council (2013), *Focus on Supporting the Backbone Photovoltaic Enterprises, Increase Fiscal Policy Support (No.24 in 2013, Issued by the State Council).* Beijing: Chinese Government Network.

Sun J. (2011), ‘The Energy Balance and Cooling of Soar Cells in Concentration’. *Power & Energy,* (32), pp.158–161.

Szab O.S., A.J.A. Ger-Waldau, and L. Szab O (2010), ‘Risk Adjusted Financial Costs of Photovoltaics’, *Energy Policy*, 38(7), pp.3807–3819.

Wang, C. (2010), ‘The Major Obstacles and Bottlenecks Restricting the Development of China’s Wang Kaike and Huang Ruliang. Studies on Path Selection for Chinese PV Industry Development in the Background of Low-carbon Economy’, *Inquiry into Economic Issues,* (10), pp.47–51.

Wang, L. L. Li, and G. Qiu (2014), ‘The Study of Germany's Journey of Solar Photovoltaic Power Price Reduction and its Enlightenment for China's PV Industry’, *Green Economy*, (1), pp.228–233.

Wang, S. (2011), ‘Speed Up the Jumping-start of the Domestic PV Market, Cope with the New Change of the International PV Situation’, *Solar Energy,* 4,5,6.

Wang, X. (2013), ‘The Golden Sun Is Coming to an End’, *China Energy News,* 13 May.

Wei, Z. and . B. Yu (2013), China's Photovoltaic Industry Today and Recommended Countermeasures to Problems Faced’, *Sino-Global Energy,* 18(6), pp.15–25.

Xie, G., H. Ying, and J. Lu (2013), ‘Some Issues in the Development of Distributed Photovoltaic Power Generation’, *China Electric Power News*, 31 July.

Xulei, Wang X. (2010), ‘Study on Dynamic Mechanism of Photovoltaic Industry Development’, *Science & Technology Progress and Policy*, 27(22), pp.91–95.

Yang S. (2013), ‘Photovoltaic Industry Development: Policy or Basic Research—Based on the Review of PV Industry Research Literature’, *Contemporary Economy & Management,* 35(3), pp.15–22.

Yu L. and Y. Yihong (2012), ‘Evaluating on the Policy System of Photovoltaic Industry: Multi-levels or Diversification’, *Reform*, (8), pp.114–122.

Zhao, Z., S. Zhang, and Y. Tian (2012), ‘The Development Route of the Photovoltaic Industry in China’, *Renewable Energy Resources,* 30(4), pp.1–5.

Zhu, J., and J. Sun (2012) ‘The New Problems and Countermeasures in the Development of Photovoltaic Industry in China’, *Enterprise Economy,* 379(3), pp.125–128.

Zhu, L. (2012), ‘Study on Excess Capacity of Photovoltaic Industry’, Master Thesis, Graduate School of Chinese Academy of Social Sciences.