



HARVARD Kennedy School
JOHN F. KENNEDY SCHOOL OF GOVERNMENT

Low-carbon leapfrogging and globalization: How China developed its solar PV industry

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Research interest

How do new (clean-tech) industries develop in space?

Why and how do they locate in latecomer countries like China?

Technology	China	Rest of the world
Wind power (global market share)	43%	57%
Photovoltaic modules (global production)	63%	37%
Solar water heaters (total installations)	66%	34%

Sources: OECD, GWEC und ADB

Often heard explanations

Government support, dumping (e.g. Solyndra), copy-cattig



Existing theories on industry formation

New industries emerge:

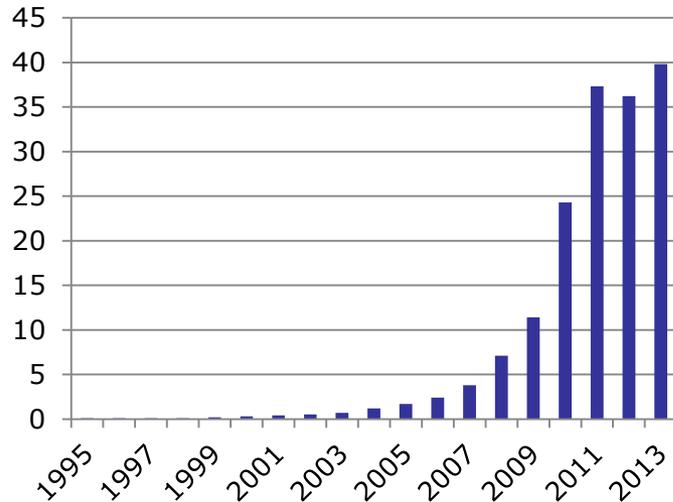
- where factor prices for production are lowest (economists)
- in regions that provide (technological) related industries and competencies (Hausmann Boschma and Frenken 2007, Coe et al. 2008)
- through gradual technology transfer and catching-up (Lee 2001, Fu 2011)

Gaps:

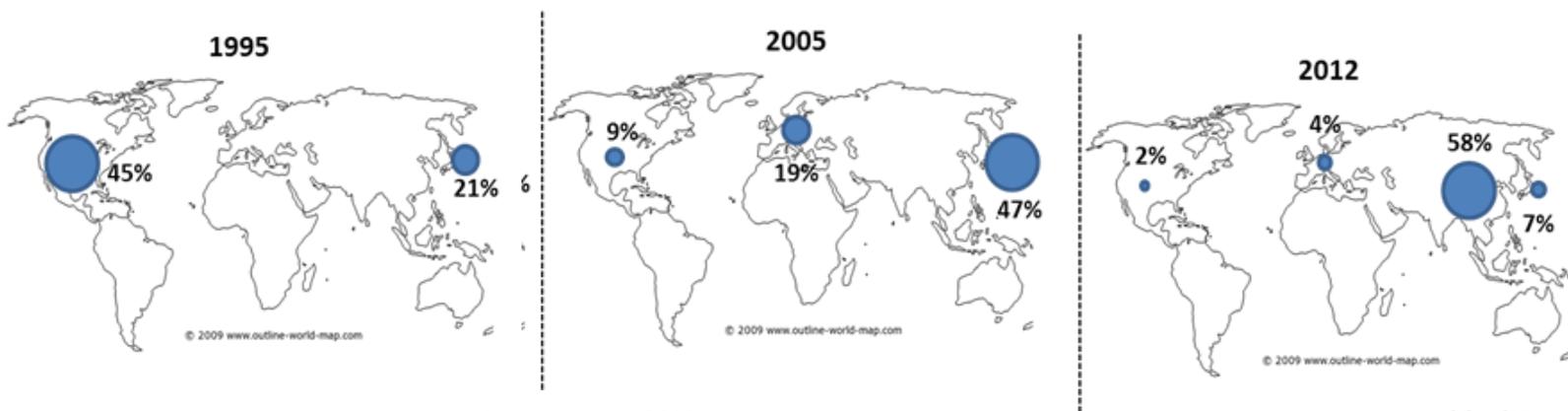
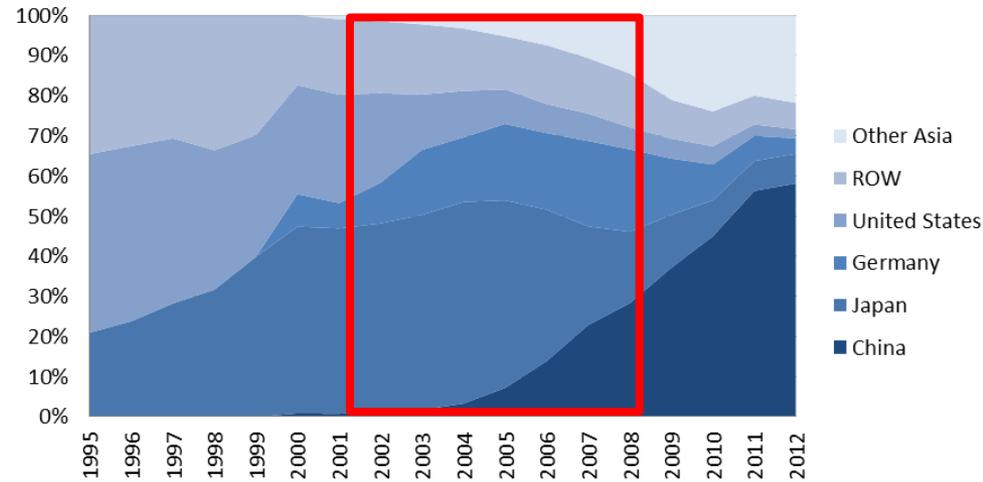
- 'Regional fetishism'
 - Increasing globalization of innovation? (Gallagher 2014, Gosens 2013)
- 'Incrementalism'
 - Technology leapfrogging? (Sauter 2008, Binz et al. 2012)

Solar photovoltaic (PV) industry a case in point

Global PV module production (GW)



Global PV module production (%)



Source: Own design, based on data from Earth Policy Institute (2013)

Research questions

Research question

- How did China leapfrog in solar PV panel production?
- What domestic and extra-regional resources were key in the early path creation stage?
- How did early Chinese entrepreneurs leverage external resources for industry build-up?

New analytical framework for early industry formation

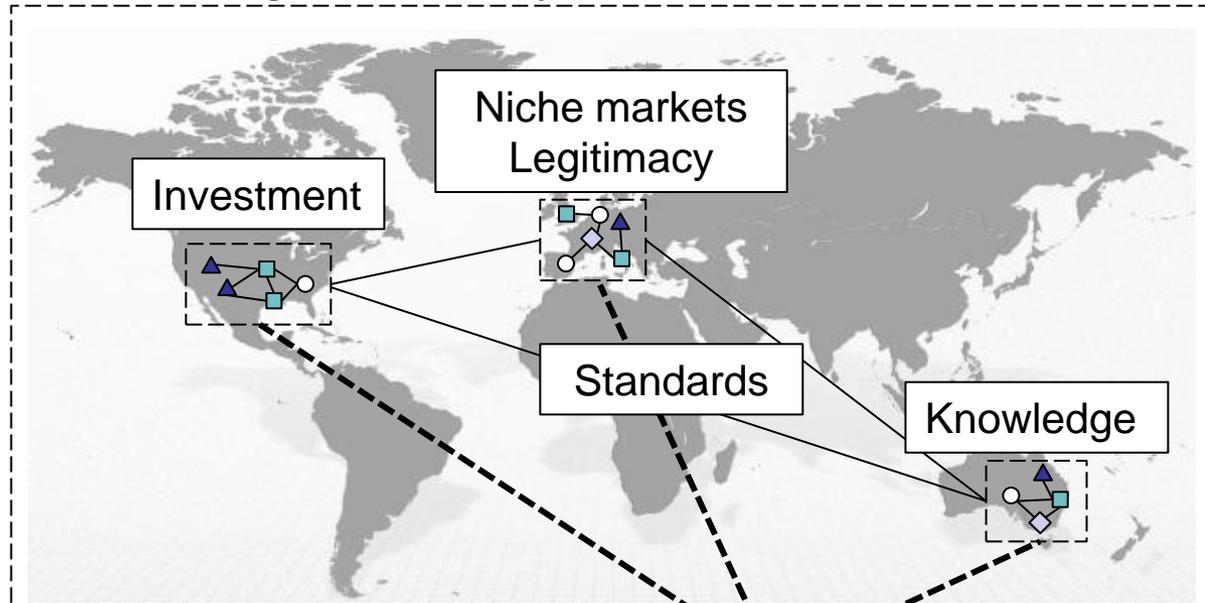
- Technological innovation systems (Bergek et al. 2008)
- Transnational entrepreneurship (Yeung 2009)
- Global innovation networks (Chaminade & Plechero 2015)

Analytical approach (1): Key resources for industry formation

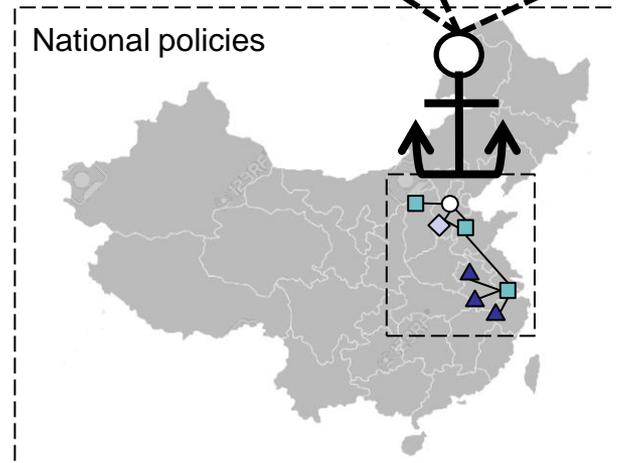
Resource	Key Literatures	References
Basic infrastructure and institutions	Development Economics	Hausmann and Rodrik 2003, Lee and Lim 2001
Knowledge/competencies	Economic Geography	Bathelt et al., 2004; Asheim and Coenen 2005; Boschma and Frenken 2006; Crevoisier and Jeannerat, 2009
(Niche) markets	Transition studies	Kemp et al. 1998; Geels 2002; Dewald and Truffer, 2011; Fligstein, 2007;
Legitimacy	Institutional sociology	Aldrich and Fiol, 1994; Johnson et al., 2006; Suchman, 1995; Zelditch, 2001
Financial investment	Business studies	Gustafsson et al., in press; Teppo, 2006; Bergek et al. 2008
Quality standards	Industrial dynamics	Klepper 1996; Musiolik et al., 2012

Analytical framework (2): Anchoring key assets from global innovation systems

Global technological innovation system



National policies



- ▲ Company
- Research Institute
- ◇ Intermediary
- Government
- Cooperation

Transnational entrepreneurs:
Using global network connections
for local system building

Research design and methods

Research design:

- Single case-study design (Yin, 2012)

Methods:

- Semi-structured expert interviews (Creswell, 2009)
- Qualitative content analysis (Pettigrew 1997)
- Triangulation with secondary data sources

Expert sampling:

- Senior experts from early PV companies and the solar PV sector

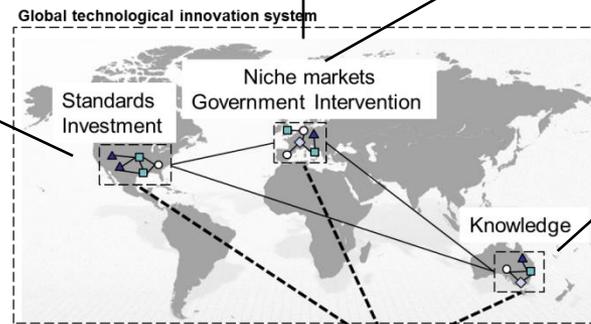
30 expert interviews - overview

Companies:
 Solarex (Founder)
 Underwriter Laboratories

Researcher:
 TU Berlin

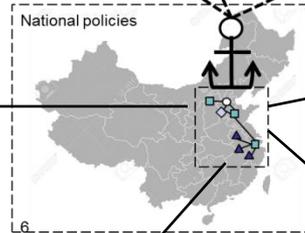
Intermediaries:
 International Energy Council

Researcher:
 University of New South Wales (2)



Companies:
 Suntech (Founder, CTO)
 Yingli (Founder, CTO, senior manager)
 Canadian Solar (Senior manager)
 Trina Solar (CTO, senior manager, technician)

Hareon Solar (Founder, CTO)
 Jinko Solar (Senior manager)
 Shanghai Solar (Founder)



Policy experts:
 Energy Research Institute of the NDRC
 Qinghua University (2)
 CAS (1)
 Greenpeace

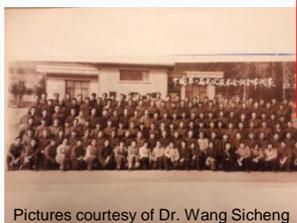
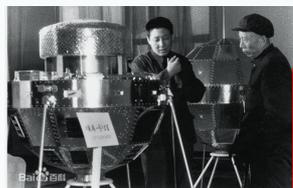
Researchers:
 Qinghua University (1)
 North China Electric Power University (2)

Intermediaries:
 Chinese Renewable Energy Industry Association
 China General Certification Center (CGC)
 China Solar PV Industry Association

▲ Company
 ■ Research Institute
 ◇ Intermediary
 ○ Government
 — Cooperation

Pre-formation

CRED ERI (2000):
 “There is a big gap between PV technology and industry in China and that in more developed countries.”

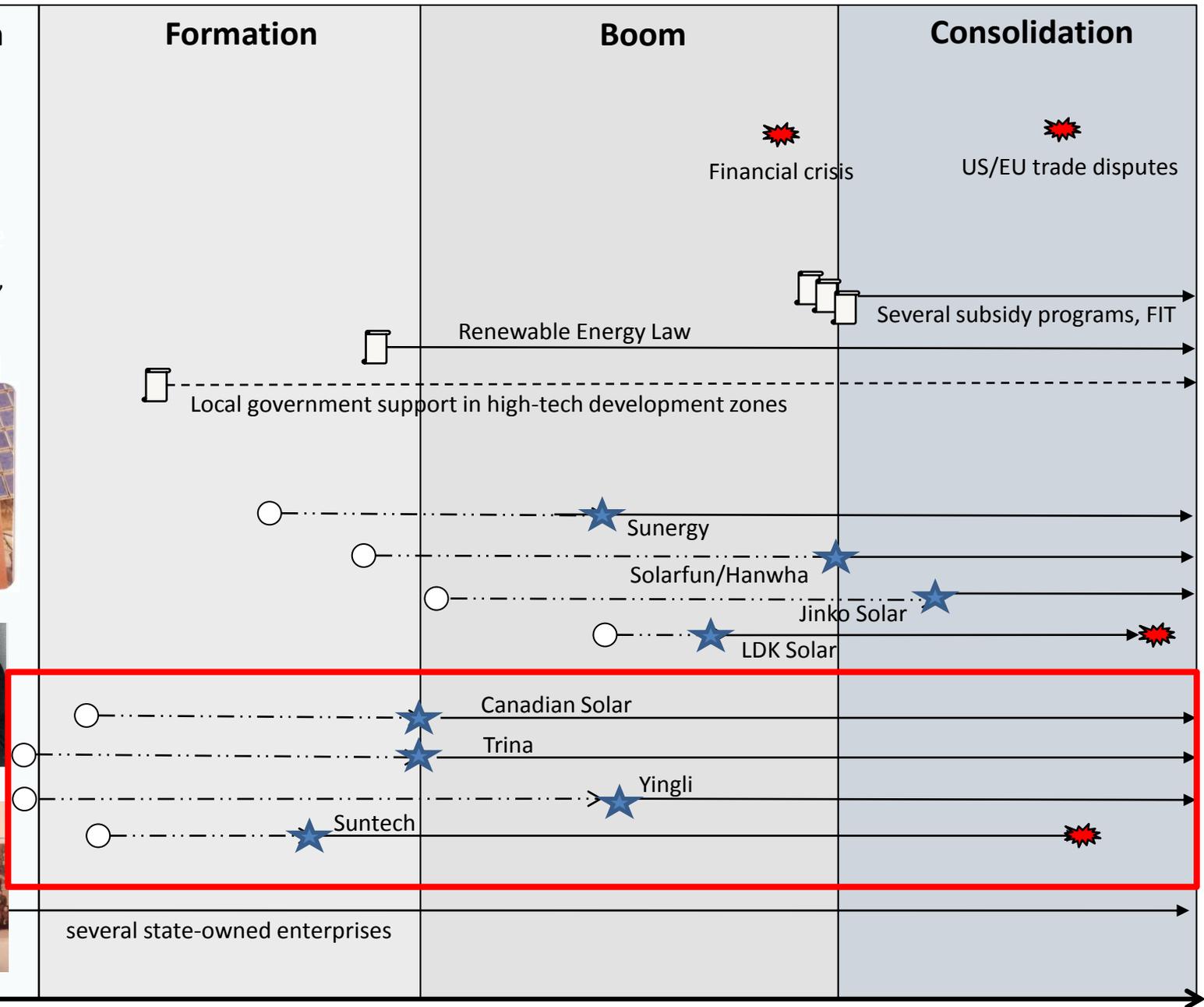


Pictures courtesy of Dr. Wang Sicheng

Formation

Boom

Consolidation



1980 1990 2000
 ★ initial public offering

○ foundation date

★ bankruptcy/disruption

2006

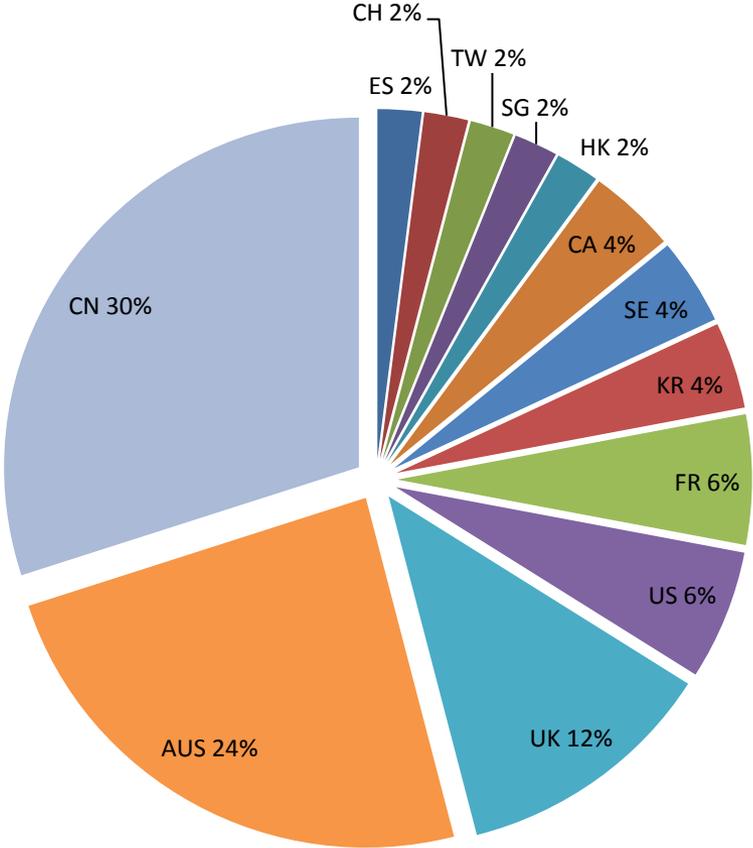
2008

2010

2015

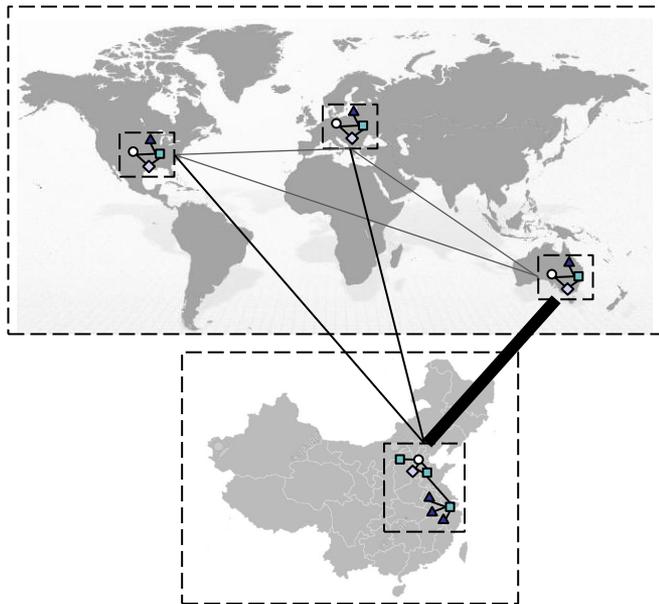
Results 1: Knowledge

Master diploma of the executive directors of 4 biggest Chinese PV companies



Source: annual reports of Yingli, Trina, Suntech, Canadian Solar (2007)

Results 1: Knowledge (ctd.)



Shi Zhengrong: "It was very clear in my mind that I would start the company with the most updated technology. Since 1989 I had spent 12 or 13 years working at the University of New South Wales on solar technology. I had accumulated a lot of knowledge and experience and I felt that I could do something dramatically different".



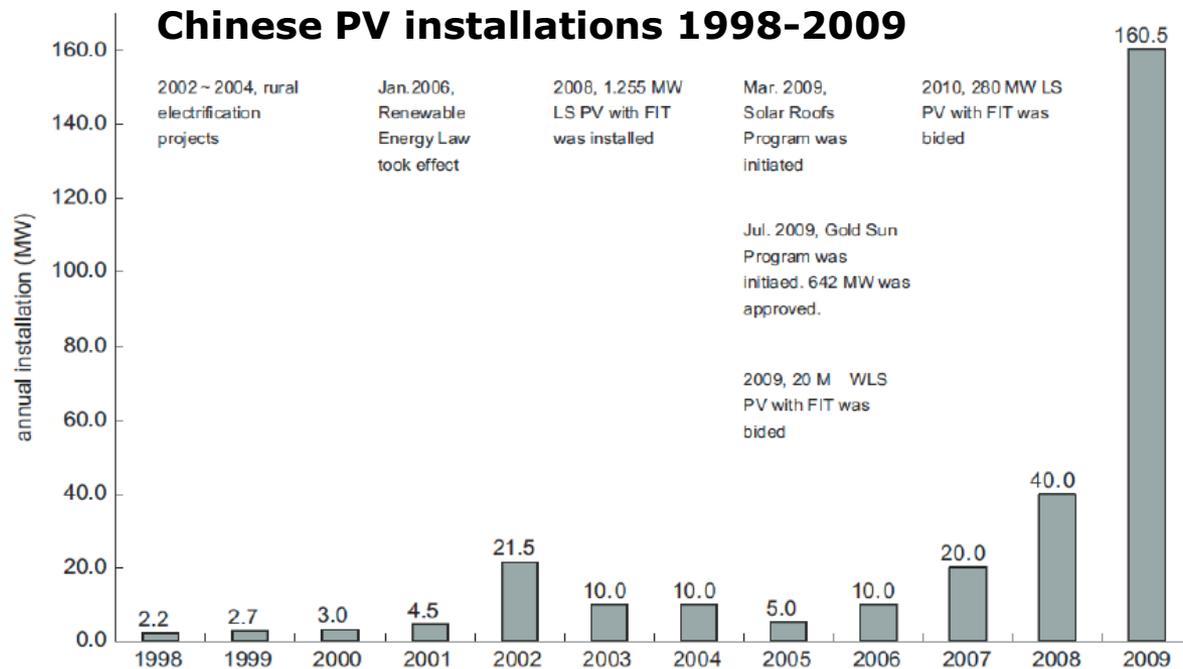
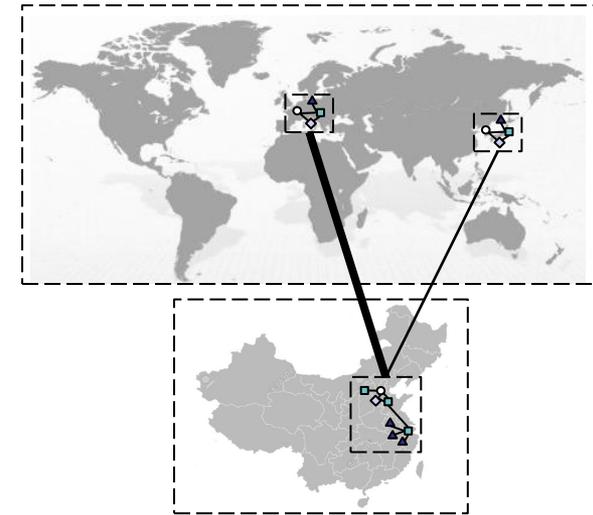
Dr. Shi Zhengrong, founder of Suntech

Anchoring external knowledge:

- Early companies sourcing equipment from US, EU, JP
- Founders of PV companies initiating local supplier networks
- Australian professors training Chinese engineers
- Chinese companies funding research center in Australia

Results 2: Niche markets

CEO of Yingli: "It was very clear in my mind from the beginning that our market would be export, mainly Europe and Japan."



Source: Huo & Zhang 2012, 42

Anchoring external resources:

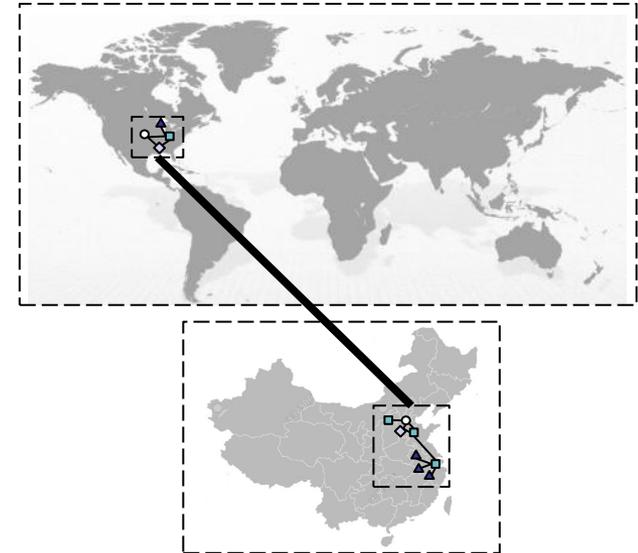
- Build-up of sales representative offices abroad
- Local service teams reporting back to Chinese headquarters

Results 3: Financial investment

CEO of Suntech: “The company needed money. We had eight local shareholders. They didn’t really want to put in more money at the time. We needed access to the capital market. There were some American banks and investors that had followed us for more than a year, which I didn’t realize.”

Who approached you with the idea of an IPO?

“Some financial experts. Goldman Sachs, Morgan Stanley.”



	Suntech	Trina	Canadian	Yingli	Total
IPO place/year	2005 NYSE	2006 NYSE	2006 NASDAQ	2007 NYSE	
Pre-IPO equity	\$96mn.	\$40mn.	\$12mn.	\$22mn.	\$170mn.
IPO revenue	\$395mn.	\$98mn.	\$115mn.	\$391mn.	~\$1bn.

Anchoring external resources:

- Initial public offerings at NYSE, NASDAQ
- Investor “roadshows” in the USA

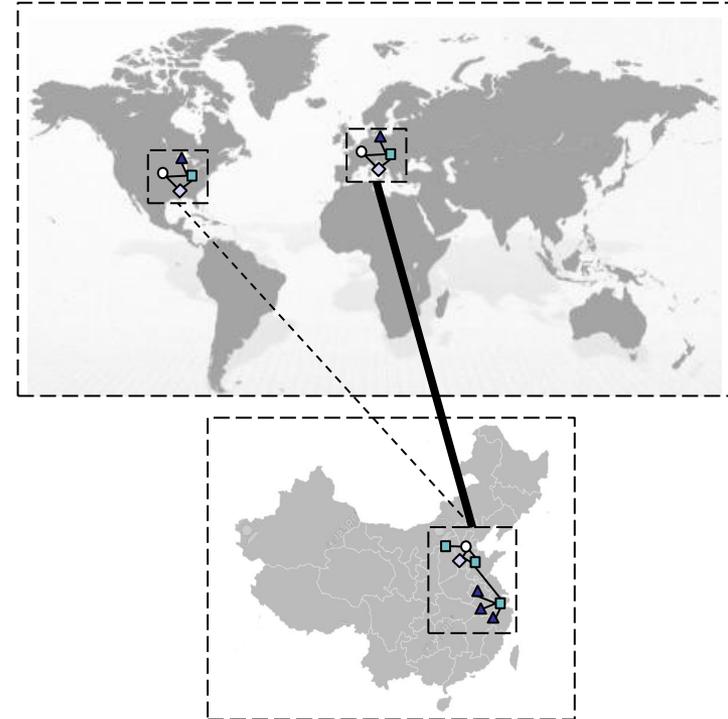
Source: Quitzow (2013: 38), annual reports

Results 4: Quality standards and legitimacy

Founder of Chinese PV company: "In Spring 2003 we had our first exhibition in Berlin. We were the only Asian company. People said, "hey, who's this guy, where did he come from?" We were so proud. We had this international certification. No other Chinese company could do it. It had quite an impact in China."

Anchoring external resources:

- Getting quality certification in Germany, Spain, USA



Discussion - Key resources in overview

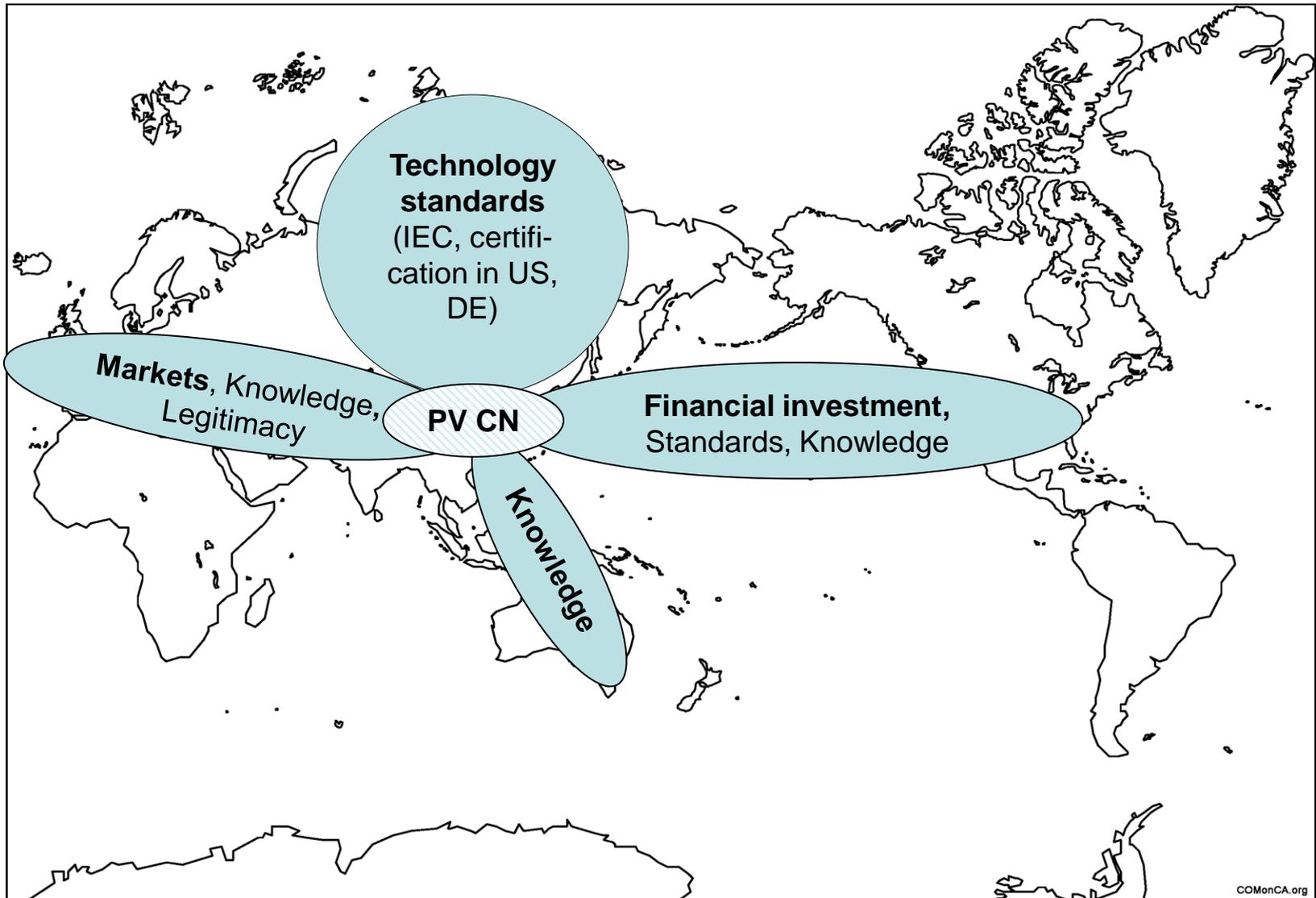
Asset	Formation phase (2001-2008)		Growth phase (2008-2012)	
	Domestic	International	Domestic	International
Knowledge/competencies	<p>+ small incumbent industry, basic research at universities</p>	<p>++ connections to Australia, Canada, Germany, Japan</p>	<p>+</p>	<p>++</p>
(Niche) markets	<p>0 domestic market not functional</p>	<p>++ sales to booming markets in Germany, Spain</p>	<p>++</p>	<p>+</p>
Quality standards and legitimacy	<p>0 domestic quality certificate only emerging</p>	<p>++ getting quality certification in Germany, Spain, USA</p>	<p>+</p>	<p>++</p>
Financial investment	<p>+ generic support by local governments (tax cuts, land) and regional banks (loans)</p>	<p>++ IPOs at US stock markets</p>	<p>++</p>	<p>+</p>

0: no activity +: weak activity ++: strong activity -: hindering activities

Basic infrastructure and institutions:

Competence in scaling-up knowledge-intensive manufacturing (Nahm 2014)
National institutional framework (firm-government interaction)

Discussion 2 – Spatial origin of key resources



COMonCA.org

Conclusions

1) How did China leapfrog in solar PV panel production?

- Not (only) factor prices, pre-existing capabilities, government intervention
- Direct integration into global innovation networks of transnational entrepreneurs
- Anchoring external system resources

2) Broader implications

- Solar PV not a single case: Other easily exportable mid-tech sectors show similar spatial properties (water recycling technology, electronics manufacturing,...)
- Strong need to 'internationalize' innovation theories

3) Policy implications

- Increasing global interdependencies not reflected in national policy making
- Strong R&D capabilities no guarantee for first mover advantage
- New (international) governance/coordination of innovation policies?

Take home messages

- 1) Forget the 'dumping-subsidizing-copycatting' story
- 2) Industry formation is geographically more complex than what existing theories (and the media) assume
- 3) New policy approaches are needed that reflect the increasing globalization of innovation

Thanks for your attention!

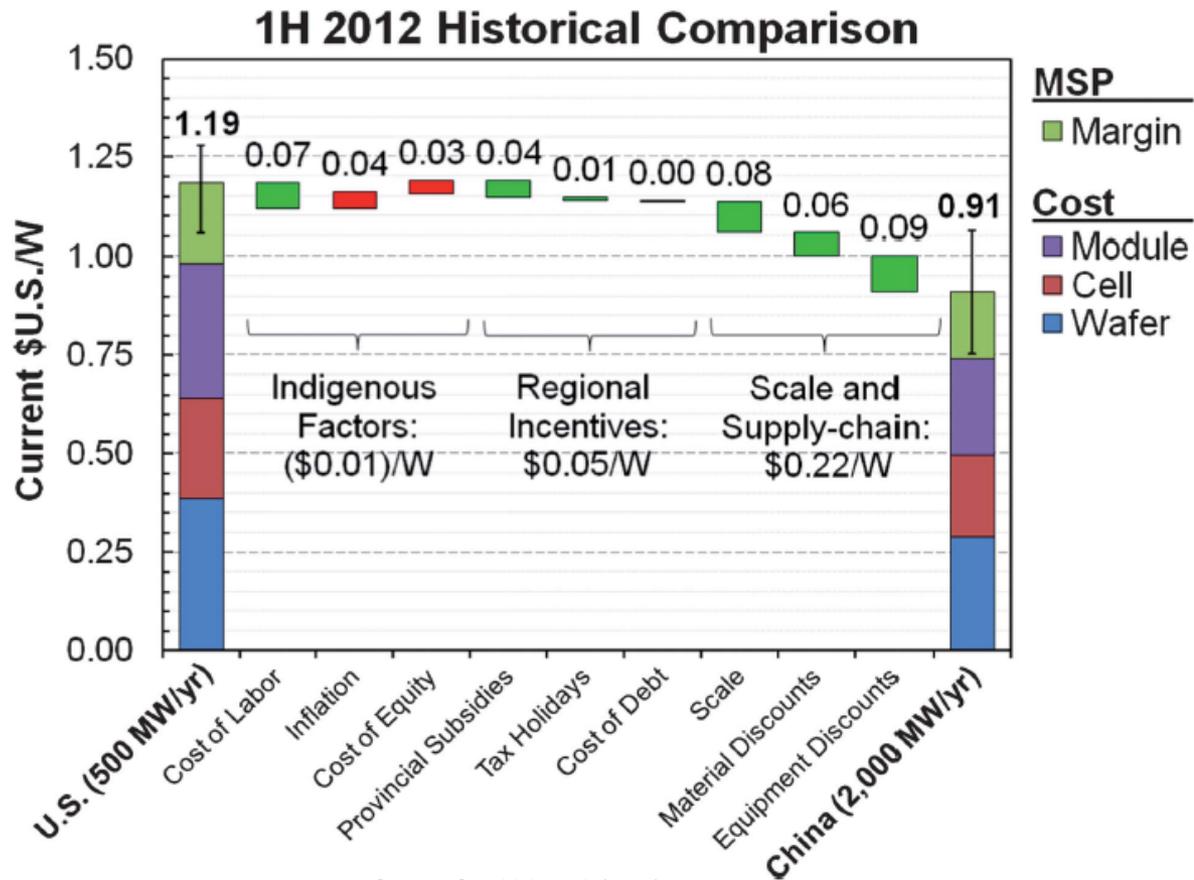
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China's price advantage in PV manufacturing



Source: Goodrich et al. (2013)

PV value chain



Source: http://www.sneresearch.com/eng/info/show.php?c_id=5016&pg=1&s_sort=&sub_cat=&s_type=&s_word=