



Rainer Quitzow

Forschungszentrum für Umweltpolitik (FFU)

Freie Universität Berlin

rainer.quitzow@fu-berlin.de

www.fu-berlin.de/ffu

A Dynamic Analysis of Internationalization in the Solar Energy Sector:

The Co-Evolution of TIS in Germany and China

Energy Systems in Transition

Karlsruhe, October 2013

SPONSORED BY THE



Federal Ministry
of Education
and Research



Objective of the Paper

- Development and application of an approach for analyzing the dynamics of innovation and industrial development...

...in *emerging industries*

...taking into consideration the role of *developed and emerging economies*

...especially during phases of *growth and internationalization*

Existing literature on Lead Markets

- Considers country-specific characteristics to explain why domestic innovations become globally successful
 - Focus on *the leader, not the follower*
 - Focus on *competition between countries*
- Focuses on *demand-side* factors
- Does *not* take into consideration *dynamics within the system*

Existing literature on Technological Innovation Systems (TIS)

- Provides a framework for the *dynamic analysis* of a TIS based on the development of *system functions*
- Has mainly focused on the empirical analysis of *single countries or the comparison of countries*
- Has largely ignored
 - *inter-linkages between countries* (and the respective actors)
 - that individual system functions within a national TIS may be *supplied by a foreign country*
 - that different country-level TIS may play *different yet complementary roles* during TIS development

Emerging literature on the TIS and the geography of innovations

- Existing contributions have focused on TIS in emerging countries embedded in an international TIS
- Implicit assumption: Innovation in industrialized country followed by diffusion in emerging countries
- Similar to lead / lag market concept

No longer applicable in all emerging environmental technology / renewable energy industries

Adaptation of the system functions approach to explain internationalization in emerging industries

- Concept of a *global, multi-level TIS* comprising multiple, *co-evolving country-level TIS*
- “*Co-evolving*” means that country-level TIS are *interdependent* but retain an important degree of *autonomy*
 - Applies to *emerging industries in policy-driven markets*, but not necessarily to mature, largely market-driven industries (esp. when multi-nationals are present)
- *Inter-linkages and asymmetries between country-level TIS* are crucial for explaining the growth phase of TIS
- System functions should explicitly include *development of economies of scale and cost reduction* in growth phase

Scope of empirical analysis

- The analysis focuses on:
 - the core value chain for *crystalline silicon PV solar modules* (i.e. from production of purified silicon to module assembly)
 - the period from *2004 to 2010* (growth phase)
 - *Germany and China*, due to their crucial roles in driving the development of the global TIS
- Considers *important inter-linkages with third countries*, but does not consider their internal dynamics

Legitimation

Germany

- Red-Green government and successful wind sector development provide boost to renewables

China

- Increasing government support for renewables from Chinese central government, but low priority for solar PV (up to 2009)
- Identification of PV industry as strategic emerging industry in 12th Five Year Plan (drafted in 2010)

Linkages

- Supply shortage in Germany provides opportunity for Chinese firms to prove themselves via licensing and supply agreements
- International success boosts legitimacy of the industry in China
- Yingli's sponsorship of the FIFA World Cup represents breakthrough in building independent brand identity

Market formation

Germany

- Feed-in tariff provides stable framework for market development

China

- No significant policies to support domestic market until 2009
- Launch of Building Integrated PV program and Golden Sun Program in 2009

Linkages

- Chinese firms exploit markets in Germany and other European countries (notably Spain and Italy)

Entrepreneurial experimentation

Germany

- Few post-2004 entrants in the area of silicon-based PV modules
- Increasing dominance of a small number of vertically-integrated firms + one large cell producer (Q-Cells)
- Entry of a number of experimental thin film producers

China

- Exponential increase in new firms focused on silicon-based PV module production („exploitative entrepreneurship“)
- Entry and growth strategies move upstream (wafers, silicon)

Lack of linkages

- Surprising lack of joint ventures

Resource mobilization

Germany

- *Demand-side*: Investment boom supported by KfW, local banks and eventually investment funds
- *Supply-side*:
 - Investment enabled by public subsidies, German stock exchange, bank lending, company revenues
 - Investments lag behind demand, esp. in production of silicon

China

- Investment boom facilitated by local industrial policy
- Strategic financing from China Development Bank from 2010

Linkages: US and China

- Wave of IPOs on NYSE and NASDAQ between 2005 and 2009

Influence on the direction of search

Germany

- R&D and innovation influenced by public R&D agenda and firm strategies (Solar World model and Q-Cells model)
- Focus of public R&D funding on cost reducing innovations in crystalline PV (ca. 50%) and innovations in thin film (ca. 30 %)
- Innovations with medium-term time horizon (approx. 5 years)

China

- Public R&D agenda plays a minor role for module producers
- Industrial development driven by „exploitative entrepreneurship“ and herd investment
- Innovation driven mainly by Chinese comparative advantage in low-cost manufacturing (i.e. short term cost reduction)

Knowledge development and diffusion

Germany

- Ambitious R&D policy promotes knowledge development
- Cooperation between manufacturers and equipment industry enables rapid knowledge development and diffusion

China

- Limited public R&D funding, focus on silicon production
- Domestic diffusion of knowledge from pioneers to second mover firms via human resources

Linkages

International knowledge transfer facilitated by:

- German equipment suppliers
- Knowledge partnerships with the University of New South Whales
- Chinese returnees

Development of positive externalities

Germany

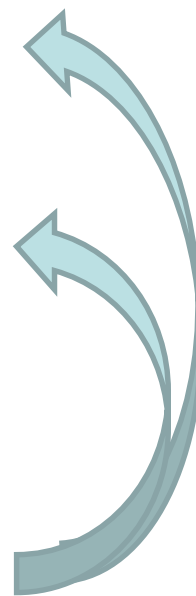
- Manufacturing cluster in former East Germany, R&D clusters in Southern Germany

China

- Cluster development in Jiangsu and Jiangxi Provinces
- Second and third tier producers benefit from the presence of Chinese brands (i.e. Yingli, Suntech, etc.)

Linkages: Global Externalities

- Diffusion of feed-in tariff scheme = export opportunities
- Availability of more specialized machinery as well as turnkey production lines at increasingly lower cost, due to
 - German innovation alliances
 - Chinese investments in manufacturing capacity



Economies of scale and cost reduction

Germany

- Cost reductions through innovation and scaling-up of production, supported by public investment subsidies
- Lack of timely investment in production of purified silicon and silicon wafers causes supply shortages and hence price increases

China

- Cost reductions via:
 - rapid development of scale economies
 - aggressive industrial policy and access to low-cost finance
 - development of significant over-capacity

Feedbacks and cumulative causation

- Large scale investment in China leads to build-up of domestic and international over-capacity
 - Parallel investments in silicon production enable corresponding expansion in output
 - Competition / learning among project developers in Germany reduces BOS costs
-
- *Rapid declines in system prices from 2009*
 - *Rapid market expansion in Germany (and Spain)*
 - *Hasty adjustments to Germany FIT (and collapse of Spanish market)*
 - *Increasing policy / market uncertainty*
 - *Chinese demand-side policy*
 - *Development of Chinese market*

Conclusion: Co-evolution matters

TIS development in both countries was determined by a combination of:

- Domestic policy and innovation system dynamics
- Key linkages with foreign countries in particular between China and Germany

Missing system functions were supplied by foreign countries

► **Inter-linkages enabled an acceleration of TIS development in both Germany and China**

Conclusion and a question: TIS and Lead Market concepts

Expanded TIS framework:

- is needed for explaining dynamics in particular during phase of **growth and internationalization**
- helps shed light on **shifts in the geography of industrial development and innovation**
- **lead market / lead supplier** dynamics as **alternative** mode of internationalization to **lead / lag market** dynamics

Question: Which sector or industry characteristics help explain different modes of internationalization?