An Analysis of Industrial Policy Support for the Indian Solar Photovoltaic Manufacturing Sector

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Industrial policy part of India's solar energy policy

Jawaharlal Nehru National Solar Mission (NSM) part of India's National Action Plan on Climate Change and aims to:

- Install 22GW (20GW) of (grid-tied) solar power capacity by 2022
- Grow a domestic solar power technology manufacturing base

NSM policy includes:

- Federal support for solar power purchase agreements
- Industrial policy support, in form of domestic content requirements (DCRs), to support local industrial base

NSM progresses in phases, and DCR has tightened since beginning:

- Phase I, Batch I required 100% of crystalline (c-Si) modules to be domestically sourced; current policy also includes cells
- Proposed expansion would include thin-film modules and cells

Analysis examines efficacy of NSM industrial policy

Motivation: To what extent will NSM industrial policy

1. Threaten NSM deployment goals?
2. Yield greater consumption of domestic c-Si cells and modules?
3. Ensure global competitiveness of the domestic solar industry?

Our analysis has four central findings; NSM industrial policy:

1. Will not constrain deployment goals
2. Unlikely to ensure global competitiveness
   - Evidence suggests industry has become less competitive over time
   - Proportion of (domestic) c-Si unchanged relative to non-NSM plants
   - Institutional gaps challenge implementation
3. Unlikely to increase consumption of domestic c-Si cells/modules
4. Implies likely losses in dynamic efficiency that will be borne by project developers and/or electricity consumers

NSM industrial policy does not constrain deployment

Proposition 1: Domestic c-Si supply constraints unlikely to bind

- Current capacity 1.7GW; in NSM PI, BII target is 350MW
- With linear deployment expansions, Indian cell and module capacity would remain non-binding over the NSM
- Note exposure to supply bottlenecks upstream
- Switch to thin-film DCR could constrain deployment

Indian solar PV sector has become less competitive

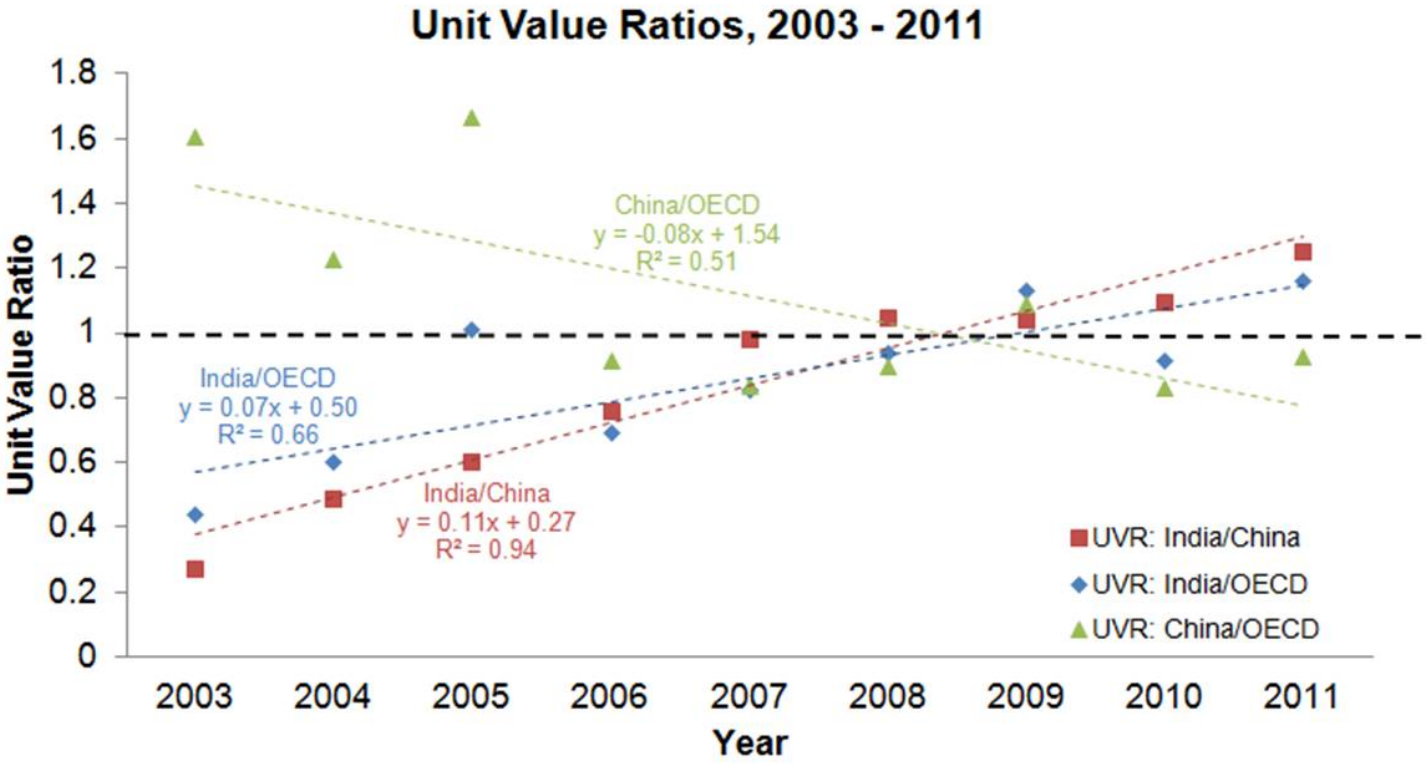
Proposition 2: Competitiveness metrics suggest the Indian solar PV industry has become less competitive over time:

1. Unit Value Ratio (UVR): compares the unit value of Indian exports with those of other countries
2. Revealed Competitive Advantage (RCA): compares the proportion of good in a country's export mix to that in the global export mix
3. Utilization of cell and module manufacturing capacity
4. Apparent sensitivity to export market feed-in-tariff support

The India/China and India/OECD UVRs have decreased

Across countries for a given industry, higher UVRs indicate decreasing competitiveness:

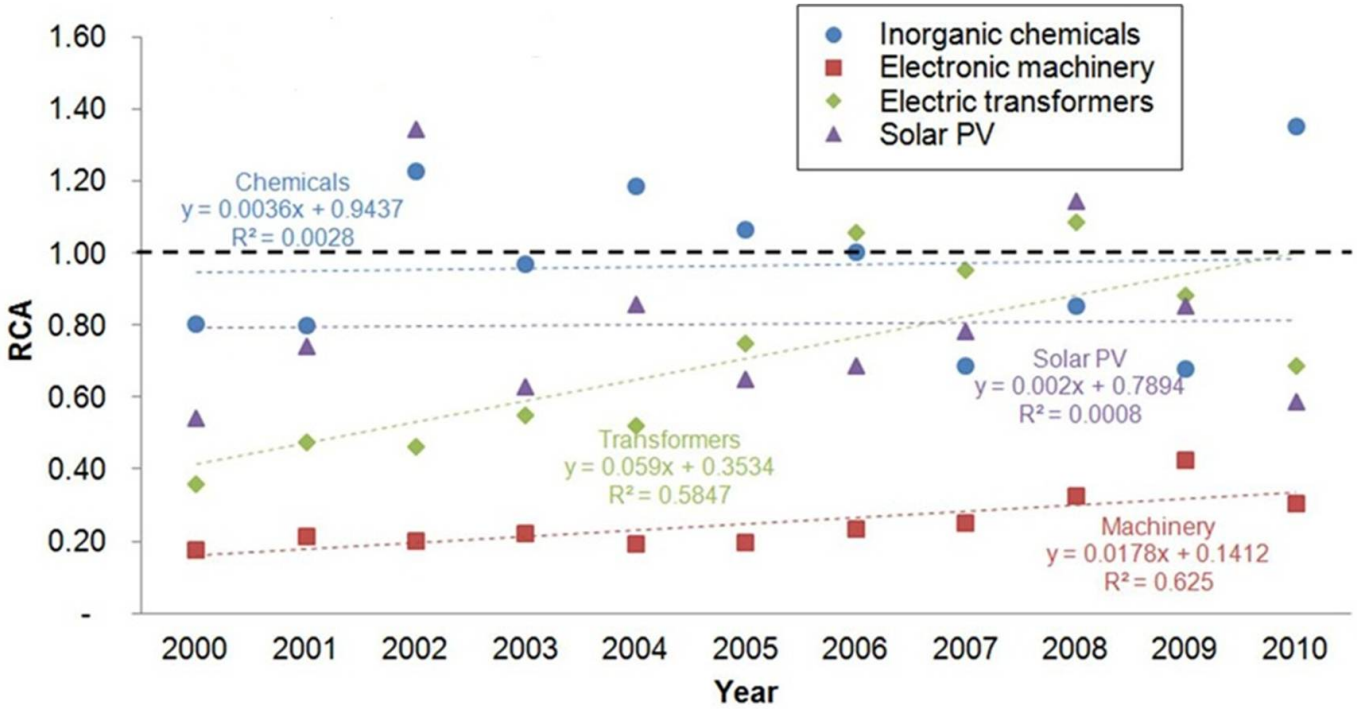
$$UVR_{India/OECD} = \frac{\frac{ValuePVexports_{IndiatoOECD}}{QuantityPVexports_{IndiatoOECD}}}{\frac{ValuePVexports_{OECDtoOECD}}{QuantityPVexports_{OECDtoOECD}}} \tag{1}$$



Adjacent industries unlikely to support solar sector

RCAs suggest neither solar PV nor ancillary industries competitive:

$$RCA_{c,i} = \frac{\frac{x_{c,i}}{\sum_i x_{c,i}}}{\frac{\sum_c x_{c,i}}{\sum_{c,i} x_{c,i}}} \tag{2}$$



NSM Phase I, Batch I has not altered technology choice

Proposition 3: Choice data do not reveal statistically significant differences in (1) the c-Si share and (2) the fraction of domestic c-Si modules in NSM Phase I, Batch I and non-NSM plants

We built a database of PV plants to test 4 hypotheses:

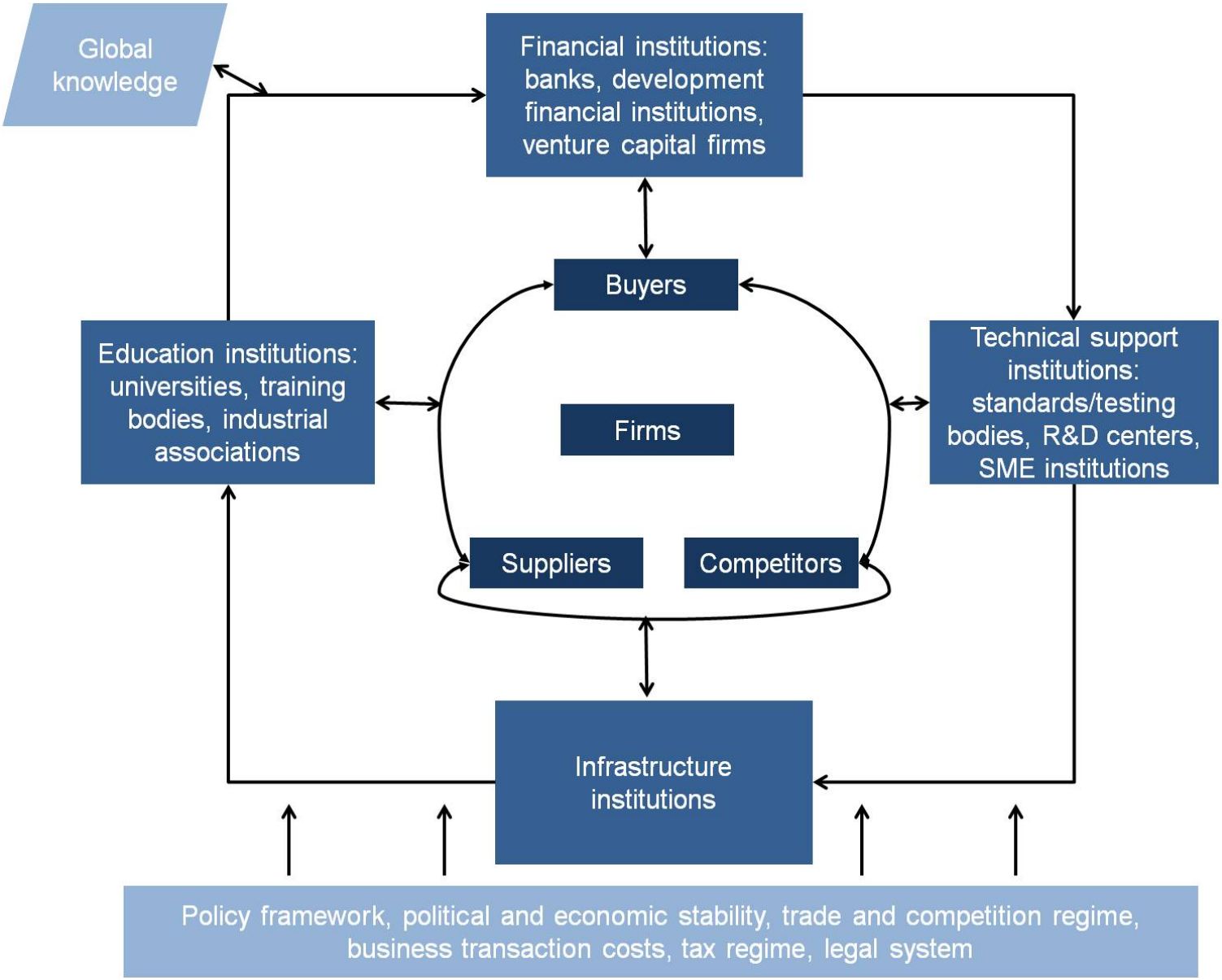
H1 (H3): PI, BI (BII) c-Si share equal to that in non-NSM plants

- c-Si share about equal between non-NSM (49%) and PI, BI (50%); appears to differ in PI, BII (41%)
- Shift in PI, BII suggests DCR could fail to achieve intent

H2 (H4): Share of domestic c-Si modules in PI, BI (BII) equal to that in non-NSM plants

- No evidence that NSM PI, BI plants used domestic c-Si modules in higher or lower proportion than non-NSM plants

Policy must work with national innovation system



Industrial policy has supported RET industries elsewhere

Four strengths identified in Chinese industrial policy:

1. Deployment: Domestic demand triggered and now supporting industry, even with weaker export demand
2. Manufacturing: Complementary strengths helped Chinese PV sector expand upstream
3. Infrastructure: Strong private sector R&D allowed competitive advantages to develop
4. Coordination: Incentives synchronized at national and local levels

Despite NSM deployment, DCR unlikely to achieve objectives partly because of national innovation system gaps in points 2, 3 and 4

Concluding Remarks

NSM DCR will not constrain deployment...

...but unlikely to expand or protect production possibilities frontier

- NSM has not triggered uptake of domestic c-Si modules; developers may increasingly prefer foreign thin-film substitutes
- NSM industrial policy uncoordinated, challenged by gaps in national innovation system
- Indian firms have become less competitive over time
  - Utilization rates below global, Chinese and Japanese benchmarks
  - Ancillary industries are uncompetitive

Current DCR will entail non-positive changes in economic efficiency, and an expansion to include thin-film modules would strengthen result

Future research to examine batch II technology choice

- Need to characterize optimal response to anticompetitive policies and policies to plug gaps in national innovation system

Goal of ind. policy to shift production possibilities curve

Can justify industrial policy, including DCRs, as actions to:

- Trigger external dynamic learning and training effects
- Address informational externalities
- Coordinate private investment
- Mitigate security externalities
- Protect against anti-competitive strategies by other countries
- Enhance balance of payments

Industrial policy has a mixed record:

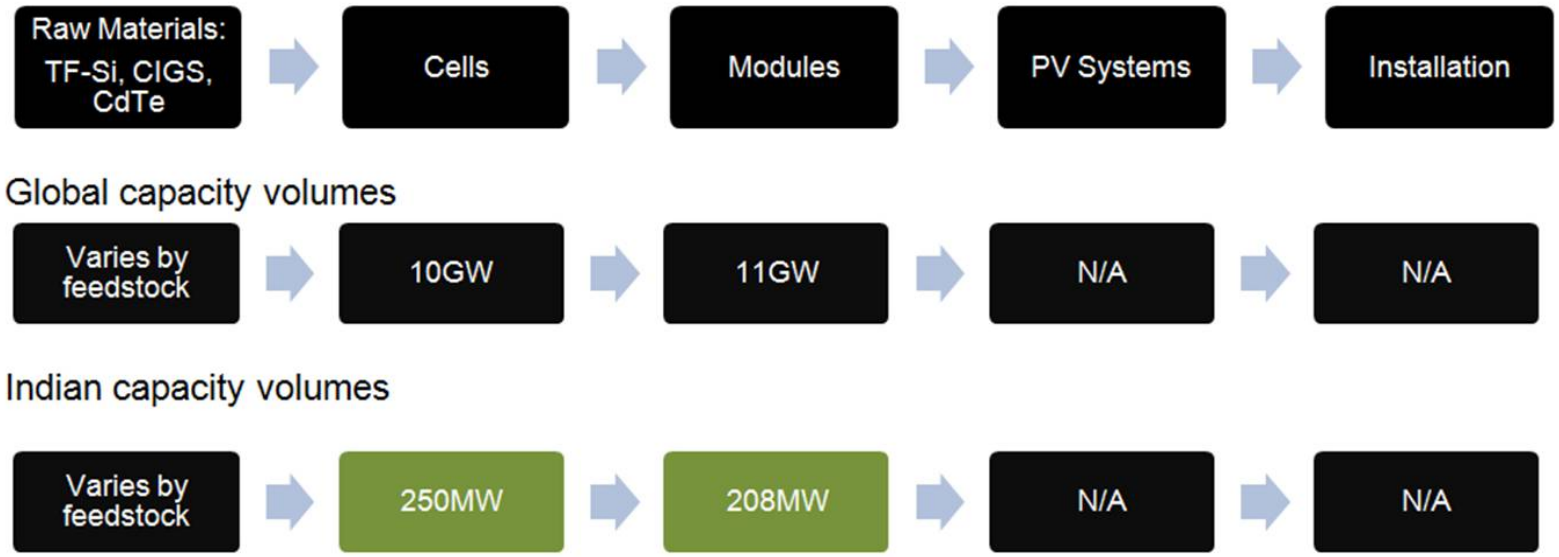
- Difficult to absorb new technology, and industrial protection has driven the importation of obsolete technology
- Effective rate of protection negatively associated with sectoral factor productivity growth

Thin-film DCR could constrain deployment

Switch to thin-film DCR could constrain deployment; e.g., if:

- Thin-film manufacturing capacity stays constant
- Even split between PV and concentrated solar power continues
- Developers continue to use thin-film modules in 50% of capacity

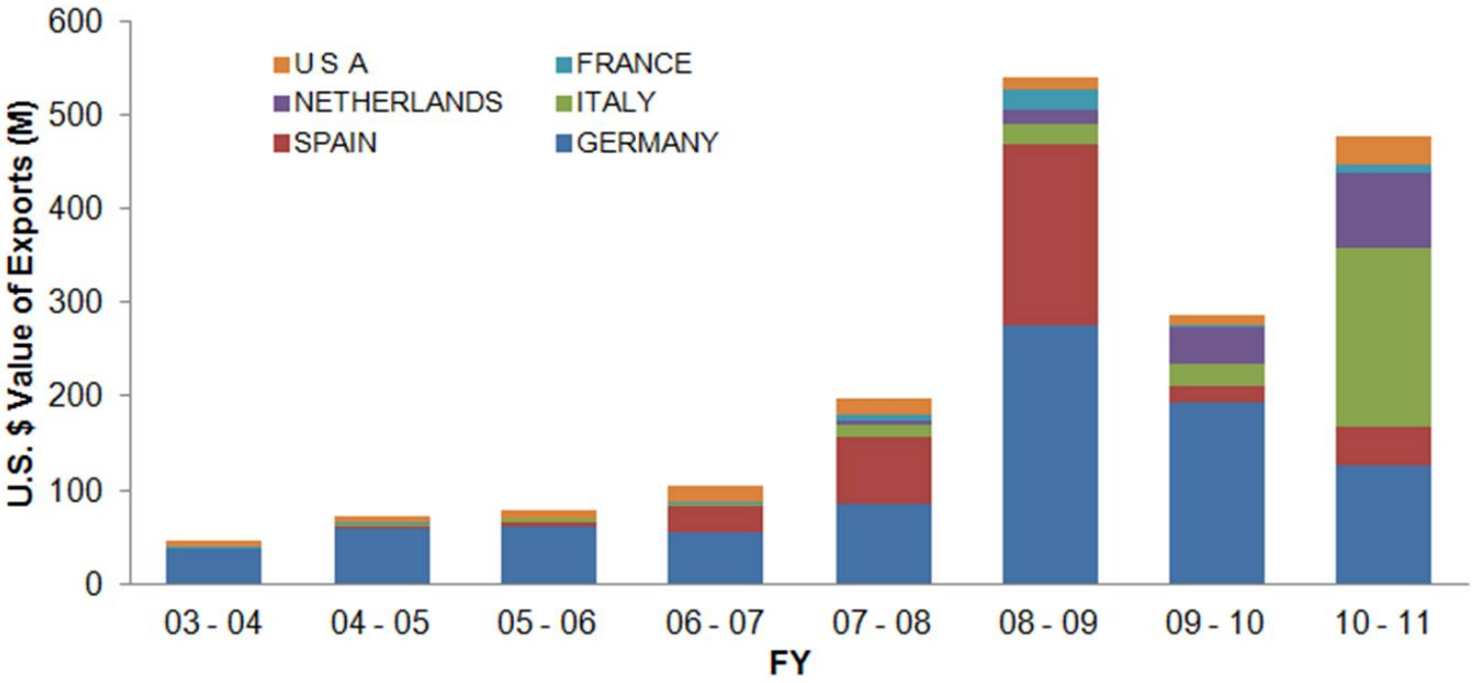
Annual thin-film demand of 800MW would out-strip manufacturing capacity:



Indian exports may be providing marginal capacity

Export value drops in tandem with feed-in-tariff (FiT) decreases:

- Spain introduced FiT in FY 07-09 and reduced in FY 08-09
- Germany has been lowering tariff to track module costs
  - Demand could have sustained FY 08-09 value in FY 09-10
- FY 10-11 exports to Italy reflect near parity of solar PV LCOE

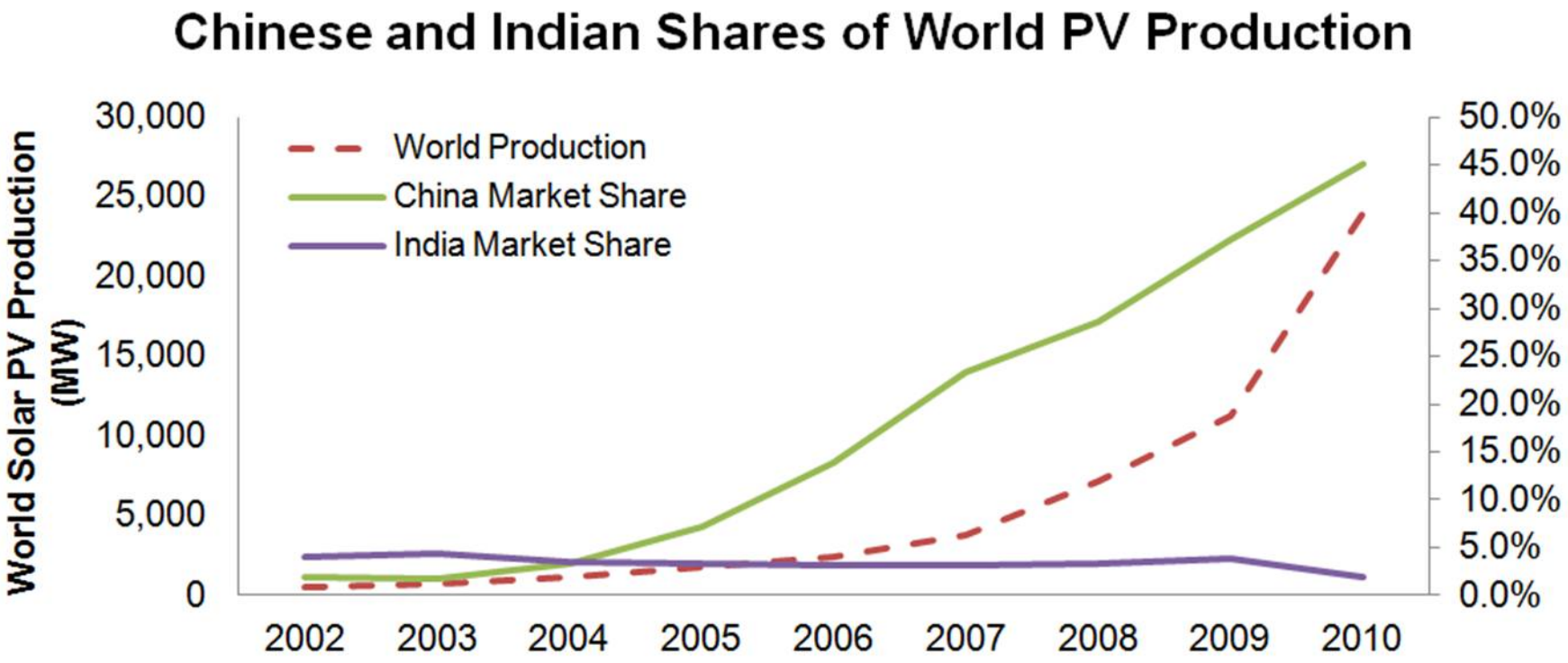


N.B. Markets shown account for about 80% of exports

Falling market share suggests decreased competitiveness

If drop in export values solely attributable to lower module prices, India should maintain at least an equal share of the global PV market.

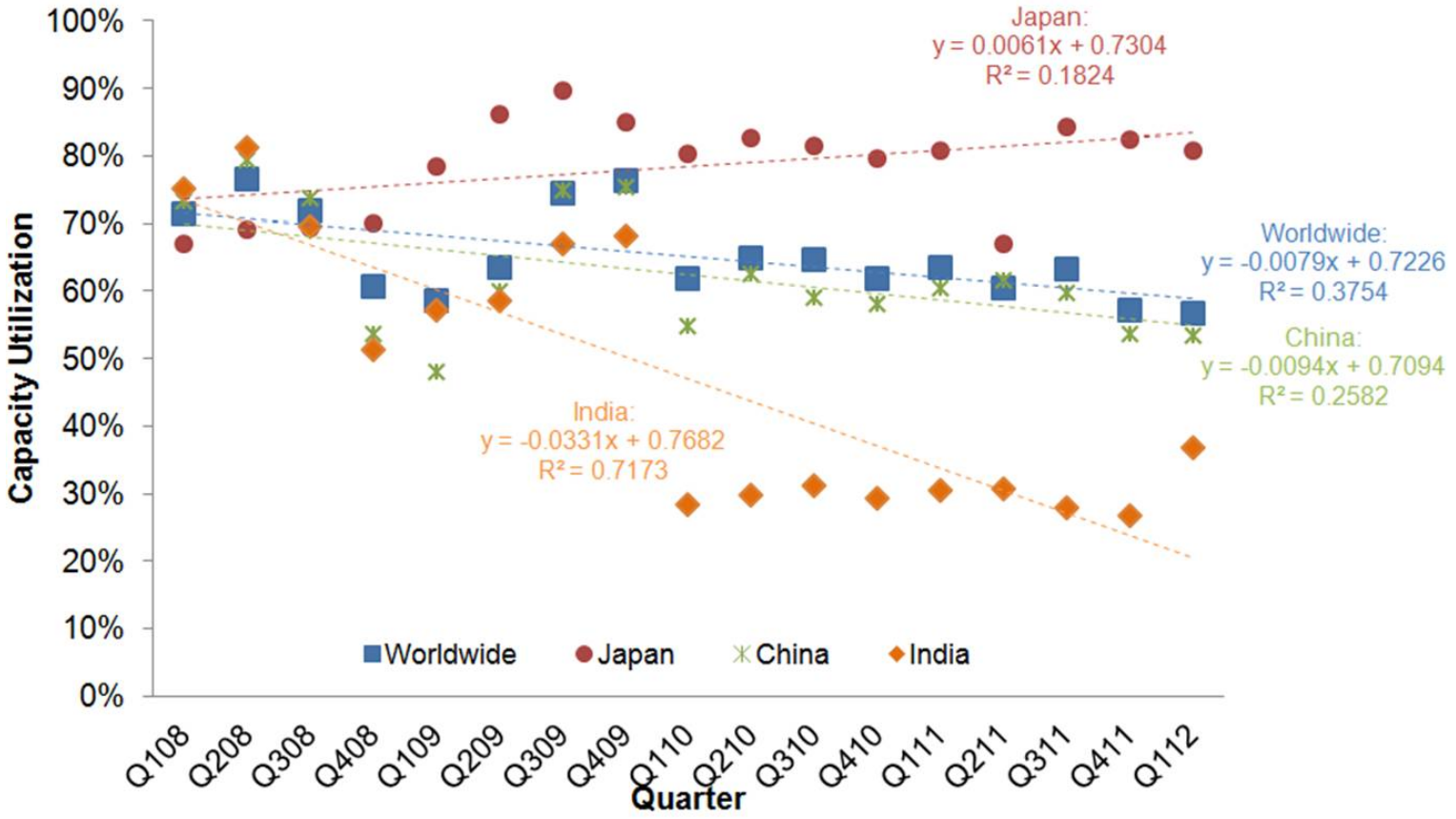
Market share has fallen from 4.1% in 2002 to 2.0% in 2010



Low competitiveness implied by low utilization (I)

Indian cell utilization rates markedly lower

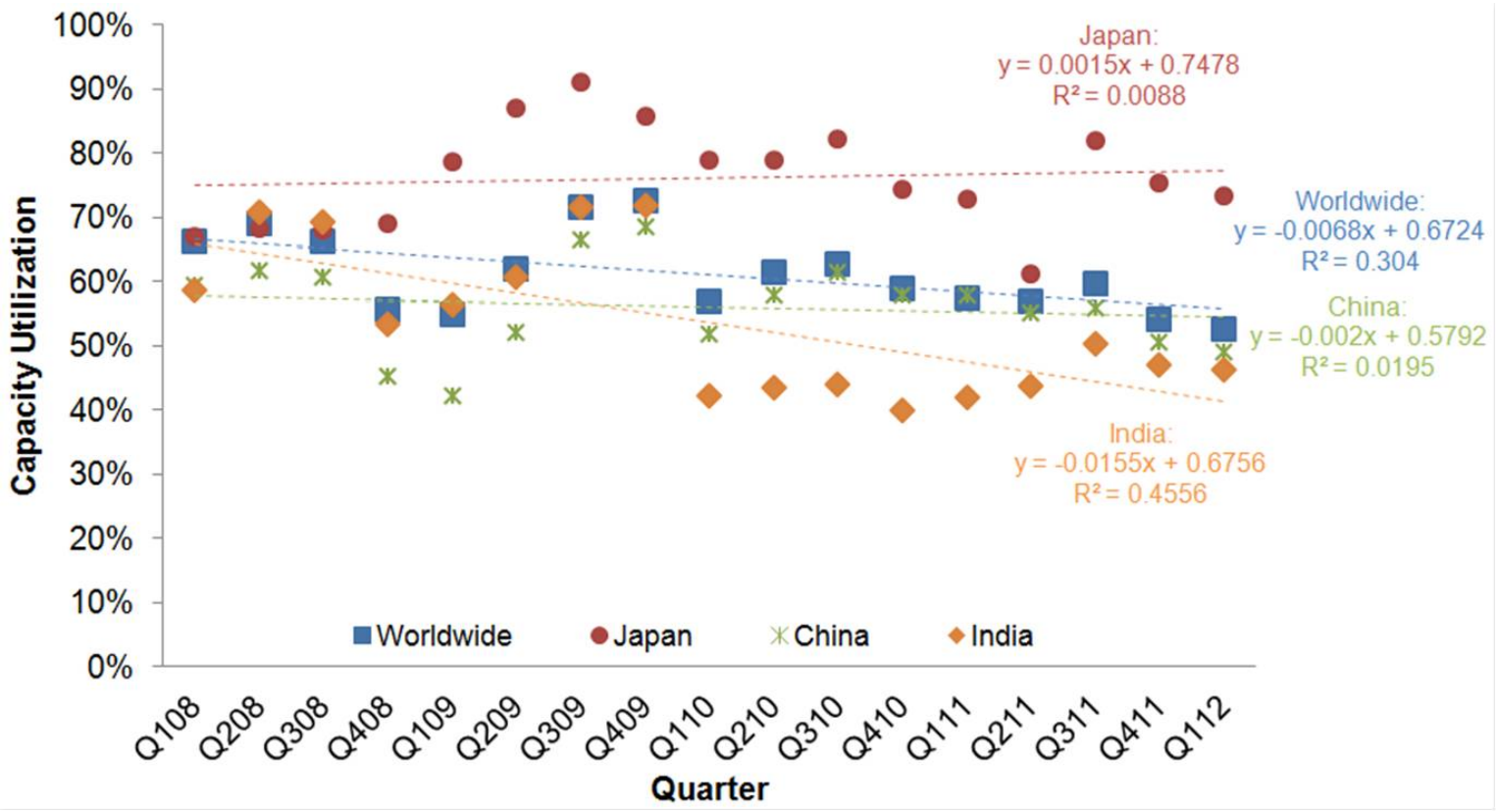
- Reflect capacity growth (545MW in 2009 to 1.9GW in 2011)
- Utilization increasing in Japan, despite larger increases in capacity
- Decreases are not inevitable given China's dominance



Low competitiveness implied by low utilization (II)

Module utilization rates below global and Chinese levels

- Reflect capacity growth (645MW in 2009 to 1.9GW in 2011)
- Decreases in utilization not inevitable



No change in proportion of c-Si modules in PI, BI

Fraction of c-Si modules about same between non-NSM (49%) and PI, BI (50%); appears to differ in PI, BII (41%)

- Shift in PI, BII suggests DCR could fail to achieve intent; share of domestic c-Si modules in plants may decrease over time
- Preference for foreign thin-film modules is not new
- Specifications to model developers' choices of technology below:

Variables	(1) Crystalline	(2) Crystalline	(3) Crystalline	(4) Crystalline	(5) Crystalline	(6) Crystalline
NSM_I	1.05	0.824	0.762	0.762	0.742	0.877
	(0.448)	(0.423)	(0.420)	(0.424)	(0.489)	(0.711)
Gujarat_Policy	-	0.676	0.655	0.655	0.714	0.602
		(0.310)	(0.305)	(0.307)	(0.525)	(0.467)
Capacity (MW)	-	-	0.993	0.993	0.989	0.991
			(0.018)	(0.018)	(0.019)	(0.020)
Robust s.e.	No	No	No	Yes	Yes	Yes
Log likelihood	-77.61	-77.24	-77.17	-77.17	-74.45	-70.59
Observations	112	112	112	112	109	107
State FE	No	No	No	No	Yes	Yes
Time FE	No	No	No	No	No	Yes

No change in fraction of domestic c-Si modules in PI, BI

NSM PI, BI has not triggered additional domestic c-Si production that could prompt renewed competitiveness

Specifications to model choices of domestic and foreign c-Si modules:

Variables	(1) Domestic Crystalline	(2) Domestic Crystalline	(3) Domestic* Crystalline	(4) Domestic* Crystalline	(5) Domestic* Crystalline	(6) Domestic* Crystalline
NSM_I	1.170	1.954	2.623	2.200	0.823	0.658
	(0.789)	(2.276)	(1.558)	(1.697)	(0.459)	(0.504)
Gujarat_Policy	0.475	0.381	0.607	0.324	0.549	0.780
	(0.299)	(0.333)	(0.349)	(0.274)	(0.259)	(0.654)
Capacity (MW)	0.71	0.981	0.987	0.996	0.976	0.969
	(0.036)	(0.035)	(0.024)	(0.030)	(0.026)	(0.024)
Robust s.e.	Yes	Yes	Yes	Yes	Yes	Yes
Log likelihood	-50.65	-44.91	-59.28	-51.46	-73.72	-67.71
Observations	82	77	112	101	112	107
State FE	No	Yes	No	Yes	No	Yes
Time FE	No	Yes	No	Yes	No	Yes

What do Propositions 2 and 3 imply about efficiency?

Proposition 4: Decreasing competitiveness and inability of DCR to expand domestic c-Si consumption imply non-positive change in societal welfare. Developers and electricity consumers will bear efficiency costs.

Approach decomposes efficiency analysis

Decomposition of change in welfare allows comments on efficiency and equity implications of the DCR:

$$\Delta W_s = \Delta DeveloperSurplus + \Delta ManufacturerSurplus + \Delta ElectricityConsumerSurplus = \Delta DS + \Delta MS + \Delta CS \tag{3}$$

Developer is in upstream module (1) and downstream electricity (2) markets, so we re-write:

$$\Delta W_s = \Delta DS_1 + \Delta DS_2 + \Delta MS + \Delta CS \tag{4}$$

A dynamic analysis is more appropriate:

$$\Delta W_d = \Delta DS_0 + \Delta MS_0 + \Delta CS_0 + \Sigma_t(\Delta DS_t + \Delta MS_t + \Delta CS_t)\delta^t \tag{5}$$

Improvement requires that in at least one time period the sum of changes in developer, manufacturer and consumer surplus is positive

Efficiency loss occurs in thin-film DCR setting

Example: combined thin-film and c-Si DCR:

- Domestic supply increases from S_1 to S_2, price from P_w to P_{Dom}.
- Implies $\Delta MS > 0$ and $\Delta DS_1 < 0$

Welfare loss obtains in either of two extreme scenarios:

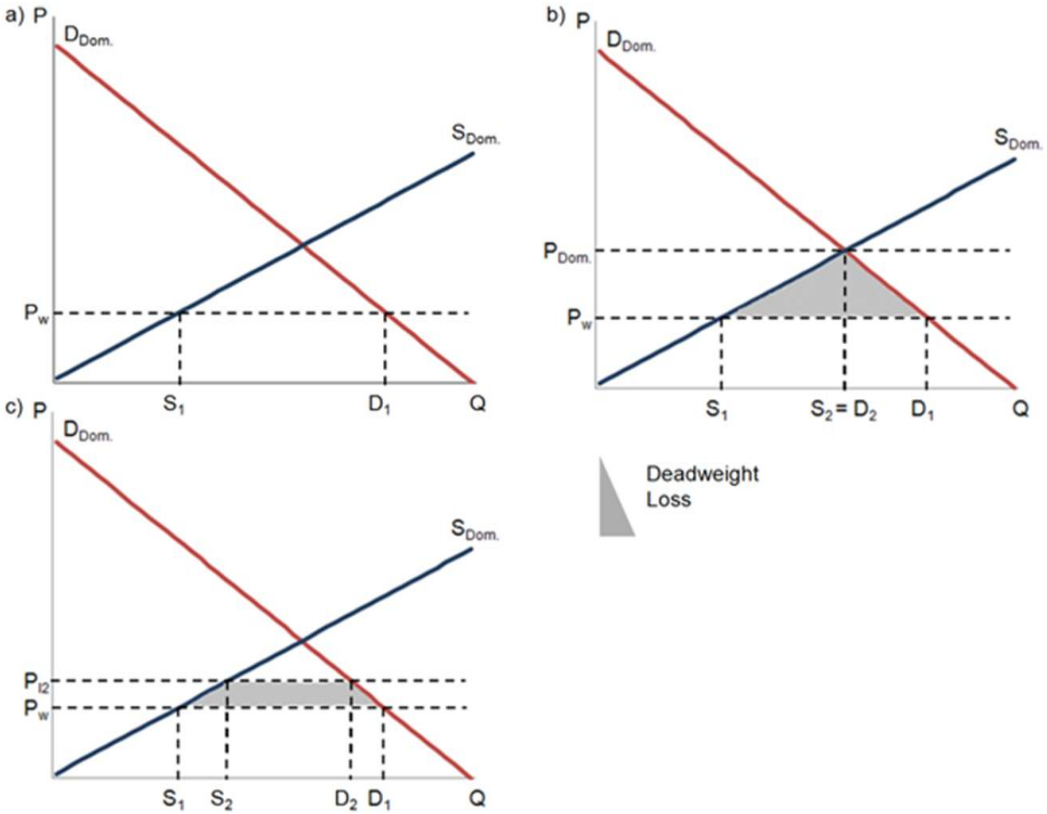
1. Developers unable to pass surplus loss to electricity consumers: $\Delta DS_2 = \Delta CS = 0$. Since $|\Delta DS_1| > |\Delta MS|$, $\Delta W_s < 0$
2. Developers bid higher LCOE to completely pass surplus loss: $\Delta DS_2 = -\Delta DS_1 > 0$ and $\Delta CS < 0$. DWL in downstream market implies $|\Delta DS_2| < |\Delta CS|$. Since $|\Delta DS_1| > |\Delta MS|, |\Delta DS_2| > |\Delta MS|$ and $|\Delta CS| > |\Delta MS|$. Thus, $\Delta W_s < 0$.

If domestic manufacturers are not globally (super) competitive by time t, above would hold; stream of losses implies dynamic welfare loss.

Efficiency loss occurs in all three DCR settings

If, as analysis suggests, DCRs unable to reverse declining competitiveness, partial equilibrium welfare implications hold in all three DCRs:

- Thin-film and c-Si DCR: a $\rightarrow b$
- c-Si DCRs: a $\rightarrow c$



Domestic demand important to Chinese manufacturers

Chinese PV industry seeded by rural electrification

Chinese firms able to respond to European FiT fueled demand:

- Cheap debt allowed manufacturers to vertically integrate and avoid exposure to polysilicon scarcity in 2008/09
- Firms cost advantaged: Production costs \$0.50 - \$0.60/W lower than those in OECD, reflecting differences in wage rates (OECD: \$23 - \$26/hour; China: \$2.10/hour)

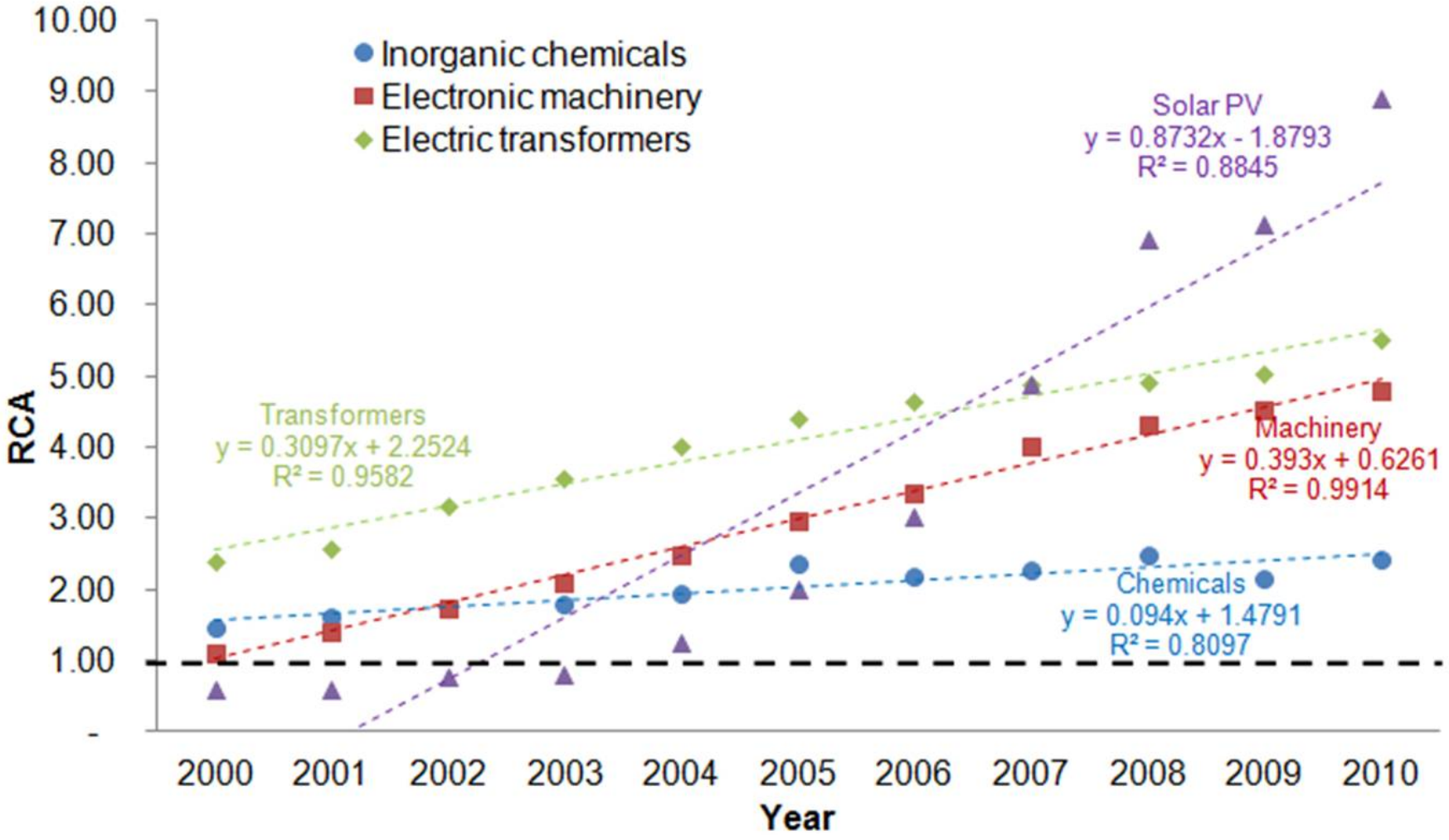
Domestic demand reduces impact of reduced foreign FiTs:

- 2015 (2020) goal to deploy 20GW (48GW) domestically
- Goals supported by feed-in-tariffs
- Deployment goals part of broader electrification efforts

NSM similarly seeking to build domestic market in India

China competitive in ancillary industries

Ancillary industries uncompetitive in India but strong in China:



R&D in India driven by public sector; in China by firms

Chinese firms have built R&D strengths

- Some (e.g., Suntech) began with strong in-house R&D capabilities
- Others (e.g., Trina) built strength by partnering with state laboratories and acquiring upstream producers

In China, state funds support R&D at different stages:

- 863 Program for tech. near commercial stage; $76.8 per year fund focused on lowering production costs and increasing efficiency
- 973 Program for tech. further from market; Ministry of Science & Technology sets technological targets

India's R&D flat at 0.7% of GDP; China's growing from 1.5% (2007)

- 80% of Indian R&D publicly funded, higher than in China (30%), OECD (36%), Korea (26%) or Japan (22%); few private links
- NSM mentions university R&D but not firms' participation
- Commercialization path unclear: no analog to U.S. Bayh-Dole Act

Indian policy less synchronized than that in China

Chinese solar PV support prioritized by highest levels of government

- Coordinated by goals and programs in Five Year Plans
- May span up to 200 subsidies

NSM industrial policy counter to broader liberalization goals

- Dept. of Industrial Policy and Promotion (DIPP) liberalizing industrial policy
- No coordination with Dept. of Electronics and Information Technology, which oversees semiconductor industry development
  - Effective policy could incent multiple overlapping industries and capture spillover effects