

Too Fast, Too Soon? The Rise of the Chinese Wind Turbine Manufacturing Industry

Long Lam, CMU

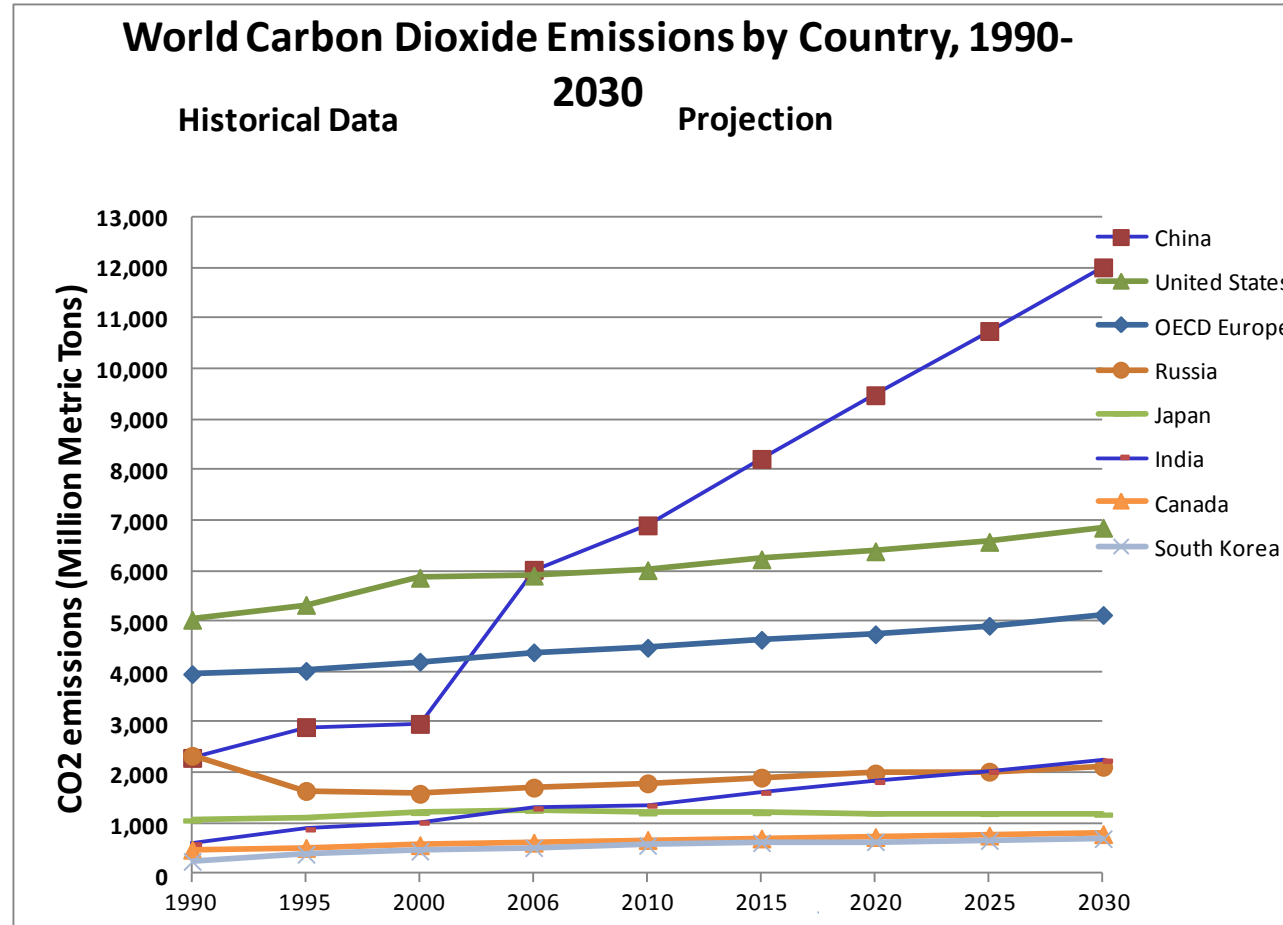
Lee Branstetter, CMU, NBER, and Peterson Institute

Ines Azevedo, CMU

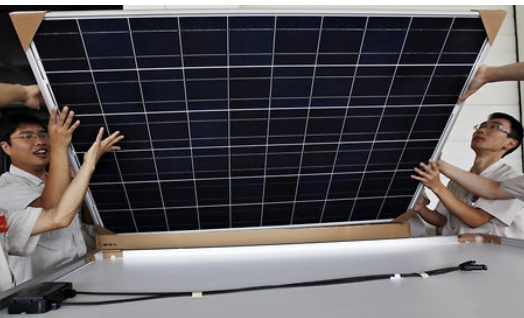
With Support From:



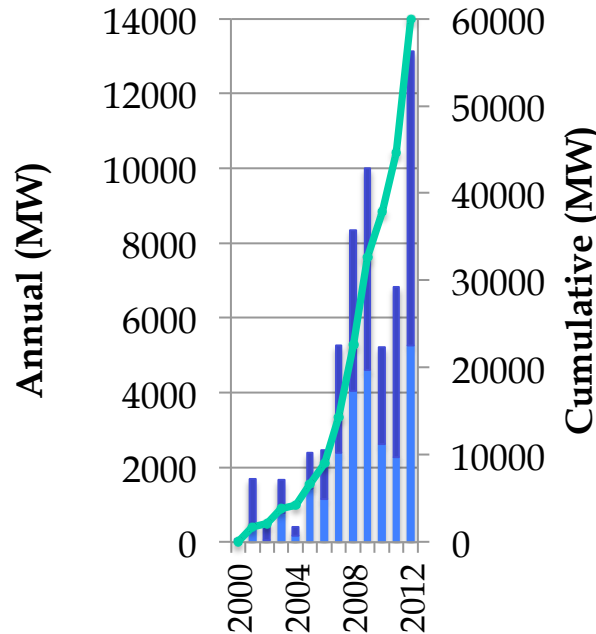
The environmental costs of China's rapid growth are increasingly evident...



China has launched an aggressive effort to develop indigenous “green energy” industries...

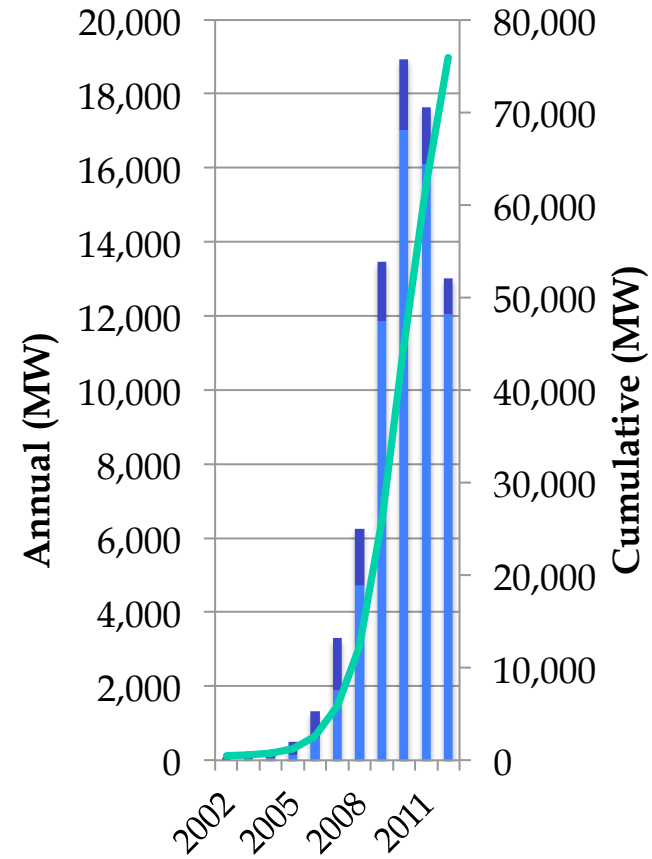


US Installations



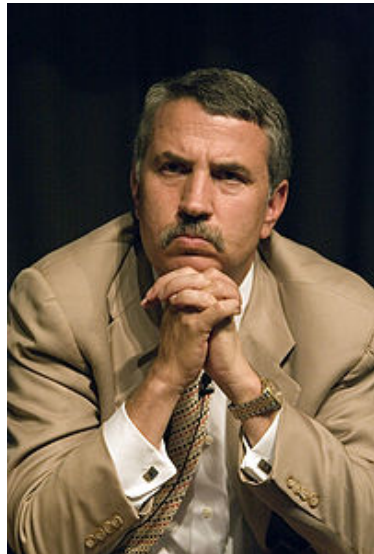
■ Domestic ■ Foreign — Cumulative

China Installations



■ Domestic ■ Foreign — Cumulative

These efforts are widely viewed as successful – a coup for China and a benefit for the world...



Thomas Friedman



Energy Policy 60 (2013) 234–250



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From lagging to leading? Technological innovation systems in emerging economies and the case of Chinese wind power

Jorrit Gosens^{a,b}, Yonglong Lu^{a,*}

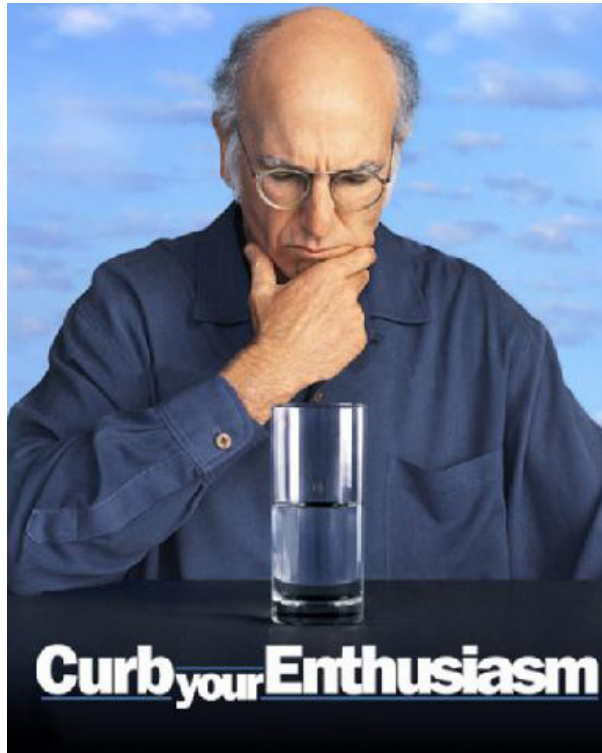
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An industrial policy success story that could challenge core beliefs about the way international trade rules should apply to alternative energy industries?

- Is protectionism bad if it incubates a highly competitive set of green power hardware producers?
- Should export subsidies be banned if they help the world deal with environmental externalities?
- Are local content requirements bad if they breathed into existence China's dynamic wind turbine industry?
- Should First World IP be protected if it slows the development of a highly innovative green power hardware industry in a developing country?

Our message: curb your enthusiasm...



- Wind turbine production has expanded aggressively in China
- Driven by the biggest wind farm construction boom in the industry's history...
- One that effectively shut out foreign products for years, in violation of WTO trade rules
- But, so far, no significant Chinese product innovations have emerged from this industrial expansion...
- And technological opportunities may be limited in this sector in any case
- Chinese producers' impressively low prices appear to have reflected, in part, low/negative margins on the part of many manufacturers
- And the Chinese industry is only now emerging from a significant consolidation
- Setbacks in other alternative energy industries in China suggest that the story of wind power may apply more broadly

Agenda

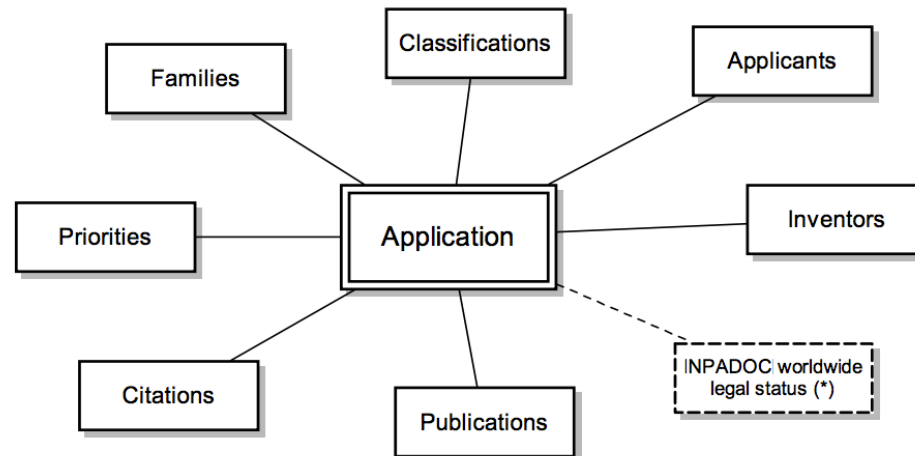
Innovation in wind power in China and beyond

China's wind farm construction boom and its consequences

The state of China's wind turbine industry, 2012-2014

We use patent data to measure global innovation trends in wind power...

- European Patent Office (EPO) is a regional patent office
 - Maintains and publishes all-inclusive Worldwide Patent Statistical Database aka “PATSTAT”



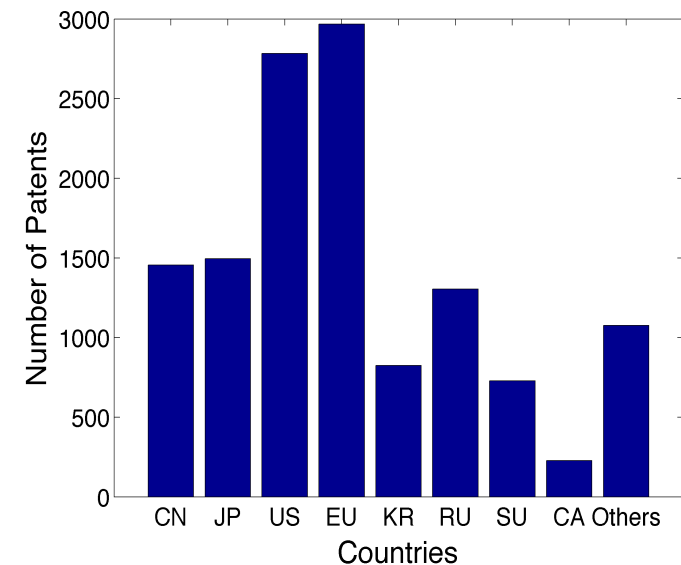
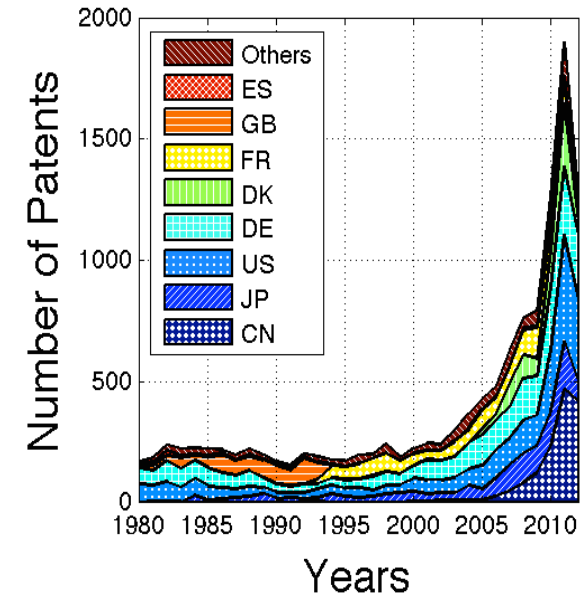
We follow the methods of earlier studies in identifying wind power innovations

- Sample identification based on patent classes and abstract keyword search
 - IPC patent class “F03D” (Johnstone et al, 2009)
 - Abstract search (Nemet, 2009) in EN, DE, FR, & ES

| | | | |
|--|--|--------------------------------------|--|
| (12) | EUROPEAN PATENT APPLICATION | | |
| (43) Date of publication: 01.08.2012 Bulletin 2012/31 | (51) Int Cl: F03D 7/02^(2006.01) | F03D 7/04^(2006.01) | |
| (21) Application number: 12075006.2 | | | |
| (22) Date of filing: 20.01.2012 | | | |
| (54) Pitch control system and method for wind turbine | | | |
| (57) The invention discloses a pitch control system for a <u>wind turbine</u> and a method, comprising a main controller, a secondary controller, a motor and a pitch gearbox, wherein the main controller is connected with a plurality of the secondary controllers through a communication bus; each <u>blade</u> corresponds to one controller and | at least two motors, and one pitch gearbox is driven by each motor. The main controller is used for calculating a pitch expected value according to <u>wind</u> speed as well as power and rotation speed of a <u>generator</u> ; and the motor is driven by the secondary controller according to the pitch expected value, so as to drive the pitch gearbox and hence drive the <u>blades</u> to vary a pitch angle. | | |

Technological opportunity in wind turbines: is a revolution at hand?

- The number of patents has skyrocketed...
- Based on patent applications and grants at home, Chinese inventors appears to account for a large number of them
- Industry boosters suggest the possibility of revolutionary change
- But not all patents are created equal...

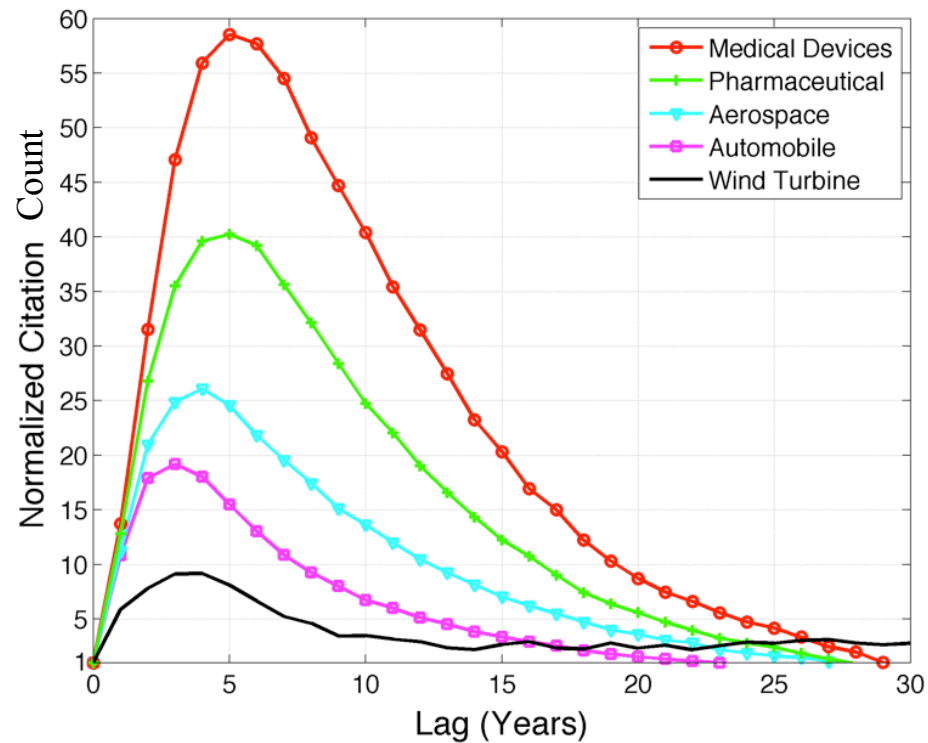


Measuring the quality of innovation with a patent citation function

- Uses patent citations to measure the impact of an invention on later innovative activity – more highly cited patents are more “impactful”
- Caballero & Jaffe (1993) and Jaffe & Trajtenberg (1996)
 - The likelihood (“citation frequency”) that a patent in group \mathbf{K} , granted in year \mathbf{T} , will cite a particular patent in group \mathbf{k} granted in year \mathbf{t} is a function of the combination of two exponential processes and relevant characteristics of the patent groups α (technology type, years granted, etc.)

$$\Pr(k, K) = \alpha(k, K) \cdot \exp(-\beta_1(k, K)(T - t))(1 - \exp(-\beta_2(k, K)(T - t)))$$

The time path of citations follows a double-exponential shape...



Citation functions, continued

- Wind technology only
- Organize patents into cells

$$\text{Prob}(k, K) = (1 + \delta_{kK})\alpha_k\alpha_K \cdot \exp(-\beta_1(T - t))(1 - \exp(-\beta_2(T - t))) + \varepsilon_{kK}$$

and

$$\text{Prob}(k, K) = \frac{E[\textit{citation}_{kK}]}{n_k n_K}$$

where δ is the year dummy, n_K the number of potentially citing patents, and n_k the number of potentially cited patents

Use nonlinear least squares, weighting by

$$w = \sqrt{n_k n_K}$$

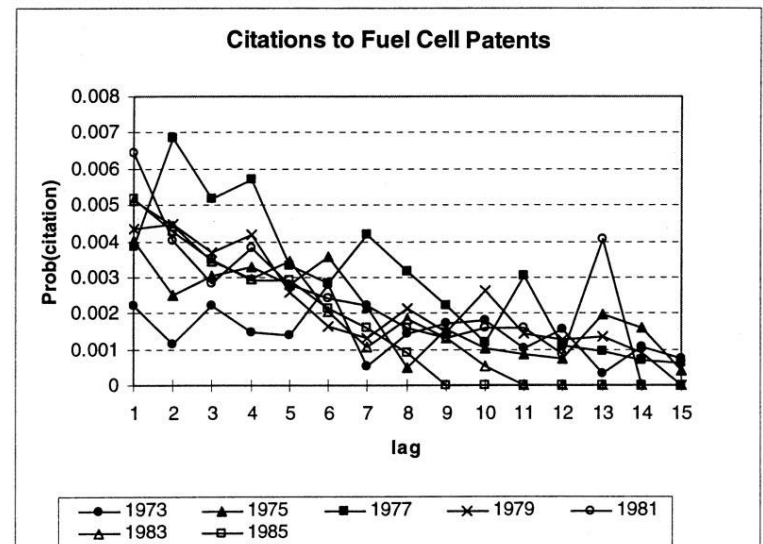
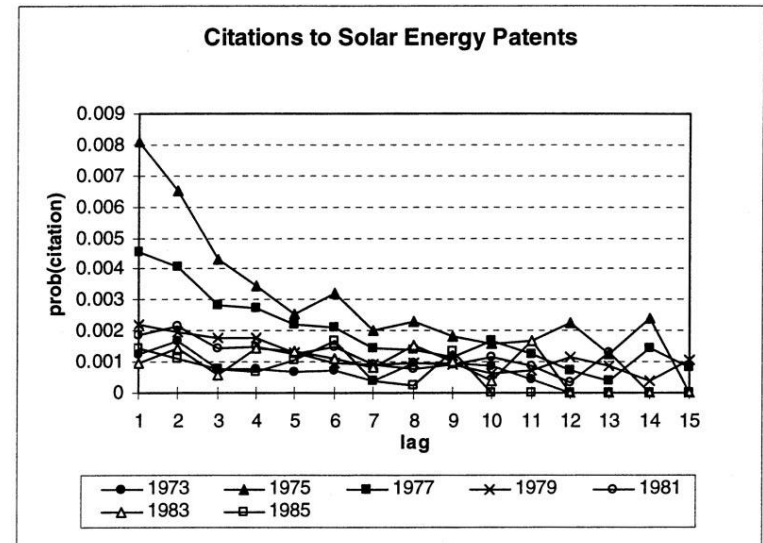
The quality of wind power patents appears to have declined over time...

- Patents, citations are obtained from PATSTAT
- Patents are aggregated into 2-year cohorts
- “Citedness” coefficients decline substantially over time
- More recent cohorts of patents appear to represent more incremental innovation

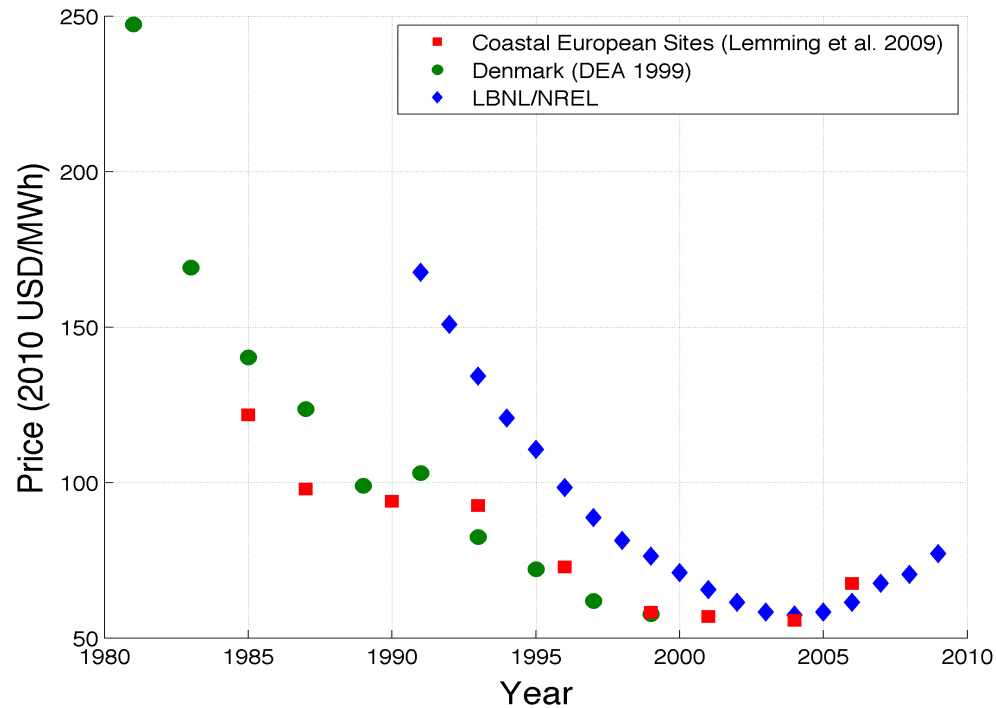
| | Parameter | Standard Error |
|--|------------|----------------|
| Cited year effects (Base = 1980-81) | | |
| 1982-1983 | -0.0404 | 0.1017 |
| 1984-1985 | -0.2663** | 0.0975 |
| 1986-1987 | -0.5260*** | 0.0524 |
| 1988-1989 | -0.7215*** | 0.0612 |
| 1990-1991 | -0.7874*** | 0.0550 |
| 1992-1993 | -0.7970*** | 0.0586 |
| 1994-1995 | -0.7996*** | 0.0656 |
| 1996-1997 | -0.8911*** | 0.0411 |
| 1998-1999 | -0.9196*** | 0.0341 |
| 2000-2001 | -0.9010*** | 0.0457 |
| 2002-2003 | -0.9172*** | 0.0421 |
| 2004-2005 | -0.9310*** | 0.0384 |
| 2006-2007 | -0.9487*** | 0.0313 |
| 2008-2009 | -0.9615*** | 0.0264 |
| 2010-2011 | -0.9789*** | 0.0219 |
| Obsolescence | 0.2496*** | 0.0227 |
| Diffusion | 0.0017*** | 0.0009 |
| N = 171 | | |
| R-squared = 0.99 | | |

This is consistent with the more general innovation trends in alternative energy documented in Popp (2002)

- Citation function analysis of innovation in alternative energy
- Found evidence of declining invention quality
- Aggregated across all main alternative energy technologies
- Data ceased before the recent green innovation boom began

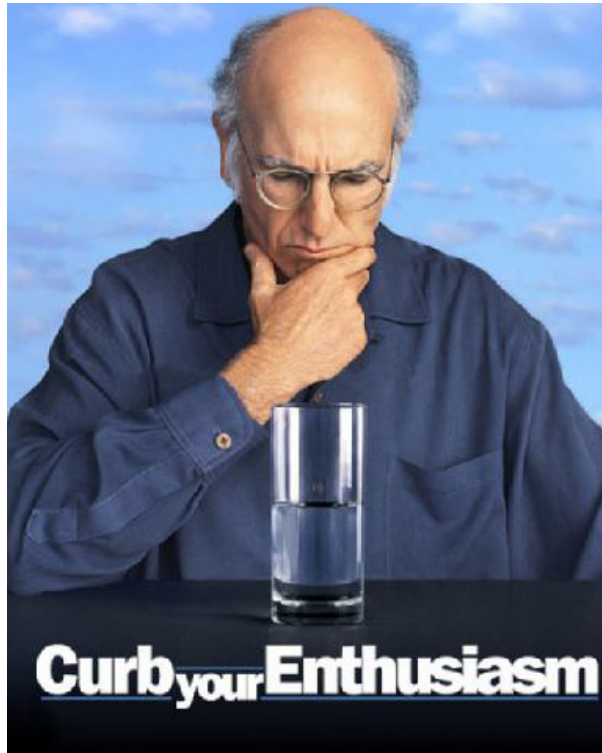


This is also consistent with a series of engineering studies focused on the cost of wind energy



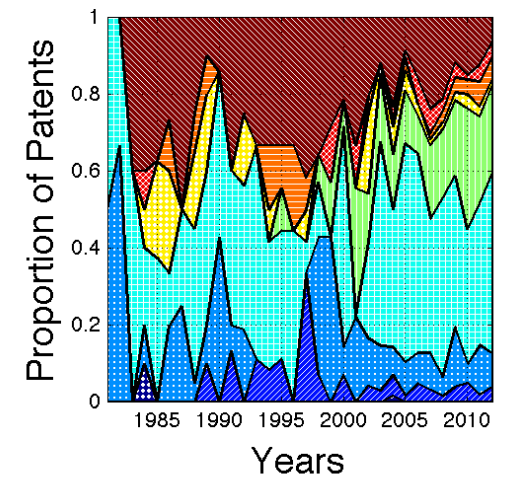
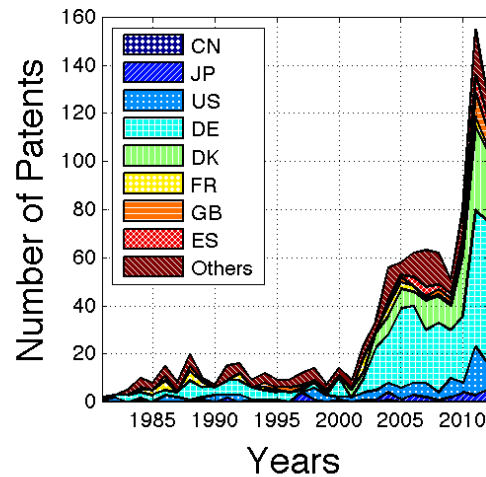
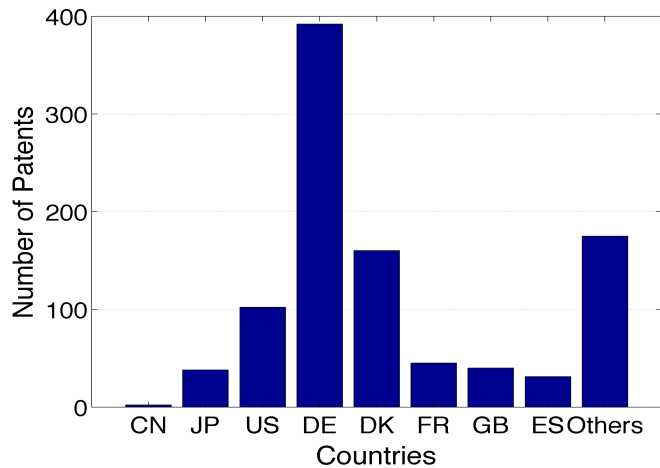
Lantz et al. (2012)

A new breeze blowing or just a bunch of hot air?



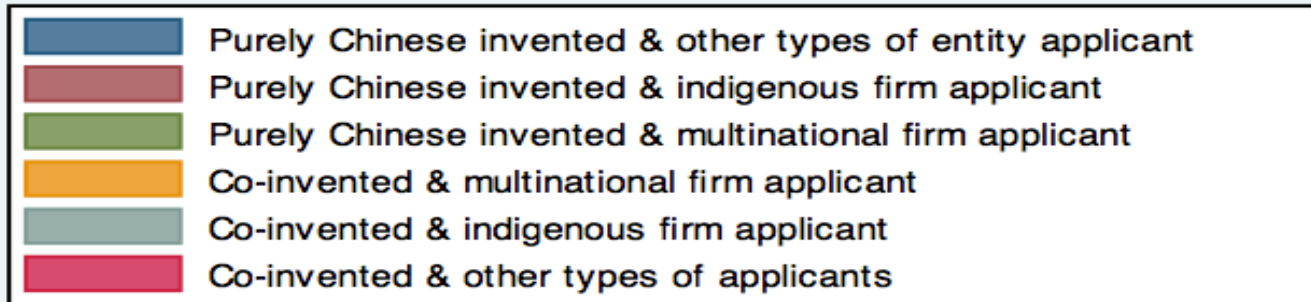
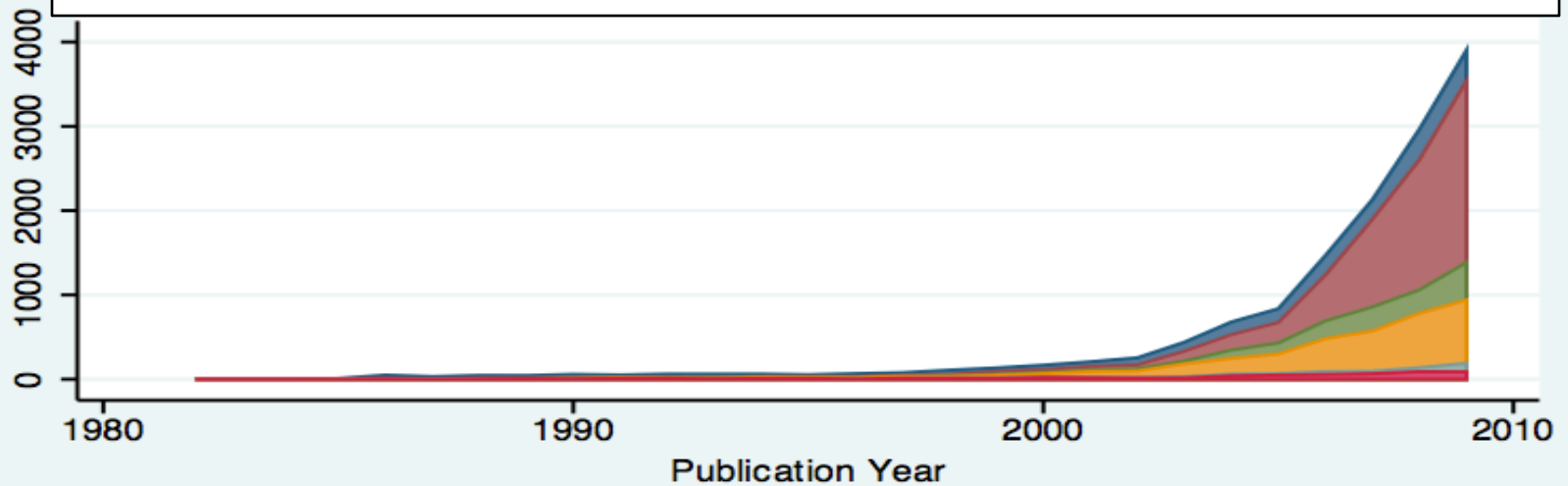
- Wind turbine technology is fairly mature...
- Recent developments have been incremental in nature relative to the advances of the 1970s and 1980s
- Exploding patent counts exaggerate the real rate of innovative progress in this domain
- But a relatively mature technology is exactly the sort of context in which a “late developer” economy might make its mark...

China's new wind energy giants do not patent outside China...



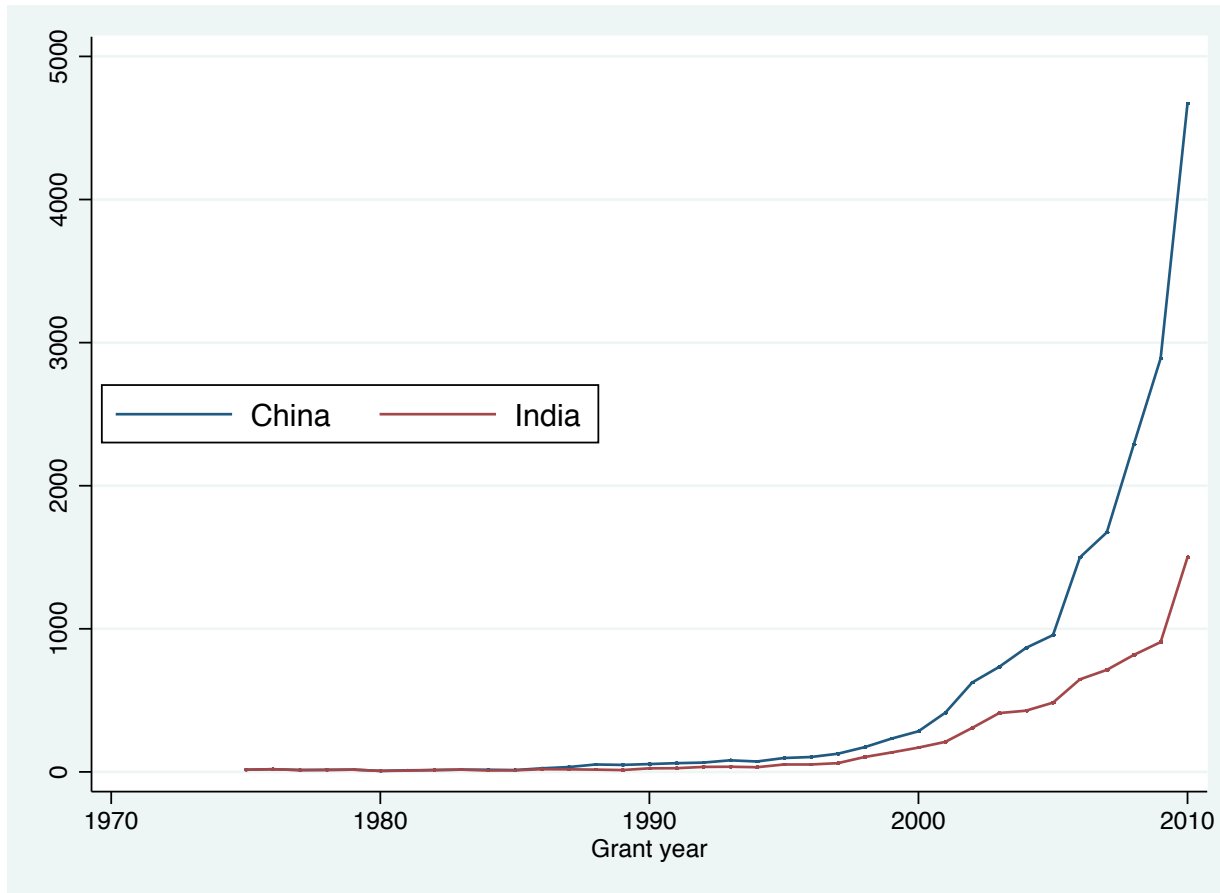
Even though other Chinese industries do patent aggressively in major export markets...

Chinese patenting at the EPO, 1980-2009

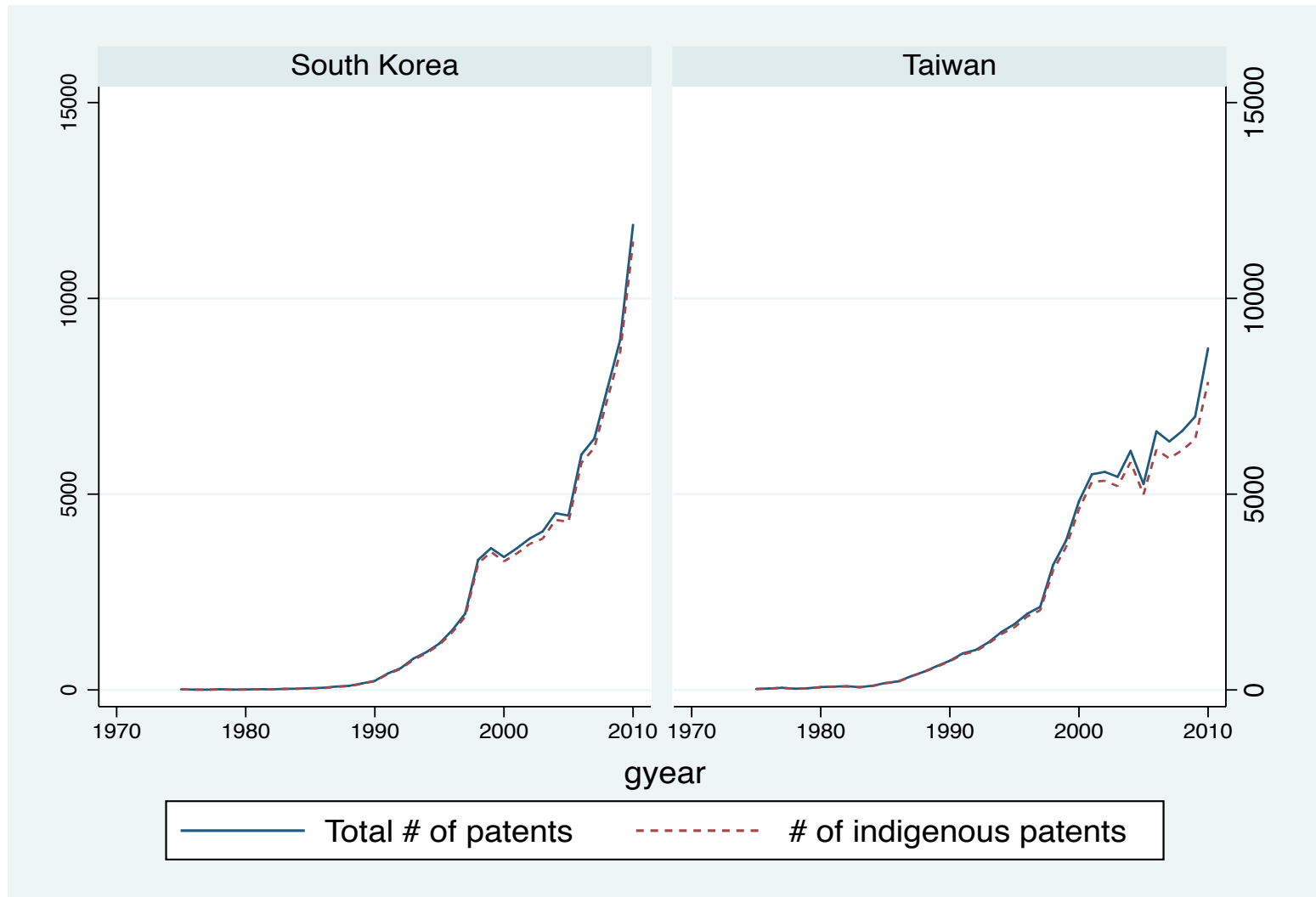


Even though other Chinese industries do patent aggressively in major export markets...

USPTO patent grants to Chinese and Indian inventors



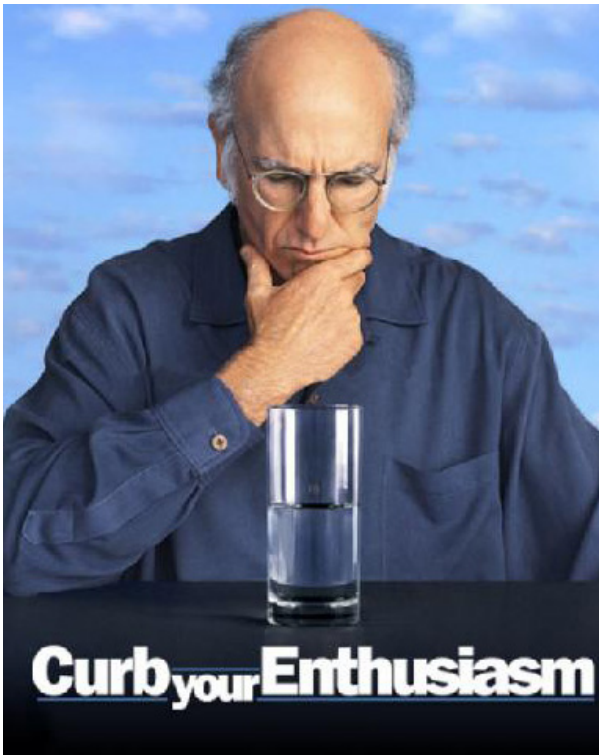
As did the Asian countries that preceded China on the path to innovation-led growth...



Other researchers have questioned the value of Chinese (domestic) patent grants

- Brian Wright and his students have found that Chinese indigenous inventors inflate their patent applications to meet local government targets...
- ...And to benefit from local government subsidies
- Domestic patents of low quality can also be an asset in an evolving legal system that struggles to distinguish between a good patent and a bad patent
- The number and growth rate of domestic patenting may (substantially) overstate the true innovation of indigenous Chinese firms

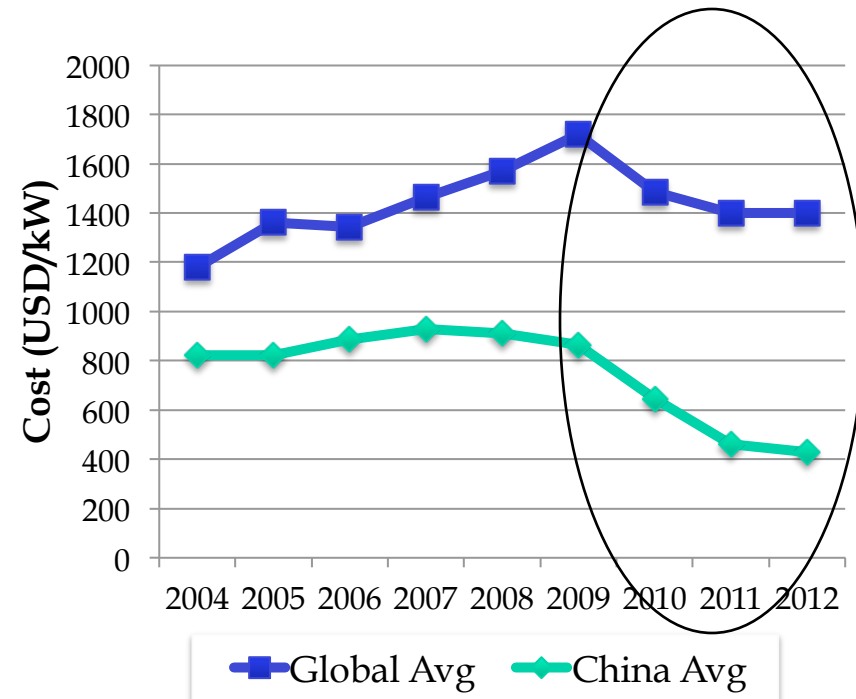
China's recent "success" in growing a domestic wind turbine industry has little to do with significant product innovation!



- A series of papers in the energy journals hails the rising innovative capacity of Chinese wind turbine producers
- But China's manufacturers are not producing innovations that significantly advance the global state-of-the-art
- And if China is not producing new technology, one wonders if its recent success in cost reductions can be sustained...

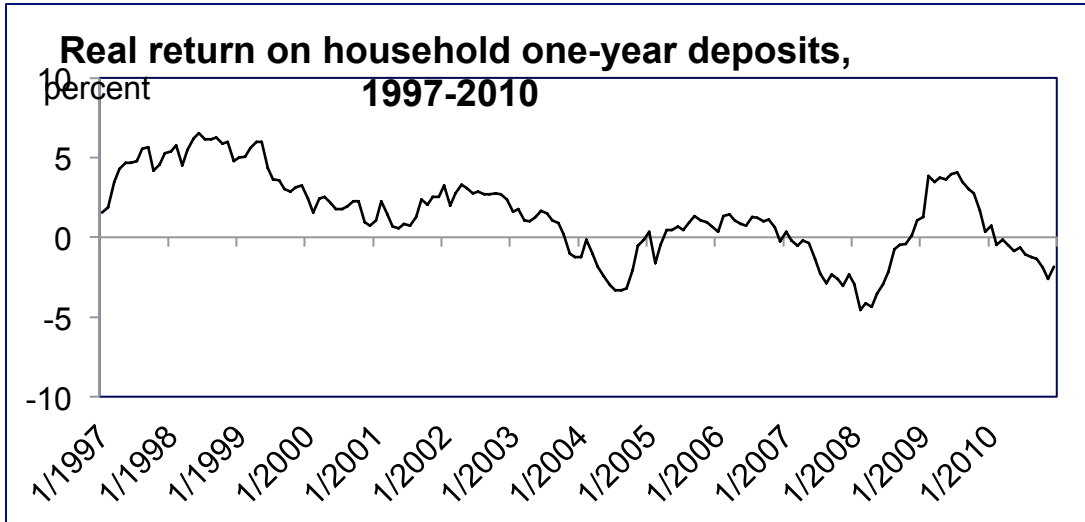
Is our focus on patent data missing the point?

- We draw a distinction between technology absorption and innovation
- Technology has clearly been effectively absorbed
- But has it been substantively improved?
- Nahm and Steinfeld (2013) document process/design changes – but can we assign economic value to these changes?
- Prices have fallen dramatically, but that is not necessarily driven by substantive innovation

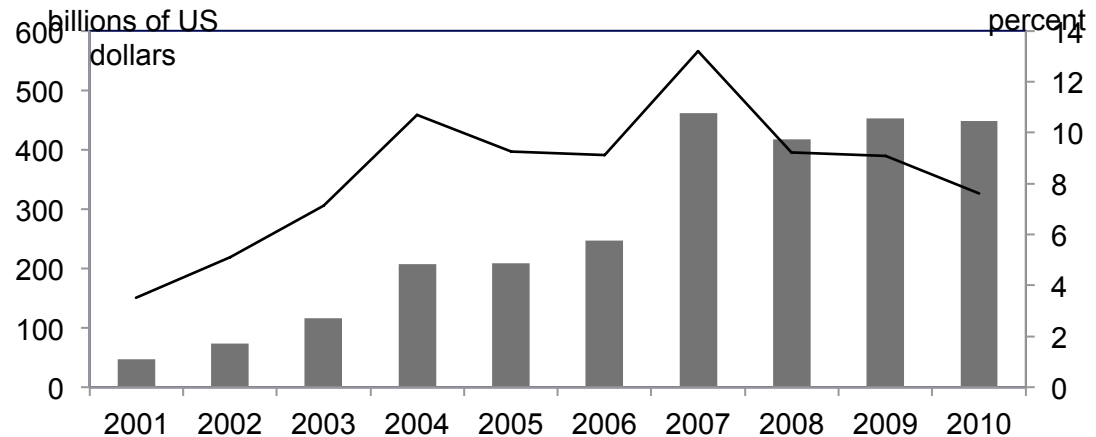


IEA, IRENA, KGI (2013)

China's (distorted) prices could also confer a cost advantage on Chinese wind turbine producers...



Change in foreign exchange reserves, 2001-10



Agenda

Innovation in wind power in China and beyond

China's wind farm construction boom and its consequences

The state of China's wind turbine industry, 2012-2014

China pushes renewables hard, starting in 2005

- The Renewable Energy Law of the People's Republic of China, passed in 2005, implemented in 2006.
 - Established a regulatory framework for renewable energy
 - Signaled strong central government interest
 - Notice 1204 imposed a 70% local content requirement
- The State Council's Mid- and Long-Term Development Plan for Renewable Energy.
 - Target: 10% of primary energy consumption by 2010; 15% by 2020
 - Starting point: 6%, almost entirely from hydropower
- Complementary regulations from the State Electricity Regulation Commission (SERC) and the National Development and Reform Commission (NDRC)
 - Mandatory connection and purchase requirements, priority dispatch
 - Feed in tariffs
 - Electricity surcharges to subsidize clean energy
- Interactions with existing industrial/technology development policies
 - The "863 Program" subsidized foreign technology licensing

2005 Renewable Energy Law

Renewable Energy Targets

10% RE by 2010, 15% RE by 2020

10GW wind by 2010, 30GW by 2020

Grid
Companies

Mandatory
Grid
Connect

Mandatory
Electricity
Purchase

Priority
Dispatch
& Grid
Mgmt

RE
Customer
Surcharge

Project
Developers

Mandatory
Market
Share Req.

Tender-
based
Pricing

Tiered FIT
(2009)

WTG
Manufacturers

70% Local
Content
Req.

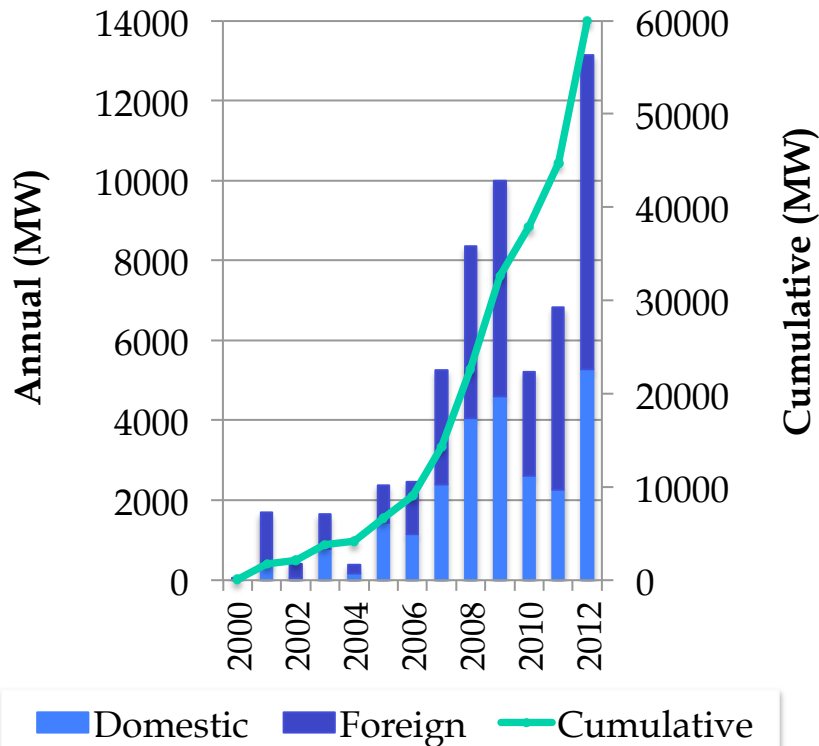
R&D
Support

Chinese primary energy consumption

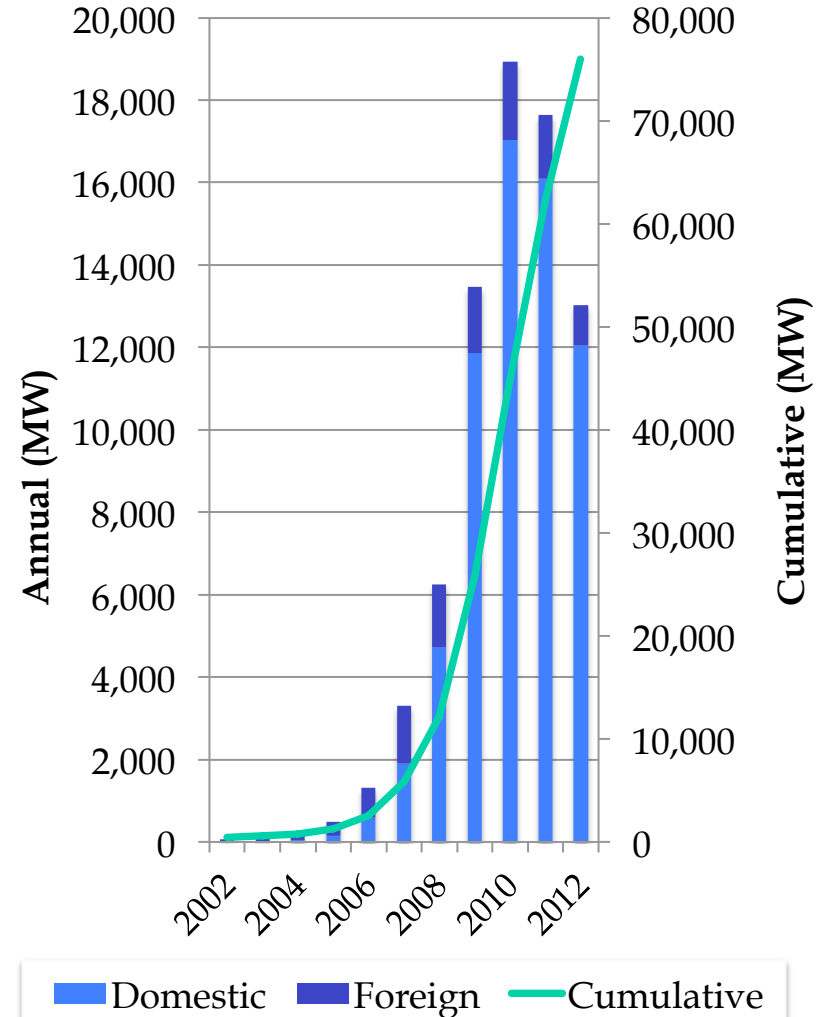
| Year | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Oil | 378.7 (20.1) | 390.2 (19.3) | 402.1 (18.2) | 444.7 (18.1) | 477.5 (18.6) | 501.6 (18.2) |
| Natural Gas | 64.6 (3.4) | 75.0 (3.7) | 83.3 (3.8) | 101.6 (4.1) | 120.2 (4.7) | 132.0 (4.8) |
| Coal | 1321.1 (70.0) | 1413.3 (69.7) | 1564.4 (70.7) | 1719.9 (70.0) | 1768.5 (68.8) | 1880.9 (68.1) |
| Nuclear | 14.1 (0.7) | 15.5 (0.8) | 15.9 (0.7) | (16.7) (0.7) | 19.5 (0.8) | 22.0 (0.8) |
| Hydro electricity | 109.8 (5.8) | 132.4 (6.5) | 139.3 (6.3) | 163.1 (6.6) | 158.2 (6.2) | 194.8 (7.0) |
| Renewables | 1.9 (0.1) | 3.6 (0.2) | 6.9 (0.3) | 12.1 (0.5) | 25.4 (1.0) | 31.9 (1.2) |
| Total | 1888.3 | 2026.3 | 2212.0 | 2458.1 | 2569.3 | 2763.2 |

Explosive growth...

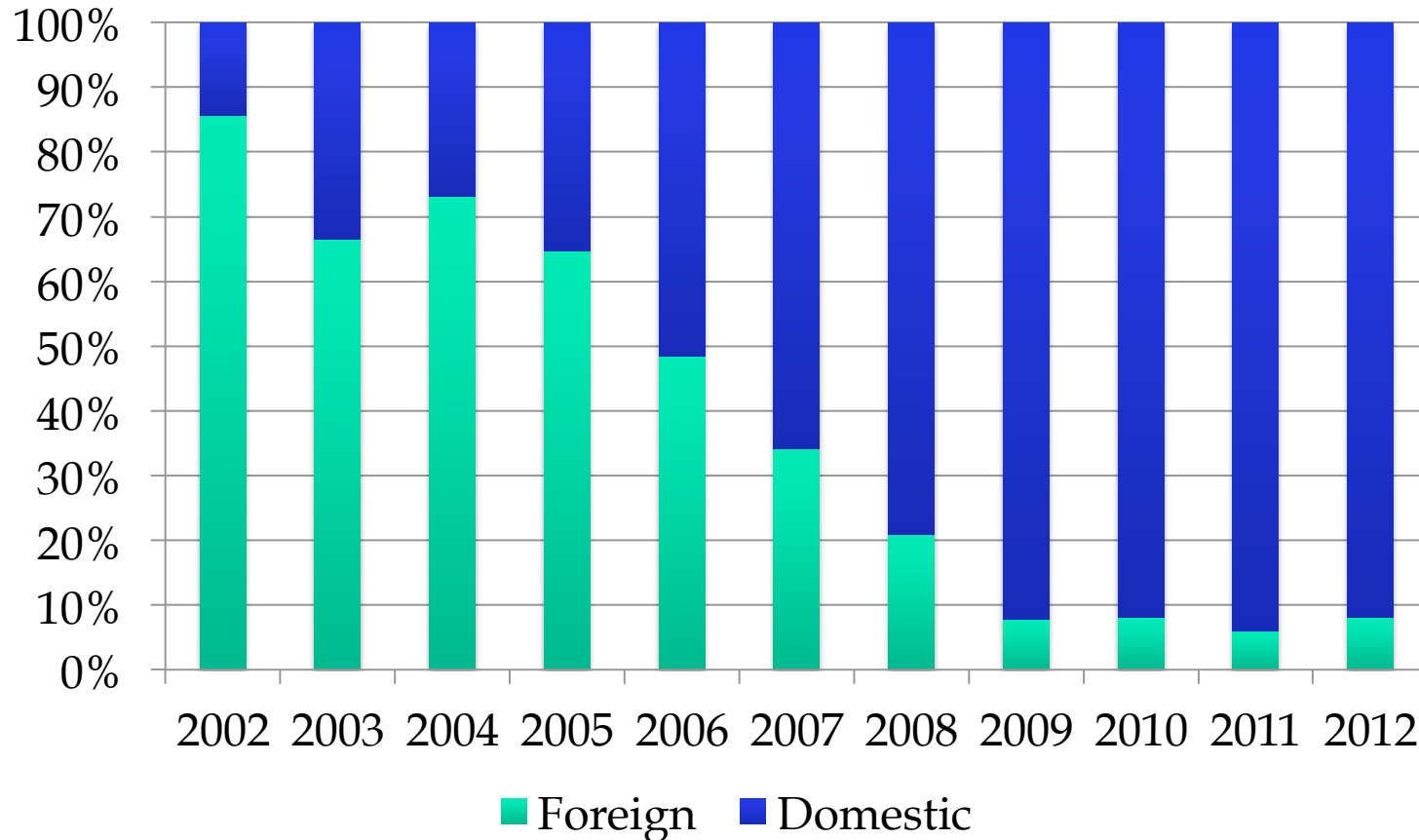
US Installations



China Installations



Domestic producers take over the (protected) domestic market in record time...



Chinese primary energy consumption

| Year | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Oil | 378.7 (20.1) | 390.2 (19.3) | 402.1 (18.2) | 444.7 (18.1) | 477.5 (18.6) | 501.6 (18.2) |
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| Total | 1888.3 | 2026.3 | 2212.0 | 2458.1 | 2569.3 | 2763.2 |

NDRC Notice 1204 locks foreign firms out of the mother of all wind farm construction booms...

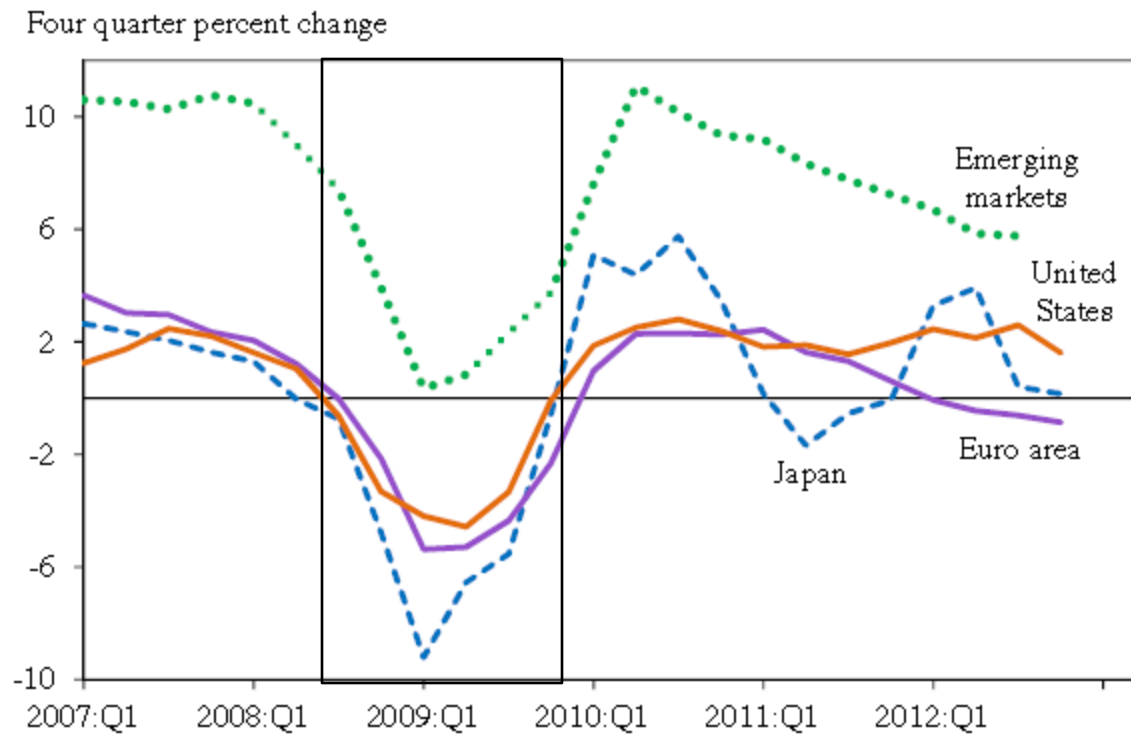
- Local content requirement
 - “The approval of wind farm construction shall be based on the wind energy development plan... The rate of using domestic equipment in the production of the wind farm must be above 70 percent.”

- Manufacturers established bases in China
 - Gamesa: constructed local assembly plant, trained local companies

- Revoked in 2009
 - Foreign manufacturers already built in-country facilities
 - Worries of excess capacity in the supply chain

But a funny thing happened on the way to China's green power revolution...

Figure 7-1
Real GDP Growth by Country, 2007–2012



Note: Data through 2012:Q4 for all but emerging markets, for which data is available only for 2012:Q3.

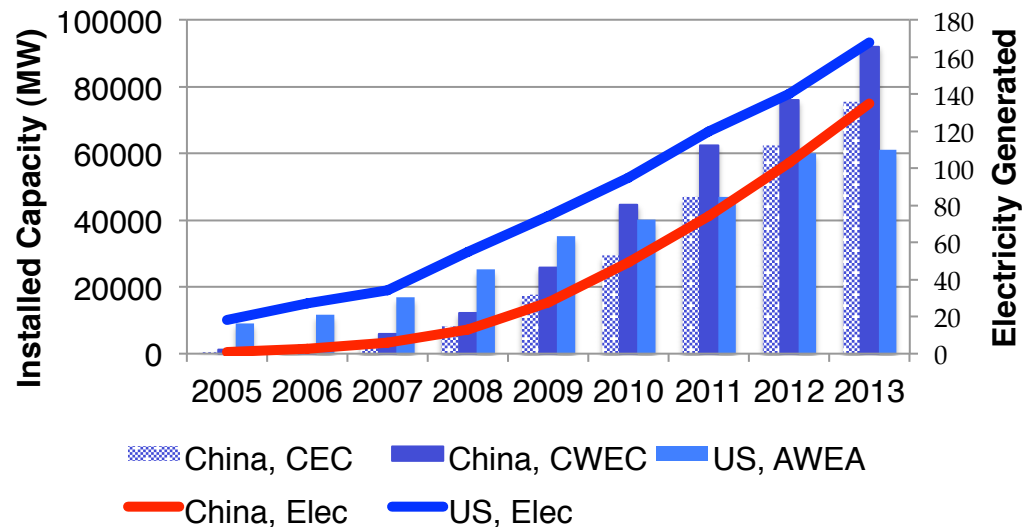
Source: Country sources; U.S. Department of Commerce, Bureau of Economic Analysis; Cabinet Office of Japan; Statistical Office of the European Communities; CEA calculations.

Facing declining fossil energy prices and a sharp slowdown at home, China basically ignored its green energy targets...

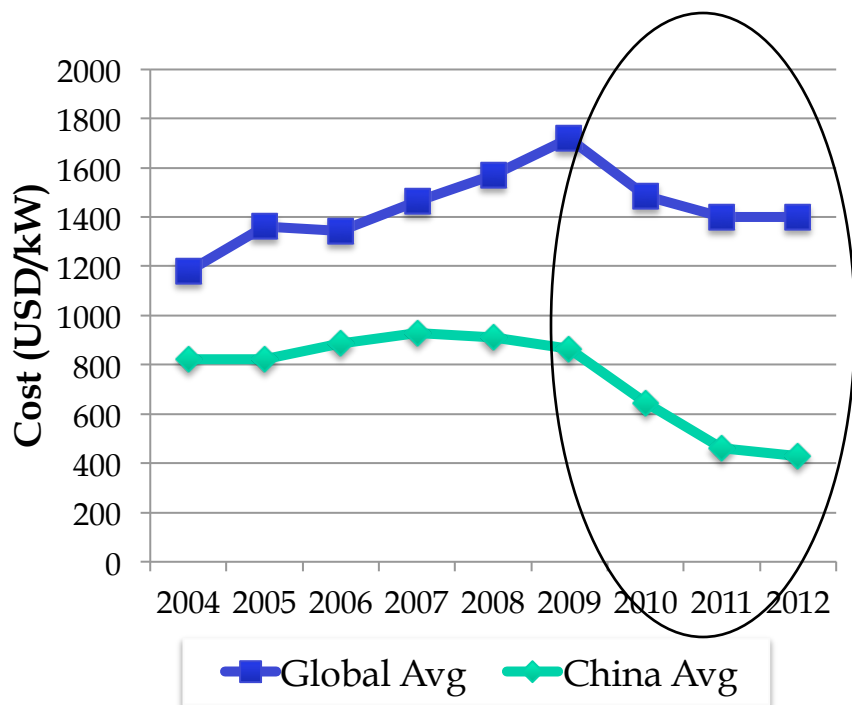
- China missed its renewable energy targets by a mile...
- The State Grid company was allowed to curtail expensive green energy
- A large fraction of installed wind turbines were left unconnected the grid
- Demand, supposedly guaranteed by State Council edict, weakened just a tidal wave of new production hit the market...
- Sensing a massive accumulation of production capacity within marginal firms, MIIT imposed the requirement that only firms capable of building 2.5 MW turbines were eligible to compete for domestic contracts...

By the way, wind power generation still lags far behind wind power installation in China...

Installed Capacity and Electricity Generated From Wind, US and China



Wind turbine prices collapsed in China, but so did the financial condition of most domestic producers...



- Equity values of domestic wind turbine manufactures shriveled after fall 2010
- By 2013, the number of turbine manufactures had declined from over 80 to approximately 30!
- Even China's largest and most successful firms had suffered massive sales declines and/or profit reversals

IEA, IRENA, KGI (2013)

Agenda

Innovation in wind power in China and beyond

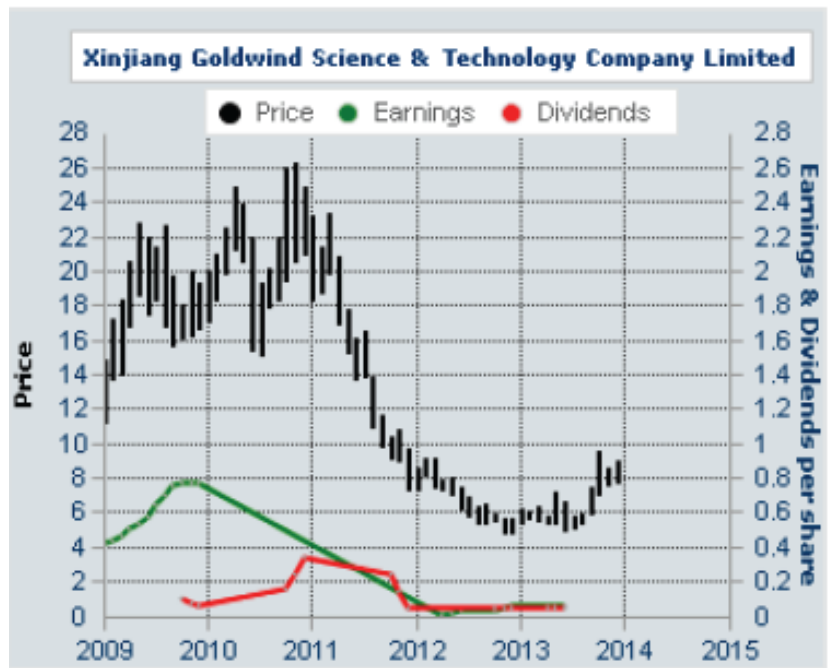
China's wind farm construction boom and its consequences

The state of China's wind turbine industry, 2012-2014

A significant industry consolidation is underway

- In 2010, there were more than 80 wind turbine manufacturers in China
- By 2013, that number had fallen to about 30!
- Wind turbine sales fell by more than 30% in quantity terms from 2010-2012

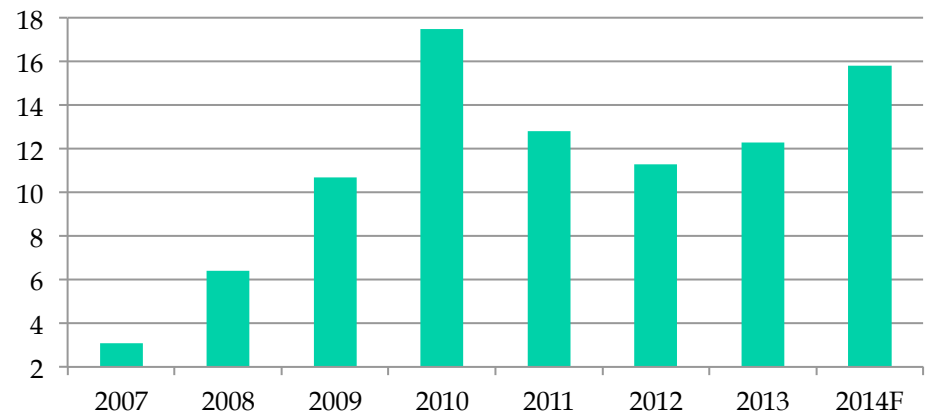
Goldwind, China's leading firm, has suffered a sharp sales decline and a collapse of its equity price...



Source: KGI Securities

Goldwind Revenues, 2007-2014

Billions of Chinese RMB



Source: UBS Securities

Goldwind's profits during the downturn came almost entirely from "non-operating income," and its rate of return has been low

Profit & Loss

| Year to 31 Dec (Rmb mn) | 2011A | 2012A | 2013F | 2014F | 2015F |
|---|---------------|---------------|---------------|---------------|---------------|
| Sales | 12,756 | 11,225 | 13,156 | 14,468 | 15,915 |
| Cost of Goods Sold | 10,699 | 9,633 | 10,535 | 11,653 | 12,843 |
| Gross Profit | 2,057 | 1,592 | 2,621 | 2,815 | 3,072 |
| Operating Expenses | 1,808 | 1,699 | 2,302 | 2,503 | 2,753 |
| Operating Profit | 249 | (107) | 319 | 312 | 318 |
| Net Interest Income | (204) | (303) | (218) | (307) | (399) |
| Interest Income | 54 | 89 | 64 | 61 | 63 |
| Interest Expense | 258 | 392 | 282 | 368 | 461 |
| Net Investment Income/(Loss) | 0 | 0 | 0 | 0 | 0 |
| Net other Non-op. Income/(Loss) | 820 | 617 | 408 | 550 | 668 |
| Net Extraordinaries | (111) | (12) | (15) | (20) | (25) |
| Pretax Income | 753 | 194 | 494 | 535 | 563 |
| Income Taxes | 146 | 41 | 76 | 83 | 88 |
| Net Profit After Extraordinaries | 607 | 153 | 418 | 452 | 475 |
| EBITDA | 387 | 80 | 538 | 672 | 818 |
| EPS (Rmb) | 0.22 | 0.06 | 0.15 | 0.17 | 0.18 |

Source: Company data; KGI Asia Limited estimates

| Year to 31-Dec | Operating Margin | x | Capital Turnover | x | Cash 1 - Tax Rate | = | After-tax Return on Inv. Capital |
|----------------|------------------|---|------------------|---|-------------------|---|----------------------------------|
| 2011A | 2.0% | | 0.9 | | 83.1% | | 1.5% |
| 2012A | (1.0%) | | 0.9 | | 80.0% | | (0.7%) |
| 2013F | 2.4% | | 0.8 | | 85.0% | | 1.7% |
| 2014F | 2.2% | | 0.8 | | 85.0% | | 1.5% |
| 2015F | 2.0% | | 0.8 | | 85.0% | | 1.4% |

Source: Company data; KGI Asia Limited estimates

Goldwind's revenues and gross profits are projected to rise, but its ROA remains meager...

Profit & Loss

| Year to 31 Dec (Rmb mn) | 2012A | 2013A | 2014F | 2015F | 2016F |
|---|---------------|---------------|---------------|---------------|---------------|
| Sales | 11,225 | 12,196 | 15,323 | 17,538 | 18,363 |
| Cost of Goods Sold | 9,633 | 9,742 | 11,732 | 13,082 | 13,324 |
| Gross Profit | 1,592 | 2,454 | 3,591 | 4,456 | 5,038 |
| Operating Expenses | 1,699 | 2,196 | 2,758 | 3,157 | 3,305 |
| Operating Profit | (107) | 258 | 833 | 1,299 | 1,733 |
| Net Interest Income | (303) | (282) | (491) | (665) | (841) |
| Interest Income | 89 | 38 | 20 | 10 | 20 |
| Interest Expense | 392 | 320 | 510 | 676 | 861 |
| Net Investment Income/(Loss) | 0 | 0 | 0 | 0 | 0 |
| Net other Non-op. Income/(Loss) | 617 | 530 | 528 | 535 | 546 |
| Pretax Income | 194 | 500 | 860 | 1,154 | 1,418 |
| Income Taxes | 41 | 72 | 135 | 187 | 237 |
| Net Extraordinaries | (12) | (6) | (10) | (15) | (20) |
| Net Profit After Extraordinaries | 153 | 428 | 725 | 967 | 1,181 |
| EBITDA | 128 | 490 | 1,177 | 1,788 | 2,409 |
| EPS (Rmb) | 0.06 | 0.16 | 0.27 | 0.36 | 0.44 |

Source: Company data; KGI Asia Limited estimates

Profitability (%)

| | 2012A | 2013A | 2014F | 2015F | 2016F |
|-------------------|-------|-------|-------|-------|-------|
| Gross Margin | 14.2 | 20.1 | 23.4 | 25.4 | 27.4 |
| Operating Margin | (1.0) | 2.1 | 5.4 | 7.4 | 9.4 |
| EBITDA Margin | 1.1 | 4.0 | 7.7 | 10.2 | 13.1 |
| Net Profit Margin | 1.4 | 3.5 | 4.7 | 5.5 | 6.4 |
| ROAA | 0.5 | 1.3 | 1.9 | 2.1 | 2.3 |

Sinovel and Ming Yang have fared substantially worse...

SINOVEL WIND GROUP CO LTD 'A'CN (601558.SS) - Shanghai

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3.61 ↓ 0.02 (0.55%) 1:59AM EST

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China Ming Yang Wind Power Group Limited (MY) - NYSE

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2.65 ↑ 0.15 (6.00%) 4:03PM EST

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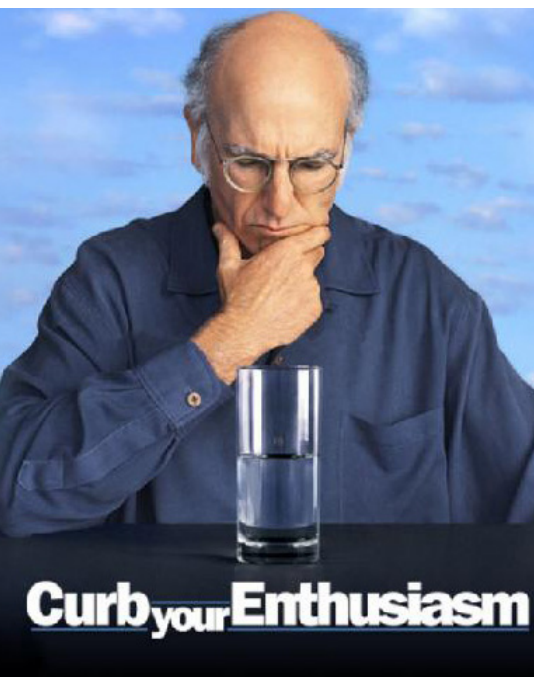


China's champions versus the best of the West

Table 1: Stock performance of various public companies from 2011- present

| Firm | Exchange | 2011 Price | All time low | Current Price |
|-------------------|-----------------|-------------------|---------------------|----------------------|
| Xinjiang Goldwind | Hong Kong | 17 | 1.5 (-91%) | 10 (-41%) |
| Sinovel | Shanghai | 18 | 3.5 (-81%) | 3 (-83%) |
| Vestas | Copenhagen | 180 | 30 (-83%) | 273 (+51%) |
| Gamesa | Madrid | 5.5 | 1.5 (-73%) | 8.9 (+62%) |
| Nordex | Frankfurt | 5.5 | 2 (-64%) | 15.94 (+191%) |

Closer inspection suggests that China's wind industry "miracle" has come at a cost...



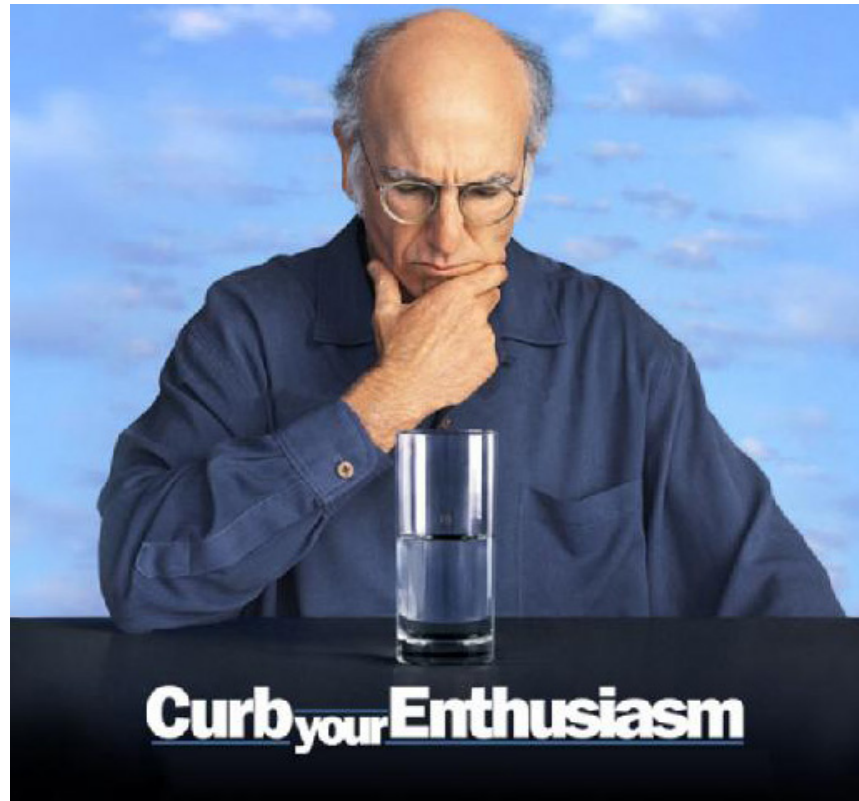
- Rapid expansion of China's market, combined with WTO-illegal protectionist measures, incubated the development of large domestic firms...
- But the majority of domestic firms brought into existence by this policy have already ceased production
- And even some of the large players may not survive the next few years
- The national ROI on this experiment – at least so far – does not appear terribly compelling
- And none of the local firms have engaged in meaningful product innovation

The myth of the Chinese jolly green giant?

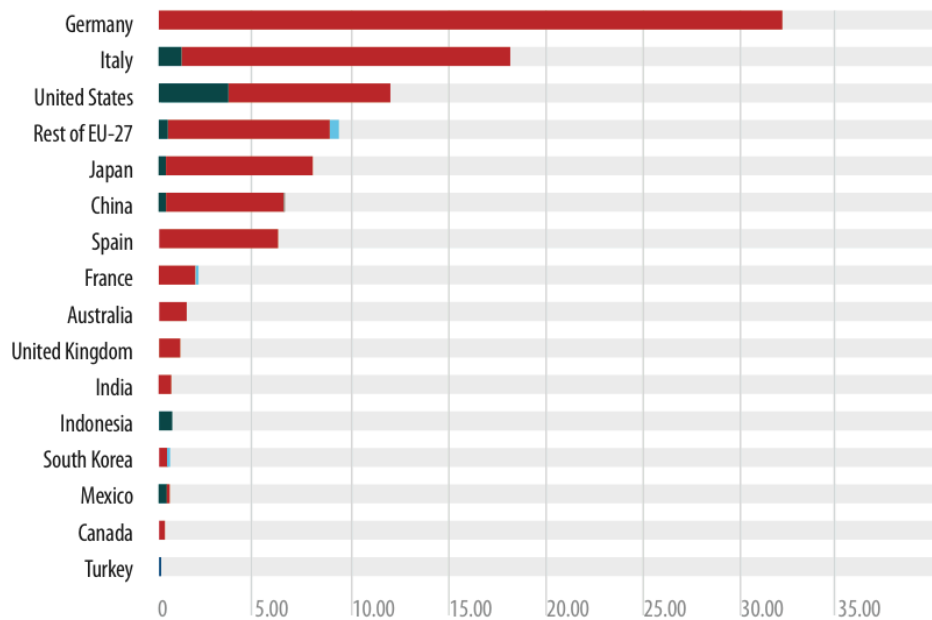
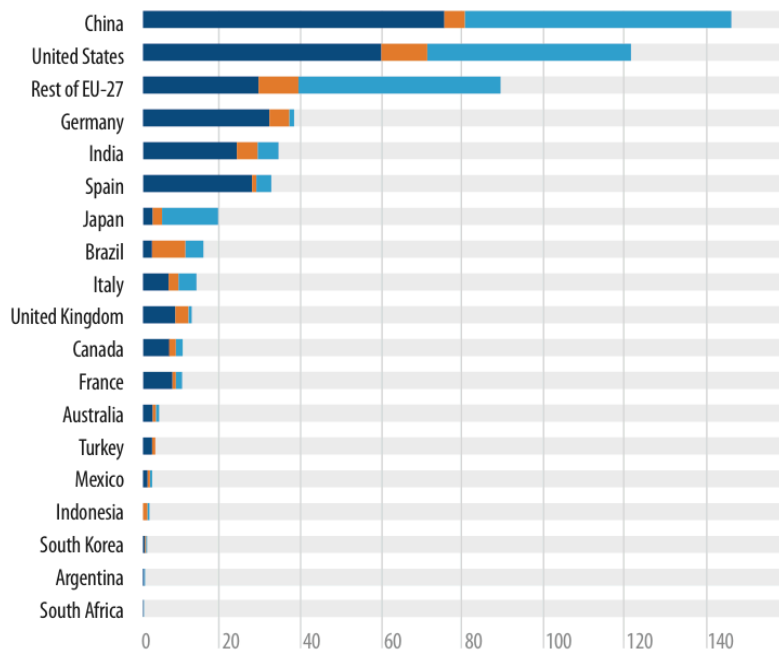


- China's solar PV industry has achieved large scale, but producers earn thin margins and have produced little real innovation
- High profile electric automaker BYD is struggling to sell its electric cars, despite financial backing from Warren Buffett
- China's green energy surge looks less promethean today than it appeared 2-3 years ago...
- But that may not stop other countries from imitating it

We (enthusiastically) look forward to your questions and comments!

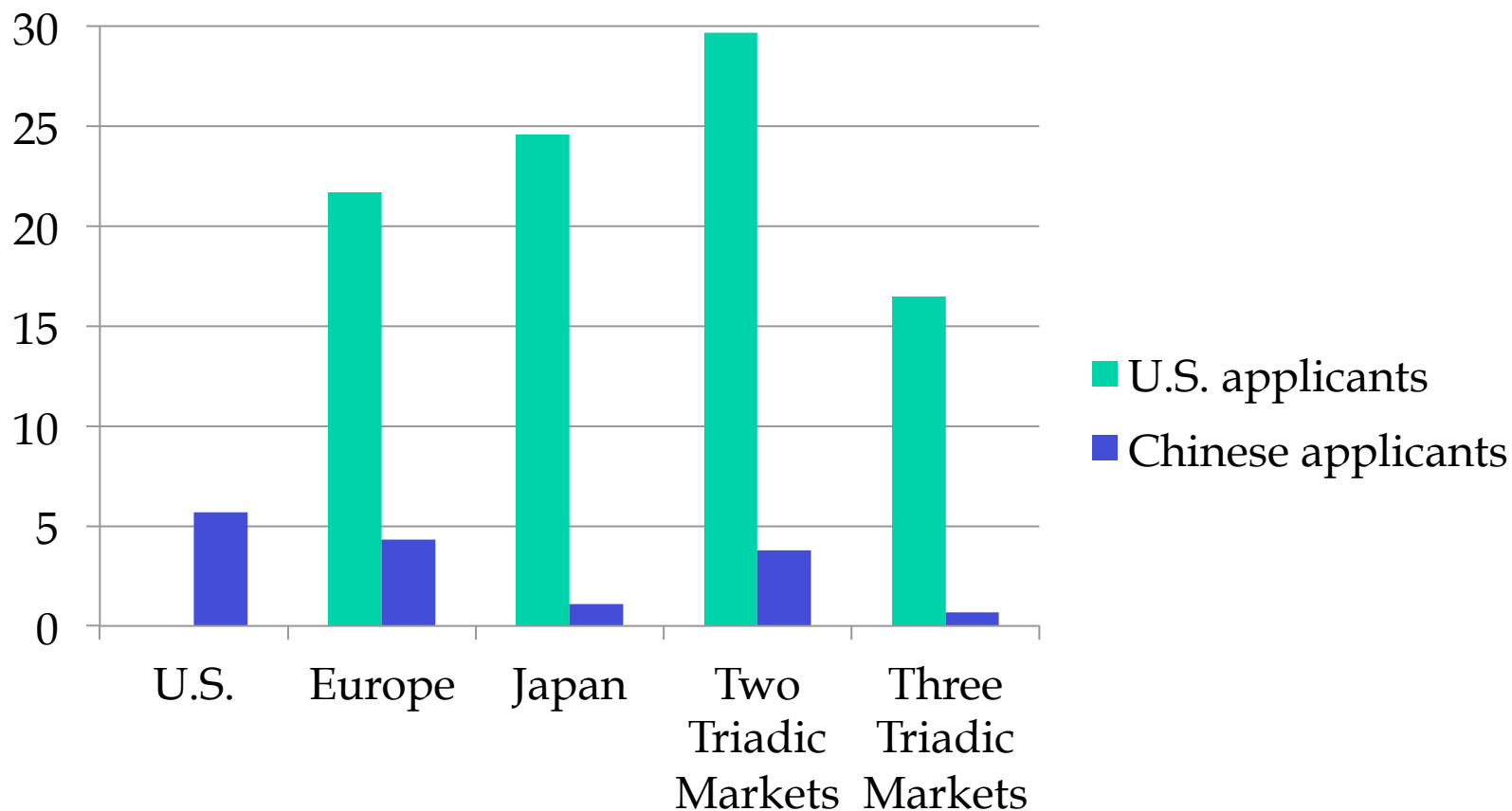


RE Market, Worldwide



Bloomberg New Energy Finance (2012)

But the top 100 indigenous Chinese applicants patent only a small fraction of their inventions outside China



Curtailment rate in US

| | 2007 | 2008 | 2009 | 2010 | 2011 |
|--|-----------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| Electric Reliability Council of Texas (ERCOT) | 109 (1.2%) | 1,417 (8.4%) | 3,872 (17.1%) | 2,067 (7.7%) | 2,622 (8.5%) |
| Southwestern Public Service Company (SPS) | N/A | 0 (0.0%) | 0 (0.0%) | 0.9 (0.0%) | 0.5 (0.0%) |
| Public Service Company of Colorado (PSCo) | N/A | 2.5 (0.1%) | 19.0 (0.6%) | 81.5 (2.2%) | 63.9 (1.4%) |
| Northern States Power Company (NSP) | N/A | 25.4 (0.8%) | 42.4 (1.2%) | 42.6 (1.2%) | 54.4 (1.2%) |
| Midwest Independent System Operator (MISO), less NSP | N/A | N/A | 250 (2.2%) | 781 (4.4%) | 657 (3.0%) |
| Bonneville Power Administration (BPA) | N/A | N/A | N/A | 4.6* (0.1%) | 128.7* (1.4%) |
| Total Across These Six Areas: | 109 (1.2%) | 1,445 (5.6%) | 4,183 (9.6%) | 2,978 (4.8%) | 3,526 (4.8%) |

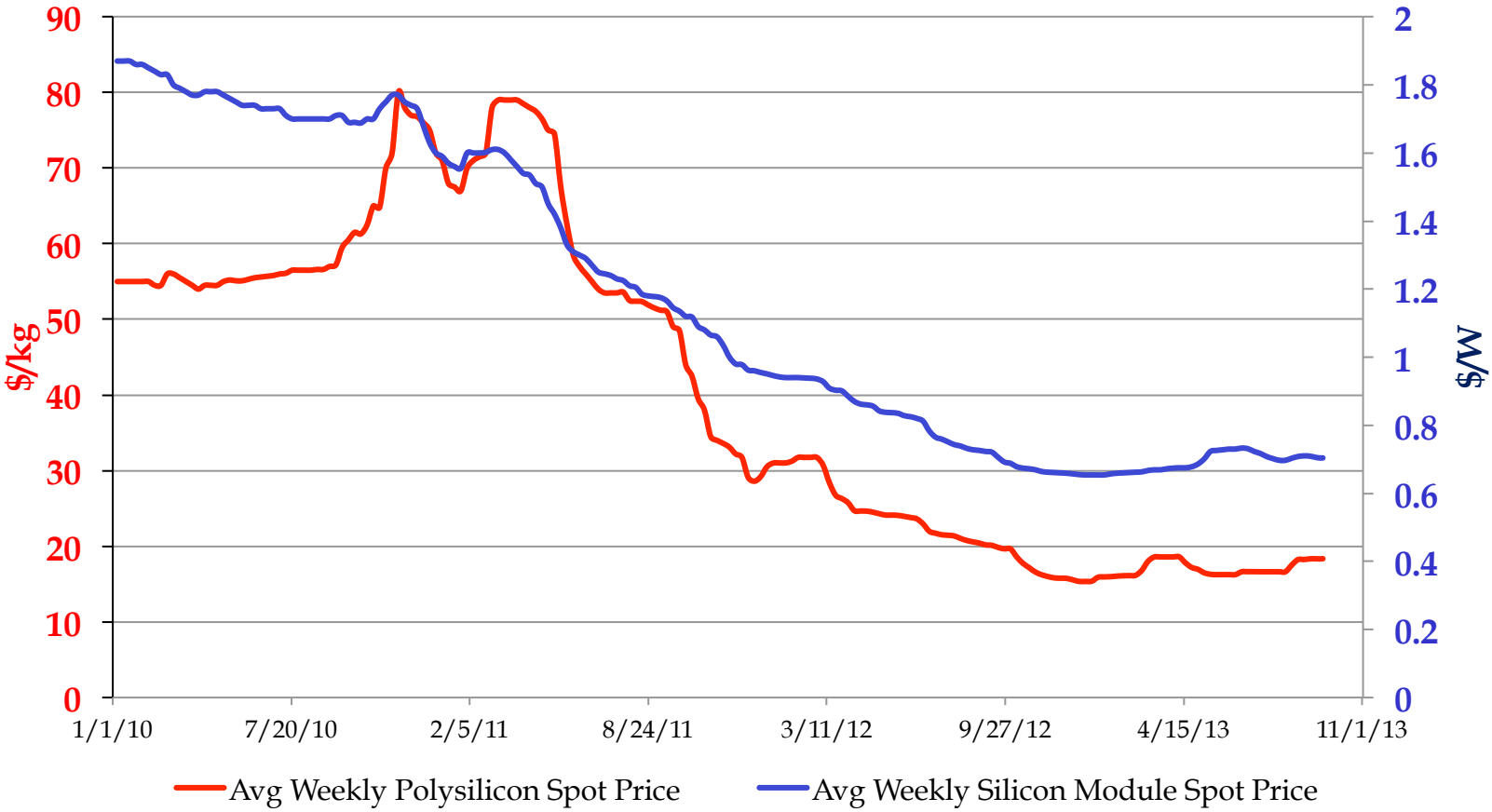
*A portion of BPA's curtailment is estimated assuming that each curtailment event lasts for half of the maximum possible hour for each event.

Source: ERCOT, Xcel Energy, MISO, BPA

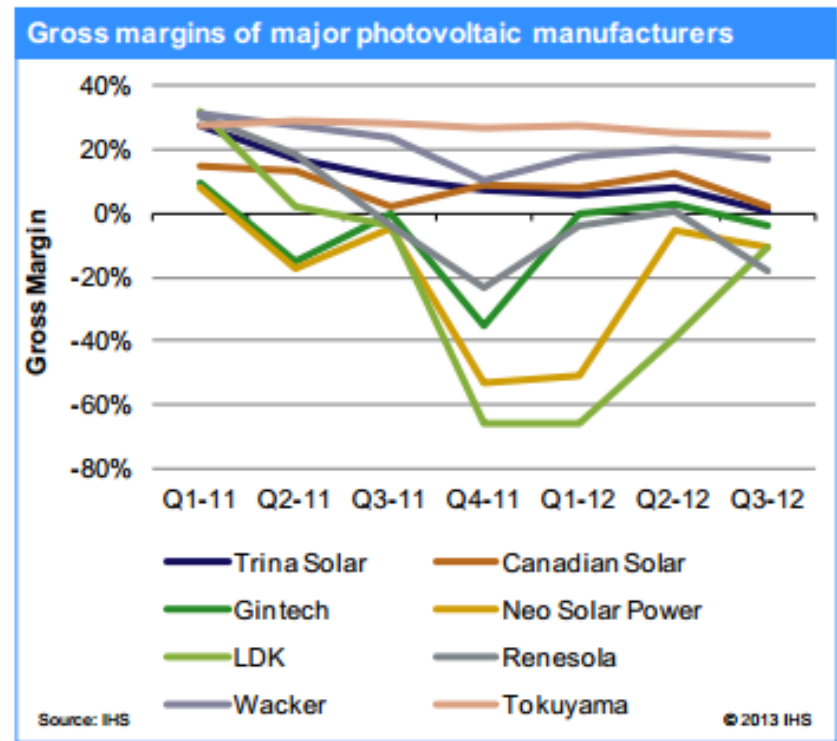
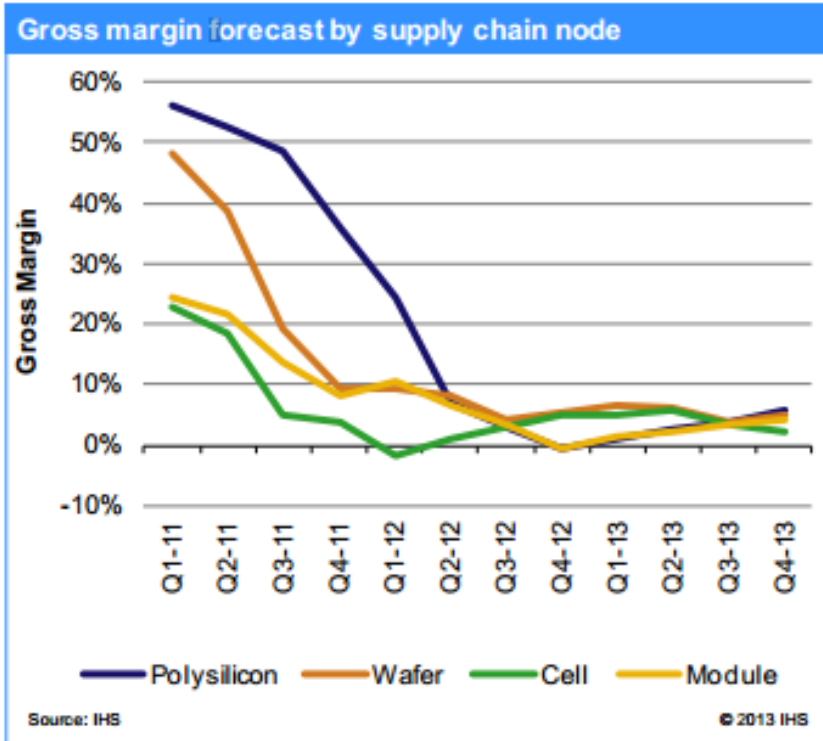
Popular Panels in California's Residential Market, 2012

| Manufacturer | ID | Rating | Efficiency |
|------------------------------------|---------------|--------|------------|
| SunPower | SPR-220-BLK-U | 220 | 17.68% |
| Sanyo Electric of Panasonic Group | VBHN220AA01 | 220 | 17.64% |
| Kyocera Solar | KD220GX-LFBS | 220 | 15.40% |
| Suntech Power | PLUTO220-Udm | 220 | 14.97% |
| Canadian Solar | CS6P-220PE | 220 | 14.20% |
| Sharp | ND-220UCJ | 220 | 13.99% |
| LG Electronics Solar Cell Division | LG220R1W-G2 | 220 | 13.81% |
| Trina Solar | TSM-220DA05 | 220 | 13.60% |
| Yingli Energy (China) | YL220P-29b | 220 | 13.46% |
| REC Solar | REC220PE-US | 220 | 13.33% |

Avg Weekly Polysilicon vs Module Spot Prices, 2010-2013



Gross margins are bottoming out for every step of the supply chain



Source: IHS Market Solar Research

Does this look familiar?

Yingli Green Energy Holding Co. Ltd. (YGE) - NYSE

3.73 $\uparrow 0.21$ (5.96%) 10:07AM EDT - Nasdaq Real Time Price

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JA Solar Holdings Co., Ltd. (JASO) - NasdaqGS

10.72 $\uparrow 0.45$ (4.38%) 10:09AM EDT - Nasdaq Real Time Price

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Trina Solar Limited (TSL) - NYSE

12.48 $\uparrow 0.40$ (3.28%) 10:08AM EDT - Nasdaq Real Time Price

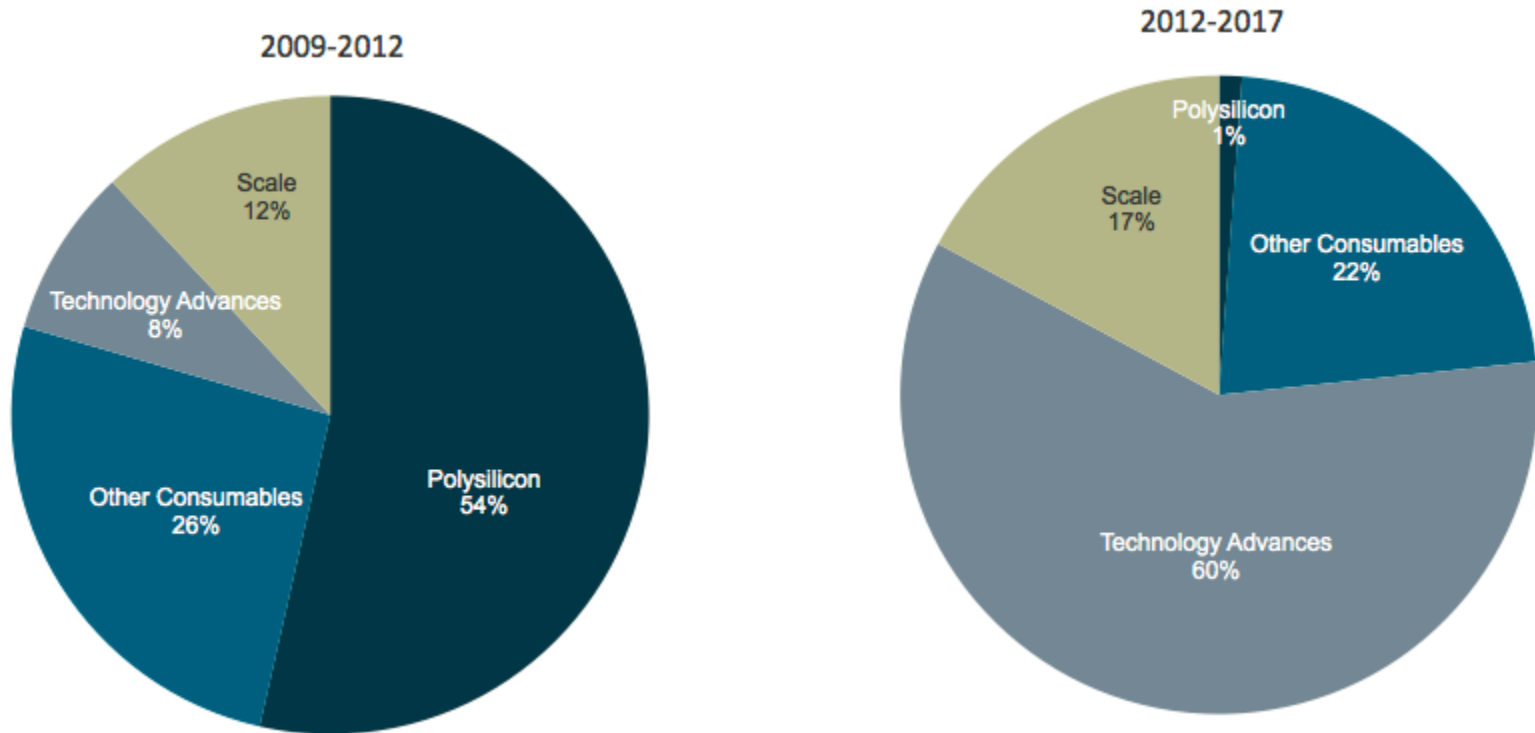
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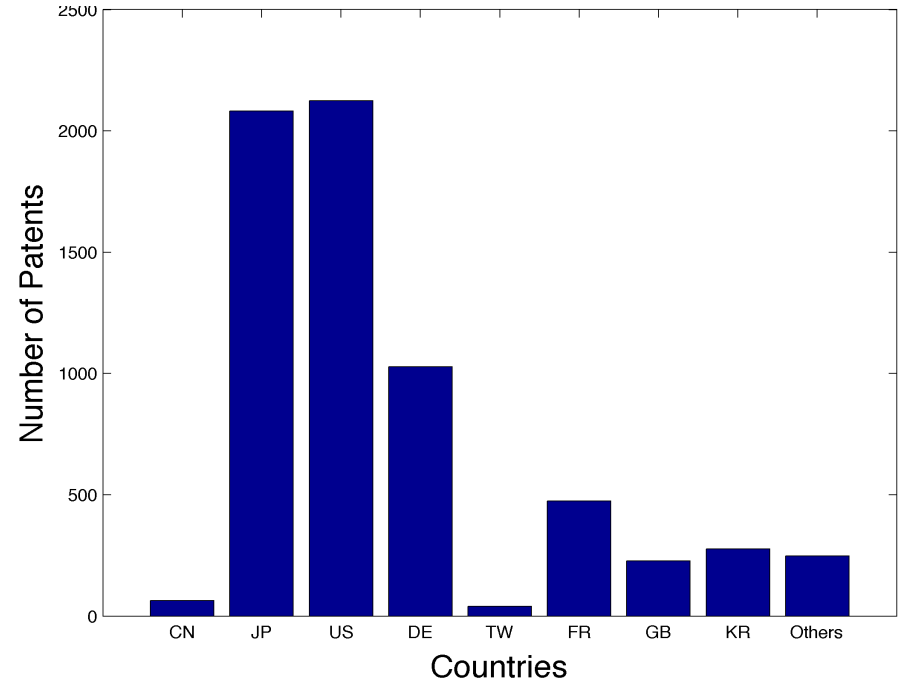
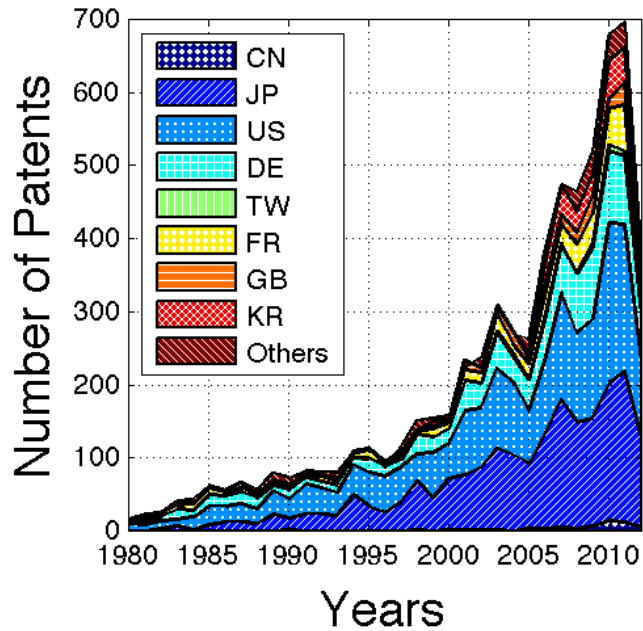


How do we get to \$0.45/watt by 2017?



Source: <http://www.greentechmedia.com/articles/read/solar-cost-reduction-drivers-in-2017>

Chinese solar firm's international patenting



EP Solar PV Patent Total: 6565

| China | Japan | US | Germany | Taiwan | France | Britain | Korea | Others |
|-------|-------|------|---------|--------|--------|---------|-------|--------|
| 64 | 2982 | 2124 | 1028 | 40 | 475 | 228 | 277 | 247 |