Epidemic, rank, stock and order effects in renewable energy diffusion:

a model and empirical evidence from China’s wind power sector

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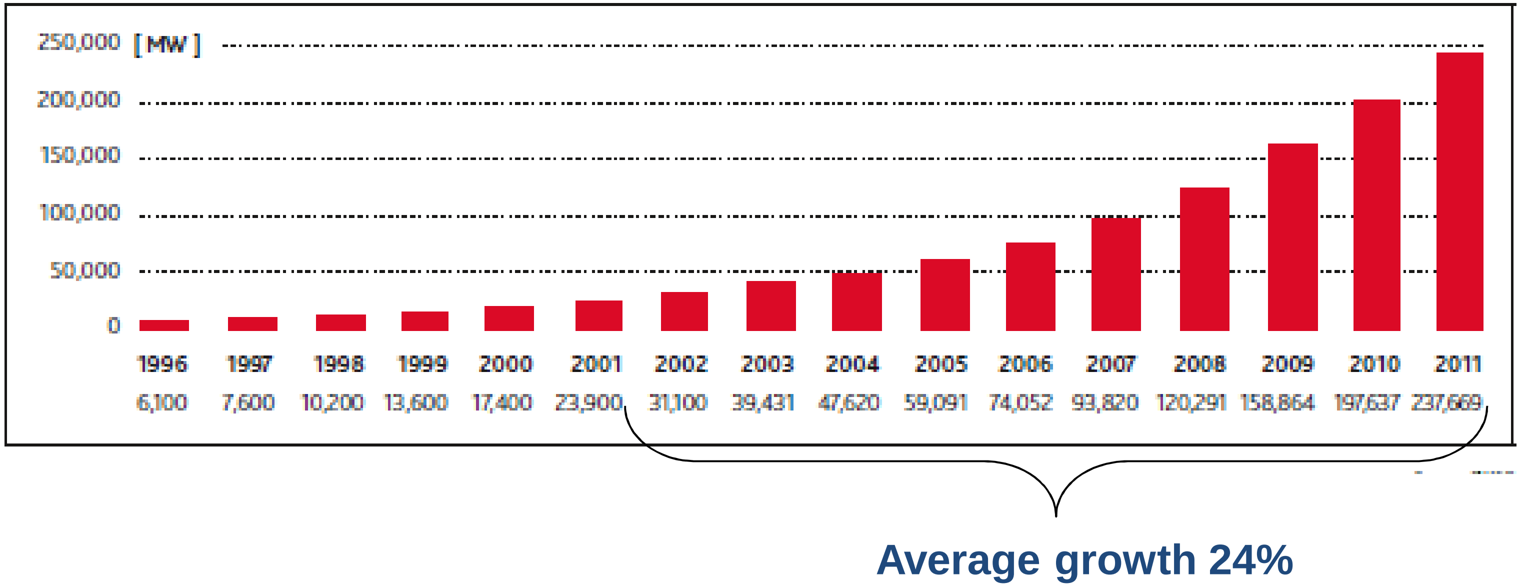
Overview on global wind energy

- The onshore wind power market experiences a rapid development.

Global Cumulative Installed Wind Capacity 1996-2011 (Source: Global Wind Energy Council, 2012)

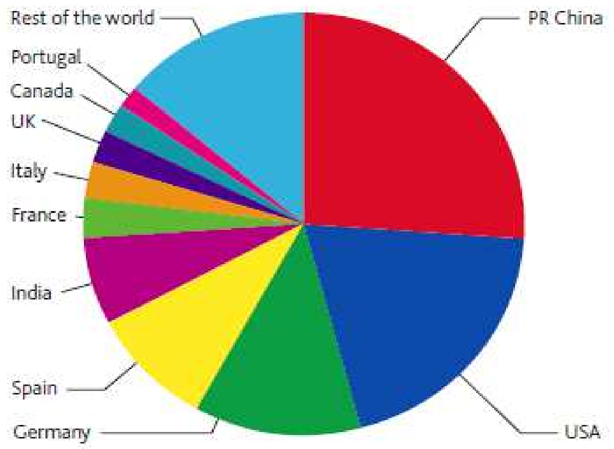


- However wind energy remains a relatively small fraction of worldwide electricity demand and estimated technical potential (IEA,2010).
  - 1.8% of worldwide electricity production (20 200 TWh in 2008)
  - 0.4% of the estimated technical potential by the end of 2009 (50 000 TWh/yr).

Overview on global wind energy

- The market growth has been concentrated in top 10 countries . The majority of wind power installations are outside OECD since 2010.

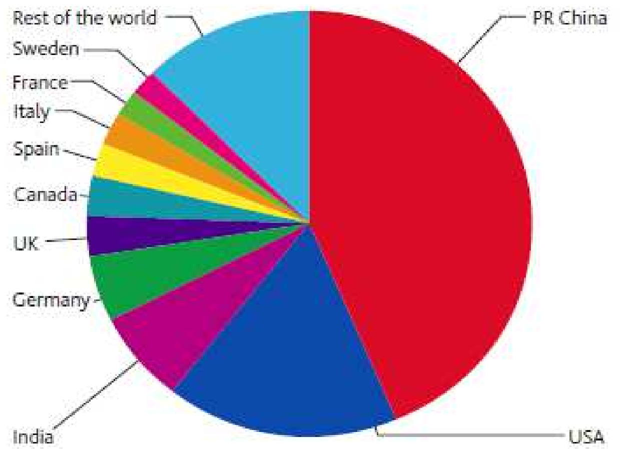
Top 10 cumulative capacity Dec 2011



Country	MW	% SHARE
PR China	62,364	26.2
USA	46,919	19.7
Germany	29,060	12.2
Spain	21,674	9.1
India	16,084	6.8
France**	6,800	2.9
Italy	6,737	2.8
UK	6,540	2.7
Canada	5,265	2.2
Portugal	4,083	1.7
Rest of the world	32,143	13.5
Total TOP 10	205,526	86.5
World Total	**237,669**	**100.0**

** *Provisional Figure* — *Source: GWEC*

Top 10 new installed capacity Jan-Dec 2011



Country	MW	% SHARE
PR China	17,631	43
USA	6,810	17
India	3,019	7
Germany	2,086	5
UK	1,293	3.2
Canada	1,267	3.1
Spain	1,050	2.6
Italy	950	2.3
France**	830	2.0
Sweden	763	1.9
Rest of the world	4,865	12.0
Total TOP 10	35,699	88
World Total	**40,564**	**100.0**

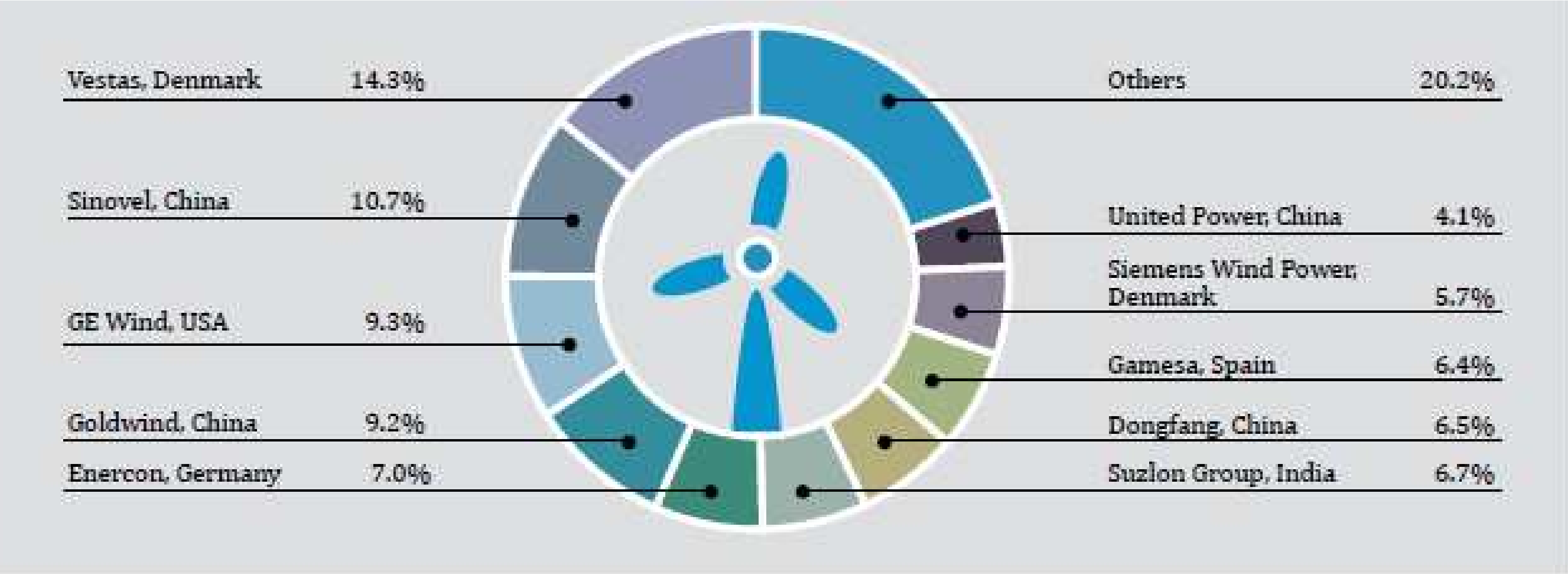
** *Provisional Figure* — *Source: GWEC*

(Source: Global Wind Energy Council, 2012)

Overview on global wind energy

- The global wind turbine market remains regionally segmented, with just six countries hosting the majority of wind turbine manufacturing (China, Denmark, India, Germany, Spain and USA).

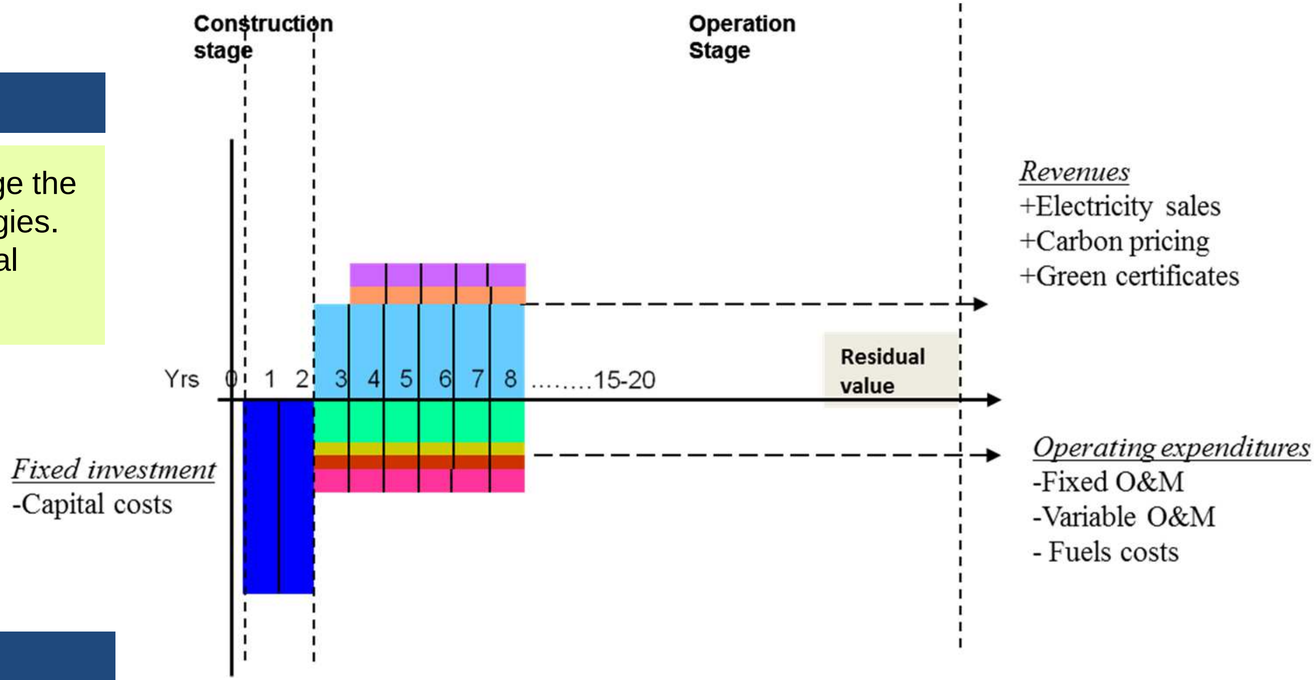
Market shares of Top 10 wind turbine manufacturers, 2010



Source: Global Wind Energy Council, 2011

Motivation

- **Research question**: How will a renewable energy technology, once introduced, diffuse at a reasonably rapid pace?



Demand pull policy

- Enhance the **profitability** and enlarge the market opportunity for new technologies. (i.e. feed-in tariff, carbon price, capital subsidy, low-interest loan)

Technology push policy

- **National system of innovation**: network of institutions and coordinating role of the government in influencing these interactions. (human capital, research capacity, proximity between user and supplier, absorptive capacity)
- Freeman (1987), Lundvall (1992), Nelson (1993), and Metcalfe (1995).

Motivation

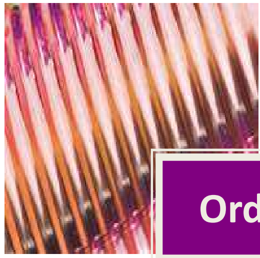
Market forces

Rank effect

- *R*ank firms in terms of the benefit from technology adoption; highest ranked firms adopt the technology earlier than others.

Stock effect

- Prices of output product and market demand might change along with technology diffusion, leading to a negative impact on profitability of marginal adoption (Reinganum 1981).



Order effect

- First mover advantages such as prime geographic sites or skilled labor encourage firms to be first adopters (Fudenberg and Tirole 1985).

Non market forces

Epidemic effect

- Increasing spread of information between previous and potential adopters reduces the uncertainty and leads further rapid adoption (Mansfield 1963; Bass 1969, 2004).

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Model

- A logistic demand function with two components: profitability effect and epidemic effect.
  - $Q_t = \frac{a_t \cdot Q^{max}}{a_t + (Q^{max} - a_t) \cdot e^{-b \cdot NPV_t}} + Dif_t$ (1)
- Time-varying baseline demand of technology adoption: incorporate the previous time's diffusion into the current time's base demand.
  - $a_t = a_{t-h} \cdot \left(\frac{Q_{t-h} + Dif_{t-h}}{Q_{t-h}} \right)$ (2)
- The epidemic effect converges to zero as the newly installed capacity in previous time approaches its maximal capacity.
  - $Dif_t = \gamma \cdot Q_{t-h} \cdot \left(1 - \frac{Q_{t-h}}{Q^{max}}\right)$ (3)
- Empirical models:
  - Model A: $\ln(Q_t) \cong \frac{1}{2}\gamma \cdot t - \frac{\gamma}{2Q^{max}} QS_t + \frac{1}{2} b \cdot NPV_t,$
  - Model B: $\ln(Q_t) \cong \frac{1}{2}\gamma \cdot t - \frac{\gamma}{2Q^{max}} QS_t + \frac{1}{2} b \cdot NPV_t + c \cdot NPV_t^2$
  - Model C: $\ln(Q_t) \cong \frac{1}{2}\gamma \cdot t + \frac{1}{2} b \cdot NPV_t + c \cdot NPV_t^2$
  - $NPV_t = -C_t^{Invest} + \sum_{n=1}^{T} \frac{(FIT_t + P_t^{CO2} \cdot \pi^{emission}) \cdot yield - C_t^{Operation}}{(1+i)^n}$

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Empirical analysis

- A **panel data** of 30 provinces over the period 2004-2011 based on **1207 China's wind projects**.
- The coefficient of the **epidemic effect** (γ) is estimated to be **in the range of 0.76-0.9**.
- The **order effect** has **a decreasing marginal effect** on wind technology diffusion.
- The sign of cumulative capacity (QSt) confirms the **negative impact of stock effect** on technology diffusion, but the impact is not important.
    - The stock effect is channeled through the project profitability.

Variables	Model A	Model B	Model C
Time duration (t)	0.45 (0.05) ***	0.42 (0.05) ***	0.38 (0.03) ***
Net present value (NPV_t)	0.02 (0.02)	0.16 (0.10) *	0.18 (0.07) **
Cumulative capacity (QS_t)	-0.00009* (0.00005)	-0.00008 (0.53)	
NPV_t^2		-0.04 (0.02) **	-0.05 (0.02) ***
Constant	6.15 (0.36) ***	6.07 (0.35) ***	5.51 (0.28) ***
Provincial fixed effects	Yes	Yes	Yes
Adj. R-Squared	0.733	0.744	0.745
Number of observations	117	117	144
F-test value (Model)	11.61***	11.86***	14.04***
F-test value (provincial effects)	7.05***	6.02***	10.03***

Note: Standard errors in parentheses. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

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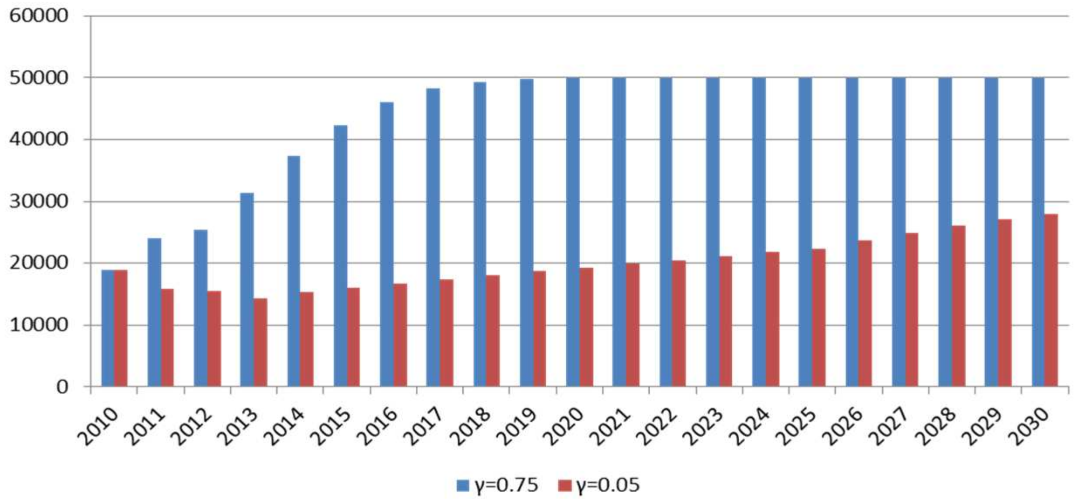
Numerical simulation

- The goal of the policy maker is to set up a time path of subsidies which **maximizes the discounted present value of net social benefits.**
  - + Avoided external environmental costs from fossil-fuel electricity replaced by wind electricity
  - + Customer benefits from policy-induced learning effects
  - - Subsidy as a cost to taxpayers

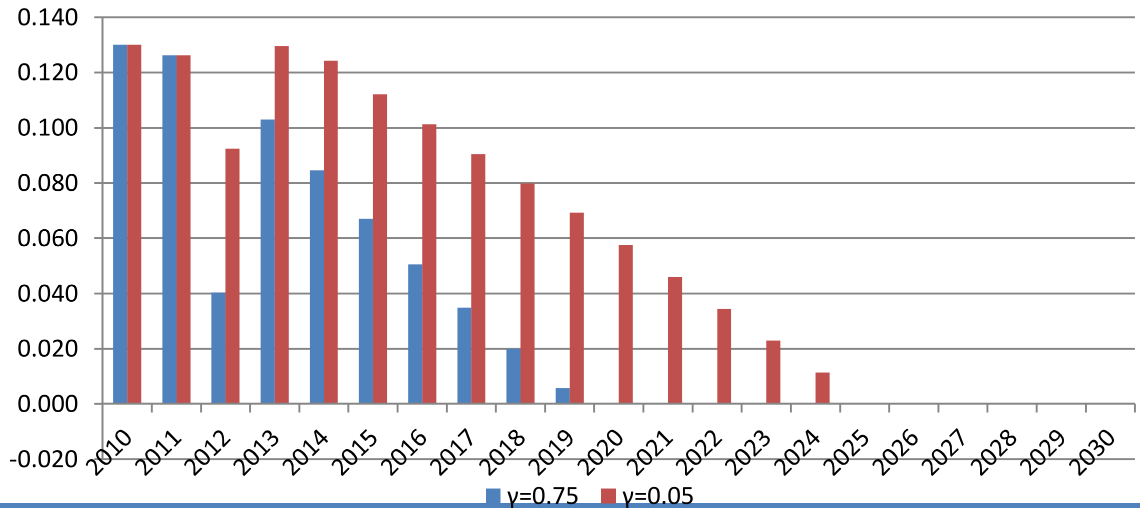
$$\max_{\boldsymbol{S_t}} W\,(S_t) = \sum_{t=1}^{T} \frac{Q_t\,(S_t) \cdot \{C^{ext} \cdot yield + CB_t(S_t, QS_t) - S_t \cdot yield\}}{(1+r)^t}$$

Simulation result (1)

➢ Annually installed wind capacity (Unit=MW)



➢ Optimal subsidy path (Unit= Yuan/kWh)



Simulation result (2)

- With the same magnitude of subsidy cost
  - Subsidy costs = 566.5 (γ =0.75, Unit=billion Yuan)
  - Subsidy costs = 539.7 (γ =0.05, Unit=billion Yuan)

- Optimal social benefits more than **doubles**, depending on the importance of the epidemic effect, .

γ =0.75	γ =0.05
8642	3487

Conclusion

- The epidemic effect may significantly **influence the pattern of renewable technology diffusion** and markedly **enhance the social benefits** with limited subsidy cost **.**

- The epidemic effect **is not** derived from the traditional market failure-based policy perspective.
  - It may be largely influenced by a broad set of institutions and patterns of interactions (i.e. absorptive capacity, user-innovator interaction, and institutional cooperation.)
  - It may offer policymakers a wider set of justifications for policy, and a wider set of policy goals.

- We also provide empirical **evidence on the existence of market competition effects** on renewable technology diffusion.
  - The profitability of wind investment has a decreasing marginal effect to encourage newly installed capacity.

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