R&D, Energy, and Growth - A Progress Report

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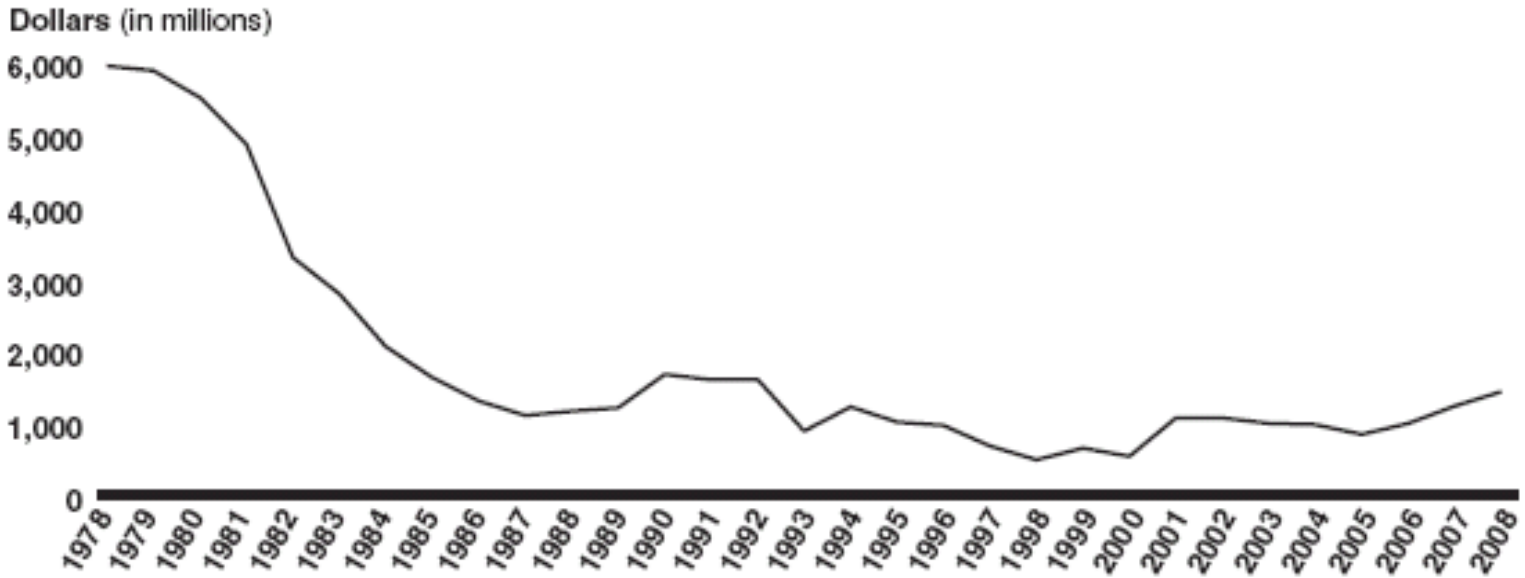
Questions

- Between 1978 and 1998, DOE's budget authority for renewable, fossil, and nuclear energy R&D fell by 92% ($6B in 1978 to $505M in 1998; rebounded to $1.4 billion in 2008)
- Is there under-investment in renewable energy R&D?
- **This study:** R&D in renewable energy as an engine of *GDP* growth
- Role for subsidy policies
- Other considerations: energy independence, global warming

Budget Authority for Renewable, Fossil, and Nuclear Energy R&D



A Popular View: Implications of R&D for Growth

- "The economic benefit from a 5- to 10-fold increase in R&D spending would repay the country in job creation,... building a vibrant, environmentally sustainable engine of new economic growth."
- "A major investment in alternative energy technologies could add more than 3.5 million new jobs to America's economy, stimulate $1.4 trillion in new GDP... The new clean energy economy will be built on innovation."
- "Renewable energy can create millions of additional jobs and entire new industries"

- Our study: Frame the issue in the context of a macro model

Plan for this Presentation

A progress report on our study

- Some related data
- Modeling the innovation process
- Discuss *qualitative* implications of the model
- Model offers theoretical argument for under-investment in R&D...

- ... but also reasons to be skeptical about significant beneficial effects of R&D subsidies on GDP growth

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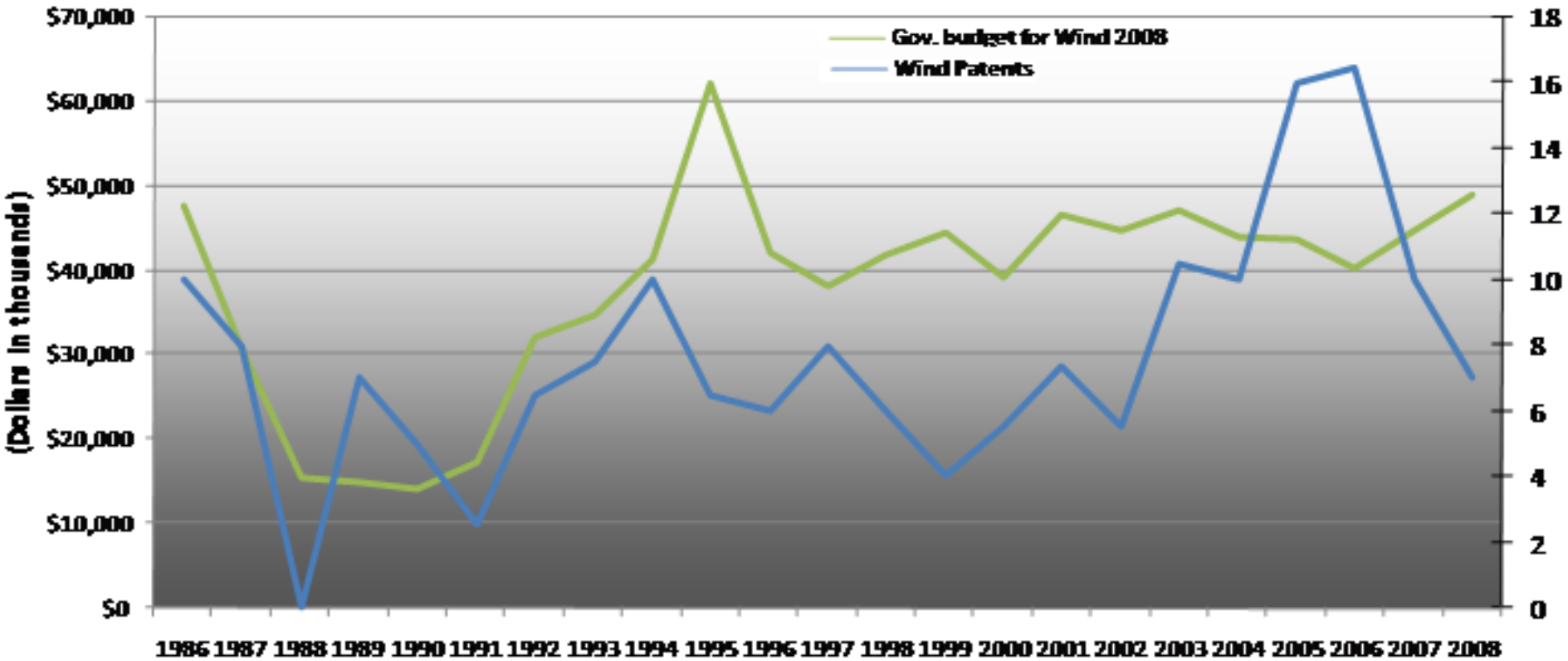
- *(I)* Decreasing returns to R&D
- *(II)* Recent related Spanish experience

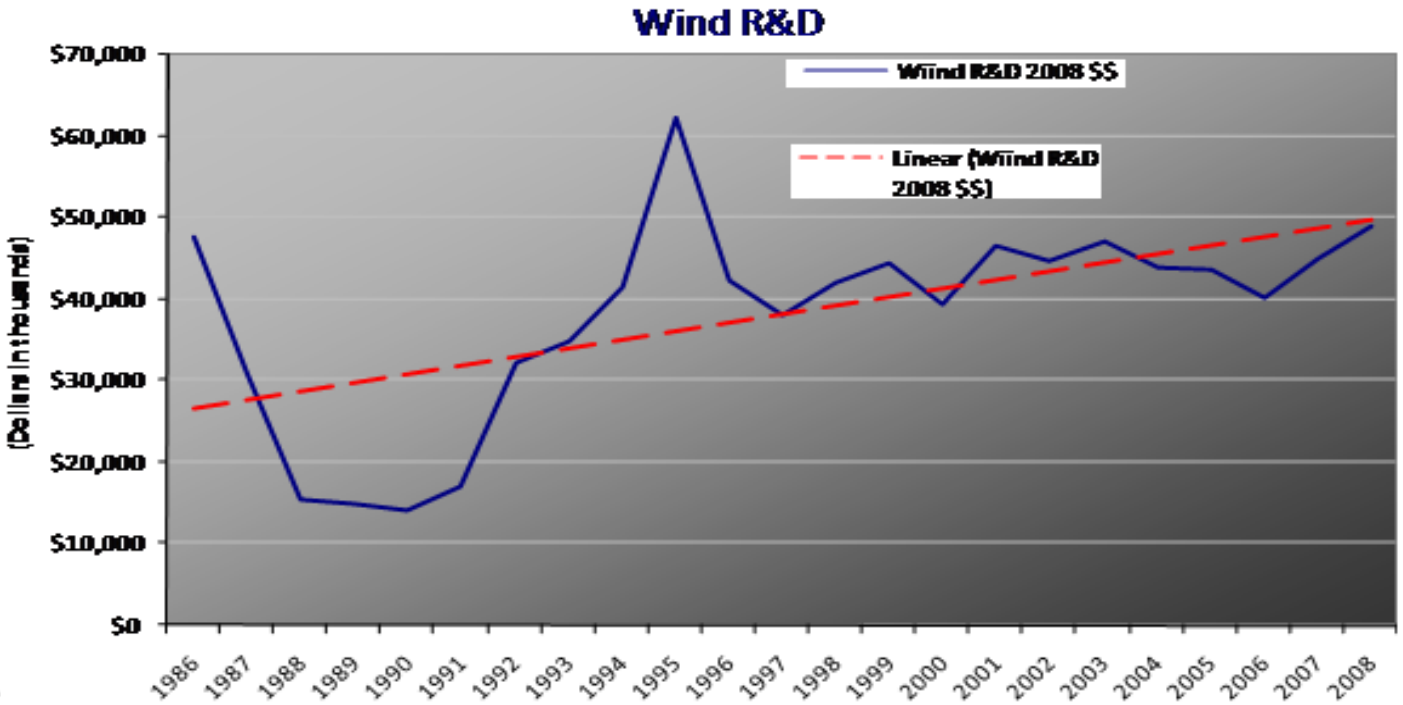
Data on Innovation

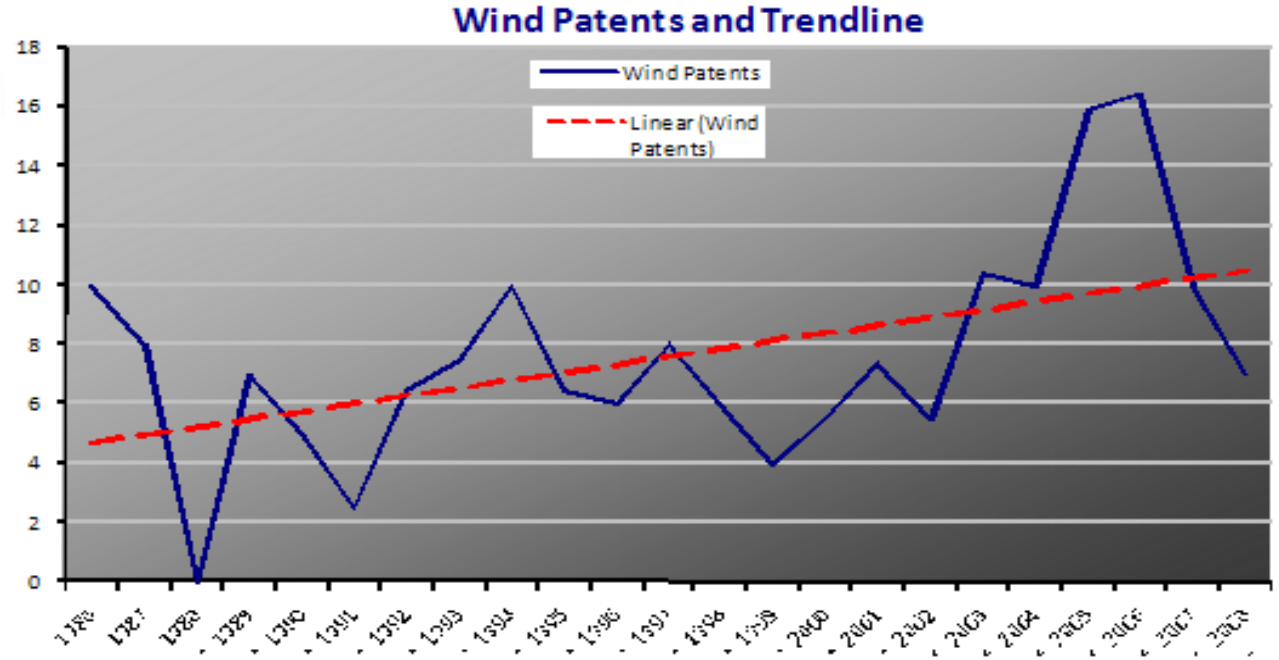
- Standard approach (R.J. Caballero and A.B. Jaffe, *MIT*, *Harvard*, *NBER*):
- Use (cited) patents to evaluate effect of subsidies on innovation (not without problems)
- Use productivity data to evaluate effect of patents on *GDP* growth

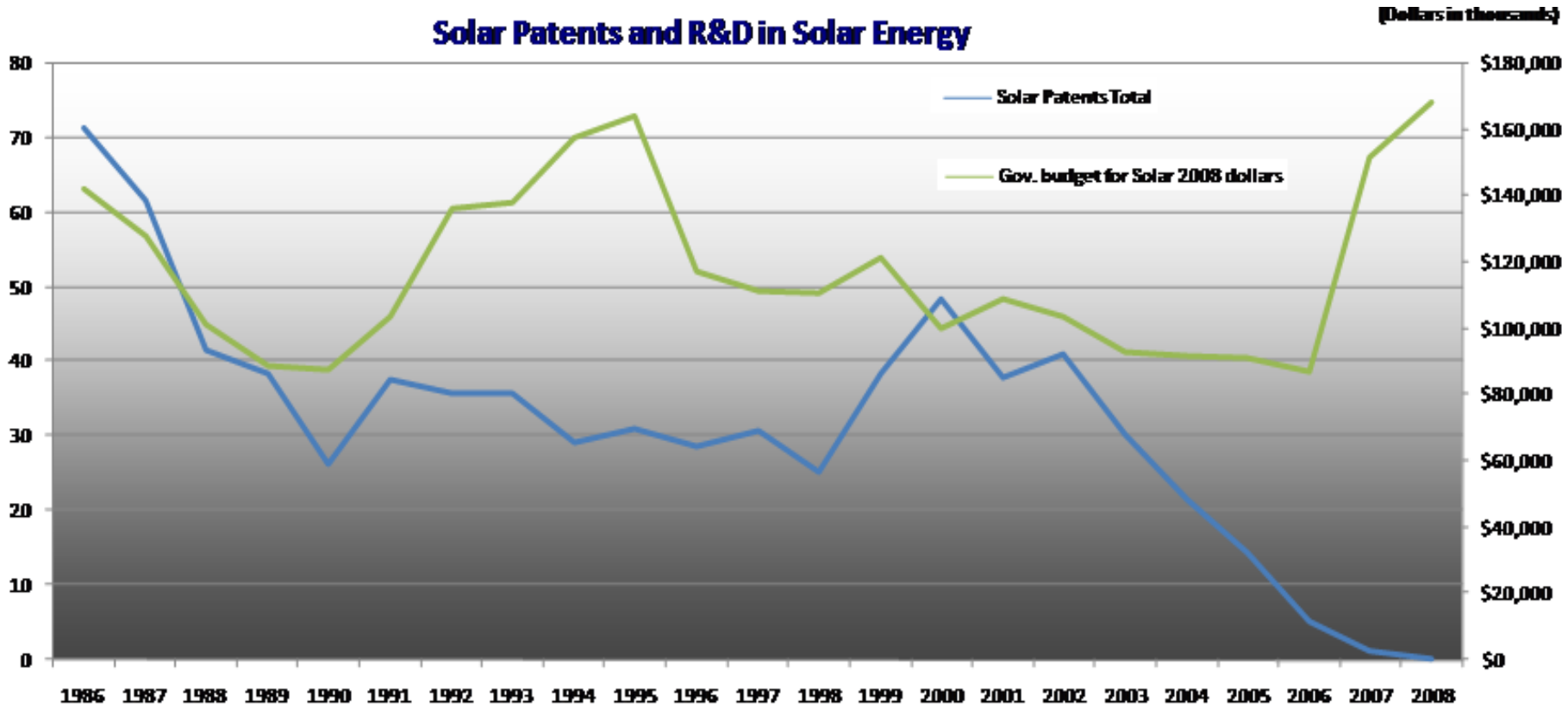
- Difficulties in locating private/VC R&D data
- Use Federal (DOE) R&D budget data
- Creating our own database on patents (thanks to: Jane Kliakhandler, Kristen Hallberg, James Coan, Debra Pyle)
- Right now: wind, solar (P.V. and thermal)

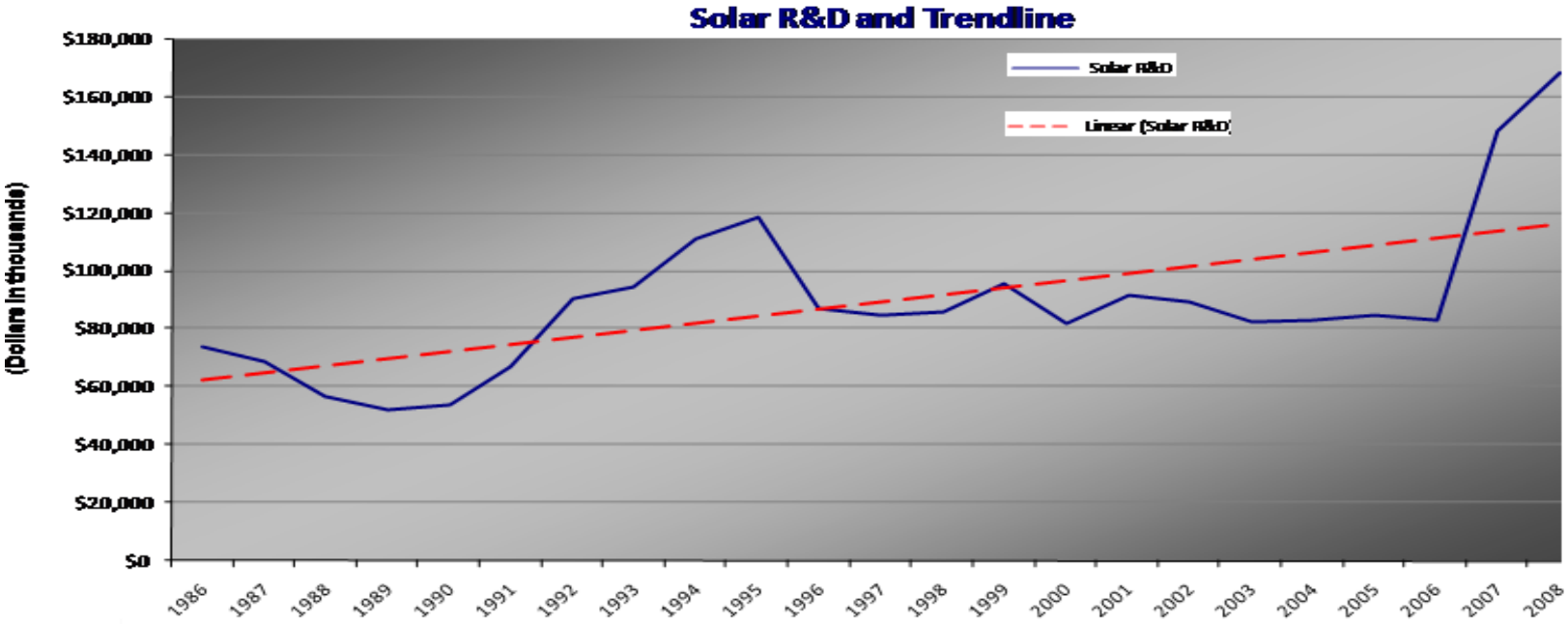
Wind R&D and Wind Patents

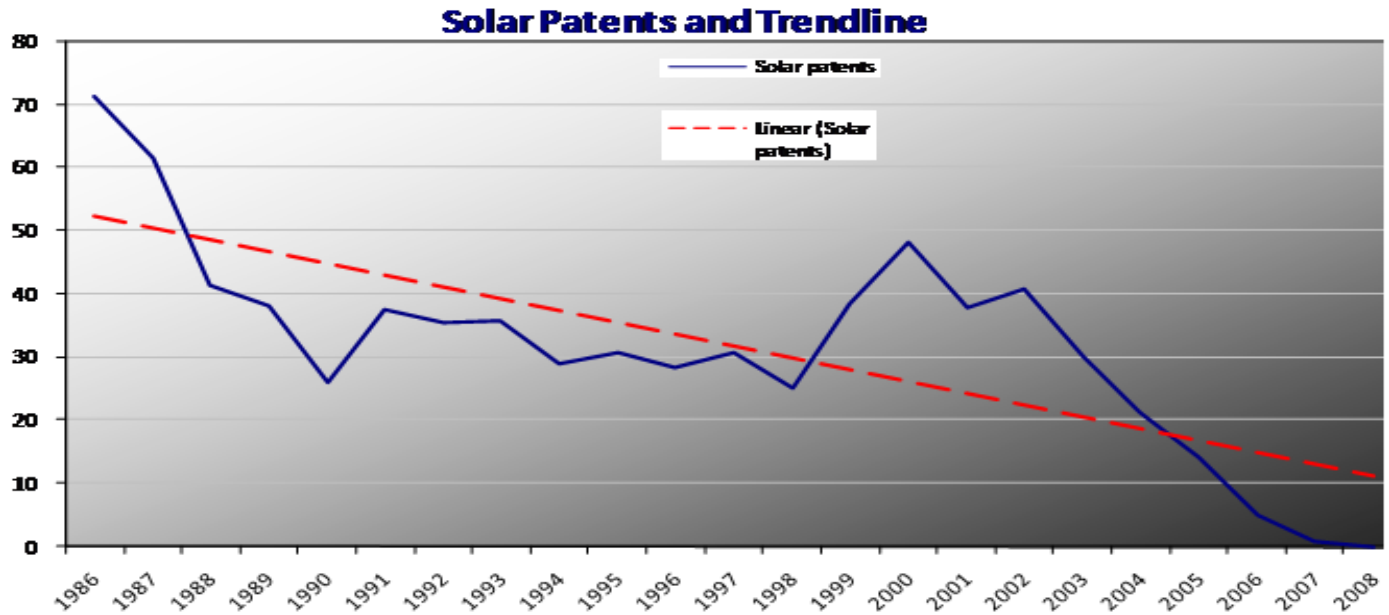


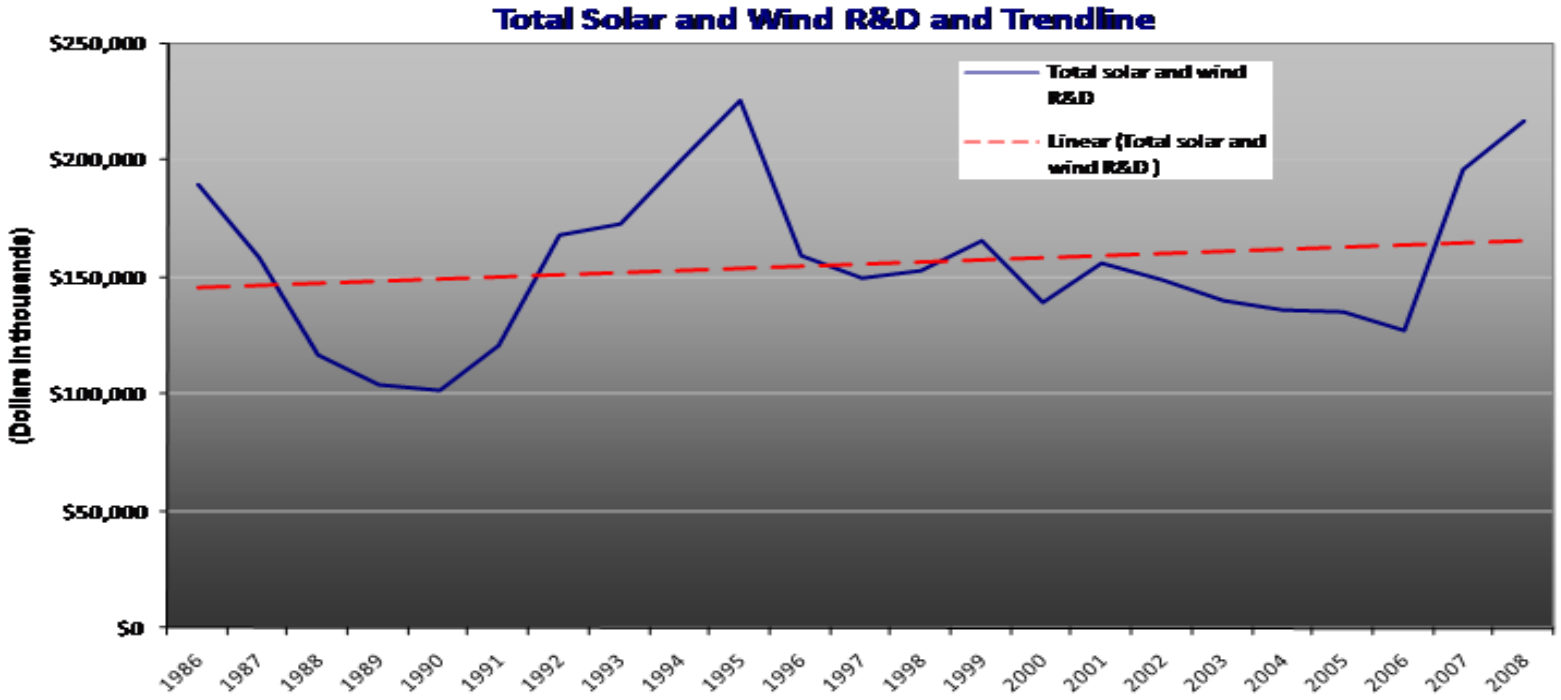

Wind R&D
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$0
Wind R&D 2008 $$
Linear (Wind R&D 2008 $$)
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

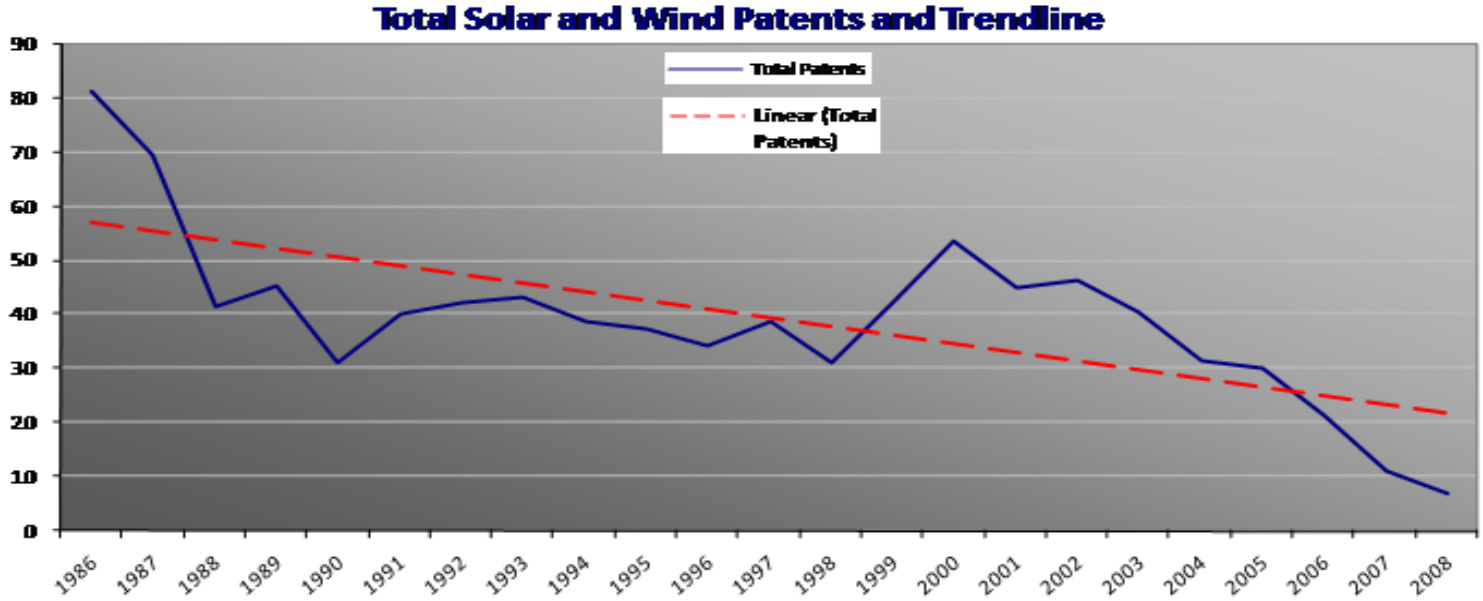

Wind Patents and Trendline
18
16
14
12
10
8
6
4
2
0
Wind Patents
Linear (Wind Patents)


Solar Patents and R&D in Solar Energy
(Dollars in thousands)
Solar Patents Total
Gov. budget for Solar 2008 dollars
80
70
60
50
40
30
20
10
0
$180,000
$160,000
$140,000
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$0
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008


Solar R&D and Trendline
(Dollars in thousands)
$180,000
$160,000
$140,000
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$0
Solar R&D
Linear (Solar R&D)
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008


Solar Patents and Trendline
80
70
60
50
40
30
20
10
0
Solar patents
Linear (Solar patents)
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008


Total Solar and Wind R&D and Trendline
(Dollars in thousands)
$250,000
$200,000
$150,000
$100,000
$50,000
$0
Total solar and wind R&D
Linear (Total solar and wind R&D)
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008

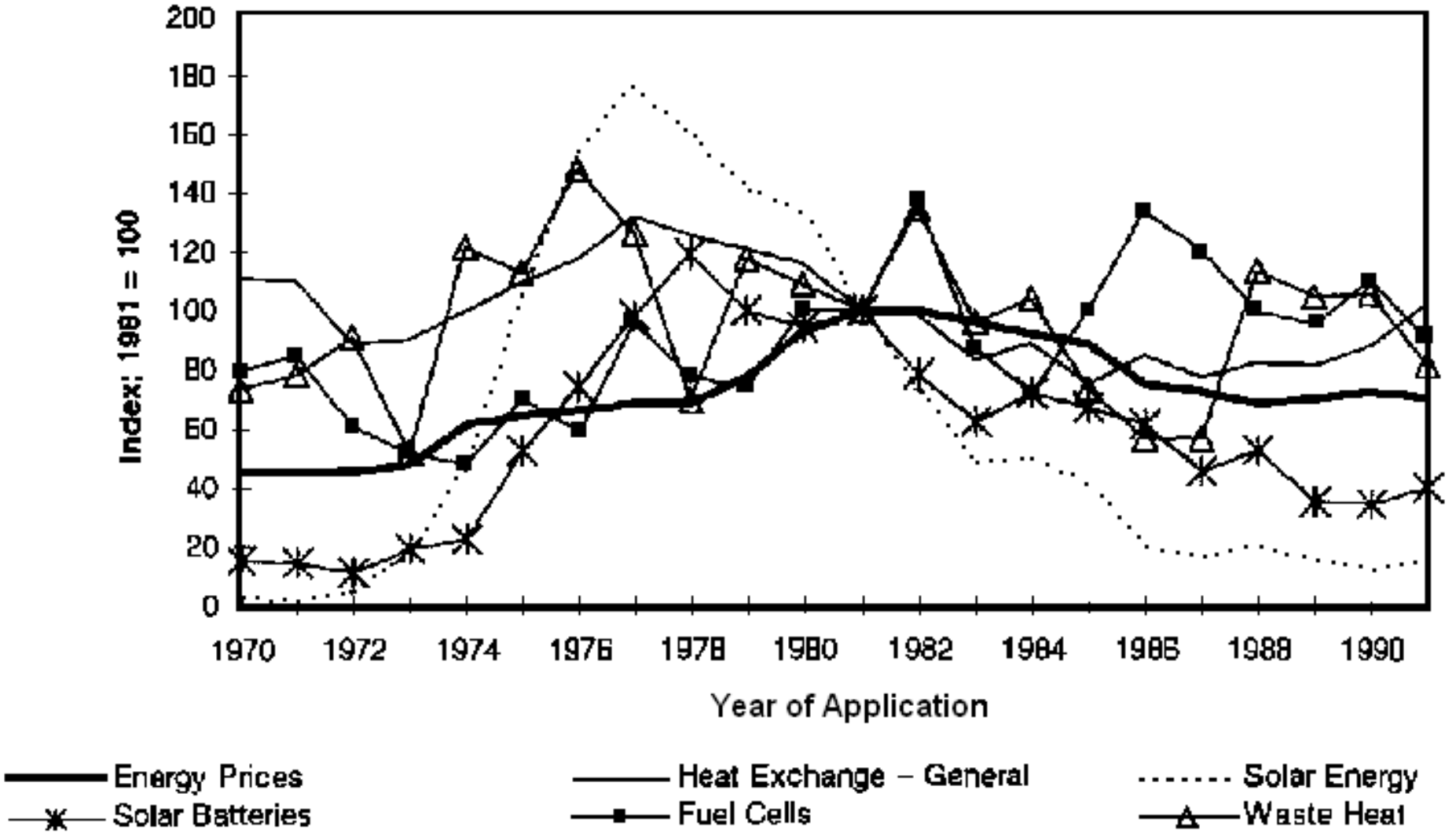

Total Solar and Wind Patents and Trendline
90
80
70
60
50
40
30
20
10
0
Total Patents
Linear (Total Patents)
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008

(I) Decreasing Returns to R&D

Main factors affecting R&D in energy (D. Popp, AER): (i) Demand for energy (prices), *(ii)* Productivity (patent/R&D ratio)

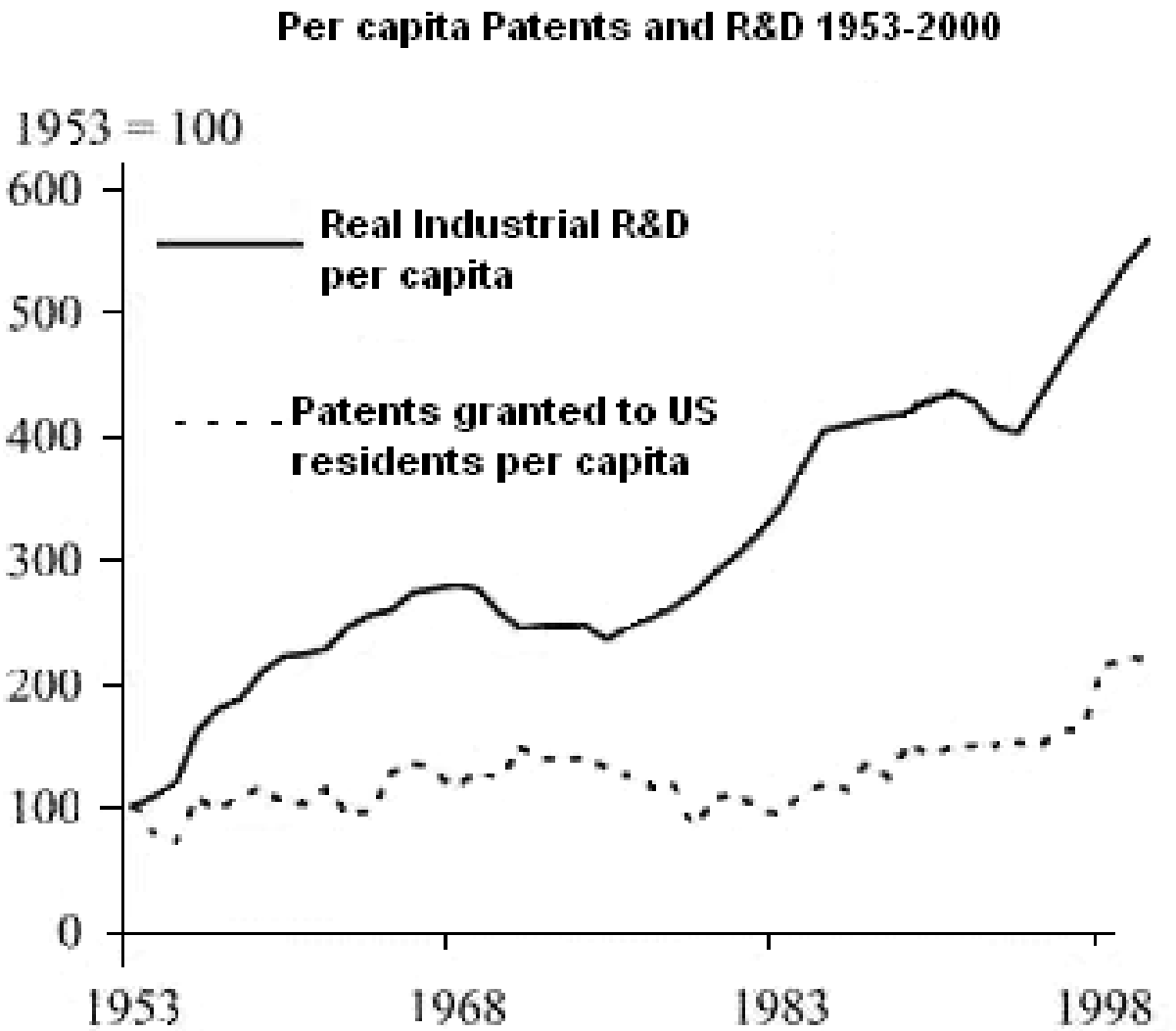
- Separate the two factors and study relative merits

- Patent applications by US investors:



- Energy prices do not pick till 1981... but patenting activity in most cases picks in late 1970s
- Similarly, some evidence that patents begin to decline prior to R&D budget drop
- **Diminishing Returns** to R&D (patents/R&D declines)
- Our data set is consistent with this interpretation

- **Note:** in US manufacturing R&D/employment ↑ over last 50 years but patents/researcher ↓, and *TFP* growth constant (also true in France, Germany, Japan)



Summary:

- Our preliminary data set seems consistent with older data
- Declining R&D levels possibly an optimal response to continued decreased productivity of R&D

Modeling R&D and GDP Growth

- Building on Hartley and Medlock (2005)
- Production of goods uses energy and capital
- Consumption goods, c, produced using fossil fuel, R, or renewable energy, B
- Past and present R&D generates a "technological frontier" representing the efficient techniques for producing energy

- *Optimization problem:*

$$\max \int_0^{\infty} e^{-\beta\tau} U(c(\tau)) d\tau$$

$$\text{budget set: } c + i + i_R + p_R R + p_B B \leq Ak - T$$

$$k\text{-accumulation: } \dot{k} = i - \delta k;\ \dot{k}_R = i_R - \delta_R k_R + S$$

$$\text{energy use: } \varepsilon(R + B) \approx Ak$$

- *Profit maximization*: Choose resources devoted to R&D to equate the marginal expected future *private* benefit from innovation to the marginal current *private* cost

- FOCs define a system of differential equations in (k, k_R)
- Unique stationary equilibrium with positive level of R&D
- Balanced growth where back-stop technology takes over in the long run, after a critical level of innovation has taken place

Trede-offs

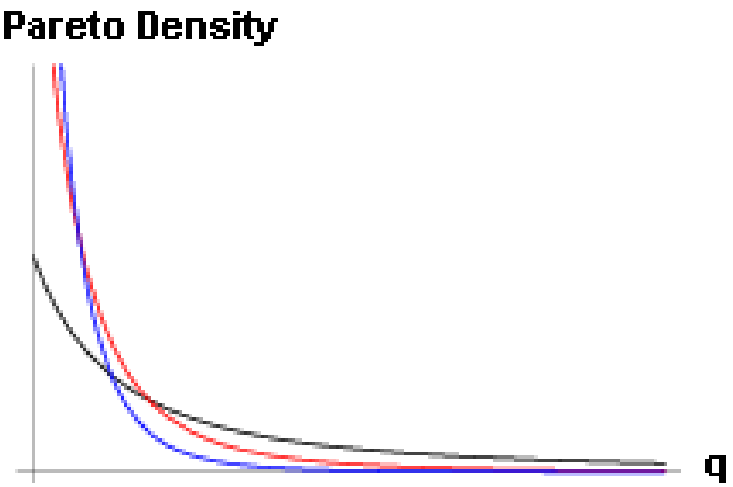
- Newest (most efficient) techniques reduce MCs and result in patents and corresponding profits...
- ...but also "destroy" profits of previous (now obsolete) patents (*"creative destruction"*)
- This can lead to under-investment in R&D

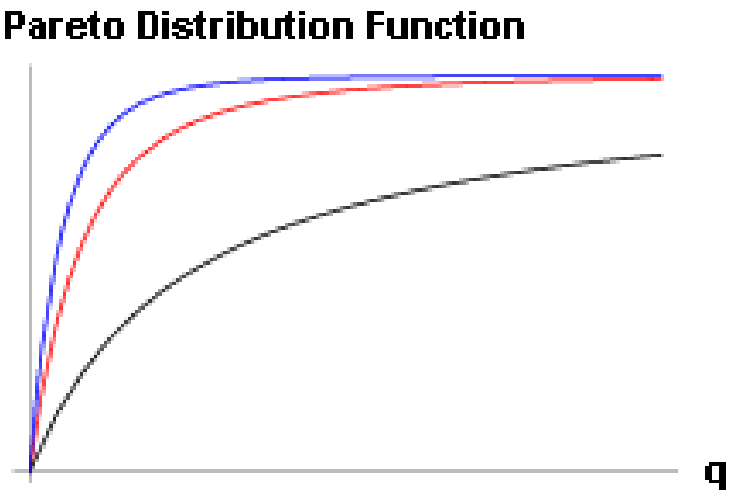
- At the same time...
  - More R&D takes resources (capital) away from other sectors
  - Taxation can create additional distortions
  - **Critical question:** sensitivity of innovations to $ invested in R&D

Modeling Innovation

Expected arrival of Innovations

- Researchers "sampling" for new techniques whose efficiency is a *random variable* drawn from distribution that depends on present and past research
- To be consistent with diminishing returns to R&D, distribution function of efficiency of new ideas, q, is *Pareto:* $F(q) = 1 - q^{-1/\lambda}$, $0 < \lambda < 1$
- **Implication:** "weak" response of patent creation (and resulting *GDP*/employment growth) to increases in R&D budget





- Next step: Calibrate the distribution using data from patents

(II) The Spanish Experience (2000-08) (Universidad Rey Juan Carlos study)

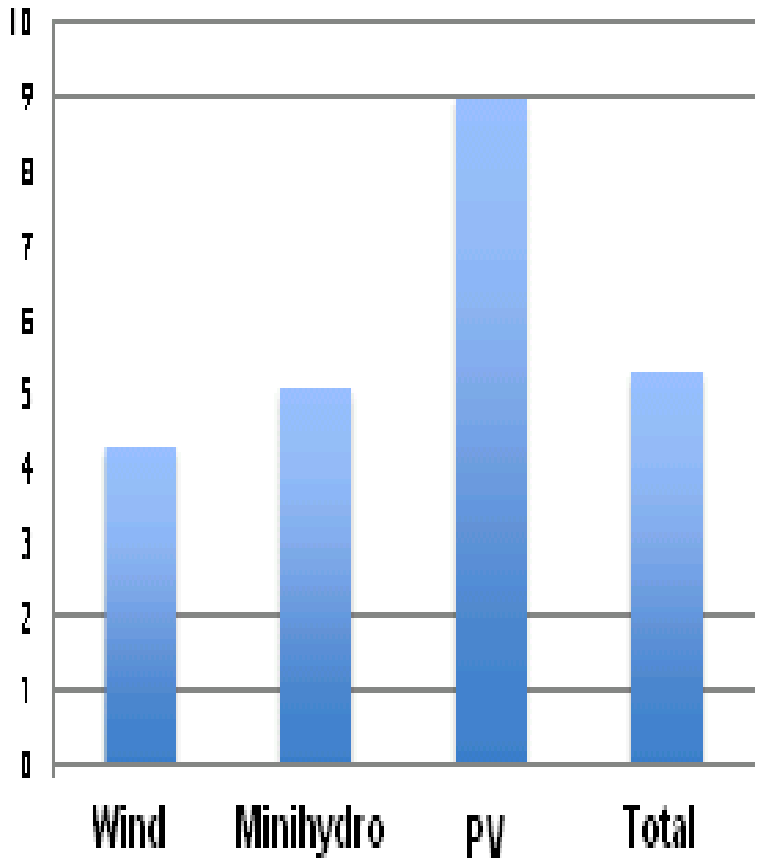
- Cited by president Obama; relevant for US study as factors not unique to Spain
- $36B subsidy created (estimated) 50,000 jobs (R&D, construction, maintenance, operation, administration, etc.)
- Subsidy on Wind, mini-hydro, solar PV
- Spanish macro study concludes: average subsidies of EURO 571,000 per job in renewable energy... lead to estimated 9 jobs lost for every 4 created

Effects of Subsidies

- Higher energy prices (costing approximately $10B): most jobs lost in metallurgy, mining, food/beverage/tobacco processing
- Subsidies "absorbed" capital away from other parts of the economy

- To measure **capital destruction:** compare average subsidy necessary to create a "green job" against average amount of capital required per job in private sector
- $571,000/259,100$, or 2.2 jobs destroyed per job created
- In addition, excess spending leads to a combination of higher future energy prices/taxes/debt

Employment destroyed per installed megawatt



Remarks

- In position to quantify effects of different R&D subsidy scenarios in the US (Spanish experience suggests effect not necessarily beneficial...)
- **Emerging hypothesis:** Low R&D budgets possibly a sign of decreasing returns rather than under-investment in R&D
- Lessons for US (and other countries: China **$20B**, EU Desertec project **$500B** (!), UK **£150B** expected)

Two important caveats:

- Substantial cost reductions may come through innovations **not** reflected in patents
- recent PV cost reduction appears to be due to **less** conversion-efficient modules that resulted in 15-20% price reduction (however, more widespread use needed to reach the same power output)
- **Energy independence, global warming** considerations might make subsidies worthwhile even if it leads to job destruction

- Stay tuned for quantitative results...

Sources

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