R&D in Energy and Growth

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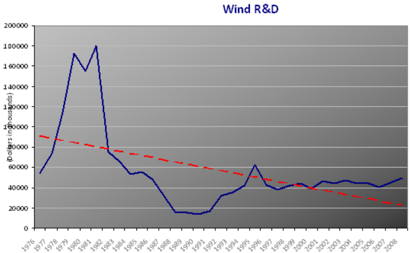
Introduction

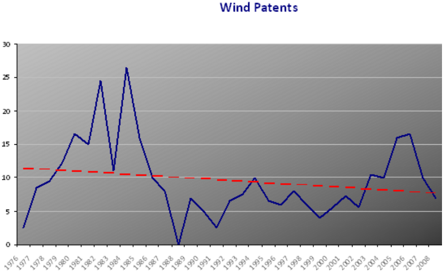
- R&D in renewable energy and the macroeconomy
- Most studies assume optimal size of R&D in (renewable) energy is 5 to 10 times the current level
- Proposal to spend \$15B/year in renewable energy R&D over next 10 years compared to current \$5B/year
- Our project:
  - Inform the policy discussion through rigorous modeling
  - Study effects of energy taxes/subsidies on the macroeconomy

Plan for the Presentation

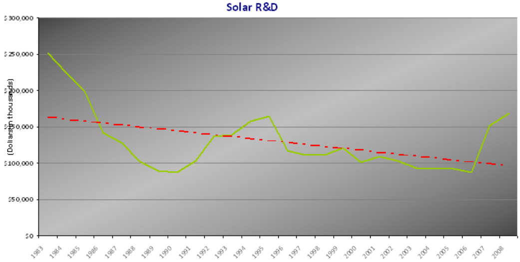
- How to measure and predict *technological progress*?
  - Patents
  - Experience Curves
- Imbed version of experience curves into macroeconomic model
- Calibration
- Policy scenarios

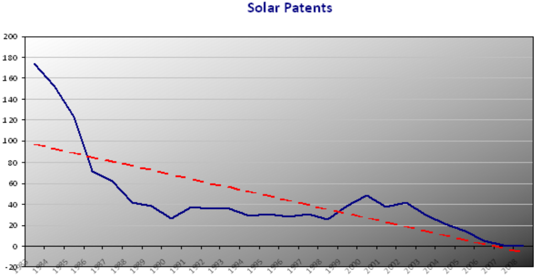


Wind R&D
(Dollars in thousands)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008



Wind Patents
30
25
20
15
10
5
0
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008

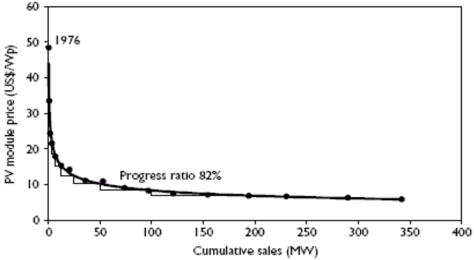

Solar R&D
$300,000
$250,000
$100,000
$50,000
$0
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008


Solar Patents
200
180
160
140
120
100
80
60
40
20
0
-20

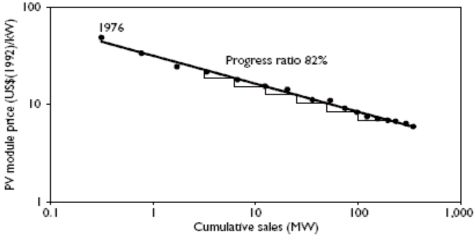
Experience Curves

- Describe how costs decline with cumulative production
- $P_t = P_0 X^{-\alpha}$ *"power law"*
  - P_0, the initial price (*$ cost of* first *MW of sales)*
  - X, cumulative production
  - For each doubling of cumulative production (sales), price ↓ to a fixed % of its previous value
  - Relationship holds for various technologies

Experience Curve for Photovoltaic Modules

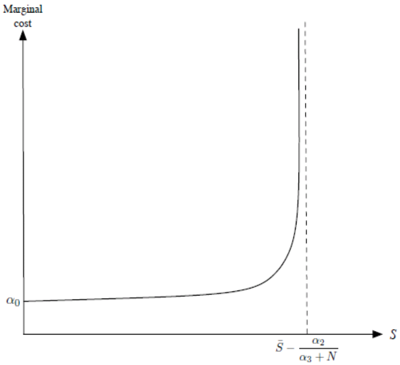


Experience Curve for Photovoltaic Modules, 1976-1992



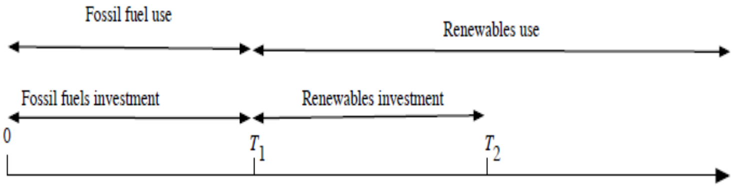
Macroeconomic Modeling

- Production uses energy
- Most easily-mined/richest fields exhausted first → Marginal costs of extraction increase
- Allow for investment and technical change → More efficient mining exploration



- Marginal cost of the energy produced using renewable technology declines as knowledge gained through
  - Experience
  - Investment in research
- *Optimal Growth objective:* maximize discounted welfare subject to budget/technology constraints, evolution of costs of energy

Equilibrium Regimes

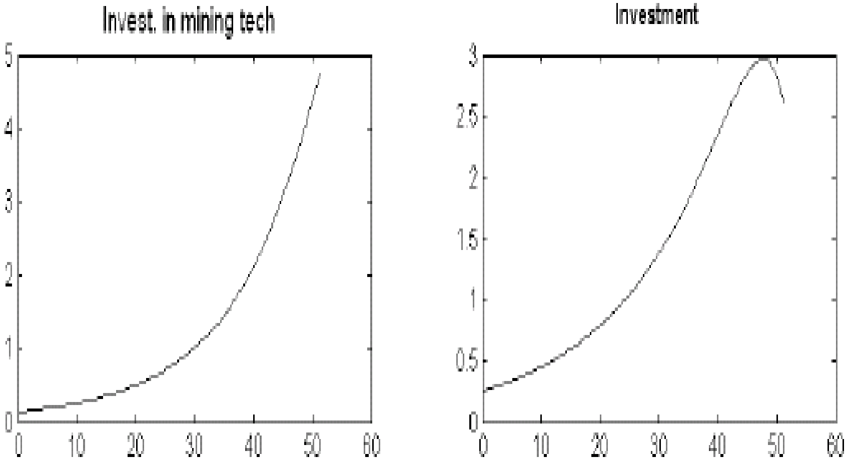


Calibration

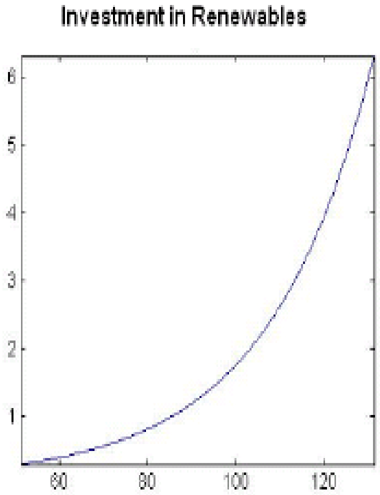
- Taking model to data: Kydland and Prescott, 1982 (Nobel prize, 2004)
- Assign numerical values to parameters so that model consistent with actual economy
- Allows rigorous study of “general equilibrium” effects of policy across different sectors

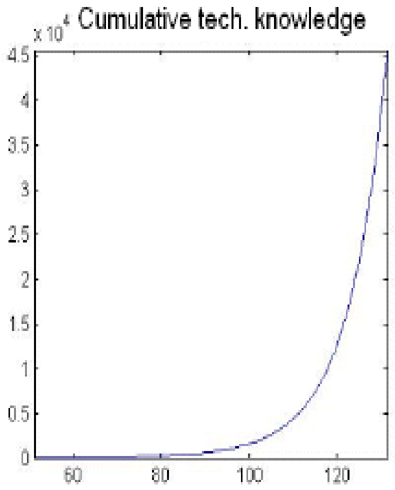
- Data sources:
  - *Food And Agriculture Organization (UN)*
  - *Energy Information Administration (EIA)*
  - *Survey of Energy Resources, World Energy Council (WEC)*
  - *Center for Global Trade Analysis (Purdue University)*
  - *Cambridge Energy Research Associates (CERA)*
  - *National Energy Technology Laboratory (NETL)*
  - *United States Geological Survey (USGS)*

- $T_1 = 51$; $T_2 = 131$
- Regime 1:



- Regime 2:


Investment in Renewables
6
5
4
3
2
1
60
80
100
120


x 10⁴ Cumulative tech. knowledge
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
60
80
100
120

Policy Scenarios

- Tax on Fossil Fuel Energy

Table 1: Values of key variables with fossil fuel taxes

	$\tau_n = 0$	$\tau_n = 0.02$	$\tau_n = 0.05$	$\tau_n = 0.2$
T_1	51.2249	46.3859	45.19	39.9463
$N(T_1)$	64.6412	58.0567	57.5293	55.1507
$S(T_1)$	382.9009	350.9142	348.3918	334.1527
T_2	131.4168	126.5756	125.347	120.1413

- Taxing fossil fuels accelerates adoption of renewable energy
- Total extraction of fossil fuels declines
- *Tax creates wedge between equilibrium and socially optimal investment*

- Subsidy for Renewable Energy

Table 2: Values of key variables with renewable investment subsidies

	$\tau = 0$	$\tau = 0.02$	$\tau = 0.05$	$\tau = 0.2$
T_1	51.2218	34.9859	28.7297	17.6351
$N(T_1)$	64.6412	95.4224	113.4596	126.0906
$S(T_1)$	382.9009	516.5132	585.6372	629.2025
T_2	131.4168	105.0398	94.7115	77.2363

- Subsidy accelerates adoption of renewable energy
- Appears to be more effective than tax on fossil fuels
- *Fossil fuel reserves used more intensively under subsidy*
- Intuition: opportunity cost of using fossil fuel in the short run declines

Summary

- Calibrated model incorporating technological change through use of experience curves
- Important *general equilibrium* effects:
  - *Taxes might disrupt socially efficient investment*
  - *Subsidies in one industry might affect other industries and emissions*
- Analysis does not consider *emissions/climate change* or *energy independence* issues