# What We Know About R&D

- Spillovers make the opportunity costs of R&D important
  - Potential sources of new R&D spending:
    - $Y_t = C_t + I_t + R_{E,t} + R_{O,t}$
  - Losing \$1 of $R_{O,t}$ has same effect as losing \$4 of $I_t$ or $C_t$
  - Moreover, in many climate models, non-energy technological change is *exogenous*
    - $Y = (C, K, E(H(R)), t)$
    - Essentially, *t* represents overall technological change
      - If there is crowding out, not adjusting this *exogenous* rate will double-count gains from *induced* technological change

# What We Know About R&D

- Implications of crowding out
  - For modeling
    - Explains differences across model results
      - E.g. Nordhaus (R&DICE 2002) & Buonanno *et al.* (2003)
      - Results from ENTICE (2004)

| | |
|---|---|
| No crowding out: | 45.3% |
| Partial crowding out: | 9.4% |
| Full crowding out: | 1.9% |

    - LBD models may be more optimistic because they ignore the opportunity costs of research
  - For policy
    - Limits potential of ITC under more stringent policies
      - More R&D induced => opportunity costs magnified
    - Limits potential of R&D subsidies

# R&D and Climate Change

- **Many climate policy proposals include large increases in energy R&D (de Coninck et al 2008; Newell 2007)**
  - **1997 PCAST & 2004 National Commission on Energy Policy reports both recommended doubling U.S. government energy R&D spending**
  - **Kammen & Nemet (2005) advocate 5-10X increase in energy R&D (an energy "Manhattan Project")**

# R&D and Climate Change

- Two concerns with energy R&D policies
  1. Need incentives to adopt technology, not just create technology (e.g. Popp 2006)
  2. Opportunity cost of energy R&D will be high if large increases draw R&D resources from other sectors
     - Goolsbee (1998) suggests scientists and engineers (S&E) benefit from increased government R&D support, as this support increases the wages of a fixed supply of S&E

# Crowding Out from Energy R&D

- Unfortunately, there is little empirical work documenting the extent to which increases in energy R&D draw R&D resources away from other sectors.

- Where we look:
  - Sectoral-level R&D data
    - Do increases in economy-wide energy R&D spending draw R&D resources from non-energy sectors to energy sectors?
  - Firm-level patent data
    - Do increases in energy patents lead to decreases in other types of patents

# Crowding Out Across Sectors

- Does R&D flow across sectors when energy R&D levels change, so that there is a net draw on R&D away from specific sectors?

- Model:

  (1) $IRD_{i,t} = f(IRD_{i,t-1}, Y_{i,t-1}, FEDRD_{t-1}, ERD_t)$

  - *IRD*: company-financed R&D performed in industry *i* (NSF)
  - *Y*: value added in industry *i* (BEA)
  - *FEDRD*: federally-funded R&D performed by industry (NSF)
  - *ERD*: total company-financed energy R&D (NSF)
    - Instruments: lagged independent variables, price of energy, defense spending, & lagged federal energy R&D spending

# Crowding Out Across Sectors

- **Data limitation:**
  - Energy R&D variable is *economy-wide*, rather than *industry-specific*
    - Industry-level data only available for select industries and for certain years
- **Identification strategy**
  - Separate industries by % energy R&D
    - Low energy R&D industries: 0 coefficient on ERD => no crowding out
    - High energy R&D industries: 0 coefficient on ERD => crowding out

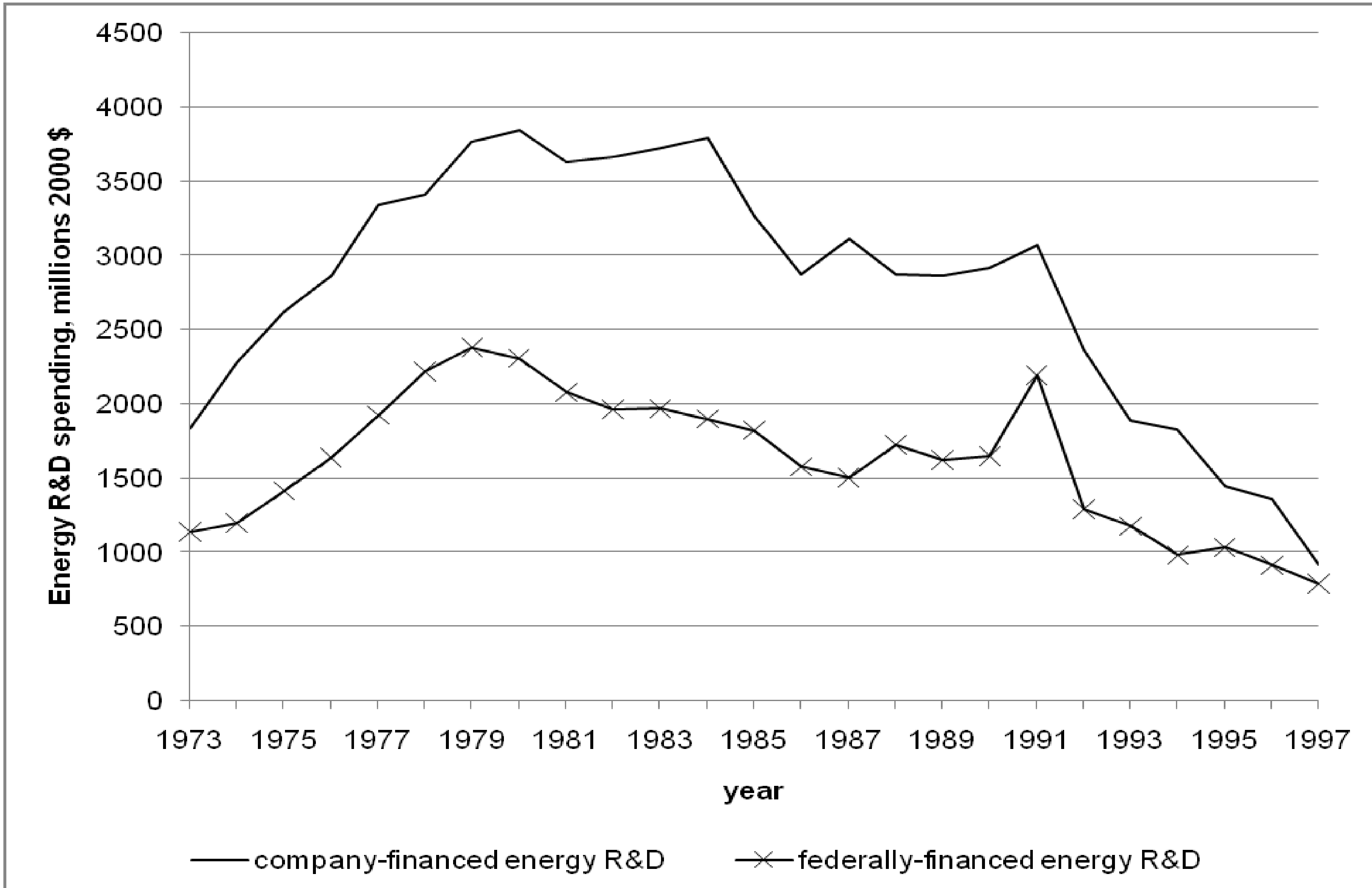
# Industry Data, 1983-1997

| Industry | mean R&D | mean VA | mean R&D/VA | mean % energy R&D |
|---|---|---|---|---|
| Petroleum refining and extraction | 2,429 | 135,536 | 1.9% | 51.4% |
| Electrical equipment | 13,197 | 125,682 | 10.4% | 8.7% |
| Nonmanufacturing | 15,789 | 487,836 | 2.9% | 8.4% |
| Primary metals | 817 | 49,976 | 1.7% | 7.1% |
| Transportation equipment | 16,727 | 132,207 | 12.6% | 5.9% |
| Fabricated metal products | 975 | 80,015 | 1.2% | 3.5% |
| Chemicals and allied products | 13,945 | 117,558 | 11.8% | 3.2% |
| Lumber, wood products, and furniture | 250 | 53,943 | 0.5% | 2.4% |
| Rubber products | 1,078 | 39,516 | 2.7% | 2.1% |
| Machinery | 12,971 | 128,508 | 10.1% | 2.0% |
| Stone, clay, and glass products | 734 | 30,349 | 2.5% | 1.9% |
| Other manufacturing industries | 856 | 103,745 | 0.8% | 0.7% |
| Professional and scientific instrument | 6,974 | 44,042 | 16.1% | 0.6% |
| Paper and allied products | 1,083 | 48,454 | 2.2% | 0.4% |
| Food, kindred, and tobacco products | 1,460 | 118,867 | 1.2% | 0.3% |
| Textiles and apparel | 300 | 53,845 | 0.6% | 0.2% |
| all industries w/energy R&D > 5% | 9,792 | 186,247 | 5.9% | |
| all industries w/energy R&D < 5% | 3,693 | 74,440 | 4.5% | |

# Industry Data, 1973-1997

| Industry | mean R&D | mean VA | mean R&D/VA | mean % energy R&D |
|---|---|---|---|---|
| Petroleum refining and extraction | 2,163 | 121,537 | 1.9% | 56.3% |
| Nonmanufacturing | 10,707 | 443,782 | 2.0% | 16.1% |
| Electrical equipment | 11,097 | 108,781 | 10.0% | 12.5% |
| Primary metals | 856 | 57,170 | 1.5% | 7.7% |
| Chemicals and allied products | 11,166 | 102,409 | 10.5% | 3.8% |
| Fabricated metal products | 889 | 76,251 | 1.2% | 3.5% |
| Machinery | 10,807 | 121,355 | 8.8% | 1.7% |
| all industries w/energy R&D > 5% | 6,206 | 182,818 | 3.9% | |
| all industries w/energy R&D < 5% | 7,621 | 100,005 | 6.8% | |

# Energy R&D Trends, 1973-1997



# Results: 1983-1997

- **Low energy R&D sectors:**
  - **No evidence of crowding out**
  - **Economy-wide energy R&D increases do not draw R&D from non-energy R&D performing sectors**

not draw R&D from non

# Results, 1983-1997

| | low energy R&D | | high energy R&D | | | |
|---|---|---|---|---|---|---|
| | | | | | no refineries | |
| **Variable** | < 1% | < 5% | > 1% | > 5% | > 1% | > 5% |
| R&D(i,t-1) | 0.9069 | 0.8790 | 0.7924 | 0.7749 | 0.7458 | 0.6640 |
| | (0.0628) | (0.0778) | (0.0702) | (0.0795) | (0.0897) | (0.0971) |
| energy R&D (t) | 0.0150 | 0.0241 | 0.0138 | -0.2665 | 0.2858 | 0.1217 |
| | (0.0266) | (0.0809) | (0.1247) | (0.1841) | (0.1325) | (0.1835) |
| Value Added(i,t-1) | 0.0046 | 0.0076 | 0.0264 | 0.0272 | 0.0390 | 0.0485 |
| | (0.0027) | (0.0077) | (0.0089) | (0.0092) | (0.0125) | (0.0125) |
| Federal R&D(t-1) | -0.0059 | -0.0118 | -0.0274 | -0.0521 | -0.0467 | -0.1129 |
| | (0.0028) | (0.0071) | (0.0156) | (0.0284) | (0.0152) | (0.0296) |
| N | 75 | 165 | 165 | 75 | 150 | 60 |
| r2 | 0.8963 | 0.7320 | 0.9188 | 0.9480 | 0.9241 | 0.9539 |

standard errors in parentheses

# Results: 1983-1997

- **Low energy R&D sectors:**
  - **No evidence of crowding out**
  - **Economy-wide energy R&D increases do not draw R&D from non-energy R&D performing sectors**

- **High energy R&D sectors:**
  - **Results suggest crowding out**
  - **Increases in energy R&D are not *new* R&D**
  - **Harder to interpret:**
    - **What about intermediate industries?**
    - **What level represents no crowding out?**

# Results, 1983-1997

| | low energy R&D | | high energy R&D | | | |
|---|---|---|---|---|---|---|
| | | | | | no refineries | |
| **Variable** | < 1% | < 5% | > 1% | > 5% | > 1% | > 5% |
| R&D(i,t-1) | 0.9069 | 0.8790 | 0.7924 | 0.7749 | 0.7458 | 0.6640 |
| | (0.0628) | (0.0778) | (0.0702) | (0.0795) | (0.0897) | (0.0971) |
| energy R&D (t) | 0.0150 | 0.0241 | 0.0138 | -0.2665 | 0.2858 | 0.1217 |
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standard errors in parentheses

# Results: 1983-1997

- **Low energy R&D sectors:**
  - **No evidence of crowding out**
  - **Economy-wide energy R&D increases do not draw R&D from non-energy R&D performing sectors**

- **High energy R&D sectors:**
  - **Results suggest crowding out**
  - **Increases in energy R&D are not *new* R&D**
  - **Harder to interpret:**
    - **What about intermediate industries?**
    - **What level represents no crowding out?**

- **Other variables consistent with expectations**
  - **Gradual adjustment**
  - **About 1-4% of industry output devoted to R&D**
  - **Some evidence of crowding out from federal R&D**

# Results, 1983-1997

| | low energy R&D | | high energy R&D | | | |
|---|---|---|---|---|---|---|
| | | | | | no refineries | |
| **Variable** | < 1% | < 5% | > 1% | > 5% | > 1% | > 5% |
| R&D(i,t-1) | 0.9069 | 0.8790 | 0.7924 | 0.7749 | 0.7458 | 0.6640 |
| | (0.0628) | (0.0778) | (0.0702) | (0.0795) | (0.0897) | (0.0971) |
| energy R&D (t) | 0.0150 | 0.0241 | 0.0138 | -0.2665 | 0.2858 | 0.1217 |
| | (0.0266) | (0.0809) | (0.1247) | (0.1841) | (0.1325) | (0.1835) |
| Value Added(i,t-1) | 0.0046 | 0.0076 | 0.0264 | 0.0272 | 0.0390 | 0.0485 |
| | (0.0027) | (0.0077) | (0.0089) | (0.0092) | (0.0125) | (0.0125) |
| Federal R&D(t-1) | -0.0059 | -0.0118 | -0.0274 | -0.0521 | -0.0467 | -0.1129 |
| | (0.0028) | (0.0071) | (0.0156) | (0.0284) | (0.0152) | (0.0296) |
| N | 75 | 165 | 165 | 75 | 150 | 60 |
| r2 | 0.8963 | 0.7320 | 0.9188 | 0.9480 | 0.9241 | 0.9539 |

standard errors in parentheses

# Results: 1973-1997

- Results are similar
  - No crowding out in low energy R&D industries
  - However, negative sign for high energy R&D industries is a concern
    - Doesn't go away when eliminate petroleum refining

# Results, 1973-1997

| | low energy R&D | | high energy R&D | | | |
|---|---|---|---|---|---|---|
| | | | | | no refineries | |
| **Variable** | < 5% | < 10% | > 5% | > 10% | > 5% | > 10% |
| R&D(i,t-1) | 0.8628 | 0.8922 | 0.8891 | 0.8419 | 0.9094 | 0.7217 |
| | (0.0893) | (0.0716) | (0.0629) | (0.0712) | (0.0830) | (0.1070) |
| energy R&D (t) | 0.2198 | 0.1482 | -0.3363 | -0.5292 | -0.3037 | -0.5702 |
| | (0.1928) | (0.1424) | (0.1275) | (0.1863) | (0.1498) | (0.2830) |
| Value Added(i,t-1) | 0.0255 | 0.0159 | 0.0172 | 0.0219 | 0.0158 | 0.0384 |
| | (0.0151) | (0.0098) | (0.0063) | (0.0076) | (0.0096) | (0.0141) |
| Federal R&D(t-1) | 0.0244 | 0.0248 | -0.0106 | -0.0312 | -0.0073 | -0.0654 |
| | (0.0176) | (0.0146) | (0.0146) | (0.0221) | (0.0203) | (0.0344) |
| N | 72 | 96 | 96 | 72 | 72 | 48 |
| r2 | 0.9019 | 0.8986 | 0.9698 | 0.9693 | 0.9718 | 0.9729 |

standard errors in parentheses

# Estimate Firm-level R&D

- Problem for high-energy industries: not all energy R&D spending does not go to a single industry

- Solution: estimate economy-wide energy R&D going to each industry
  - Multiply economy-wide energy R&D data by average share of energy R&D going to that industry from years in which industry-specific data are available
  - Null hypothesis of no crowding out => coefficient equals 1
  - We can reject the null hypothesis, but the results are very imprecise

# Results with Estimated Energy R&D

| | high energy R&D 1973-1997 | | | | high energy R&D 1983-1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | | | no refineries | | | | no refineries | |
| **Variable** | > 5% | > 10% | > 5% | > 10% | > 1% | > 5% | > 1% | > 5% |
| R&D(i,t-1) | 0.8689 | 0.8408 | 0.9079 | 0.7475 | 0.8159 | 0.7777 | 0.7935 | 0.6811 |
| | (0.0664) | (0.0738) | (0.0831) | (0.1059) | (0.0701) | (0.0818) | (0.0809) | (0.1004) |
| energy R&D (i,t) | -0.9370 | -1.0558 | -2.5069 | -3.2278 | -0.9229 | -1.0799 | 2.5437 | 1.1388 |
| | (0.5051) | (0.5711) | (1.3927) | (2.1695) | (0.6200) | (0.6953) | (2.9061) | (2.6775) |
| Value Added(i,t-1) | 0.0214 | 0.0256 | 0.0151 | 0.0357 | 0.0236 | 0.0298 | 0.0313 | 0.0449 |
| | (0.0069) | (0.0084) | (0.0094) | (0.0138) | (0.0080) | (0.0096) | (0.0113) | (0.0135) |
| Fed R&D(t-1) | -0.0055 | -0.0307 | -0.0026 | -0.0578 | -0.0256 | -0.0581 | -0.0423 | -0.1047 |
| | (0.0151) | (0.0240) | (0.0200) | (0.0346) | (0.0145) | (0.0258) | (0.0149) | (0.0301) |
| N | 96 | 72 | 72 | 48 | 165 | 75 | 150 | 60 |
| r2 | 0.9693 | 0.9694 | 0.9716 | 0.9730 | 0.9201 | 0.9488 | 0.9226 | 0.9538 |

# Crowding Out Within Sectors

- **While our results for high energy R&D sectors suggest possible crowding out, data limitations lead to weak results.**
  - **Thus, we turn to a more detailed, firm-level analysis.**

- **Do increases in energy R&D *at the firm level* crowd out other types of R&D?**

- **Because energy R&D data are not available at the firm level, we use patents to identify energy R&D**

- **Two focuses:**
  - **Alternative energy**
  - **Energy R&D in the automotive sector**

# Crowding Out Within Sectors

- **Model:**

  (2) $OPAT_{i,t} = f(OPAT_{i,t-1}, EPAT_{i,t}, X_{i,t}, a_i, b_t)$

  - $OPAT_{i,t}$: other patents assigned to firm *i* from app year *t*
  - $EPAT_{i,t}$: energy patents assigned to firm *i* from app year *t*
  - $X_{i,t}$: other firm characteristics (Capital, Sales)
  - $a_i$: firm fixed effects
  - $b_t$: year fixed effects

- **Estimation:**
  - GMM estimation, correcting for both autocorrelation and heteroskedasticity
  - Lagged independent variables used as instruments

# Data

- Two sources for patent data (1971-2002)
  - Identify relevant patents using Delphion data base
    - Alternative energy patents include:
      - Coal Liquefaction
      - Coal Gasification
      - Solar Energy
      - Solar Energy – Batteries
      - Fuel Cells
      - Wind
      - Using waste as fuel
      - Geothermal energy
    - Automotive energy patents include:
      - Hybrids
      - Fuel Cells
      - Improved energy efficiency
  - Used the NBER patent database (Hall, Jaffe, Trajtenberg 2001) to identify all patents assigned to these firms

# Data

- Next step: identify relevant firms
  - Focused on firms where energy patents are 1.5 - 67% of all patents
    - Eliminates firms where most patents are energy related (crowding out not an issue) or few patents are energy related
  - Searched for Compustat data for the remaining firms
    - 14 firms for automotive technologies
    - 32 firms for alternative energy

- Sort patents by year of application
  - To avoid truncation problems, use data from 1970-1999

# Who Patents?

- The distribution of patenting firms is highly skewed
  - Alternative energy: 18,107 total patents
    - Firms in our regression have 2,011 patents (11%).
    - 3,059 unique patent assignees
      - Of these, 1,935 have just one alternative energy patent
    - Only 17% of alternative energy patents are assigned to the top 20 assignees
  - Automotive energy technologies: 9,895 total patents
    - Firms in our regression have 1,269 patents (13%)
    - 1,438 unique patent assignees
      - Of these, 813 have just one automotive energy patent
    - 32% of patents are assigned to the top 20 assignees (not counting individually assigned patents)

# Top 20 Assignees – Total Energy Patents

Alternative Energy

| Assignee | Energy patents | All patents | % energy |
|---|---|---|---|
| Individually Owned Patents | 4457 | 521560 | 0.85% |
| Exxon | 340 | 7839 | 4.34% |
| Canon | 318 | 24454 | 1.30% |
| US Department of Energy | 303 | 6028 | 5.03% |
| Siemens Aktiengesellschaft | 216 | 16024 | 1.35% |
| United Technologies | 201 | 5655 | 3.55% |
| Westinghouse Electric | 180 | 10891 | 1.65% |
| International Fuel Cells Corp | 179 | 244 | 73.36% |
| General Electric | 147 | 27557 | 0.53% |
| Mobil | 137 | 6798 | 2.02% |
| Atlantic Richfield Copmany | 131 | 2323 | 5.64% |
| Sanyo Electric | 122 | 3047 | 4.00% |
| Hitachi | 116 | 24920 | 0.47% |
| Texaco | 115 | 4523 | 2.54% |
| Chevron | 111 | 3332 | 3.33% |
| Foster Wheeler | 106 | 565 | 18.76% |
| NASA | 106 | 4177 | 2.54% |
| Mitsubishi | 101 | 20951 | 0.48% |
| Energy Conversion Devices | 94 | 429 | 21.91% |
| Fuji Electric | 91 | 1478 | 6.16% |
| TOTAL (top 20 except ind.) | 3114 | | |
| **ALL ASSIGNEES** | 18107 | 2933721 | 0.62% |

Automotive

| Assignee | Energy patents | All patents | % energy |
|---|---|---|---|
| Individually Owned Patents | 1624 | 521560 | 0.31% |
| Ford Motor Company | 345 | 7785 | 4.43% |
| Toyota | 335 | 7083 | 4.73% |
| Honda | 300 | 7243 | 4.14% |
| Nissan | 209 | 6947 | 3.01% |
| International Fuel Cells | 199 | 244 | 81.56% |
| United Technologies Corp | 181 | 5655 | 3.20% |
| General Motors | 180 | 11408 | 1.58% |
| Mitsubishi | 159 | 20951 | 0.76% |
| Hitachi | 153 | 24920 | 0.61% |
| General Electric | 150 | 27557 | 0.54% |
| Westinghouse Electric | 138 | 10891 | 1.27% |
| Siemens | 133 | 16024 | 0.83% |
| Robert Bosch | 108 | 9002 | 1.20% |
| Mobil | 98 | 6798 | 1.44% |
| US Department of Energy | 98 | 6028 | 1.63% |
| Daimler-Chrysler | 88 | 2196 | 4.01% |
| Cummins Engine | 85 | 682 | 12.46% |
| Ballard Power Systems | 84 | 90 | 93.33% |
| NGK Insulators Ltd. | 82 | 2597 | 3.16% |
| TOTAL (top 20 except ind.) | 3125 | | |
| **ALL ASSIGNEES** | 9895 | 2933721 | 0.34% |

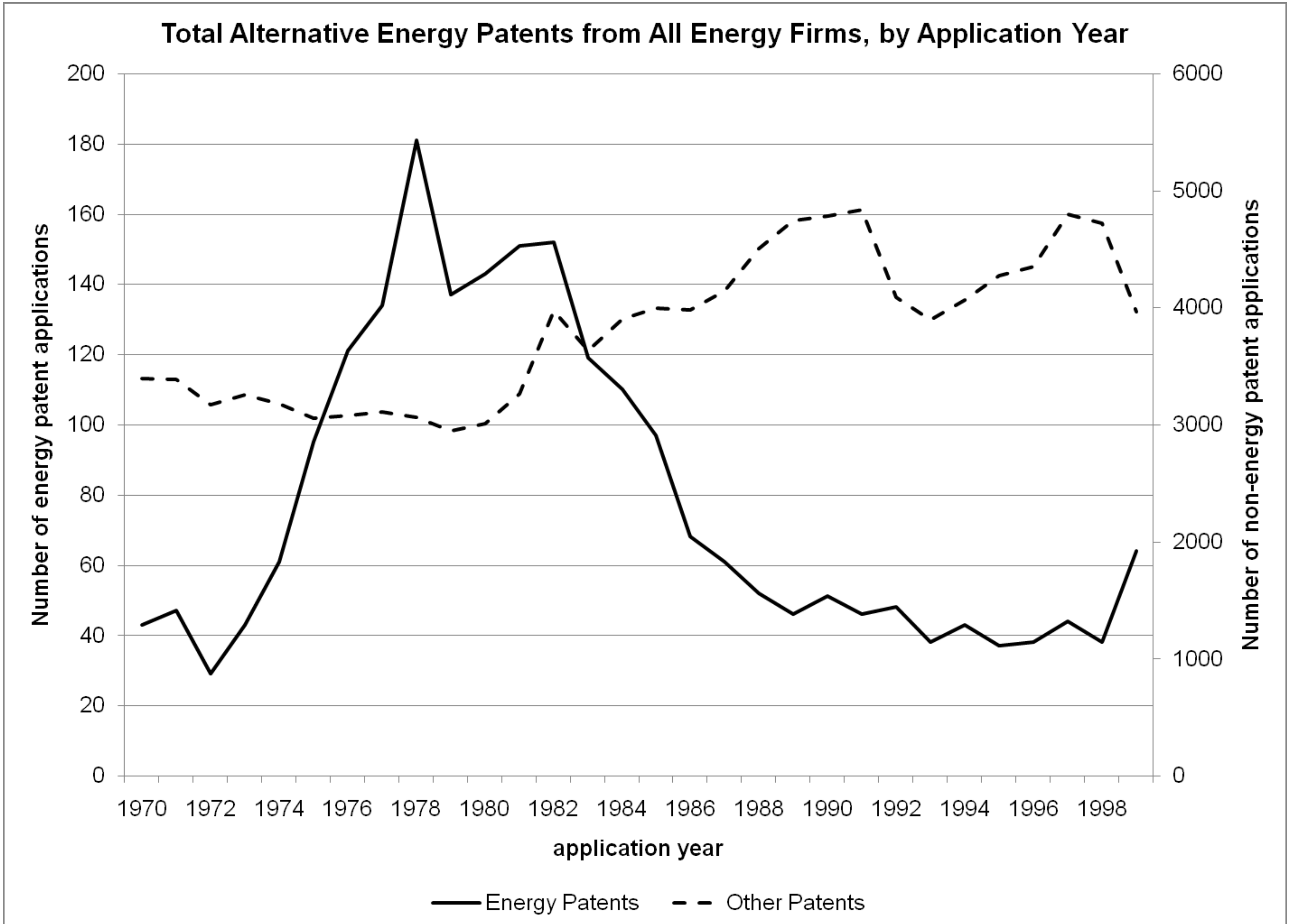
# Top 20 Assignees – % Energy Patents

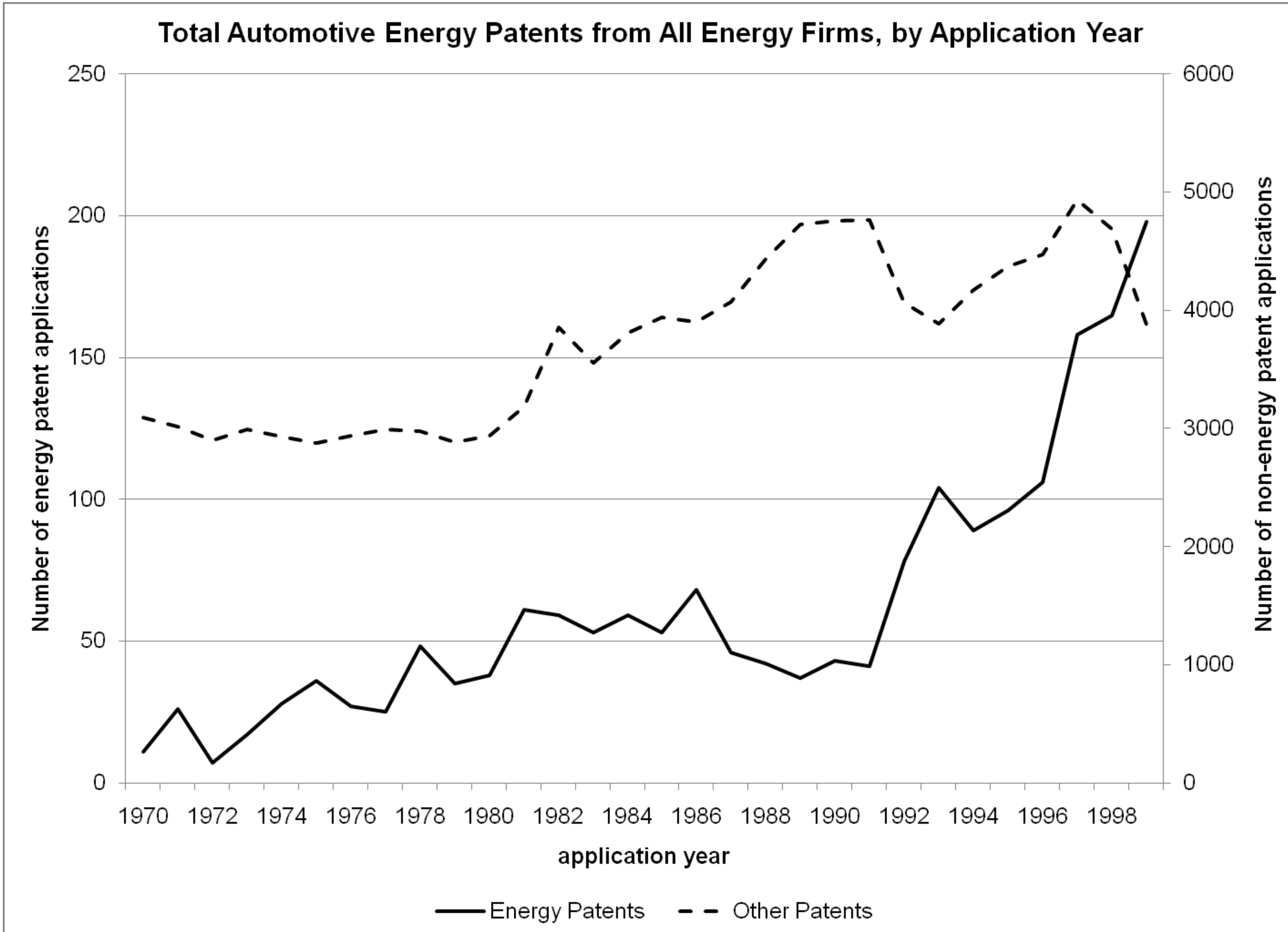
Alternative Energy

| Assignee | Energy patents | All patents | % energy |
|---|---|---|---|
| JX Crystals, Inc. | 23 | 23 | 100.00% |
| Solarco Corporation | 12 | 12 | 100.00% |
| Sunworks, Inc. | 12 | 12 | 100.00% |
| Magma Power Company | 10 | 10 | 100.00% |
| H-Power Corp. | 15 | 16 | 93.75% |
| Electrochemische Energieconversie N.V. | 12 | 13 | 92.31% |
| Solarex Corporation | 55 | 60 | 91.67% |
| M-C Power Corporation | 11 | 12 | 91.67% |
| Chronic Corporation | 24 | 27 | 88.89% |
| Plug Power L.L.C. | 53 | 60 | 88.33% |
| Sovoncis Solar Systems | 19 | 23 | 82.61% |
| Spectrolab, Inc. | 13 | 16 | 81.25% |
| ZTek Corporation | 13 | 16 | 81.25% |
| Ballard Power Sytems, Inc. | 73 | 90 | 81.11% |
| Astropower, Inc. | 12 | 15 | 80.00% |
| AER Energy Resources, Inc. | 38 | 49 | 77.55% |
| United Solar Systems Corp | 33 | 44 | 75.00% |
| International Fuel Cells | 179 | 244 | 73.36% |
| Evergreen Solar, Inc. | 11 | 15 | 73.33% |
| Photon Power, Inc. | 16 | 23 | 69.57% |
| TOTAL (top 20) | 634 | | |
| **ALL ASSIGNEES** | 18107 | 2933721 | 0.62% |

Automotive

| Assignee | Energy patents | All patents | % energy |
|---|---|---|---|
| H-Power Corp. | 16 | 16 | 100.00% |
| ZTek Corporation | 16 | 16 | 100.00% |
| Ballard Power Systems, Inc. | 84 | 90 | 93.33% |
| Plug Power L.L.C. | 54 | 60 | 90.00% |
| M-C Power Corporation | 10 | 12 | 83.33% |
| International Fuel Cells Corp | 199 | 244 | 81.56% |
| Phillips & Temro Industries | 11 | 16 | 68.75% |
| Energy Research Corp | 58 | 91 | 63.74% |
| National Power PLC | 11 | 19 | 57.89% |
| Xcellsis GmbH | 17 | 31 | 54.84% |
| Electric Fuel Limited | 16 | 36 | 44.44% |
| AER Energy Resources, Inc | 18 | 49 | 36.73% |
| Kabushikikaiha Equos | 23 | 64 | 35.94% |
| Lynntech, Inc. | 21 | 61 | 34.43% |
| Energy Development Assoc | 21 | 68 | 30.88% |
| Tanaka Kikinzoku Kogyo | 19 | 77 | 24.68% |
| Reveo, Inc. | 19 | 77 | 24.68% |
| SMH Management Services | 10 | 53 | 18.87% |
| Detroit Diesel Corporation | 19 | 113 | 16.81% |
| Ceramatec, Inc. | 10 | 61 | 16.39% |
| TOTAL (top 20) | 652 | | |
| **ALL ASSIGNEES** | 9895 | 2933721 | 0.34% |


Total Alternative Energy Patents from All Energy Firms, by Application Year
Number of energy patent applications
Number of non-energy patent applications
200
180
160
140
120
100
80
60
40
20
0
6000
5000
4000
3000
2000
1000
0
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998
application year
Energy Patents
Other Patents



Total Automotive Energy Patents from All Energy Firms, by Application Year
Number of energy patent applications
Number of non-energy patent applications
250
200
150
100
50
0
6000
5000
4000
3000
2000
1000
0
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
application year
Energy Patents
Other Patents

# Results: Alternative Energy

- Results suggestive of crowding out, but only significant at 10% level

# Estimation Results: Alternative energy

| **Variable** | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
|---|---|---|---|---|---|---|
| Other Patents (t-1) | 0.547 | 0.840 | 0.682 | 0.630 | 0.857 | 0.731 |
| | (3.161) | (3.338) | (4.078) | (3.966) | (3.360) | (4.808) |
| Energy Patents(t) | -1.177 | -1.167 | -1.547 | -1.065 | -0.446 | -1.169 |
| | (-1.877) | (-1.147) | (-1.875) | (-1.687) | (-0.533) | (-1.541) |
| Sales (t-1) | 0.947 | | 0.795 | 0.802 | | 0.699 |
| | (2.175) | | (2.204) | (2.101) | | (2.075) |
| Capital(t) | | -0.476 | -0.551 | | -0.174 | -0.375 |
| | | (-0.627) | (-1.028) | | (-0.216) | (-0.728) |
| trend | | | | -0.983 | -0.545 | -0.813 |
| | | | | (-3.854) | (-1.607) | (-3.043) |
| Year Dummies | YES | YES | YES | NO | NO | NO |
| N | 620 | 620 | 620 | 620 | 620 | 620 |
| r2 | 0.598 | 0.621 | 0.618 | 0.602 | 0.609 | 0.610 |
| p-value for Hansen's J | 0.587 | 0.355 | 0.853 | 0.450 | 0.105 | 0.583 |
| Kleibergen-Paap rk Wald F statistic | 3.731 | 1.844 | 2.079 | 3.528 | 1.478 | 2.259 |
| p-value from underidentification test | 0.002 | 0.130 | 0.033 | 0.001 | 0.229 | 0.013 |

# Results: Alternative Energy

- **Results suggestive of crowding out, but only significant at 10% level**
- **Lagged coefficient supports gradual adjustment**

# Estimation Results: Alternative energy

| Variable | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Other Patents (t-1) | 0.547 | 0.840 | 0.682 | 0.630 | 0.857 | 0.731 |
| | (3.161) | (3.338) | (4.078) | (3.966) | (3.360) | (4.808) |
| Energy Patents(t) | -1.177 | -1.167 | -1.547 | -1.065 | -0.446 | -1.169 |
| | (-1.877) | (-1.147) | (-1.875) | (-1.687) | (-0.533) | (-1.541) |
| Sales (t-1) | 0.947 | | 0.795 | 0.802 | | 0.699 |
| | (2.175) | | (2.204) | (2.101) | | (2.075) |
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| Year Dummies | YES | YES | YES | NO | NO | NO |
| N | 620 | 620 | 620 | 620 | 620 | 620 |
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# Results: Alternative Energy

- Results suggestive of crowding out, but only significant at 10% level
  - In these models, all variables are insignificant
- Lagged coefficient supports gradual adjustment
- Sales have a positive effect
  - Suggestive of firms facing financial constraints
- Capital insignificant

# Estimation Results: Alternative energy

| Variable | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Other Patents (t-1) | 0.547 | 0.840 | 0.682 | 0.630 | 0.857 | 0.731 |
| | (3.161) | (3.338) | (4.078) | (3.966) | (3.360) | (4.808) |
| Energy Patents(t) | -1.177 | -1.167 | -1.547 | -1.065 | -0.446 | -1.169 |
| | (-1.877) | (-1.147) | (-1.875) | (-1.687) | (-0.533) | (-1.541) |
| Sales (t-1) | 0.947 | | 0.795 | 0.802 | | 0.699 |
| | (2.175) | | (2.204) | (2.101) | | (2.075) |
| Capital(t) | | -0.476 | -0.551 | | -0.174 | -0.375 |
| | | (-0.627) | (-1.028) | | (-0.216) | (-0.728) |
| trend | | | | -0.983 | -0.545 | -0.813 |
| | | | | (-3.854) | (-1.607) | (-3.043) |
| Year Dummies | YES | YES | YES | NO | NO | NO |
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