

# Innovation under the Climate Wise Program

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# The Climate Wise Program

- The voluntary Climate Wise program ran from 1993 to 2000 under the direction of the Environmental Protection Agency and the Department of Energy.
- The program targeted non-utilities in the manufacturing sector, but other entities could also join.
- Four broad program objectives:
  - i. Change the way companies view environmental performance
  - ii. Develop productive partnerships between government and industry
  - iii. Reduce greenhouse gas (GHG) emissions
  - iv. **Foster innovation**

# Climate Wise and Innovation

- Program focused on innovation in the areas of energy efficiency, renewable energy, and pollution prevention.
- Program hoped to spur innovation by
  - ▣ Encouraging broad goals
  - ▣ Allowing organization to identify the most cost-effective ways to reduce GHG emissions
  - ▣ Providing technical assistance
- Over the course of the program, 701 entities joined Climate Wise and 353 submitted an Action Plan.

# Objectives of Study

1. Determine the motivations for participation in the Climate Wise program.
  - Pledging to participate
  - Submitting an Action Plan
3. Analyze the determinants of innovative behavior and determine whether participants in Climate Wise had significantly higher measures of innovative activity (i.e. patents) than non-participants.
  - Environmental patents
  - Non-environmental patents

# Background literature

- Studies evaluate the effectiveness of VAs using different environmental measures:
  - ▣ Most use release of emissions of toxic chemicals as measure of environmental output (33/50 program, ISO certification, Strategic Goals program).
  - ▣ Other environmental outputs include environmental rating (Sustainable Slopes), fuel/electricity usage (Climate Challenge), and compliance with regulations (33/50, ISO).
  - ▣ We propose patents as another measure of an environmental output.

# Background literature

- There exists a large literature that explores the relationship between regulation and innovation:
  - ▣ Several studies hypothesize that higher costs of pollution abatement activities (possibly due to stricter regulations) lead to innovation (Lanjouw and Mody 1996, Jaffe and Palmer 1997, Brunnermeier and Cohen 2003, Carrión-Flores and Innes 2010).
  - ▣ The impact of command and control regulations on innovation is explored in Bellas (1998), Lange and Bellas (2005), and Popp (2002, 2003, 2006).
  - ▣ Fewer studies have evaluated the relationship between VAs and innovation (Wagner 2007; Carrión-Flores, Innes, and Sam 2006).

# VAs and Innovation

- Some attributes of VAs may enhance innovation:
  - ▣ flexibility allows firms to pursue goals in cost effective manner (Sunnevag 2000).
  - ▣ Information exchanges may (i) overcome traditional market failures associated with innovation and (ii) improve technical capacity and promote collaborate learning (Aggeri 1999, de Bries et al. 2012, Skjaerseth 2005).
  
- Other attributes of VAs may limit innovation:
  - ▣ Have little monitoring and no sanctioning power (Cunningham and Clinch 2005; Ramesohl and Kristof 2002).

# Conceptual Framework

Firms will *voluntarily* participate/engage in the Climate Wise program when the benefits exceed the costs.

## *Potential Benefits...*

- Regulatory relief
- Improved reputation w/stakeholders (green consumers, investors and NGOs)
- Cost savings/efficiency gains

## *Potential Costs...*

- costs of GHG mitigation and innovation activities undertaken as a result of participation in Climate Wise.



# Conceptual Framework



Why do some firms innovate more than others?

- Economies of scale and scope for innovation
- Market structure
- (Environmental) cost savings
- Regulatory pressure

# Empirical Model – Participation

The net benefits from participating in Climate Wise for firm  $i$  at time  $t$  are

$$D_{it}^* = \beta_2 X_{2it} + \varepsilon_{2it}$$

where  $D_{it}^*$  = net benefits from participating in Climate Wise.

The net benefits are not observable, so we estimate

$$D_{it} = F(\beta_2 X_{2it}) + \mu_{it}$$

where  $D_{it} = 1$  if  $D_{it}^* > 0$  or 0 otherwise.

# Empirical Model - Patenting

The patenting behavior of firm  $i$  at time  $t$  is

$$Y_{it} = \alpha D_{it} + \beta_1 X_{it} + \varepsilon_{1it}$$

where  $Y_{it}$  = number of patents

$D_{it}$  = participation in the Climate Wise Program

$X_{it}$  = vector of exogenous explanatory variables

As with any standard treatment problem, estimation of the above equation may lead to biased results if the treatment is not random. Are there (unobserved) factors that affect both the decision to participate in Climate Wise and innovation?

# Empirical Model - Patenting

## Potential solutions to non-random treatment?

1. If one believes unobservable factors correlated with Climate Wise participation and patenting are time invariant, we can utilize a fixed effect model.
2. If one believes unobservable factors correlated with Climate Wise participation and patenting are time varying, we can use an IV approach.

Our default is to use a fixed effects approach, but we also present a fixed effects IV approach as a robustness check.

# Explanatory Variables

We organize our set of explanatory variables for the participation and innovation equations into the following five categories:

- Technical capacity
- Regulatory pressure
- Market pressure
- Financial indicators
- Controls

# Explanatory Variables

- Technical capacity
- Regulatory pressure
- Market pressure
- Financial indicators
- Controls

# Explanatory Variables

- Technical capacity
  - Climate Wise participation (Pledge and Submit)
  - Climate Wise Partner State
  - Patent stock (patent stock squared)
  - R&D intensity
  - Capital intensity
- Regulatory pressure
- Market pressure
- Financial indicators
- Controls

# Explanatory Variables

- Technical capacity
- Regulatory pressure
  - TRI releases
  - Superfund
  - Spills
  - Violations
  - Levinson index
  - Green energy programs
  - Fuel mix disclosure
  - Energy price
- Market pressure
- Financial indicators
- Controls



# Explanatory Variables

- Technical capacity
- Regulatory pressure
  - Firm specific measures: TRI releases, Superfund, Spills, Violations
  - Location specific measures: Levinson index, Green energy, Fuel mix disclosure, Energy price
- Market pressure
- Financial indicators
- Controls

# Explanatory Variables

- Technical capacity
- Regulatory pressure
- Market pressure
  - Final good
  - Concentration
  - Industry patents
- Financial indicators
- Controls

# Explanatory Variables

- Technical capacity
- Regulatory pressure
- Market pressure
- Financial indicators
  - Return on Assets
  - Debt to Assets
- Controls

# Explanatory Variables

- Technical capacity
- Regulatory pressure
- Market pressure
- Financial indicators
- Controls
  - Employees
  - Industry dummies
  - EPA region dummies
  - Year dummies

# Data and Sample

- **Sample:** Firms that are part of the NBER Patent database, the Corporate Environmental Profile Database (CEPD) from Risk Metrics, and Research Insight from Compustat.
- **Sample period:** 1993 to 2003
- **Sample size:** 5588 firm-year observation from 963 unique firms.

# Summary Statistics

- Looking at the summary statistics, Climate Wise participants ...
  - are more likely to patent: four times as many environmental and regular patents;
  - face more regulatory pressure (higher toxic releases, more violations, spills, and Superfund sites);
  - have lower R&D intensity;
  - are final good producers operating in more concentrated markets;
  - are in dirty industries (construction and heavy machinery; petroleum and chemicals)

# Results: What influences participation?

| <b>Dependent variable:<br/>Climate Wise participation</b> |                            | <b>Pledge</b>       | <b>Submit</b>       |
|---|----------------------------|---------------------|---------------------|
| Regulatory pressure                                       | TRI Releases               | 0.001<br>(0.019)    | 0.029<br>(0.028)    |
|   | Superfund                  | 0.005<br>(0.006)    | 0.013**<br>(0.006)  |
|   | Spills                     | -0.025<br>(0.027)   | -0.054*<br>(0.032)  |
|   | Energy Prices              | -0.129<br>(0.192)   | 0.021<br>(0.230)    |
| Technical capacity  | R&D                        | 0.216***<br>(0.083) | 0.384***<br>(0.111) |
|   | Climate Wise Partner State | 0.780***<br>(0.275) | 0.535*<br>(0.320)   |
| Financial   | Return on Assets           | 0.017**<br>(0.007)  | 0.011*<br>(0.006)   |
| Market  | Final                      | 0.122<br>(0.191)    | 0.077<br>(0.227)    |
| Control   | Employees                  | 0.416***<br>(0.091) | 0.412***<br>(0.107) |

# Results: What influences participation?

| Marginal Effects    |                            | Pledge              | Submit              |
|---------------------|----------------------------|---------------------|---------------------|
| Regulatory pressure | TRI Releases               | 0.125<br>(0.214)    | 0.487<br>(0.470)    |
|                     | Superfund                  | 0.050<br>(0.054)    | 0.184**<br>(0.086)  |
|                     | Spills                     | -0.007<br>(0.009)   | -0.025<br>(0.018)   |
|                     | Energy Prices              | -2.277<br>(3.407)   | 0.502<br>(5.441)    |
| Technical capacity  | R&D                        | 0.871***<br>(0.336) | 2.034***<br>(0.598) |
|                     | Climate Wise Partner State | 2.229***<br>(0.778) | 2.089*<br>(1.216)   |
| Financial           | Return on Assets           | 0.022*<br>(0.013)   | 0.046***<br>(0.015) |
| Market              | Final                      | 0.360<br>(0.558)    | 0.305<br>(0.902)    |
| Control             | Employees                  | 1.648***<br>(0.385) | 2.262***<br>(0.618) |



# Participation models

- Participation is strongly related to ...
  - technical capacity measures (Climate Wise Partner and R&D intensity),
  - financial indicators (Return on assets), and
  - controls (employees, industries, and years).
  
- Participation is only weakly related to regulatory pressures (such as Superfund and Spills for the *Submit* equation).
  
- Participation is not related to market pressures.

# Results: What influences participation?

- Among technical capacity variables:
  - ▣ R&D Intensity and Climate Wise Partner positively influence participation.
  
- Among regulatory pressure variables:
  - ▣ Most are insignificant: only Superfund and Spills influence participation.
  
- Among financial variables:
  - ▣ Return on Assets positively influence participation.
  
- Among control variables:
  - ▣ Firm size positively influences participation
  - ▣ Industry and year dummies influence participation

# Results: What influences patenting?

- We investigate the impact of Climate Wise participation on innovation behavior (patents).
  - ▣ We consider both environmental patents (Carrión-Flores and Innes 2010) and non-environmental area.
  - ▣ We use *GMM* to estimate a fixed effect Poisson model with and without IV in STATA.
    - The predicted probability of participation (based on our first stage model) serves as our instrument in our patenting equations.

# Results: What influences patenting?

|                    |                            | Non-Environmental Patents |                          |
|--------------------|----------------------------|---------------------------|--------------------------|
|                    |                            | No IV                     | IV                       |
| Technical capacity | Climate Wise participation | -0.111<br>(0.071)         | -0.533<br>(0.333)        |
|                    | R&D Intensity              | 0.639***<br>(0.089)       | 0.664***<br>(0.100)      |
|                    | Patent Stock               | 1.53e-4***<br>(5.425e-5)  | 2.36e-4***<br>(8.61e-5)  |
|                    | Patent Stock Squared       | -1.54e-8***<br>(5.18e-9)  | -2.42e-8***<br>(8.64e-9) |
|                    | Capital Intensity          | 3.71e-3<br>(2.89e-3)      | 3.37e-3<br>(2.91e-3)     |
| Market pressure    | Industry Patents           | 2.37e-5<br>(2.99e-5)      | 2.01e-5<br>(3.92e-5)     |
| Controls           | Employees                  | 0.898***<br>(0.131)       | 0.882***<br>(0.128)      |

# Results: What influences patenting?

|                     |                            | Non-Environmental Patents |                          | Environmental Patents  |                        |
|---------------------|----------------------------|---------------------------|--------------------------|------------------------|------------------------|
|                     |                            | No IV                     | IV                       | No IV                  | IV                     |
| Technical capacity  | Climate Wise participation | -0.111<br>(0.071)         | -0.533<br>(0.333)        | 0.106<br>(0.098)       | 0.043<br>(0.287)       |
|                     | R&D Intensity              | 0.639***<br>(0.089)       | 0.664***<br>(0.100)      | 0.613***<br>(0.132)    | 0.627***<br>(0.150)    |
|                     | Patent Stock               | 1.53e-4***<br>(5.425e-5)  | 2.36e-4***<br>(8.61e-5)  | 1.32e-4<br>(1.28e-4)   | 1.39e-4<br>(1.26e-4)   |
|                     | Patent Stock Squared       | -1.54e-8***<br>(5.18e-9)  | -2.42e-8***<br>(8.64e-9) | -1.42e-8<br>(1.19e-8)  | -1.50e-8<br>(1.20e-8)  |
|                     | Capital Intensity          | 3.71e-3<br>(2.89e-3)      | 3.37e-3<br>(2.91e-3)     | 5.39e-3**<br>(2.69e-3) | 5.43e-3**<br>(2.70e-3) |
| Market pressure     | Industry Patents           | 2.37e-5<br>(2.99e-5)      | 2.01e-5<br>(3.92e-5)     | 5.39e-3*<br>(2.69e-3)  | 5.43e-3*<br>(2.70e-3)  |
| Controls            | Employees                  | 0.898***<br>(0.131)       | 0.882***<br>(0.128)      | 0.617***<br>(0.172)    | 0.627***<br>(0.181)    |
| Regulatory pressure | Toxic Releases             |                           |                          | -0.024**<br>(0.011)    | -0.024**<br>(0.011)    |

# Results: What influences patenting?

- We investigate the impact of pledging to Climate Wise on innovation behavior (patents).
  - ▣ We find no evidence that the Climate Wise program impacted environmental or non-environmental patents of firms.
  - ▣ Patenting behavior is strongly impacted by the technical capacity (R&D intensity and patent stock) of firms as well as firm size.
- We consider two robustness checks:
  - ▣ We find similar results with *Submit* instead of *Pledge* as Climate Wise participation measure.
  - ▣ We find similar results with subset of *Env Patents* focused on *Energy Patents*.

# Results: What influences patenting?

- To the extent Climate Wise participation enhanced the technical capacity of firms, the impact of the program may have varied across firms with different technological know-how.
- To examine the impact of Climate Wise across firms with different technologies, we interact the Climate Wise participation measure with R&D Intensity.

# Results: What influences patenting?

|                    |                            | Non-Environmental Patents |                         |
|--------------------|----------------------------|---------------------------|-------------------------|
|                    |                            | No IV                     | IV                      |
| Technical capacity | Climate Wise participation | -0.0008<br>(0.151)        | -0.510<br>(0.711)       |
|                    | Climate Wise*R&D Intensity | -0.046<br>0.064           | -0.012<br>0.273         |
|                    | R&D Intensity              | 0.643***<br>(0.091)       | 0.666***<br>(0.100)     |
|                    | Patent Stock               | 1.67e-4***<br>(5.88e-5)   | 2.40e-4***<br>(1.02e-4) |
|                    | Patent Stock Squared       | -1.67e-8***<br>(5.67e-9)  | -2.47e-8**<br>(9.69e-9) |
|                    | Capital Intensity          | 3.63e-3<br>(2.90e-3)      | 3.35e-3<br>(3.00e-3)    |
| Market pressure    | Industry Patents           | 2.53e-5<br>(3.15e-5)      | 2.06e-5<br>(4.14e-5)    |
| Controls           | Employees                  | 0.891***<br>(0.131)       | 0.880***<br>(0.140)     |



# Results: What influences patenting?

|                     |                            | Non-Environmental Patents |                         | Environmental Patents    |                        |
|---------------------|----------------------------|---------------------------|-------------------------|--------------------------|------------------------|
|                     |                            | No IV                     | IV                      | No IV                    | IV                     |
| Technical capacity  | Climate Wise participation | -0.0008<br>(0.151)        | -0.510<br>(0.711)       | 0.651***<br>(0.147)      | 0.717<br>(0.735)       |
|                     | Climate Wise*R&D Intensity | -0.046<br>0.064           | -0.012<br>0.273         | -0.289***<br>0.065       | -0.422<br>0.384        |
|                     | R&D Intensity              | 0.643***<br>(0.091)       | 0.666***<br>(0.100)     | 0.658***<br>(0.128)      | 0.719***<br>(0.148)    |
|                     | Patent Stock               | 1.67e-4***<br>(5.88e-5)   | 2.40e-4***<br>(1.02e-4) | 2.58e-4***<br>(9.79e-5)  | 3.40e-4*<br>(2.03e-4)  |
|                     | Patent Stock Squared       | -1.67e-8***<br>(5.67e-9)  | -2.47e-8**<br>(9.69e-9) | -2.60e-8***<br>(8.95e-9) | -3.42e-8*<br>(1.90e-8) |
|                     | Capital Intensity          | 3.63e-3<br>(2.90e-3)      | 3.35e-3<br>(3.00e-3)    | 5.09e-3*<br>(2.65e-3)    | 5.07e-3*<br>(2.82e-3)  |
| Market pressure     | Industry Patents           | 2.53e-5<br>(3.15e-5)      | 2.06e-5<br>(4.14e-5)    | 1.07e-4*<br>(25.78e-5)   | 9.87e-5*<br>(5.85e-5)  |
| Controls            | Employees                  | 0.891***<br>(0.131)       | 0.880***<br>(0.140)     | 0.595***<br>(0.169)      | 0.613***<br>(0.185)    |
| Regulatory pressure | Toxic Releases             |                           |                         | -0.020*<br>(0.011)       | -0.017<br>(0.013)      |

# Results: What influences patenting?

- Investigating the impact of Climate Wise on different types of firms:
  - ▣ We continue to find that patenting behavior is strongly impacted by the technical capacity (R&D Intensity and patent stock) of firms as well as firm size.
  - ▣ We now find that the Climate Wise program may have impacted the environmental patents of low R&D intensive firms.
  
- Again, we consider two robustness checks:
  - ▣ We find similar results with *Submit* instead of *Pledge* as participation measure (coefficients on *Submit* and interaction term are larger).
  - ▣ We find similar results with subset of *Env Patents* focused on *Energy Patents*.

# Conclusions

- Objective 1: Determine the motivations for pledging to participate in the Climate Wise program.
  
- Participants in Climate Wise were more likely to ...
  - have greater technical capacity: with high R&D intensity and being located in a Climate Wise Partner State,
  - be profitable (high Return on assets),
  - be a larger firm,
  - and belong to a polluting economic sector.

# Conclusions

- Objective 2: Analyze the determinants of innovative behavior and determine whether participants in Climate Wise have significantly higher measures of innovative activity (environmental and non-environmental patents) than non-participants.
- Patenting is associated with technical capacity of firms (spending on R&D, past stock of patents) and the size of a firm.
- We do not find robust evidence that the Climate Wise program had an influence on patenting behavior of all firms.
  - ▣ If there was any impact, low R&D intensive firms may have benefited in their patenting in the environmental area.

# Extensions



1. Does Climate Wise participation boost other measures of innovative activity that capture either quality of innovation or specific climate-related technologies?
3. What is the trade-off between public (Climate Wise program) versus private (R&D expenditure) learning?

