Voluntary Pollution Reduction Programs: Good News and Bad News

- Presentation for VPC Conference at Ohio State University organized by Carmen Carrion-Flores and Abdoul Sam
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Voluntary Pollution Reduction Programs: Good News and Bad News

- Overview

- Loose (mildly incoherent) summary of trends in voluntary corporate environmentalism. General message:
  - Explosion in academic interest is justified by increasing prevalence of "voluntary environmentalism," in various guises, in practice
- Some results from the literature on impacts of VPRs
- Leads into specific question posed in a joint paper:

- Do Voluntary Pollution Reduction Programs Spur or Deter Environmental Innovation? Evidence from 33/50

- By Carmen Carrion-Flores, Robert Innes, and Abdoul Sam

Manifestations of the VPR phenomenon and corporate environmentalism

- Government “self-enforcement” programs:
  - Gov’t sponsored VPRs
  - Self-Reporting / Self-Policing
  - Voluntary Environmental Agreements
- Industry / NGO programs
  - Examples
  - Trends in private politics, public environmentalism
- Private enforcement of public laws by NGO’s: Citizen Suits (e.g., Langpap, 2007; Langpap, 2008; Langpap and Shimshack, 2010)

US Government Voluntary Environmental Programs

- Number of voluntary programs sponsored by the US EPA (Khanna and Brouhle, 2009):
  - 1996: 28
  - 1999: 54
  - 2005: 87
- Examples:
  - AgStar (biogas recovery at CAFO's)
  - EnergyStar
  - National Environmental Performance Track
    - Partnership w/ EPA, benefits under CAA, Water (NPDES), RCRA; expedited permit review, less frequent reporting, relaxed hazardous waste storage regulations.
    - Recognizes facilities that set three-year goals for continuous improvements in environmental performance beyond their legal requirements, have internal systems in place to manage their environmental impacts, engage in local outreach about their performance and publicly report results.
    - Ended May 2009 after 9 years. Over 500 facilities, over 200 companies.
    - Potoski and Prakash (2005) call "strong sword" due to third party audits, Annual Performance Report requirement.
    - http://www.epa.gov/performancetrack/downloads/PT_ProgRprt_2009_web.pdf
  - 33/50

The 33/50 Program

- 1991-95
- 17 key toxic chemicals
  - 70 % (by weight, 1988 releases) air pollutants
- Targets: Reduce 33/50 releases by
  - 33% by 1992,
  - 50% by 1995 (from 1988 baseline levels)
- Invitations:
  - 1991: 509 largest 1988 33/50 emitters
  - 1992: 4534 other 33/50 emitters
  - Through 1995, 10,167 firms
- Participants:
  - 1294 firms,
  - accounting for 58.8% of 1990 33/50 releases
- Requirement: Plan
- Benefit: Technical assistance
- Purely Voluntary

Self-Reporting / Self-Policing in US Environmental Law Enforcement

- Self-Reporting / Self-Policing Statutes
  - Privilege
  - Immunity
  - Limited Immunity (EPA Guidance, 1995)
- Trends: Between 1993 and 1998:
  - 42 States adopted some form of self-policing statute
    - 26 with Immunity or Privilege
      - 22 with Immunity
      - 24 with Privilege
      - 20 with both
    - 16 additional States with Limited Immunity
- Evidence
  - Stafford (2005): RCRA violations
  - Guerrero and Innes (JLEO, 2013): Toxic air releases, CAA inspections.
    - Privilege reduces pollution, inspections
    - Immunity raises pollution, inspections

Voluntary Environmental Agreements

- Often, these are referred to interchangably with VPR programs (e.g., Segerson and Miceli, 1998)
- Distinction (in my view): VEGs
  - Have teeth, specific requirements, and consequences of failure to comply
  - Come with explicit regulatory rewards (unlike 33/50, for example)
  - Central feature: uncertainty in future regulation (resolved by VEG)
- Examples (US Endangered Species regulation, Langpap and Wu (2004), Langpap (2006), Smith and Shogren (2002), Innes and Frisvold (2009)):
  - Habitat Conservation Plans with “no surprises”
  - Safe Harbor Agreements
  - Candidate Conservation Agreements with Assurances

Industry and Non-governmental Voluntary Environmental Programs

- Some examples:

- Responsible Care
  - Wake of Bhopal (Union Carbide) disaster, Dec. 1984
  - Established by CMA, Oct. 1989 (begun in Canada, 1985)
  - 10 guiding principles, 6 management practices
    - community awareness and emergency response; security; distribution; employee health and safety; pollution prevention; process and product safety
  - 3rd party verification: every 3 years, companies must renew certification (RCMS, or RC14001 – combines RC and ISO14001). (This is new, King and Lenox (2000) stress absence of 3rd party verification.)
  - Sets "input standards," requires firms to set performance targets
  - Members can (in principle) be booted out for persistent conduct contrary to RC
  - By 2008, chemical associations in 53 countries, accounting for 90% of world chemical production, had adopted RC (Gamper-Rabindran and Finger, 2010)

Industry and Non-governmental Voluntary Environmental Programs (cont.)

- ISO 14001

- Environmental management standards designed and developed by the International Organization for Standardization (ISO) in 1996.
- Objective: enable firms to reduce their environmental impacts using proactive environmental management.
- To be registered under ISO 14001, a firm must
  - document / implement EMS that
    - "checks" for environmental problems,
    - implements environmental controls / corrective actions for pollutant releases,
    - involves management review
  - be certified by a third party auditor for compliance with the standard
  - periodically review their EMS and update their certification.
  - Cost: Establishing EMS, having it audited: $25K-$100K per facility (Potoski and Prakash, 2005)
- Third party audits are rigorous, but no obligation for public disclosure of audit findings;
- Potoski and Prakash (2005) refer to the ISO 14001 as a "weak sword."
- Who is ISO?
  - **network** of national standards institutes of **163 countries**
  - **NGO bridging** public and private sectors: Gov't institutes, private sector (industry)

Industry and Non-governmental Voluntary Environmental Programs (cont.)

- Institute of Nuclear Power Operations (INPO)
  - Established in 1979 in wake of March 1979 Three Mile Island event and subsequent Kennedy commission
  - Organized and funded by nuclear power industry – example of industry self-regulation
  - Mission:
    - Establish performance objectives, criteria and guidelines for the nuclear power industry
    - Conduct regular detailed evaluations of nuclear power plants
    - Provide assistance to help nuclear power plants continually improve their performance
  - Goals: Safety and "reliability"
  - Requires "third party" verification (caveat: INPO staff, but INPO is industry sponsored)
  - NRDC (in report on BP Deep Horizon spill): Recommends industry-sponsored watchdog:
    - "The model for this is … INPO… INPO sets high standards for nuclear plant safety, regularly audits facilities and operations, then shares its findings with the companies that insure these plants. That helps hold owners and operators accountable for safe operations, equipment, and procedures. The offshore oil industry should follow that lead." (p. 15, NRDC, "The BP Oil Disaster at One Year," April 2011, http://www.nrdc.org/energy/files/bpoildisasteroneyear.pdf).

Industry and Non-governmental Voluntary Environmental Programs (cont.)

- Forest Stewardship Council (FSC)
  - Est. 1993, Sponsors include WWF, NRDC, Sierra Club, Greenpeace, Nature Conservancy
  - Certifies "environmentally friendly" wood
    - Limits clear cutting
    - Prevents clearing/conversion of diverse natural forests to ecologically simplified plantations
    - Protects old growth and high conservation value forests
    - Protects sensitive, rare, threatened & endangered species
    - Prohibits use of GMOs & invasive exotic species
    - Requires minimal use of herbicides, toxic chemicals
    - Chain of custody certification
  - Acres certified worldwide:
    - 1999: 39 million (US: 5 million)
    - Today: 375 million

Industry and Non-governmental Voluntary Environmental Programs (cont.)

- Sustainable Forestry Initiative (SFI)
  - Est. 1994, Initial Sponsor: American Forest & Paper Association
  - Third party audits started in 1998 (SFI website)
  - Claim (SFI website):
    - "SFI Inc. is an independent, non-profit organization responsible for maintaining, overseeing and improving a sustainable forestry certification program that is internationally recognized and is the largest single forest standard in the world." http://www.sfiprogram.org/sustainable-forestry-initiative/basics-of-sfi.php
  - Meridian Institute (non-profit sponsored by FSC, Home Depot, AFPA) study 2001: SFI not credible
    - Allowable clear-cut size: 116 football fields
    - Almost all U.S. timber satisfies standards, as do millions of acres of old growth in Canada (Great Bear Rainforest)
  - www.dontbuysfi.com, see also greenpeace, nrdc, sierra club websites

Industry and Non-governmental Voluntary Environmental Programs (cont.)

- Marine Stewardship Council
  - Founded in 1997 by WWF and Unilever, independent in 1999
  - Goal:
    - sustainable fishing practices
    - influence consumers to buy sustainably produced seafood
  - Non-profit NGO, supported by grants from private foundations, governments, companies, other NGOs and individual supporters
  - Ecolabel and fishery certification program
    - Certifies wild capture freshwater and marine species, does not assess fish farming (aquaculture)
    - Third party certification
    - Chain of custody certification
    - 2010: 23% of the adult population is now aware of the MSC ecolabel – up from 9% in 2008
    - 2012: over 13,000 seafood products with MSC ecolabel, 74 countries, 100 fisheries certified, 1986 companies meet C-of-C standard
    - Sample Criticisms:
      - Ross Sea antarctic toothfish
      - Greenpeace: antarctic krill
      - Sierra club: British Columbia sockeye salmon
      - WWF: Denmark's North Sea plaice

Private Politics and Public Environmentalism

- Boycotts
  - Number of on-going environmental / animal-rights boycotts of companies & organizations
    - 1990: 27
    - 2011: 43
- Shareholder Actions (related to the Environment)
  - 1988-90: 26.7 per year
  - 2004-06: 67.3 per year
- Public Environmentalism (participation in NGOs):
  - US membership in environmental, conservation, animal rights organizations:
    - 1981: 5.1 million (2.25% of US population)
    - 1990: 8.3 million (3.33%)
    - 1999: 15.9 million (5.7%)
    - http://www.urban.org/UploadedPDF/411797_environmental_conservation_organizations.pdf
  - Example: Sierra Club
    - 1989-2003: Average per-capita Sierra Club membership in US States up by 35.8%
    - Up in all States except Arkansas, CA, Nevada, TX

Numbers of Members, US Environmental Organizations

Source: Urban Institute (2008)

Private Politics and Public Environmentalism

- Evidence: Private political actions (PPAs) effective
  - Eesley and Lenox (2006), Lenox and Eesley (2009):
    - Firms respond to specific PPA demands
  - Gupta and Innes (2012):
    - Boycotts promote EMS adoption (IRRC), deter ISO 14001 adoption
    - Proxies promote ISO 14001 adoption for hard targets
    - Boycotts / Proxies favored for soft targets, Proxies also favored for hard targets.

General Trends

- Increased appeal to government VPRs (at least until Obama administration)
- Growing use of private politics and public environmentalism
- Prevalence of private regimes of environmental standards
  - Self-regulation (INPO, RC, SFI)
  - NGO certification (FSC, MSC)
  - "Hybrid" certification (ISO 14001)
- Competing standards: FSC, SFI.
- Questions:
  - When / why does industry compete with NGO certification (FSC,SFI)?
  - When / why do / don't NGOs sponsor certification programs (like FSC, but not in chemicals industry)?
  - More generally,
    - Structure / governance of NG / non-profit certification
    - Role of VPRs / private environmental standards in general theory of environmental conduct, with private politics, public politics, private enforcement of public policies…

Broad Questions in literature on VPRs

- Why do firms engage in voluntary environmental programs?
- Do the programs work to improve environmental outcomes?

Some theories for corporate environmentalism

- Markets:
  - Product differentiation: Attract “green” consumers (Arora and Gangopadhyay, 1995)
- Private Politics:
  - Deter boycotts by NGO’s (Baron, 2001; Innes, 2006; others)
- Liability:
  - Avoid future environmental liability
- Public Regulation:
  - Preemption: Deter lobbying by NGO’s for tighter environmental regulation (MLH, 200)
  - Spur tighter regulation that raises rivals’ costs (Salop and Scheffman, 1983; Innes and Bial, 2002)
  - Regulatory bargain with government inspectors (Maxwell and Decker, 2006; Innes and Sam, 2008)

Evidence on drivers of VPR participation (33/50)?

	AC	VA	KD	IS / SKI
Product Diff (FG)	yes (ad)	no*	yes	no
Private Politics (BC)	n/a	n/a	n/a	yes?
Liability (Strict)	n/a	n/a	n/a	no
Preemption (Sierra)	n/a	n/a	n/a	yes**
RRC (Herf)	no	n/a	n/a	no***
Regulatory Bargain	n/a	yes+	yes+	yes

- * In VA, FG significant in WasteWise and GreenLights.
- ** Sierra may reflect Private Politics.
- *** However, Herf lowers pollution, consistent with RRC.
- + RCRA corrective actions (VA), PRP notifications (VA,KD)

Evidence on effect of programs on pollution

- Responsible Care
  - King and Lenox (2000): emission improvement in TRI releases (firm level, plant level) (+, less emission improvement)
  - Gamper-Rabindran and Finger (2010): plant-level toxic pollution in chemicals industry (+)
  - Finger and Gamper-Rabindran (2011): plant-level accidents in chemicals industry (-)
  - Earnhart (2012)
- ISO 14001
  - Dahlstrom, et al. (2003) (UK): Does not increase likelihood of compliance with pollution permit requirements
  - King, Lenox, Terlaak (2005): Reduces relative emissions by promoting EMS adoptions (but no independent ISO adoption effect).
  - Potoski and Prakash (2005): Reduces toxicity-weighted TRI emissions (Heckman selection model).
  - Toffel (2005): D-in-D (adopters, non-adopters); reduces TRI emissions.
  - Arimura, Hibiki, Katayama (2008) (Japan): Reduces natural resource use (fuel, water), solid waste generation, wastewater effluent
- 33/50 – following slides

Effects of 33/50

- Casual empiricism:
  - 33/50 releases down 52% 1990-96 vs. non-33/50 releases down 25%
  - 33/50 release reductions greater for program participants (59.3%) than non-participants (42.9%).
- Issues:
  - Other (correlated) determinants of releases
  - Self-selection
- The literature (effects of 33/50 on pollution):
  - Khanna and Damon (1999)
  - Gamper-Rabindran (2006): toxicity weights, industry-specific, off-site transfers
  - Khanna and Vidovic (2007): time effects
  - Innes and Sam (2008): wider set of firms, explanatory variables
- Possible Mechanism:
  - EMS / TQEM effect on pollution:
    - Khanna and Anton (2002)
    - Anton, Deltas & Khanna (2004)
  - 33/50 effect on EMS / TQEM, and independent effect on 33/50 releases:
    - Sam, Khanna, & Innes (2009):
      - 33/50 promotes EMS / TQEM
      - Independent effect of 33/50 in reducing pollution
      - Post-program effects of 33/50, 1996-98

The Paper

- Do Voluntary Pollution Reduction Programs Spur or Deter Environmental Innovation? Evidence from 33/50

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Our Question

- Prior literature interested in 33/50's short-run effects on pollution
- Our interest: Longer-run effects of 33/50 on innovation in environmental technologies

- Observation: Environmental innovation very important driver of pollution reduction.
  - Carrion-Flores and Innes (2010): "A doubling of innovative output… is estimated to spur over a 60 percent long-run reduction in emissions."

Our Question (cont.)

- How does participation in a VPR – in our case, the 33/50 program – affect environmental innovation?
- Measurement of innovation: Environment-related patent counts by industry by year
- Measurement of (lagged) 33/50 participation by industry, by year: 2-5 year lagged average industry rate of participation
- PR_{it}*(1994-2004) = ratio of
  - participating facilities in a 3-digit-SIC industry, TO
  - Number of 33/50 eligible facilities in the industry

The Substitution Hypothesis

- 33/50 as a regulatory bargain (Maxwell and Decker, 2006; Innes and Sam, 2008)
  - Improved environmental performance due to improved compliance programs (regulator benefit)
  - Lessened regulatory scrutiny / inspections (firm benefit)
  - Innes and Sam (2008) results
    - 33/50 participation favored for more inspection-intensive firms
    - 33/50 participation promoted fewer environmental inspections and enforcement actions

The Substitution Hypothesis

- Potential implications for innovation:
- Short-run
- Pursuit of short-run emission reduction may lead to
  - Greater investments in environmental compliance / monitoring
  - Greater exploitation of prior research (and more patenting).
  - Hypothesis 1: In the short-run, a higher industry rate of participation in the 33/50 program leads to an increase in the industry's rate of environmental patenting.

The Substitution Hypothesis

- Potential implications for innovation:
- Long-run
- Higher costs of funds for research
  - Greater investments in compliance / monitoring raises marginal cost of funds (pecking order theory of finance), implicit reflection of “environmental budgets”
- Lower benefits of research
  - 33/50 participants (favored by regulators, NGO’s) may anticipate reduced government and public pressure for future emission reduction.
- Hypothesis 2 (the substitution hypothesis): In the long-run, a higher industry rate of participation in the 33/50 program leads to a reduction in the industry’s rate of environmental patenting.
- Short-run: 1994-1998
- Long-run: 1999-2004

The Empirical Model

- Structural model building on Carrion-Flores and Innes (2010), 5 outcomes
  - 3 observables (emissions, patents, 33/50 participation rates)
  - 2 unobservables (effective emission targets, environmental R&D)

- With substitutions, we obtain the (environmental) patent equation:

- $P_{it} = a_{it} + b\, E_{t-1}(Q_{it}) + cQ_{it-1} + dPR_{it-1} + fX_{it-1} + v_{it}$

- where i = industry, t = time,
  - P = patent output index,
  - Q = emissions,
  - PR = 33/50 participation rate,
  - X = exogenous variables that drive research and patents

- We substitute actual observed emissions, Q_{it}, for the expectation, $E_{t-1}(Q_{it})$.
  - Implies measurement error for the variable, $E_{t-1}(Q_{it})$.

- Under (arguably) innocuous assumption, the (lagged) exogenous X data is uncorrelated with both the measurement error and v_{it}.

The Empirical Model (cont.)

- Two sources of endogeneity
  - Q: technological change can lead to changes in emission targets (and therefore emissions)
  - PR: more innovative industries may be more likely to participate in 33/50
- Identification: enforcement variables that important to Q and PR, but have an effect on innovation only via impact on Q and PR.

The Empirical Model (cont.)

- Patents are the outcome of a count-generating process.
- Outcome = patent counts = P_{it}^*
  - Assumed distributed Poisson with
  - $E(P_{it}^*) = \exp(P_{it})$
  - Implies mixture (multiplicative error) Poisson that allows for over-dispersion.

Data

- 127 manufacturing industries
  - 3-digit SIC codes (200-399)
- 1989-2004
- 2032 observations

Data (cont.)

- *EnvPatents* = successful environmental patent applications
  - Broad measure (CI, 2010): with primary patent classification related to air or water pollution; hazardous waste prevention, disposal and control; recycling and alternative energy
- *EnvPatentsBC* = Narrow measure (Brunnermeier and Cohen, 2003)
- *NonEnvPatents* = patents in other utility classes (vs. broad measure *EnvPatents*)

Data (cont.)

- *Emissions*
- 165 air pollutants
  - Subject to CAA standards / monitoring requirements (NESHAP)
  - Subject to TRI reporting (EPCRA)
  - Common throughout study period
  - Measured by total weight (CI, 2010; Guerrero and Innes, 2013)
  - 1989-2004

Data (cont.)

- 33/50 participation (*PR*)
- For each of program years (1991-1995), define
  - PR* = participation rate for an industry (as reported in TRI) in given year = ratio of
    - # of facilities in 33/50, to
    - # of 33/50-eligible facilities (facilities of invited firms w/ 33/50 releases)
- *PR* = average of 2-5 year lagged PR* (or last year of 33/50 for t>1999). E.g.,
  - PR_{1994} = average of PR* for 1991 and 1992
  - PR_{1997} = average of PR* for 1992-1995
  - PR_{2000} = PR* for 1995

Data (cont.)

- Enforcement Variables
  - *Actions* = counts of CAA Federal and State Enforcement Actions
  - *Outcomp* = numbers of facilities out of compliance with clean air laws
  - *Selfinspect* = numbers of on-site tests conducted by firms
- Use 4-year lags for identification
  - For PR variables that are averages of lags, we construct averages of 4-year lags from dates of PR* lags (e.g., for PR1994, average enforcement variables for 1987-88, 4 years prior to 1991-2)

Data (cont.)

- Exogenous data
- Research spillovers:
  - *R&D Intensity* = overall industry R&D expenditure (per unit sales)
  - *NonEnvPatents*
- Environmental NGO pressure:
  - *Sierra* = weighted average annual per-capita Sierra Club membership (weighting each State's membership by proportion of industry's regulated facilities in the State)
  - Expected impact
    - + (environmental consciousness)
    - - (short-run emission reduction bias)

Data (cont.)

- Exogenous data (cont.)
- Scale:
  - *Sales* = real sales
  - *Employees* = # of employees
- Nature of industry assets:
  - *Capital Intensity* = ratio of capital expenditures to sales
  - Expected impact: More capital intensive industries have more scope for cost-reducing environmental R&D.
  - *Age of Assets* = ratio of net to gross assets (Khanna and Damon, 1999)
  - Expected impact:
    - + Newer capital associated with innovative industries
    - - Older assets give more scope for cost-reducing environmental R&D.

Data (cont.)

- Exogenous data (cont.)
- *Sales Growth*
  - Expected impact:
    - + reflecting more innovative industries
    - - reflecting industries already modernized
- *Concentration* = 4-firm Herfindahl index
  - Expected impact
    - + raising rivals' costs (Innes and Bial, 2002)
    - - recognizing cost of innovation in tightened regulation (CI, 2010)
- *Export Intensity* = ratio of export sales to total sales
  - Expected impact
    - + environmental pressure from abroad
    - - less response of policy to innovation (?)

Summary Statistics

Variable	Mean	SD
EnvPatents	24.786	22.459
EnvpatentsBC	7.293	16.813
PR 1994-98	.3765	.3223
PR 1999-2004	.3584	.2974
PR 1994-2004	.3685	.3116
Emissions	24.919	126.07
Actions	93.695	194.36
Outcomp	108.13	178.9
Selfinspect	24.92	126.07

Summary Statistics

Variable	Mean	SD
Sales	64.28	226.23
Sales Growth	.0411	.1024
Employees	177.12	426.58
Concentration	.0783	.2317
Capital Intensity	.0954	.0256
Age of Capital	.5572	.1274
Export Intensity	.0483	.0317
NonEnvPatents	30.784	38.391
R&D Intensity	.5148	.2238
Sierra	81.41	97.10

Estimation

- Patents (industry environmental patents by year) take a count form.
  - *EnvPatents*: 23.72% zero's, 42.56% ≤ 5
  - *EnvPatentsBC*: 38.26% zero's, 51.53% ≤ 5
- Patent counts = P_{it}^*
  - Assumed distributed Poisson with
  - $E(P_{it}^*) = \exp(P_{it})$
- Multiplicative error (mixture) panel Poisson.
- Estimated by GMM with endogenous regressors (Blundell, et al., 2002; Windmeijer, 2002; Windmeijer and Santos-Silva, 1997)
- Fixed effects
- Fixed time effects

Identification

- Endogenous regressors:
  - *Emissions*
  - *Emissions* lagged (t-2)
  - *PR* (33/50 participation rates)
- Identifying Instruments:
- Environmental enforcement (CAA):
  - *Actions* (t-4),
  - *Outcomp* (t-4),
  - *Selfinspect* (t-4)

Identification (cont.)

- Criteria for instruments:
  - 1) Highly correlated with endogenous regressors
  - 2) Uncorrelated with error (unobservables) in patent equation
- Criteria 1
- Intuition:
  - Large literature on salutary impact of enforcement on pollution (see Gray and Shimshack, 2011)
  - Evidence that enforcement spurs 33/50 participation (the regulatory bargain theory): Innes and Sam (2008)
- Econometrics (Bound, et al., 1995, Stock and Yogo, 2005).
  - Examine performance of instruments in pseudo-first-stage regressions (Table 2).
  - F stats:
  - Emissions: 32.52
  - PR: 19.42
- Signs:
  - Actions, Outcomp: lower emissions, raise 33/50 participation (enforcement effective and spurs 33/50 participation)
  - Selfinspect: raises emissions (consistent with CI, 2010), no effect on PR

Identification (cont.)

- Criteria for instruments:
  - 1) Highly correlated with endogenous regressors
  - 2) Uncorrelated with error (unobservables) in patent equation
- Criteria 2
- Intuition
  - We can conceive of no mechanism for lagged enforcement to drive innovation other than due to effects on cost-based incentives for innovation, which are in turn driven by emission targets (our endogenous regressor)
  - Potential counterpoint: Serial correlation in both patents and enforcement, so lagging does not purge joint determination. E.g., innovation could spur fewer enforcement violations
  - However, we test for serial correlation in patents and find none
- Econometrics
  - Hansen test of over-identifying restrictions.
  - Do not reject null of no correlation (p-values > .15, except in one specification, where p=.11).

Results

- See Tables 3-5

Results: PR effects on Env Patents

	EnvPat		EnvPatBC
Model	4	6	12
PR1994-2004	-2.43***		
PR1994-1998		.134**	.072**
PR1999-2004		-3.650***	-2.374***

(p<.01), *(p<.001)

Note: These are proportional ME's (coeffs). E.g., 10% increase in PR (about 28% of avg PR) leads to 10% (of coeff) proportional ME (e.g., 24.3% estimated reduction in EnvPat in Model 4)

Signs and sizes (roughly) robust to alternative instruments

With year-specific PR effects, long-run impacts larger:

2002-04 coeffs range from -6.9 to -8.9 (all***)

Back of the Envelope: Net effects of 33/50 on R&D

- These estimates of PR effects IGNORE indirect benefits of 33/50 in stimulating environmental R&D by stimulating pollutant reductions.
- How large might these indirect (offsetting) effects be?
- Two components of indirect effects:
- 1) impact of 33/50 on emissions
- 2) impact of emissions on environmental patents

Back of the Envelope: Net effects of 33/50 on R&D (cont.)

- Two components of indirect effects of increasing 33/50 participation by 10%:
- 1) impact of 33/50 on emissions
  - Innes and Sam, 2008: reduces 33/50 pollutants by approximately 7%
  - This is a high-side estimate of impact on toxic regulated air pollutants (our aggregate) because presumes
    - Effects on "overall" toxic air pollutants proportionately the same as for 33/50 pollutants (contrast: Gamper-Rabindran, 2006)
    - Increases in participation – which come from smaller polluters – achieve same pollutant reductions as for the average (larger) 33/50 participant
- 2) impact of emissions on environmental patents
  - CI (2010): 7% reduction in toxic air emissions increases environmental patenting rates by an estimated 3%
  - Contrast: 36.5% direct long-run estimated reduction in environmental patent rates in Model 6 (larger in year-specific models)
- Upshot: Indirect effects likely to be small relative to the estimated direct long-run effects of 33/50 on environmental patents.

Back of the Envelope: 33/50 impacts on pollution

- How important are the long-run (negative) effects of 33/50 on patents, for pollution?
  - CI (2010): Very important! Model 3:
  - Long-run impact of 30% reduction in environmental patenting: Raise toxic air pollution by 18%. (Measured as proportion of sample average pollution.)
  - This is a big number ! Compare to reductions in totals (1990-2000):
  - CO: -25.7%, NOx: -11.4%, SO2: -29.2%
  - VOCs: -27.4%, On-site TRI: -42.5%, Total TRI: -33.3%
  - Sources:
    - http://www.epa.gov/ttn/chief/trends/trends06/nationaltier1upto2011basedon2008v1_5.xls
    - http://www.epa.gov/tri/tridata/tri10/nationalanalysis/tablesandcharts/2010TRIWorkbookSectionA.pdf

Other Results

Variable	EnvPat	EnvPatBC
Economies of scale / scope:		
Employees	+	+ (NS)
Internalizing policy response to innovation:		
Sales	-	-
Concentration	-	- (NS)
Research spillovers:		
NonEnvPatents	+	+
R&D Intensity	+	+
Other:		
Sierra	- (NS)	-
Sales Growth	+	+
Capital Intensity	+	+ (NS)
Age of Capital	+	+

- NS=not significant

Conclusion

- Current evidence on effects of 33/50
  - Participation promoted reductions in 33/50-pollutant emissions (both in weight, and toxicity-weighted)
  - Some doubt about whether this achieved with substitution for more toxic non-33/50 pollutant emissions (G-R, 2006)
- In this paper, we find significant negative long-run impacts of 33/50 participation on rates of environmental patenting, i.e., support for the "substitution hypothesis."
- Given importance of environmental innovation to long-run pollution reduction (CI, 2010), this conclusion is worrisome for programs like 33/50.

Conclusion (cont.)

- More general message from this work.
- Two observations:
  - Increasing prevalence of private environmental programs / efforts, likely as substitutes for traditional models of regulation
  - Importance of environmental innovation to environmental performance
- Motivates more study on impact of VPRs and other private environmental initiatives on environmental innovation (vs. short-run emissions)