

**THREE ESSAYS ON EVOLVING REGULATORY CLIMATES AND MARKET
ADJUSTMENT STRATEGIES**

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Presented to
The Academic Faculty

By

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**THREE ESSAYS ON EVOLVING REGULATORY CLIMATES AND MARKET
ADJUSTMENT STRATEGIES**

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To all my family, past and present.

To my aunt Dinara Asanova, my grandmother Marzia Kamalova, my brother Bolot Urmanbetov and my dad Nasyrkul Urmanbetov – your hearts are beating in every heart you birthed and loved...

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SUMMARY

The first essay of this dissertation aims to bridge two strands of literature on investments in the pulp and paper industry, the one that follows the assumption of continuous capital adjustments and the other which adheres to the notions of lumpy investments in capital-intensive industries. Following regional studies on capital investments, I use a first-differencing, limited probability and logit models to examine papermakers' investment decisions against a number of supply factors. The first group of factors hypothesized to influence the choice of investment location includes such 'traditional' factors of production as variable input costs – prices for materials, labor, and energy. In addition to the list of the 'traditional' cost variables, I examine the impact of regulatory stringency of local/state environmental and tax policies. To complement and expand the scope of the previous regional literature on the industry, I utilize data that span over 1984-2002 covering capital progression of all pulp and paper mills located in the U.S.

The second essay of this dissertation examines the relationship between pollution abatement and voluntary prevention efforts at pulp and paper mills and regulatory stringency they face. Using facility level data on U.S. pulp and paper mills for 1989-2002, I estimate the fixed effects negative binomial model to test the hypotheses of 'responsive regulation' and whether regulators are driven by numerical pollution targets or budgetary constraints. I find that pollution abatement and voluntary pollution prevention have greater impact on regulatory stringency than government budgetary expenditures. Additionally, state political pressure, pollution prevention legislation, firm and mill characteristics are found to be significant predictors of regulatory behavior.

The third and final essay sets to analyze the relationship between pollution prevention (P2) policy instruments and adoption of P2 modifications. Using facility level data on U.S. pulp and paper mills for 1991-2002, I estimate the negative binomial model to test the hypotheses of whether P2 state legislation and policies on target setting, reporting requirement, mandatory planning, and grants have positive impact on P2 adoptions: (1) when they are grouped together and (2) when combined in two categories – (a) management and logistical or (b) product and process modifications. In addition, I examine the effects of regulatory and political threats, P2 firm spillovers and prior mill experience with P2 modifications, firm and mill size, and type of mill product. I find that: (1) policy instruments have different effects on the two groups of P2 modifications, (2) mandatory planning and grants have perverse results, (3) regulatory and political threats, firm spillover and prior mill experience are strong predictors of P2 adoptions, and (4) there are substantial diseconomies of scale associated with P2 modifications.

CHAPTER 1

INTRODUCTION

1.1. Conceptual Framework

This dissertation consists of three empirical analyses examining the interactive and evolving nature of government regulations and how the regulated industries respond to the changes in the regulatory climate. The three essays bring together a number of strands of literature in environmental economics and policy studies discussing how changes in environmental policy were shaped by industry concerns and which strategies firms chose in order to adjust to the changes in policy. This work, however, does not attempt to document the actual interactions between regulators and the industry in order to propose a theoretical framework of how these interactions affect the environmental policy. Instead, the thesis, first, briefly documents the changes in the nature of regulations using an example of one heavily regulated capital-intensive industry and then investigates industry response through three strands of literature, each focusing on different adjustment strategies or market responses to the regulations.

The overall research question of the dissertation is how industries respond and adjust to changing regulations. The traditional reaction of the industry to government interventions is that regulations increase operating costs and when faced with increasing operating costs, decreasing productivity and profit margins, additional environmental compliance costs can drive businesses to bankruptcy or cause them to experience massive

operating net losses. As a result, firms are forced to downsize, move overseas, and employ other adjustment strategies to keep their operating costs down.

I start my investigation in Essay 1 with the often-made proposition that when industries face heavy regulations and are required to invest large amount of capital in order to comply with these regulations, they will alter their capital investment patterns to accommodate increased costs. The literature suggests that firms adjust to high compliance costs by downsizing and using other restructuring strategies (Hammer and Champy 1993; Gray et al. 2011a, 2011b), that abatement capital investment crowds out productive investment (Gray and Shadbegian 1998), and finally firms shift the production to locations with less stringent environmental regulations (Bergman and Johansson 2002; Gray and Shadbegian 1998, 2002; Lundmark 2001, 2003; Lundmark and Nilsson 2001).

The debate that the only recourse to strict regulations available to firms is to cut down their labor costs or to move to a different location altogether assumes that government-to-industry interaction is unidirectional. This, however, is not accurate and it became evident that industry concerns can be heard when in 1981 President Reagan issued an executive order to conduct cost-benefit analyses of government regulations (Koehler 2007). There has been increasing body of literature that the U.S. environmental policy changed from command-and-control or top-down and adopted a more accommodating flexible approach (to cite a few, OECD 1999; Brouhle et al. 2004, 2007; Lyon and Maxwell 2001; and Lyon 2013).

Concurrently, theoretical works appeared discussing the more complex nature of interactions of government and firms (Hemphill 1993/1994; Cothran 1993; Maxwell, Lyon, et al. 2000; Maxwell and Decker 2006; Decker 2005, 2007; Heyes and Kapur

2009; Colson and Menapace, 2012; Arguedas 2013). This strand of literature argues that government and firms engage in complex, multi-stage games, where firms would adjust their pollution levels in order to preempt regulatory stringency. Regulatory threat, the authors argue, is also shaped by budgetary constraints and political and consumer pressures. In Essay 2 of this dissertation, I examine whether firms' environmental performance has impact on the stringency of regulatory monitoring and enforcement they face. I disaggregate environmental performance by the required-to-report amounts of toxic substances released into the environment (toxics release inventory, TRI), and voluntary adoptions of pollution prevention (P2) modifications. Examining the impact of the TRI and P2 measures on the expected count of inspections and enforcements, allows for comparisons of which one is more effective as a signal of environmental stewardship. In addition and following the latest theoretical works on this subject (Hayes and Kapur 2009) I examine the extent to which regulatory actions are constrained or driven by their budgets.

Jaffe et al. (2002) and Koehler (2007) reviewed the literature on the dynamic relationship between: (i) environmental policy and firm environmental innovations and (ii) environmental policy and firms' participation in voluntary environmental programs (VEPs). According to the authors, much of the theoretical and empirical literature concurs that in the last twenty years VEPs have become part of the mainstream business strategy helping corporations address and manage their public relations image. The authors also conclude that the question of how environmental policy instruments affect the adoption and diffusion of environmental technologies remains to be one of the key research questions. In Essay 3 of the dissertation, I examine the impact of environmental

policy directed at voluntary pollution prevention practices, other market pressures, and the effectiveness of individual policy instruments resulting in the number of pollution prevention activities undertaken at individual pulp and paper facilities.

Answers to the proposed research questions in each of the three essays of this thesis help shed more light on the complex nature of evolving relationships between government regulations and regulated industries, as exemplified by the case study of the environmental regulations of the U.S. pulp and paper industry, one of the more capital-intensive manufacturing industries. The first essay helps inform whether the industry's expectations of prohibitively high environmental abatement costs translated into drastically different investment patterns. The second essay addresses more directly the pre-emptive nature of environmental efforts undertaken by producers in order to reduce regulatory stringency. And the third essay examines if more flexible government policies, which are designed to encourage pollution prevention, in fact have positive impact on pollution prevention adoption.

1.2. Empirical Focus: U.S. Paper Industry

Pulp and paper industry represents an interesting case study because it is one of the biggest and most capital-intensive traditional industries with the latest pulping and paper machines amounting up to \$1.5 billion in capital costs.¹ In addition, the technology of industrial paper-making has not changed dramatically since its invention, and only

¹ McNutt J. (2002), "The Paper Industry", Presentation for the Sloan Workshop on Globalization, Center for Paper Business and Industry Studies (CPBIS), Georgia Institute of Technology (GaTech), and Institute of Paper Science and Technology (IPST), Atlanta, GA.

marginal process and product innovations characterize its technological progression.

Theoretically, high capital expenditures associated with new mills and limited room for drastic technological advancements translate into high entry costs and inability to quickly re-engineer and/or relocate in response to such exogenous market shocks as government regulations. Hence, pulp and paper mills are expected to resist sudden changes.

On the other hand, the paper industry is, in fact, subject to heavy regulation. First, the industry is one of the most natural-resource-intensive. Its primary raw material is wood fiber accounting for up to 40% of total materials costs for some paper products and the U.S. Department of Commerce recognizes the industry as the single largest industrial process water user among U.S. manufacturers.² Furthermore, pulp and paper mills release pollutants into air, water and land, and have to comply with the regulations covering all three pollution media. Finally, the Cluster Rules of 1997, which integrated the regulations in all three media, were designed for bleached paper-grade kraft, soda, and paper-grade sulfite manufacturing processes, are specific to the pulp and paper industry only. The combination of its resistance to quick market adjustments due to its capital intensity, being one of the most regulated industries among heavy manufacturers, and having a set of regulations that are designed specifically for the industry, makes the U.S. papermaking sector an interesting case study of how traditional manufacturers respond to ever-changing demands of environmentally-conscious society and its regulatory climates.

² The U.S. Environmental Protection Agency, EPA Office of Compliance Sector Notebook Project (2002), Profile of the Pulp and Paper Industry, 2nd Edition, November 2002, EPA/310-R-02-002:
<http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp/pasn.pdf>

1.3. Industry Overview

Prior to the 2001-02 recession, the U.S. paper industry, National Industrial Classification System (NAICS) 322,³ was one of top 10 industries⁴ with the national value of shipments amounting to \$171.4 billion in 2013 and real value-added of \$51.6 billion, or 6.38% of total real value-added in the nondurable goods sector⁵. Currently, the domestic paper production amounts to about one-fifth of global paper production.⁶ And as of June 2014, the sector employed 379,300 workers with the average weekly earnings of \$1,056 with the total compensation of \$29.5 billion in 2012.

Historically, the industry has been one of the most capital-intensive industries with the latest and most modern pulping and paper machines, which are equipped with computer-based operating systems, totaling up to \$1.5 billion in capital costs.⁷ According

³ This report focuses interchangeably on the complete paper manufacturing sector, represented by the older standard industry classification (SIC) system as 26 or NAICS 322, and its subsector consisting of pulp, paper and paperboard mills, denoted as SIC 261, 262, and 263 or NAICS 3221. The rest of the paper manufacturing sector consists of paper converters and box producers and are given by SIC 265 and 267 or NAICS 3222. For more information on the two standard industry classification systems and their correspondence, see: <http://www.census.gov/eos/www/naics/index.html> and https://www.osha.gov/pls/imis/sic_manual.html.

⁴ The U.S. Environmental Protection Agency, EPA Office of Compliance Sector Notebook Project (2002), Profile of the Pulp and Paper Industry, 2nd Edition, November 2002, EPA/310-R-02-002: http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp_pasn.pdf. As of 2010, the industry is not included in the list of the top ten U.S. manufacturers.

⁵ For more information on the economic indicators related to the paper manufacturing, see CPBIS Report “Pulp and Paper Economic Indicators: A Comparative Analysis”, CPBIS-FR-2014-01, available at: <http://www.cpbis.gatech.edu/research/projects-and-final-reports>.

⁶ American Forest & Paper Association: <http://www.afandpa.org/issues/jobs-and-economic-impact>.

⁷ McNutt J. (2002), “The Paper Industry”, Presentation for the Sloan Workshop on Globalization, Center for Paper Business and Industry Studies (CPBIS), Georgia Institute

to the Bureau of the Census, pulping, paper-, and board-making facilities, representing NAICS 3221, included 486 establishments in 2007 with the average number of employees per establishment of 258.2 people and most of the establishments in 1998, or 67%, having 100 or more employees.⁸ In contrast, more than 75% of all converting facilities, captured in NAICS 3222, employ less than 100 people. When considering the whole paper manufacturing sector, pulp and paper facilities employ only 28% of the workers in the sector, while producing over 40% of the sector's shipments.⁹

1.4.Environmental Impact

Paper manufacturing is also one of the most natural-resource-intensive industries. Its primary raw material is wood fiber with up to 40% of total materials costs attributed to pulpwood for paper board production and 20% for paper production.¹⁰ In addition, the U.S. Department of Commerce recognizes the industry as the single largest industrial process water user among U.S. manufacturers. And according to the EPA, in 2000, a

of Technology (GaTech), and Institute of Paper Science and Technology (IPST), Atlanta, GA.

⁸ The Bureau of the Census data tool "Industry Snapshot" available at: http://thedataib.rm.census.gov/TheDataIb_HotReport2/econsnapshot/2012/snapshot.html?NAICS=3221.

⁹ The U.S. Environmental Protection Agency, EPA Office of Compliance Sector Notebook Project (2002), Profile of the Pulp and Paper Industry, 2nd Edition, November 2002, EPA/310-R-02-002: http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp_pasn.pdf.

¹⁰ McCarthy and Urmanbetova (2009) document that material input composition differs widely by type of paper produced. For example, the single largest input in paperboard production is credited to pulpwood – it accounts for up to 40% of all inputs. Paper production, on the other hand, uses pulpwood, chemicals, and woodpulp in approximately equal shares of about 20% with the woodpulp portion having declined since the 1980s.

typical pulp and paper mill used 4,000-12,000 gallons of water per ton of pulp produced.¹¹

The complex production process employed at pulp and paper mills accounts for substantial air and water emissions as well as solid waste disposals. The main chemical pulping process used in the U.S. – kraft/soda or sulfate pulping – accounted for up to 83% of total U.S. pulp tonnage in 2000 and is considered one of the primary sources of multi-media pollution. Other major sources of pollution come from wood processing, chemical recovery, bleaching and papermaking.¹²

Main Production Processes

Table 1.1 lists the major operations and processes of pulping and paper-making facilities. Most air emissions come from kraft and sulfite chemical pulping, evaporation and recovery boiler procedures, recausticizing and calcining during kraft chemical recovery, pulp bleaching, papermaking and water treatment. Water effluents result from all stages of wood preparation except for chipping and conveying, all stages of chemical pulping and pulp bleaching, papermaking and wastewater treatment. Finally, waste and waste byproducts emerge from debarking, chipping and conveying, kraft and sulfite pulping, and evaporation and recausticizing during chemical recovery, and wastewater

¹¹ The U.S. Environmental Protection Agency, EPA Office of Compliance Sector Notebook Project (2002), Profile of the Pulp and Paper Industry, 2nd Edition, November 2002, EPA/310-R-02-002:
<http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp/pasn.pdf>

¹² American Forest & Paper Association: <http://www.afandpa.org/issues/jobs-and-economic-impact>.

treatment. Table 1.2 summarizes environmental impacts from pulping and paper-making operations by pollution media.

Table 1.1. Major Paper Manufacturing Processes

Operation	Major Processes
Wood Preparation	Debarking Chipping & Conveying
Pulping	Chemical Pulping Kraft Process Sulfite Process Semichemical Pulping Mechanical Pulping Stone Ground Wood (SGW) Refiner Mechanical Pulping (RMP) Thermo-Mechanical Pulping (TMP) Chemi-Thermo-Mechanical Pulping (CTMP) Recycled Paper Pulping
Chemical Recovery	Evaporation Recovery Boiler Recausticizing Calcining
Bleaching	Mechanical or Chemical Pulp Bleaching
Papermaking	Paper Refining & Screening Newspaper Forming, Pressing, Finishing Linerboard Forming, Pressing, Finishing Tissue Forming, Pressing, Finishing Drying

Source: USDOE (2005).

Table 1.2. Environmental Impacts of Main Pulp and Paper Manufacturing Processes

Process	Air Emissions	Process Effluents	Wastes, Residuals, or Byproducts
Wood Preparation Processes			
Debarking	No significant air emissions	Water used for deicing, washing, debarking, and conveying containing BOD(a), TSS(b), and color(c)	Bark and fines that are burned as fuel in boilers

Table 2.1. Continued

Process	Air Emissions	Process Effluents	Wastes, Residuals, or Byproducts
Deincing and/or Washing Prior to Debarking	No significant air emissions	Water Flow: 100-300 gallons/ton of wood debarked, BOD5: 1-8 lb/ton, TSS: 5-55 lb/ton, Color: less than 50 units	No significant wastes, residuals, or byproducts
It Drum Debarking	No significant air emissions	BOD: 15-20 lb/ton TSS: 50-100 lb/ton	No significant wastes, residuals, or byproducts
Hydraulic Debarking	No significant air emissions	Water Flow: 5,000-12,000 gallons/cord of wood debarked BOD: 1-10 lb/ton TSS: 6-55 lb/ton	No significant wastes, residuals, or byproducts
Chipping & Conveying	No significant air emissions	No significant effluents	Fines that are burned as fuel in boilers. Gross heating value is estimated at 10.5 million Btu/ton (5,250 Btu/lb)
Chemical Pulping			
Kraft Process (500-1,000 ton per day pulp mill)	Noncondensibles (TRS(d), VOC(e)) from blow and vent gases	Digester condensates containing VOC, TRS. Spent liquor and byproduct spills containing BOD (a), COD(f), AOX(g), TSS(b), color(c) Water Flow: >30,000 gallons/ton of pulp BOD: 23 lb/ton pulp TSS: 12 lb/ton pulp	Turpentine, methanol

Table 2.1. Continued

Process	Air Emissions	Process Effluents	Wastes, Residuals, or Byproducts
Sulfite Process	Noncondensibles (VOC(b)) from blow and vent gases; SO ₂	Digester condensates containing VOC, TRS. Spent liquor and byproduct spills containing BOD, TSS	Lignosulfonates, sugars, organic acids for use as binders in brickette and pellet manufacturing and in other applications
Semichemical Pulping	Not available	White water from pulp refining and spent liquor and byproduct spills containing BOD, TSS	No significant wastes, residuals, or byproducts
Mechanical Pulping	No significant air emissions	White water from pulp refining, containing BOD, TSS Water Flow: 5k -7k gallons/ton of pulp	No significant wastes, residuals, or byproducts
Kraft Chemical Recovery			
Evaporation	Noncondensibles including TRS(d), VOC(e), alcohols, terpenes, phenols	Foul condensate containing BOD(a), suspended solids	Tall oil is recovered when resinous wood is being processed
Recovery Boiler	Fine particulates, TRS, SO ₂ , CO, NO _x	Potential black liquor storage tank spills	None
Recausticizing	Particulates (sodium salts), SO ₂ , TRS	No significant effluents	Dregs that are composed of unburned carbon and inorganic impurities, such as calcium and iron compounds
Calcining	Fine and coarse particulates (sodium and calcium salts), TRS, SO ₂ , CO, NO _x	No significant effluents	No significant wastes, residuals, or byproducts

Table 2.1. Continued

Process	Air Emissions	Process Effluents	Wastes, Residuals, or Byproducts
Pulp Bleaching			
Bleaching	Vent gases from bleach towers, washers, and filtrate tanks contain chlorine dioxide and VOCs Chlorine dioxide: 0.05-2.65 kg/air dried metric ton of pulp	Effluents are characterized by BOD(a), TOC(h), COD(f), color(c), AOX(g), and EOX(i) and levels vary by bleaching process For three softwood kraft pulp bleaching sequences, effluent levels are below: <u>BOD (lb/ton pulp):</u> ECF(k): 18-35 TCF(l): 26-86	No significant wastes, residuals, or byproducts
Papermaking Process			
Papermaking	Possible formaldehyde emissions from urea or melamine formaldehyde resins used for It strength; Anaerobic degradation of sulfates in water can release sulfide emissions	White water containing particulates, organic compounds, inorganic dyes, COD, acetone	No significant wastes, residuals, or byproducts

Table 2.1. Continued

Process	Air Emissions	Process Effluents	Wastes, Residuals, or Byproducts
Wastewater Treatment			
Treatment Facility	VOCs (terpenes, alcohols, phenols, methanol, acetone, chloroform, MEK)	Effluents containing BOD, TSS, COD, color, chlorophenolics, and VOCs (same as air emissions)	Sludge

Notes: (a) Biological oxygen demand (BOD) is the amount of oxygen required by aerobic microorganisms to decompose organic matter in a sample of water. BOD₅ measures the oxygen consumed in a 5-day testing period. (b) Total suspended solids (TSS) is a measure of the solids in water that can be trapped by a filter. (c) Color is measured in platinum-cobalt (Pt-Co) units. The acceptable limits of color values for the disposal of treated wastewater range from 50-100 units Pt-Co depending on the nature of the receiving body of water (river, sea, lake, etc.) (d) Total reduced sulfur (TRS) emissions include hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide. (e) Volatile organic compounds (VOC). (f) Chemical oxygen demand (COD) measures the amount of oxygen required to oxidize organic matter in the sample. COD differs from BOD in that it measures the oxygen need to digest all organic content, not just the portion which could be consumed by biological processes. (g) Adsorbable organically bound halogen (AOX) can include chlorinated organic compounds such as dioxins, furans, and chloroform. ECF bleaching and careful process control has reduced dioxin levels to undetectable levels. (h) Total organic carbon (TOC). (i) Extractable organic halogen (EOX). (k) Elemental chlorine free (ECF) bleaching process. (l) Totally chlorine-free (TCF) bleaching process. (Delimpasis 2001). Source: USDOE (2005).

Air Emissions

According to the 1997 EPA's Office of Water report, each year the U.S. pulp and paper mills, SIC 261, 262, 263 or NAICS 3221, emit about 245,000 metric tons of toxic pollutants into the air. Table 1.3 lists common air pollutants emitted from the pulp and

paper facilities. The emissions include hazardous air pollutants (HAPS), volatile organic compounds (VOCs), and total reduced sulfur (TRS) compounds.¹³

Table 1.3. Common Air Pollutants from Pulp and Paper Processes

Source	Type
Kraft recovery furnace	Fine particulates, nitrogen oxides
Fly ash from hog fuel and coal-fired burners	Coarse particulates
Sulfite mill operations	Sulfur oxides, ammonia
Kraft pulping and recovery processes	Reduced sulfur gases
Chip digesters and liquor evaporation	Volatile organic compounds
Pulp drying (non-integrated mills)	Volatile organic compounds
All combustion processes	Nitrogen oxides

Source: EPA (2002).

More recently, the EPA's toxic release inventory (TRI) data depository reports 7.9 million pounds of fugitive air and 166.2 million pounds of point air emissions, adding up to 174 million pounds of total air emissions, for pulp and paper facilities in 2000.¹⁴ Total air releases for the total paper manufacturing sector, SIC 26 or NAICS 322, in 2000 amounted to 201.5 million pounds decreasing to just under 130 million pounds in 2009 and increasing again in 2013 to 143.3 million pounds. Figure 1.1 shows this substantial drop in air emissions for the paper manufacturing sector.

¹³ U.S. Environmental Protection Agency, *The Pulp and Paper Industry, the Pulping Process, and Pollutant Releases to the Environment*, (Office of Water 4303, 1997a), EPA-821-F-97-011, available at: http://water.epa.gov/scitech/wastetech/guide/pulppaper/upload/1997_11_14_guide_pulppaper_jd_fs2.pdf.

¹⁴ The U.S. Environmental Protection Agency, EPA Office of Compliance Sector Notebook Project (2002), *Profile of the Pulp and Paper Industry*, 2nd Edition, November 2002, EPA/310-R-02-002: <http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulppasn.pdf>.

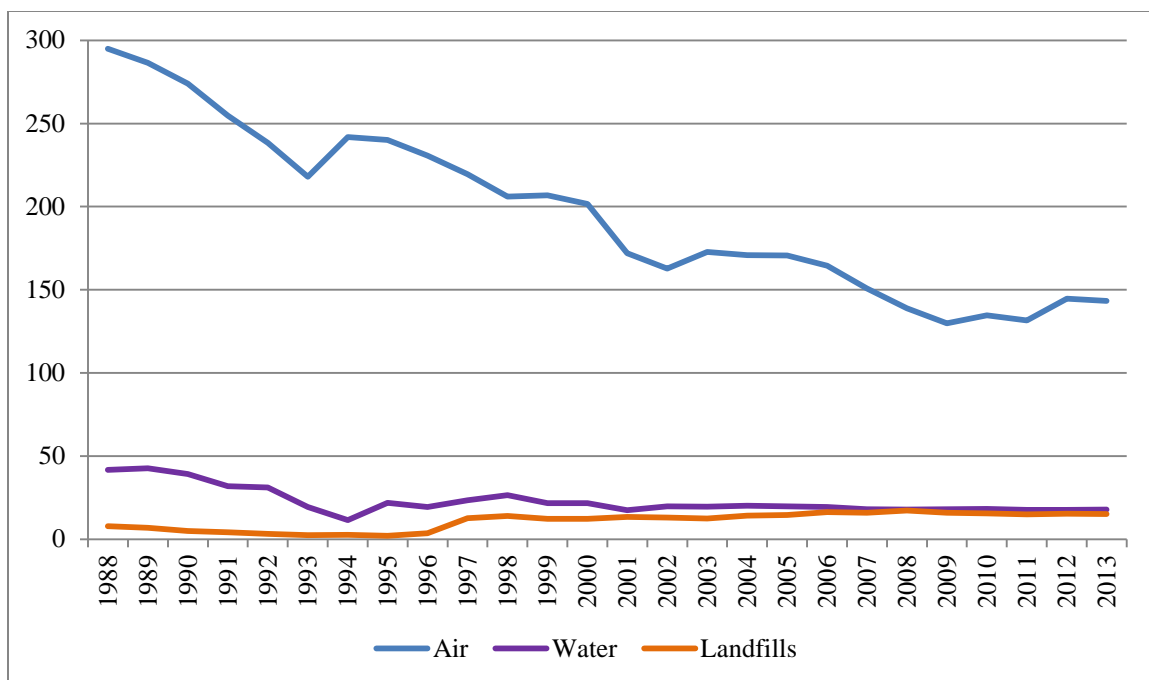


Figure 1.1. Paper Manufacturing TRI by Pollution Media
(Millions of Pounds, Source: TRI 2015)

Water Discharges

As mentioned earlier, pulp and paper mills use large volumes of water and, as a result of their manufacturing processes, generate lots of wastewater, which can contain chlorinated and sulfur compounds, volatile organic and other chemicals. In response to the 1981 EPA finding confirming that dioxin was one of the most potent carcinogens, litigious concerns arose around paper mills' discharge of chlorinated organic compounds such as dioxins and furans, often referred to as adsorbable organic halides (AOX). In mid 1990s, after a pro-longed political battle and the EPA- and industry-commissioned report "104 Mill Study," the EPA and pulp and paper industry announced a voluntary agreement to eliminate dioxin-tainted effluents and sludge disposals formalizing best management practices (BMP) such as substituting chlorine for chlorine dioxide (Powell 1997). The

substitution of chlorine dioxide enabled a dramatic reduction in the effluent chlorinated compounds, which no longer present a serious environmental and health risk.

Since 1990 and by 2004, according to the National Council for Air and Stream Improvement (NCASI), there had been a 90% decrease in the number of dioxin compounds released downstream from pulp and paper mills.¹⁵ Further, the Alliance for Environmental Technology (AET) reinforce that in 2004, only 8 waterbodies, representing less than 0.2% of total 3,221 U.S waterbodies subject to any type of advisory, have a dioxin advisory downstream of bleached chemical pulp mills (Figure 1.2).¹⁶ As of 2000, the industry released 320 pounds of dioxin and dioxin-like compounds in total, with 162, 103, and 55 pounds released into land, water and air, respectively, and with the average facility release of only 4 pounds. Similarly, total water releases decreased from 41.6 million pounds in 1988 for the whole paper manufacturing sector to 17.8 million pounds in 2013 (Figure 1.1).¹⁷ Finally, the effluents of 20.7 million pounds in 2000 for pulp and paper mills¹⁸ represented 96% of water effluents for the entire paper

¹⁵ The full NCASI (2013a) report “Effects of Decreased Release of Chlorinated Compounds on Discharge to Water, Wastewater and Water Quality Impacts Associated with Pulp Bleaching,” see: <http://www.paperenvironment.org/index.html>.

¹⁶ See the full AET (2005) report here:

http://aet.org/reg_market_news/press_releases/2005/Eco051.html#Dioxin.

¹⁷ TRI (2015).

¹⁸ The U.S. Environmental Protection Agency, EPA Office of Compliance Sector Notebook Project (2002), *Profile of the Pulp and Paper Industry*, 2nd Edition, November 2002, EPA/310-R-02-002:

http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp_pasn.pdf.

manufacturing sector.¹⁹ Figure 1.3 shows the dramatic decrease in chlorinated organic compounds, measured by the adsorbable organic halides over time.²⁰

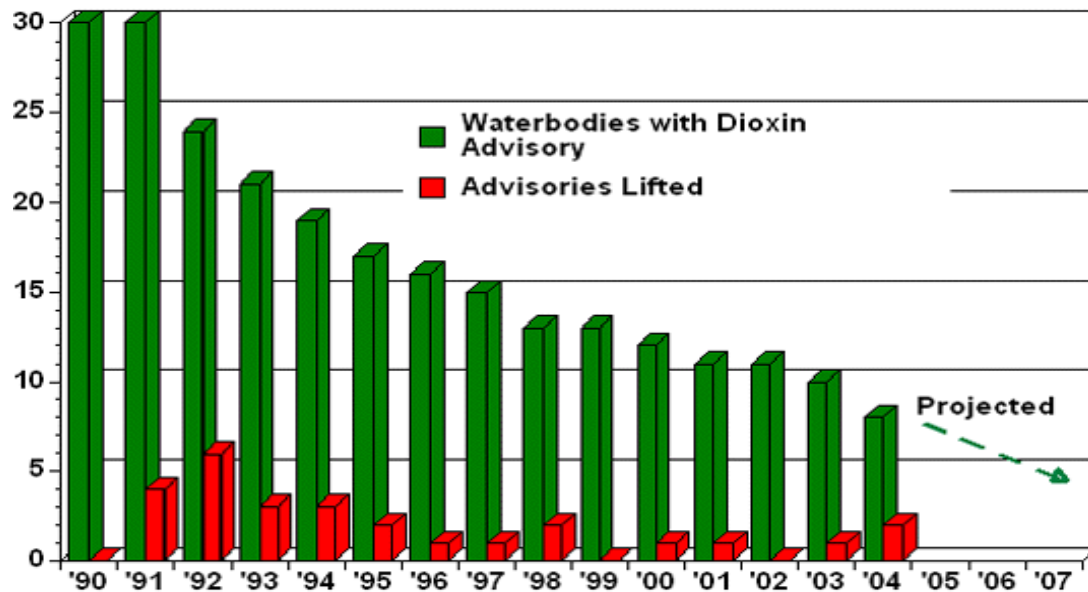


Figure 1.2. Dioxin Advisories Downstream Of Pulp Mills
(Source: AET 2005)

Land Disposals

In addition to air and water emissions, the pulp and paper industry generates more than 12 million tons per year of solid waste, which consists primarily of de-watered

¹⁹ Authors' calculations.

²⁰ NCASI (2013b), *Environmental Footprint Comparison Tool, A Tool for Understanding Environmental Decisions Related to the Pulp and Paper Industry*, National Council for Air and Stream Improvement:
<http://www.vtgreenhotels.org/articles/ChlorineInPaperIndustryEPA2013.pdf>.

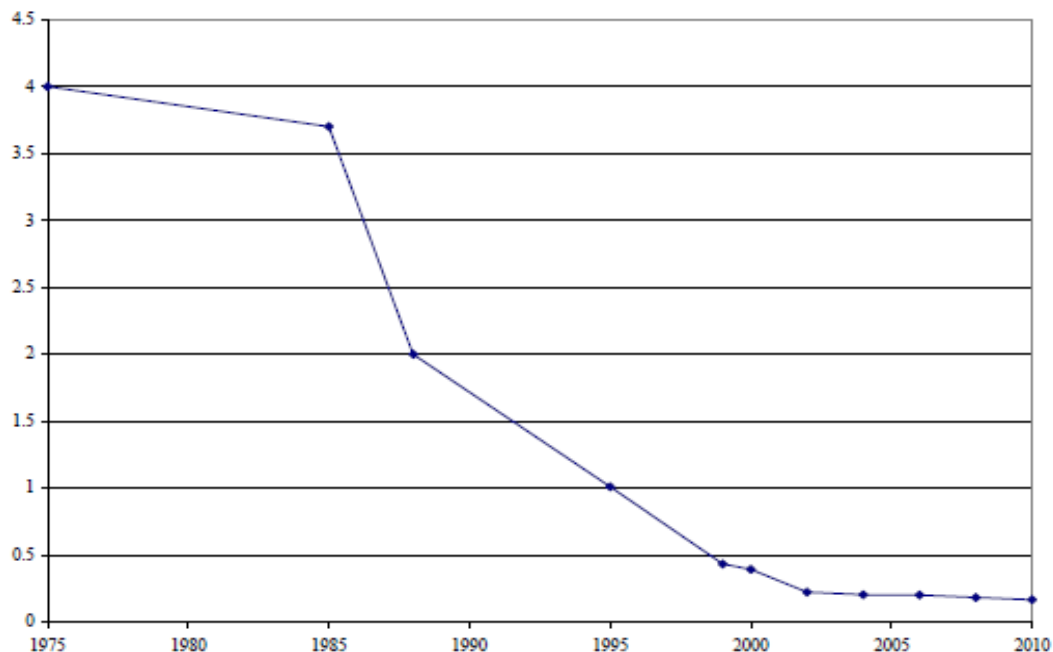


Figure 1.3. Effluent Adsorbable Organic Halides
(Kg/Tonne Pulp, Source: NCASI 2013b)

sludge masses. While traditionally most of the sludge masses were released in landfills, currently other methods of disposals include incineration and land application.²¹ In 2000, the total land releases amounted to 16.8 million pounds per year.²² Unlike air and water releases, however, landfill deposits have grown from 7.8 million pounds in 1988 to 15.2

²¹ USDOE (2005), Energy and Environmental Profile of the U.S. Pulp and Paper Industry Columbia, Maryland, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program, Prepared by Energetics Incorporated; full report can be downloaded here:

http://energy.gov/sites/prod/files/2013/11/f4/pulppaper_profile.pdf.

²² The U.S. Environmental Protection Agency, EPA Office of Compliance Sector Notebook Project (2002), Profile of the Pulp and Paper Industry, 2nd Edition, November 2002, EPA/310-R-02-002:

http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp_pasn.pdf.

million pounds in 2013. Finally, 1995 marks the year with the lowest landfill deposits of only 2.1 million pounds, peaking to 17.3 million pounds in 2008 (Figure 1.1).²³

1.5.Main Pieces of Legislation and History of Compliance

Conventional End-of-pipe Regulations: Air, Water, and Solid Waste

Table 1.4 provides the main federal regulations directed at the pulp and paper industry including the Clean Air Act (CAA), Clean Water Act (CWA), Resource Conservation and Recovery Act (RCRA), Toxic Substances Control Act (TSCA), and the Cluster Rules (CR). In addition to the federal requirements, states can impose additional emissions and effluent restrictions. Yet, the list of regulations is not the same for all the mills even in one state and depends on such factors as the age of main pulping and papermaking equipment used at the mill, production processes, product mixes, and mill location.

Table 1.4. Federal Regulations Affecting Paper Manufacturing

Regulation	Industry-Specific Provisions
Air Quality Standards Act (Clean Air Act) (1970)	Establishes standards for specific hazardous chemicals; applies to dissolving kraft, bleached paper-grade kraft/soda, unbleached kraft, dissolving sulfite, paper-grade sulfite, and semichemical mills; may require companies applying for state permits to install best available pollution control technologies
Occupational Safety & Health Act (OSHA) (1970)	Defines “safe and healthful” working conditions for all workers; regulates safety of moving equipment, use of hazardous materials and chemicals

²³ TRI 2015.

Table 1.4. Continued

Regulation	Industry-Specific Provisions
Environmental Pesticide Control Act (1972)	Regulates application of pesticides and their interstate and intrastate marketing to protect humans and the environment
Water Pollution Control Act Amendments (Clean Water Act) (1972)	Limits amount of toxic pollutants in industrial discharges; protects surface waters, rivers, lakes; discharger obtains state permit; applies to dissolving kraft, bleached paper-grade kraft/soda, unbleached kraft, dissolving sulfite, paper-grade sulfite, and semichemical mills; and to mechanical pulp, nonwood chemical, secondary fiber deink and nondeink, fine and lightweight papers and tissue, filter, nonwoven, and paperboard from purchased pulp
Endangered Species Act (1973), amended 1988	Lists threatened and endangered species of plants and animals that must be conserved, including their habitats; prevents the forest products industry from logging various areas
Clean Air Act Amendments (1973, 1974, 1989-1990)	Regulates VOCs and other ozone precursors; provides National Emission Standards for Hazardous Air Pollutants; addresses acid rain
Resource Conservation and Recovery Act (RCRA) (1976)	Defines solid waste to include hazardous waste; charges EPA with “cradle-to-grave” tracking of hazardous wastes; requires standards and regulations for handling and disposing of solid and hazardous wastes
Toxic Substances Control Act (1976)	Regulates land application of sludge generated by pulp and paper mills that use chlorine or chlorine derivatives for bleaching
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (“Superfund”) (1976, 1980)	Regulates processing wastes containing CERCLA-listed hazardous substances above specific levels; includes past releases
Clean Water Act Amendments (1987, 1990)	Addresses excessive levels of toxic pollutants, non-point pollution, and water quality in the Great Lakes

Table 1.4. Continued

Regulation	Industry-Specific Provisions
Emergency Planning and Community Right-to-Know (EPCRA) (1986)	Created a national database , Toxic Release Inventory (TRI), identifying facilities, chemicals manufactured and used at those facilities, and the annual accidental and routine releases of these toxic substances
Pollution Prevention Act (1990)	Focused industry, government, and public attention on reducing the amount of pollution through cost-effective changes in production, operation, and raw materials use; expanded the TRI
Great Lakes Initiative (1995)	Applies to industrial discharges in 8 states bordering the shores of the Great Lakes; affects more than 40 pulp and paper mills; limits release of 22 long- lasting toxic bioaccumulative chemicals of concern (BCCs)
Cluster Rules (1997) Issued under the Clean Air and Clean Water Acts	Regulates air and water pollution from mills; provides National Emission Standards for Hazardous Air Pollutants (NESHAP) for bleached paper-grade kraft, soda mills, and paper-grade sulfite mills; sets air limitations based on maximum achievable control technology (MACT); requires 100% substitution of chlorine dioxide for chlorine; lists oxygen delignification as a way to meet targets; calls for elimination of dioxin

Source: USDOE (2005), EPA (2015).

The CAA and its amendments oversee emissions of hazardous air pollutants and such *criteria pollutants* as carbon monoxide, lead, ozone, nitrogen dioxide, sulfur dioxide, and particulate matter. Emissions of *criteria pollutants* are controlled by the National Ambient Air Quality Standards (NAAQS). Under the NAAQS permit programs, mills that are located in counties that meet the air quality standards, or in attainment areas, are mandated to develop and implement best available control technology (BACT).

Mills in non-attainment areas are required to employ lowest achievable emission rate (LAER) technologies and process-specific new source performance standards (NSPS). The EPA has developed the National Emission Standards for Hazardous Air Pollutants (NESHAP) for two processes that are specific to the pulp and paper industry, pulping and chemical recovery, and that generate substances suspected to cause cancer and other dangerous health and environmental effects.²⁴

Regulations covering effluents from the pulp and paper sector are postulated by the Clean Water Act (CWA) and specifically by the National Pollution Discharge Elimination System (NPDES). The NPDES regulations lay out instructions on how to control: (1) toxics such as adsorbable organic halides, chloroform, dioxin and furan, (2) conventional pollutants such as biological oxygen demand (BOD), total suspended solids (TSS), chemical oxygen demand (COD), fecal coliform, oil and grease, and pH; and (3) non-conventional pollutants which include all chemicals not listed under the first two categories.²⁵ The full list of potential water pollutants from pulp and paper mills is included in Table 1.5.

²⁴ The U.S. Environmental Protection Agency, EPA Office of Compliance Sector Notebook Project (2002), Profile of the Pulp and Paper Industry, 2nd Edition, November 2002, EPA/310-R-02-002: <http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp/pasn.pdf>.

²⁵ U.S. Environmental Protection Agency, *The Pulp and Paper Industry, the Pulping Process, and Pollutant Releases to the Environment*, (Office of Water 4303, 1997a), EPA-821-F-97-011, available at: http://water.epa.gov/scitech/wastetech/guide/pulppaper/upload/1997_11_14_guide_pulppaper_jd_fs2.pdf.

Table 1.5. Potential Water Pollutants From Pulp and Paper Processes

Source	Effluent characteristics
Water used in wood handling/debarking and chip washing	Solids, BOD, color
Chip digester and liquor evaporator condensate	Concentrated BOD, reduced sulfur compounds
"White waters" from pulp screening, thickening, and cleaning	Large volume of water with suspended solids, can have significant BOD
Bleach plant washer filtrates	BOD, color, chlorinated organic compounds
Paper machinewater flows	Solids
Fiber and liquor spills	Solids, BOD, color

Source: EPA (2002).

Finally, solid wastes from pulp and paper mills are regulated by two main pieces of legislation – the Resource Conservation and Recovery Act (RCRA) and the Toxic Substances Control Act (TSCA). Both sets of regulations aim to control possible hazardous pollutants such as chlorinated organic compounds, which are byproducts of elemental chlorine bleaching process. However, substituting the traditional chlorine bleaching by elemental chlorine-free (ECF) and totally chlorine-free bleaching (TCF) technologies during late 1990s- early 2000s, has diminished the related health and environmental threats. On the other hand, as the 2002 EPA report points out, some of the solid waste may still have high content of pH and, as such, are defined as corrosive hazardous waste and have to meet the RCRA disposal guidelines.²⁶

²⁶ The EPA indicates pH>12.5 as corrosive hazardous waste threshold. The U.S. Environmental Protection Agency, EPA Office of Compliance Sector Notebook Project (2002), Profile of the Pulp and Paper Industry, 2nd Edition, November 2002, EPA/310-R-02-002:
<http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp/pasn.pdf>.

Flexible Regulations: the Cluster Rules and Pollution Prevention Regulations

The late 1980s and early 1990s mark initially subtle, yet quickly growing, changes in the focus and character of environmental policies from rigid command-and-control to more flexible and cognizant of economic and market contexts, under which the regulated industries were operating. According to Brouhle et al. (2004, p.4), “in 1999 OECD identified 42 voluntary initiatives in the U.S. with an estimated 13,000 participants. The U.S. EPA, the primary environmental regulatory agency in the U.S., administered 33 of these initiatives (OECD, 1999). Currently, the U.S. EPA’s Partners for the Environment website lists 40 voluntary initiatives (U.S. EPA, 2004a). At the federal level alone, we identify over 50 voluntary initiatives in the U.S.” The authors identify three types of VEPs: (1) public voluntary programs, (2) negotiated agreements, and (3) unilateral industry commitments.

Within the framework of public voluntary programs, the regulatory authorities – whether federal or local – design a program and firms are invited and free to participate. The often-cited examples of the first group of VEPs are the 33/50, Energy StarTM and WasteWise. The second type of VEPs – negotiated agreements between regulators and firms – are more common to the EU than to the U.S. Lastly, the authors identify unilateral commitments or industry-led initiatives that are typically proposed by the industry groups with no or minimal involvement of government. The examples of this third type of VEPs are the Chicago Climate Exchange and Responsible Care® program (Brouhle et al. 2004). According to a more recent taxonomy of voluntary programs developed by Lyon and Maxwell (2001) and updated by Lyon (2013), policies geared

towards firms' self-regulation fall under Public Voluntary Schemes (PVS) and Public Voluntary Programs (PVP). Reviewing the existing literature, the authors emphasize that the PVS' and PVPs can be effective in complementing more traditional regulations and help raise public awareness of and stimulate public discourse over environmental initiatives.

Increasing pressures from the industry to take into account prohibitively high abatement costs, having to comply to different statutes for each pollution media and the confusing nature of numerous abatement and reporting requirements when taken separately for each media and even more so when put together (as is the case with the pulp and paper industry), and the realization that the existing regulations did little in the area of using market mechanisms to incentivize industries to take environmental pollution issues to heart – all have contributed to the emergence of the industry- and/or market-smart environmental policies. From the many shortcomings of the existing pollution regulations, the intense debates gave rise to two prominent themes: (1) the role and potentially large impact of emerging voluntary action on the part of the business community, later termed corporate environmentalism, and (2) natural precedence and cost-effectiveness of pollution prevention vs. abatement efforts.

With the understanding that the existing end-of-pipe technologies fell short of curbing pollution occurring at all stages of manufacturing, not just the end stage, and having more accurate methods to detect pollutant escape/release, the policy-makers developed and enacted the Pollution Prevention Act of 1990. In order to diminish any future contamination issues well before they caused environmental crises, the new legislation explicitly recognized the elusive nature of many difficult-to-control sources of

pollution and called industries to implement day-to-day preventative practices aimed at reducing pollution by minimizing waste, spills, and leaks during all stages of production.²⁷

In contrast to end-of-pipe pollution abatement measures, they are less costly in terms of capital, technological, and personnel investments. By definition, the pollution prevention programs are voluntary or quasi-regulatory programs that do not require a change in polluting behavior, but may require other types of actions, such as submitting reports under the TRI disclosure requirements.^{28,29} As such, the P2 legislation represents the newer form of environmental policies, which have evolved from top-down command

²⁷ The EPA (2015) defines pollution prevention as “reducing or eliminating waste at the source by modifying production, the use of less-toxic substances, better conservation techniques, and re-use of materials” (EPA, Pollution Prevention, Basic Information: <http://www.epa.gov/p2/pubs/basic.htm>). Additional information about the Pollution Prevention Act of 1990 can be found at: <http://www2.epa.gov/laws-regulations/summary-pollution-prevention-act>, <http://www.epa.gov/p2/pubs/p2policy/act1990.htm>, and <http://www.epa.gov/p2/pubs/basic.htm>.

²⁸ P2 activities are voluntary to adopt, yet facilities are mandated to file reports of any pollution prevention modifications for chemicals reported under the TRI and to submit plans to implement new P2s for hazardous waste.

²⁹ In 1986, in response to the fatal chemical release accident in Bhopal, India and less severe yet similar accidents in the U.S., the EPA amended the Superfund legislation and added the Emergency Planning and Community Right-to-Know (EPCRA) provisions, which required facilities that manufactured or used in manufacturing toxic chemicals to report the amounts of each of these chemicals released into the environment. For history of the TRI, see the U.S. Environmental Protection Agency, EPA Office of Pollution Prevention and Toxics, Environmental Assistance Division (1997b), *Toxics Release Inventory, the History of TRI*, Fall 1997, EPA 749-R-97-001b: <http://www.epa.gov/oppt/cie/archive/issue06j.pdf>. Later, the Pollution Prevention Act of 1990, required manufacturing facilities to report information on the amount of toxic materials leaving a facility in waste. Overall since 1986, the original list of 300 chemicals expanded to the current 594 individually-listed chemicals and 31 chemical categories, including four categories containing 68 specifically-listed chemicals. For more information on chemicals included in the TRI, see the EPA’s site on Toxics Release Inventory (TRI) Program, TRI-Listed Chemicals: <http://www2.epa.gov/toxics-release-inventory-tri-program/tri-listed-chemicals>.

regulations, to market-based incentives, to voluntary pollution and waste prevention and reduction programs that are more broadly termed as voluntary environmental programs.

Finally, to help the industry reduce the costs of compliance by not having to refer to different sets of regulations and because of the multi-media nature of pollution control and prevention, in 1997 the EPA issued an integrated set of regulations covering air and water emissions – the Cluster Rules. The new regulations cover guidelines for air emissions in 115 and water discharges at 96 mills, which manufacture mostly bleached papergrade kraft and soda, and papergrade sulfite products.³⁰ Further, to promote voluntary action, the Cluster Rules give a choice for pulp and paper mills to participate in the Voluntary Advanced Technology Incentives Program (VATIP), which sets more rigorous wastewater regulations while letting mills have more flexible time schedules to achieve the pollution standards.³¹ Most of these requirements became effective as of April of 2001.³²

³⁰ The U.S. Environmental Protection Agency, EPA Office of Compliance Sector Notebook Project (2002), *Profile of the Pulp and Paper Industry*, 2nd Edition, November 2002, EPA/310-R-02-002: http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp_pasn.pdf.

³¹ U.S. Environmental Protection Agency, *The Pulp and Paper Industry, the Pulping Process, and Pollutant Releases to the Environment*, (Office of Water 4303, 1997), EPA-821-F-97-011, available at: http://water.epa.gov/scitech/wastetech/guide/pulppaper/upload/1997_11_14_guide_pulppaper_jd_fs2.pdf.

³² U.S. Environmental Protection Agency, *Retrospective Study of the Costs of EPA Regulations: A Report of Four Case Studies*, (National Center for Environmental Economics, August 2014), EPA 240-F-14-001, available at: [http://yosemite.epa.gov/ee/epa/erm.nsf/vwAN/EE-0575.pdf/\\$file/EE-0575.pdf](http://yosemite.epa.gov/ee/epa/erm.nsf/vwAN/EE-0575.pdf/$file/EE-0575.pdf).

1.6.Costs of Command-and-control Policies: Case of Pulp and Paper Mills,

Essay 1

When the 2014 EPA report examined the estimated ex-ante and ex-post environmental compliance costs in the pulp and paper industry, they came to a surprising conclusion that the actual costs of compliance were significantly lower than the estimates made by both the government and industry groups. Tables 1.6 and 1.7 lay out ex-ante cost estimates of complying with the Cluster Rules and related regulations. MACT stands for maximum achievable control technology requirements that were included in the final version of the Cluster Rule. MACT I and MACT III cover regulations on emission control of toxic air and water pollutants released during pulping and bleaching stages of the papermaking process while MACT II, added in 2001, regulates chemical recovery combustion sources in the pulp and paper industry. In addition to MACT II and Cluster Rules regulations, estimates for implementing the best available technologies (BAT) and pretreatment standards for existing sources (PSES) are also provided.

Table 1.6. EPA Ex Ante Compliance Cost Estimates (in thousands of 1995 dollars)

	MACT I	MACT II	BAT/PSES	Cluster Rules (MACT I + BAT/PSES)	Cluster Rules + MACT II
Capital	500,758	258,389	1,039,388	1,540,146	1,798,535
Operations and Maintenance	74,718	5,202	158,413	233,131	238,334
Post tax, annualized	81,767	23,139	171,619	253,386	276,525

Source: EPA (2014, p.30)

Taking 1995 as their baseline year, the EPA estimated the capital expenditures associated with the Cluster Rules (MACT I and III or air and water regulations) and

MACT II (solid waste) to amount to \$2.8 billion with \$238 million in annual operating and maintenance costs (Table 1.6). Interestingly, the estimates from some industry sources, such as American Forest and Paper Association (AF&PA), were virtually the same – \$2.6 billion and \$273 million for capital expenditures and annual operating costs, respectively. Other industry groups, in contrast, provided much higher estimates with the maximum of \$4 billion in capital investment costs for both the Cluster Rules and MACT II (Table 1.7).

Table 1.7. Non-EPA Ex Ante Cost Estimates of the Compliance Costs

Source	Capital Expenditures	Operating Costs
Cluster Rules + MACT II		
AF&PA	\$2.6 billion	\$273 million
Pulp & Paper Project Report, April 1998	\$3.2+ billion	---
Cluster Rule		
Parthasarathy and Dowd (2000, p. 41)	\$2.625 billion*	---
NCASI (2003, p. 5)	\$3 billion (1999-2005)	---
Jensen (1999, p. 72)	\$2.675-2.916 billion	---
MACT II		
Parthasarathy and Dowd (2000, p. 41)	\$0.35 billion	---
Garner (2001, p. 45)	\$0.90 billion	---
NCASI (2003, p. 5)	\$1 billion or less	---

Notes: * \$1.375 billion for MACT I & III and \$1.250 billion for BAT and best management practices (BMP); ** MACT I (April 2001 compliance); *** MACT I (HVLC pollutants, April 2006 compliance); Source: EPA (2014).

Table 1.8 provides an examination of actual pollution abatement costs at pulp and paper mills during 1990-2002. First, the total compliance costs appear to have been over-estimated by both the EPA and industry groups. If one followed the EPA and took 1995

as the baseline year for when the initial Cluster Rules expenditures were anticipated to take place, then from Table 1.8 it is clear that these costs had been substantially overestimated. The total capital costs of compliance in 1995 were 625 million of 1995 dollars. Even if one were to take an average between 1995 and 1997, the year of the Cluster Rules enactment, the average total compliance costs for those years is 632 million of 1995 dollars. Another interesting finding is that the average rate of growth in total abatement costs during 2000-2010 was negative 3.3% and went down to negative 24.2% during 2000-2002. And although abatement costs constituted on average only about 15% of total capital expenditures during 2000-2002, the average annual rate of growth of this proportion was 6.7% during 2000-2010. Hence, despite the overall decreasing rate of annual average growth in abatement capital costs, the proportion they represent within the total capital costs has grown over 2000-2010.

Finally, the EPA (2014) report stipulates that the early cost estimates did not account for substitution of mandatory abatement requirements by more flexible compliance procedures adopted by the regulators and mills, suggesting that these other, more flexible, pollution abatement strategies provided substantial cost-savings and are preferred by mills.³³

³³ EPA (2014): " Among the reasons for EPA's overestimates of these capital costs are the mills' use of the clean condensate alternative (CCA), flexible compliance options, extended compliance schedules, site specific rules, use of equivalent-by-permit, and equipment/mill shutdowns and consolidations. However, the lack of detail in the available data means we can only speculate on which reason(s) is primarily responsible for EPA's overestimate," p. 52.

Table 1.8. Pollution Abatement Capital Expenditures (millions of 1995 dollars)

Year	Air	Water	Solid Waste	Total	Percent of Total Capital Expenditures
1990	553	669	272	1,494	12%
1991	542	765	214	1,521	19%
1992	416	533	201	1,150	18%
1993	289	354	131	774	14%
1994	252	289	188	729	14%
1995	219	309	97	625	12%
1996	244	343	133	720	13%
1997	142	305	105	552	12%
1998	119	288	172	579	13%
1999	294	340	65	699	17%
2000	633	364	74	1,071	23%
Average Annual Growth Rate, 1990-2000	1.4%	-5.9%	-12.2%	-3.3%	6.7%
2001	170	287	72	529	12%
2002	105	170	29	304	9%
Average Annual Growth Rate, 2000-2002	-21.4%	-23.0%	-36.5%	-24.2%	-13.4%

Note: Current dollar value values are deflated to 1995 dollar values using the Engineering New-Record Construction Cost Index. Calculation for annual growth rates: $[(I_e/I_s)^{(1/t)} - 1] \times 100$, where I_e and I_s is the ending and starting index, respectively, and t is the number of time periods between the starting and ending period. For air capital expenditures, for instance, the growth rate between 1990 and 2000 is $[(633/553)^{(1/10)} - 1] \times 100 = 1.4\%$. Source: EPA (2014).

Compliance Costs and Investment Decisions

The descriptive analyses of costs of abatement compliance, substantially overestimated by both the EPA and industry groups, need empirical examinations of how compliance costs affect the existing mill cost structures, which in turn, influenced papermakers' investment decisions. Geographically, mills differentiate themselves by the type of product they produce. Pulp mills locate in regions with high-yield natural and farmed tree harvests: all of the East coast, Northwest and North-central states. Pulping

operations using recycled pulp choose to locate near urban centers where there is access to waste paper. Paper mills, typically, co-locate with pulping facilities or with converting centers. Figure 1.4 maps out the location of all pulp, paper and board mills by their size – up to 60, 61-200, 201-600, and over 601 thousand short tons per year – that operated in 2011.³⁴

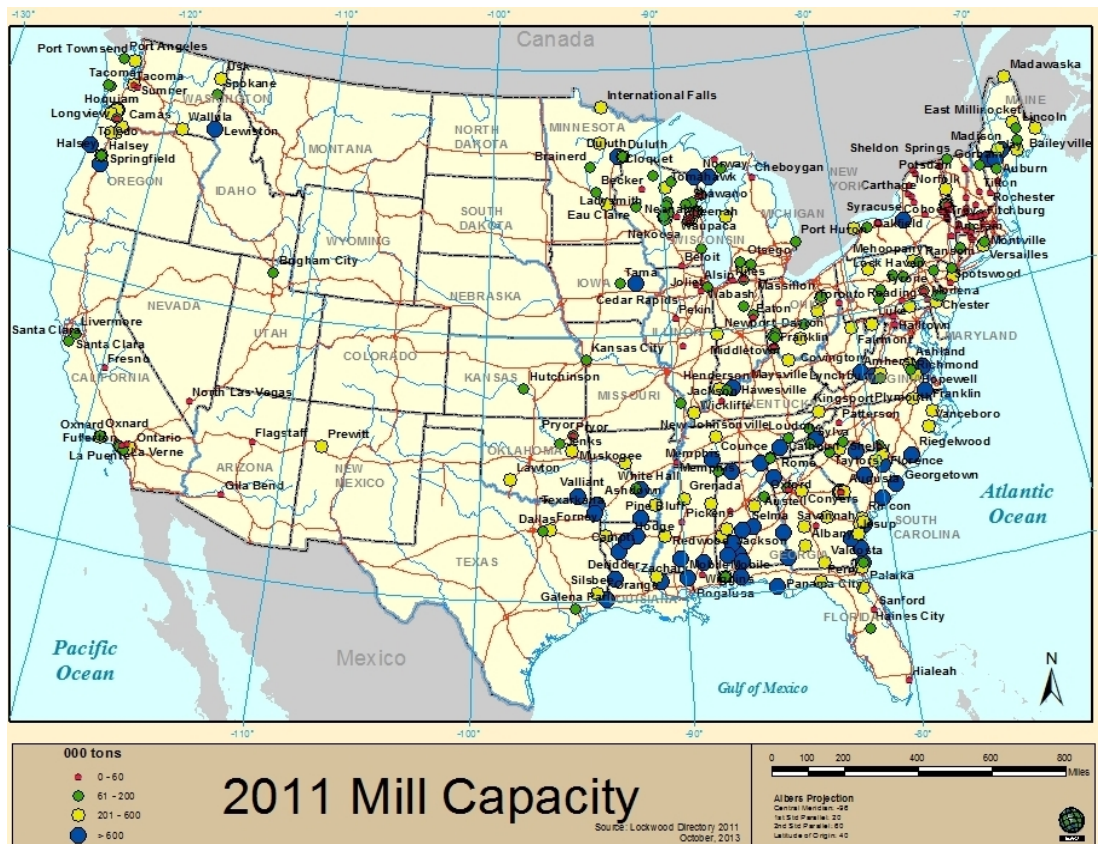


Figure 1.4. U.S. Pulp and Paper Mills in 2011
(Thousand Short Tons, Source: CPBIS 2013)

³⁴ The map was built using CPBIS Mills Online data. For more information, see: <http://www.cpbis.gatech.edu/data/mills-online-new>.

The literature characterizes the investment decisions as either (a) continuous investments or stay-put decisions or as (b) radical investments in new or existing locations by increasing operating capacity in large chunks. Earlier research on new branch plant location decisions for all manufacturing industries in general failed to document if location characteristics had significant impact on the choice of new plant location (Carlton 1983, Bartik 1985).³⁵

Later studies, however, find that such local characteristics as state environmental regulations affect behavior of pollution-intensive industries (Gray and Shadbegian 1993, Henderson 1996, Levinson 1996, Gray 1997, List 2001, List et al. 2004, Gray and Shadbegian 2005a, Condliffe and Morgan 2008). Further, works that narrowly focused on the pulp and paper industry examined the investment decisions of existing plants (Bergman and Johansson 2002, Gray and Shadbegian 2002, 2003a, 2003b, 2003c, 2004, Lundmark 2001, Lundmark and Nilsson 2001, and Lundmark 2003). Without explicitly noting that a firm's decision to invest into an existing production site is also a 'stay put' location decision, these studies recognize that local and regional factors play a role in firms' investment planning. Principally, these studies find that wage rates and such agglomeration factors as the size of existing pulp and paper industry and consumer market are significant determinants of investment flows.

Building upon these latter works, Essay 1 of the thesis estimates a first-differenced, limited probability and logit models of a firm's decision to invest in an

³⁵ More specifically, Carlton (1983) found that energy costs and existing concentrations of employment had strong impact on new plant openings; Bartik (1985) showed that differences in unionization across states had major effect on business location, while state taxes did not.

existing plant against a number of variables that reflect cost factors, regulatory environment, and specifically environmental compliance costs, measured by regulatory stringency. To complement and expand the scope of the previous regional literature on the industry, I utilize data over 1984-2002 covering capacity progression of all pulp and paper mills located in the U.S.

The contribution of this essay lies in its focus on the differences between the two theoretical approaches to model capital investments – continuous vs. lumpy. More practical implications of this work will inform (1) policy-makers and industry analysts about the site/state characteristics and environmental requirements to which traditional manufacturing employers respond most sensitively, and (2) entrepreneurial firms, investment analysts and regional planners about those combinations of location-specific factors and regulatory stimuli that attract further investments under profit maximization.

1.7.Responsive Regulation, Essay 2

History of Monitoring and Enforcement at Mills

Returning to the history of environmental monitoring and compliance, the number of inspections and enforcement actions across all media in paper manufacturing has been increasing since the mid-1970s to 2014. Figures 1.5 and 1.6 lay out the number of federal and state inspections and enforcements at pulp, paper and board mills and converting facilities between 1974 and 2014. The number of inspections at pulp, paper and board mills peaked in 1986 and 2006, rising to the annual of 1,309 and 1,769, respectively. The number of inspections at pulp and paper mills, on the other hand, represented less than a

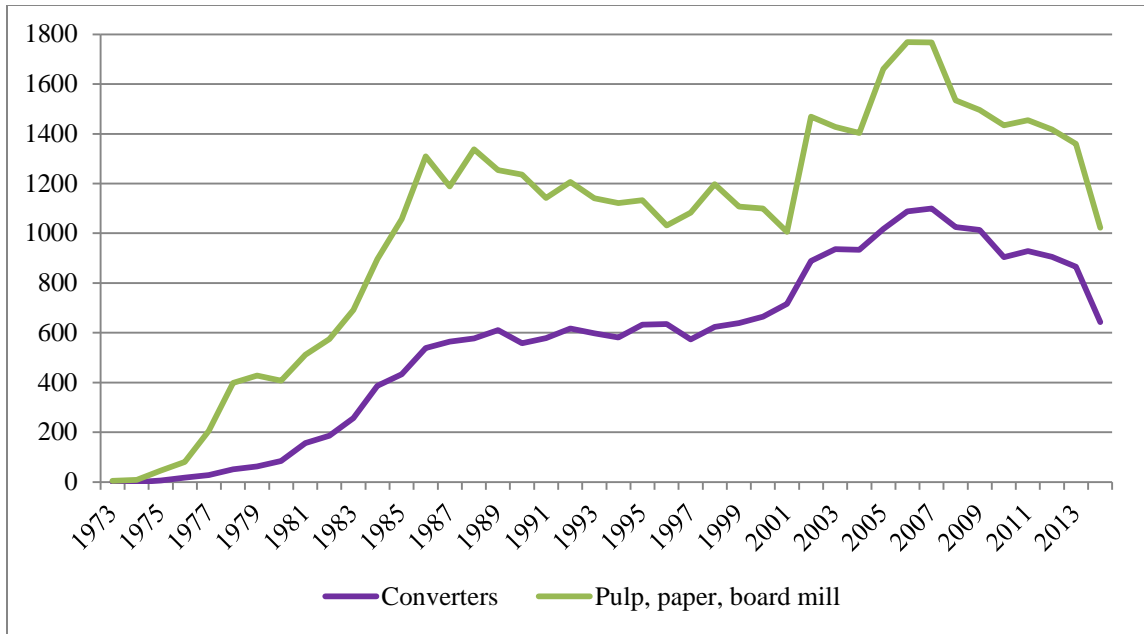


Figure 1.5. Number of Inspections at Paper Manufacturing Facilities
(Source: EPA 2014)

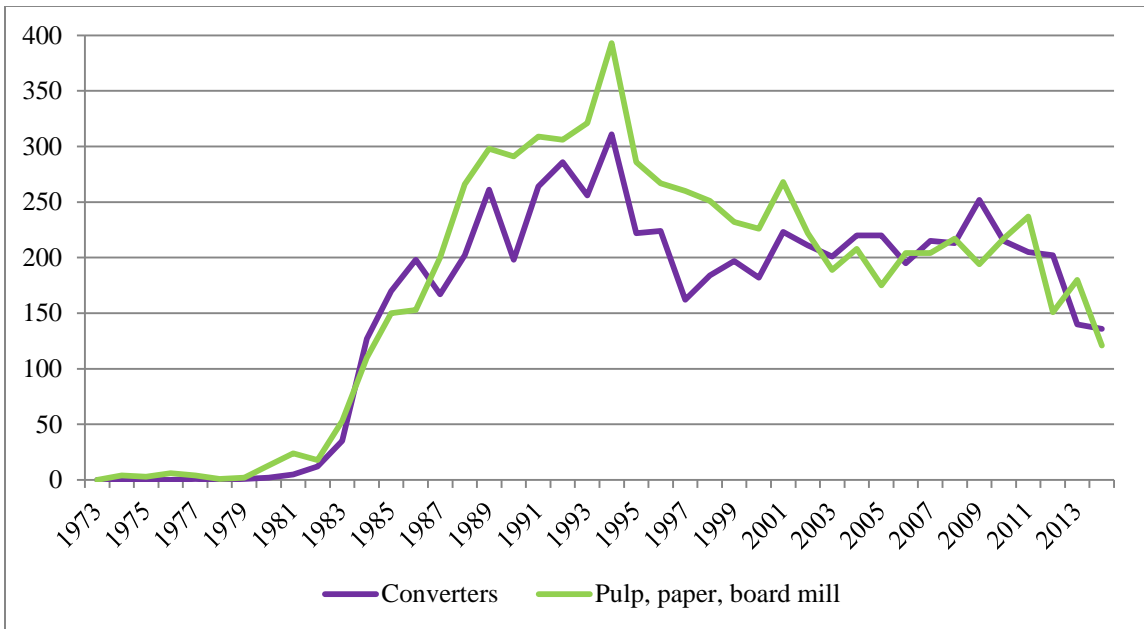


Figure 1.6. Number of Enforcements at Paper Manufacturing Facilities
(Source: EPA 2014)

fifth, 16%, of total inspections on average and peaked in 1994 to 393 for all media combined. Table 1.9 breaks down national aggregates into regional and is consistent with the national-level analyses presented in Figures 1.5 and 1.6. At the regional level, the enforcement to inspection rate is 0.19 in NJ, NY, PR, and VI, 0.13 in AK, ID, OR, WA, and the average of 0.6 for the rest of the regions.

The overall decreases in the number of monitoring and enforcement actions and very low enforcement to inspection ratios can be explained by a number of competing hypotheses. On the one hand, the proponents of the deterrence model can postulate that the regulatory enforcement has been such an effective mechanism in changing mill behavior that overtime there has been less need to oversee facility compliance behavior. Gray and Shimshack (2011) review empirical literature on the effectiveness of environmental monitoring and enforcement and find that most analyses measure firm deterrence, or how plants respond to enforcement activities. There are a number of studies on pulp and paper industry that find evidence of the effectiveness of enforcement on facility compliance (Nadeau 1997, Gray and Shadbegian 2005a, Shimshack and Ward 2005, 2008). Shimshack and Ward (2005, 2008) find that an additional fine induced state-wide compliance. More specifically, Shimshack and Ward (2008) document that fines at violating facilities induced facilities that were operating within the permitted level of discharges to discharge even less, or go beyond compliance. Gray and Shadbegian (2007) find that inspections at one plant tend to increase compliance at both the inspected and nearby facilities.

Table 1.9. Five-Year Enforcement and Compliance Summary for the Pulp and Paper Industry, by Region

Region	Facilities In Search	Facilities Inspected	Number of Inspections	Average Months Between Inspections	Facilities with 1 or More Enforcement Actions	Total Enforcement Actions	Percent of State Lead Actions	Percent of Federal Lead Actions	Enforcement to Inspection Rate
National	585	495	6383	5	332	503	85%	15%	0.08
CT, MA, ME, RI, NH, VT	92	73	571	10	38	37	95%	5%	0.06
NJ, NY, PR, VI	71	57	383	11	34	73	96%	4%	0.19
DC, DE, MD, PA, VA, WV	57	47	899	4	26	77	77%	23%	0.09
AL, FL, GA, KY, MS, NC, SC, TN	105	96	2024	3	90	116	91%	9%	0.06
IL, IN, MI, MN, OH, WI	144	120	721	12	48	44	70%	30%	0.06
AR, LA, NM, OK, TX	45	40	944	3	32	56	70%	30%	0.06
IA, KS, MO, NE	7	7	33	13	2	1	100%	0%	0.03
CO, MT, ND, SD, UT, WY	2	2	3	40	0	0	0%	0%	0
AZ, CA, HI, NV, Pacific Trust Territories	22	18	140	9	16	12	100%	0%	0.09
AK, ID, OR, WA	37	32	537	4	40	72	94%	6%	0.13

Source: EPA (2002).

On the other hand, the theorists of voluntary corporate self-regulation propose that paper-manufacturers preemptively lowered their TRI levels and adopted P2 modifications in order to signal their environmental stewardship to the regulators in the hope of softening regulatory stringency they face (Maxwell and Decker 2006, and Decker 2007).

Target-driven Regime and Pre-emptive Compliance

Maxwell and Decker (2006) and Decker (2007) corroborate theoretically that profit-maximizing firms, under ‘responsive regulation,’ overinvest in environmental compliance; hence, regulatory fines are likely to be an over kill and must be lowered. Corroborating this theory, Arguedas (2013) documents how the EPA legislation offers firms lighter penalties if those self-report/pollute in a timely manner.³⁶

Two additional important aspects of environmental enforcement and compliance that require attention are (1) the multi-media nature of the pollution and (2) budget constraints faced by the regulators. Figures 1.7 and 1.8 present the number of inspections and enforcement by pollution media. The graphs for air, water, and land inspections picture drastically different scenarios. In Figure 1.7, inspections are initially dominated by water, yet gradually in the mid 1990s air inspections took precedence, rose to the record high of 1,368 in 2007, and slid down to 845 in 2014. Also, for both water and air, inspections far exceeded the number of enforcements (Figures 1.7, 1.8).

Land inspections, on the other hand, trailed at 25 inspections per year during 1974-2014, but were significantly lower than the annual average of 76 enforcement actions per year. In fact, among the three media, land pollution received the highest

³⁶ Arguedas (2013), p. 157.

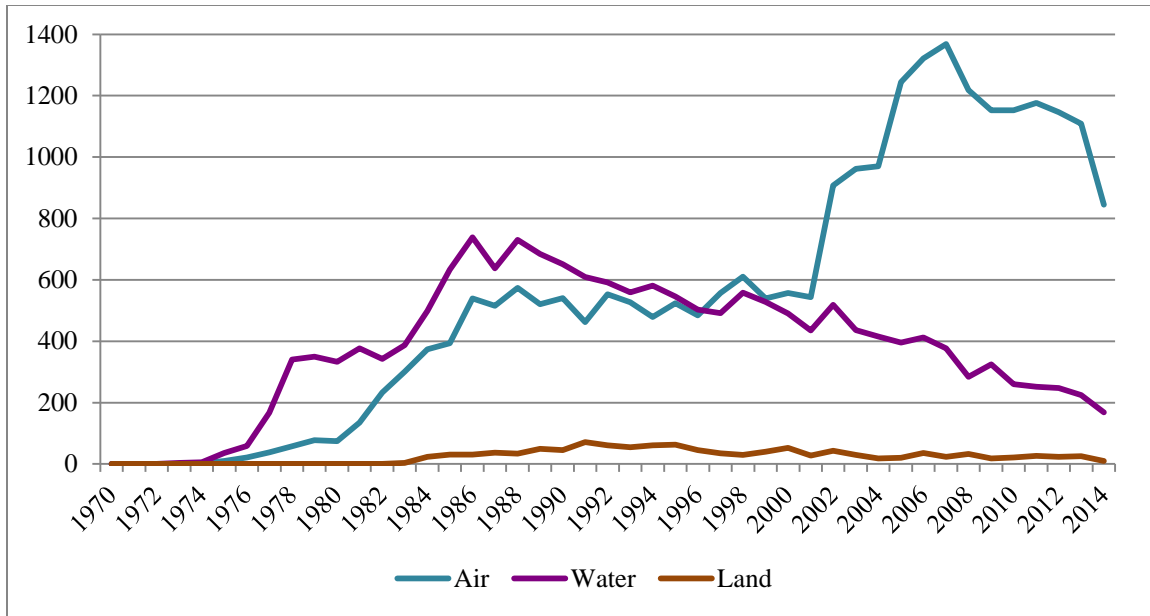


Figure 1.7. Number of Inspections for Pulp, Paper and Board Mills by Pollution Media
(Source: TRI 2015)

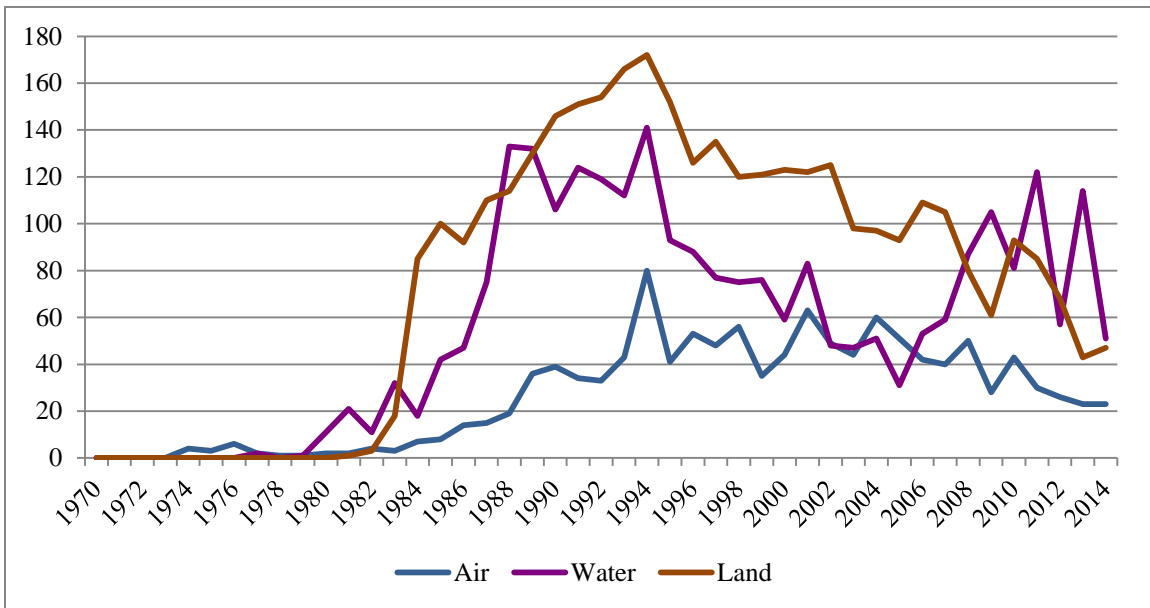
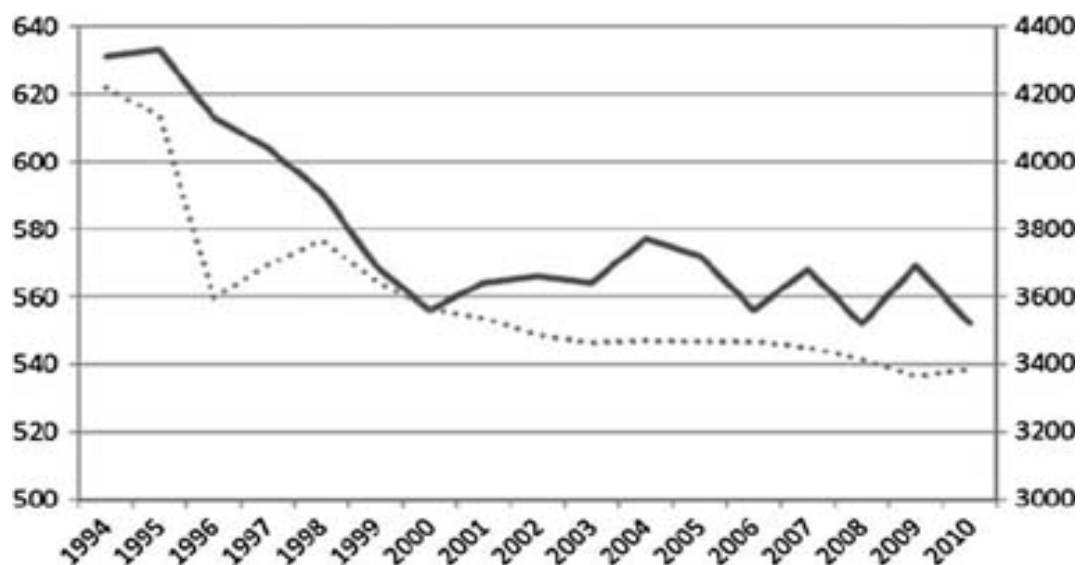


Figure 1.8. Number of Enforcements for Pulp, Paper and Board Mills by Pollution Media
(Source: TRI 2015)

number of enforcement actions during the entire period. Enforcement actions in all three media peaked in the mid-1990s and trailed afterwards down with the exception of water enforcement which rose again after 2005 (Figure 1.8).

Budget-driven Regime: Role of Budgetary Constraints

The decreases in the total number of monitoring and enforcement actions could result from decreasing federal and state budgets specifically allocated to compliance enforcement. Figure 1.9 documents the federal budget disbursements between 1994 and 2010. The average real EPA operating enforcement budget amounted to \$580 million, according to Gray and Shimshack (2011a). Yet, both the budget as well as the number of



Note: The solid line represents budget allotments for Office of Enforcement and Compliance Assurance (OECA) activities, measured in millions of US dollars along the left-side y-axis. The dotted line represents staffing levels for OECA activities, measured in FTEs along the right-side y-axis.

Figure 1.9. EPA Enforcement Budgets and Full-time Equivalents, 1994–2010
(Source: Gray and Shimshack 2011a).

staff employed at the Office of Enforcement and Compliance Assurance, measured in full-time equivalents (FTE), decreased significantly overtime. More specifically, the budget decreased from just over \$630 million in 1994 to just over \$530 million in 2010, and FTE decreased from over 4,200 in 1994 to just under 3,400 in 2010.³⁷

To better understand the dynamics between the regulators and mills, in Essay 2 of the thesis I examine the behavior of regulators within the context of their motivations and constraints as well as within the voluntary mill compliance. In this essay, I analyze if and how the behavior of the mills affects regulators' monitoring and enforcement responses. Specifically, I study whether there is a relationship between voluntary pollution abatement and prevention activities at mills and the regulatory stringency they face; additionally, I explore if the monitoring and enforcement actions are driven by target or budget motivations. Compliance with the environmental command-and-control policies has been examined previously, yet within separate pollution media. Given the significant differences in inspection and enforcements by media, it makes sense that the analyses be done for both monitoring and enforcement within each pollution media separately and together.

1.8. Voluntary Pollution Prevention at Pulp and Paper Mills, Essay 3

The progression of environmental policies from command-and-control regimes to voluntary corporate self-regulation became possible with the recognition on the part of the regulated industries that voluntary programs can help reduce long-term compliance costs, rebrand their public image, and enhance their long-term competitiveness. This

³⁷ Source: Gray et al. (2011a), p. 3-24.

recognition is first marked by the establishment of the World Business Council for Sustainable Development at the 1992 Rio Earth Summit and subsequent emergence of the ISO 14001 environmental management system (EMS) leading the way to the bigger movement towards programs aimed at voluntary environmental self-regulation (Koehler 2007). The movement has been corroborated by numerous researchers who examined the nature and dynamics of corporate self-regulation, both theoretically and empirically (Maxwell et al. 2000, Decker 2005, Maxwell and Decker 2006, Decker 2007, Koehler 2007, Khanna et al. 2009, Harrington 2012, Harrington 2013).

To examine if the legislation aimed at voluntary compliance is effective in terms of encouraging facilities to adopt more VEPs, in Essay 3 I study pollution prevention (P2) legislation and its impact, among other factors, on the adoption of P2 modifications at pulp and paper mills. In contrast to command-and-control policies, P2 legislation is characterized as a soft policy that encourages information sharing, numerical targeting, and mandatory planning, all of which are designed to appeal to the wide scope of the P2 activities. Since 1990, 36 states adopted P2 programs, prescribing varying combinations of regulatory-, information-, and management-based policies (Harrington 2013).

In addition to examining P2s as strategic self-regulatory tools, I propose a definition of P2 modifications as soft technologies or soft technology innovations. The typical taxonomy characterizes technology innovations as: (1) product and/or service innovations, (2) process innovations, including new practices or delivery, (3) organizational innovations such as changes in management structure, methods and information management, and (4) marketing innovations (Youtie et al. 2005, OECD 1997). P2s are not new products, hardware technologies or machines and they are not

new management or marketing methods. Yet, the application of P2s spans across all stages of modern industrial systems, from inventory control and administrative book-keeping to equipment maintenance, and production process and product modifications. Given that P2s are a set of every-day hands-on managerial and production practices, they can be classified as active experiential knowledge, or applied know-how. And, in spite of being spread out across all administrative and manufacturing operations, P2 activities fit into a narrow niche of technology innovations referred to as soft technologies.

Figure 1.10 demonstrates all eight broader categories of new P2 activities adopted at paper manufacturing sector from 1991 to 2013: (1) operating practices, (2) inventory control, (3) spill and leak prevention, (4) raw-material modifications, (5) process modifications, (6) cleaning and degreasing modifications, (7) surface preparations and finishing modifications, and (8) product modifications. The three top P2 activities for the

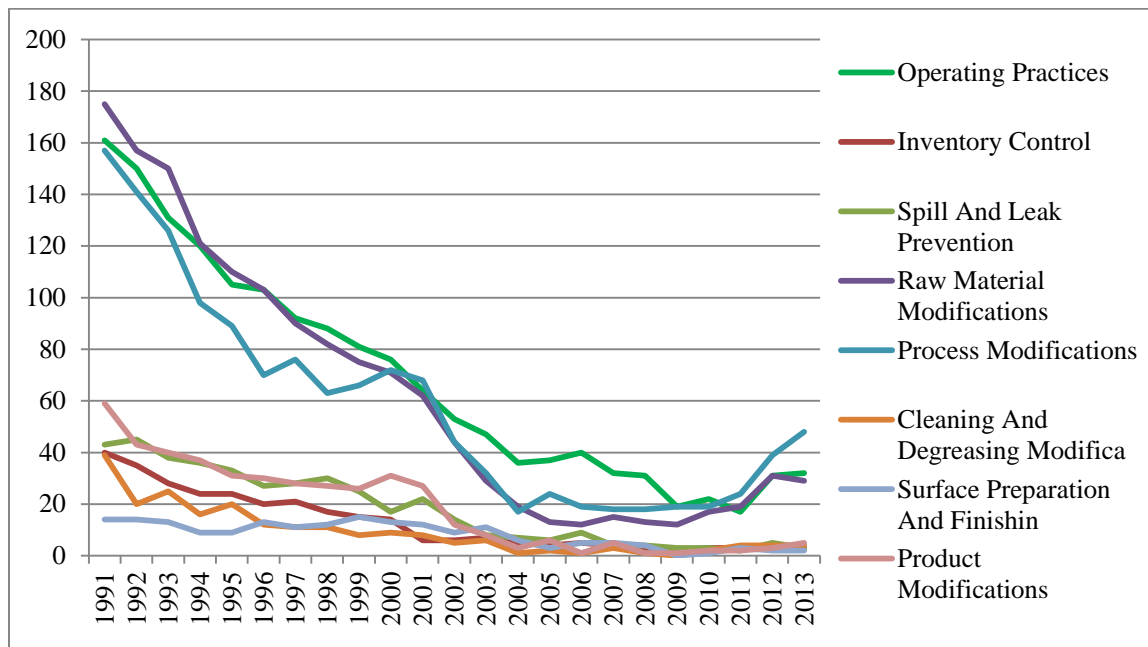


Figure 1.10. Number of New P2 Activities at Paper Manufacturing Facilities by P2 Type (Source: TRI 2015)

paper sector are raw-material modifications, operating practices, and process modifications. Operating and raw material modifications totaled up to over 100 new P2 counts each until 1997 with the numbers sliding further down to under 50 in 2003, where they have fluctuated until 2011. In 2012 and 2013, there was a slight rise the counts of new P2 activities across all eight categories.

In Essay 3, I analyze the effectiveness of P2 policy tools on the adoption of new P2 modifications in total and when grouped in two more general categories. The first one consists of: (1) operating practices, (2) inventory control, (3) spill and leak prevention, (4) raw-material modifications; and rest of the modifications form the second group: (5) process modifications, (6) cleaning and degreasing modifications, (7) surface preparations and finishing modifications, and (8) product modifications. For the purposes of this analysis, I loosely term the first group as management and logistical and second as process and product modifications. Figure 1.11 depicts the total number of new P2 adoptions and when separated into two general groups. The first group of modifications outpaces the count of new P2 modifications within the second group.

The contribution of the third analysis is to shed further light on the effectiveness of policy and policy tools that encourage the adoption of P2 activities as well as other determinants identified in the previous literature. I am interested in looking at whether the given policy instruments and financial assistance in the form of state P2 grants are effective: (1) for all P2 activities and (2) for specific P2 activity groups related to either (a) management and logistical modifications or (b) product and process. Because of their unique definition as soft technologies, or applied knowledge skills directed at reducing and preventing production-related pollution, P2s exhibit the characteristics of knowledge-

based technology innovations and are influenced by prior experience and knowledge spillovers.

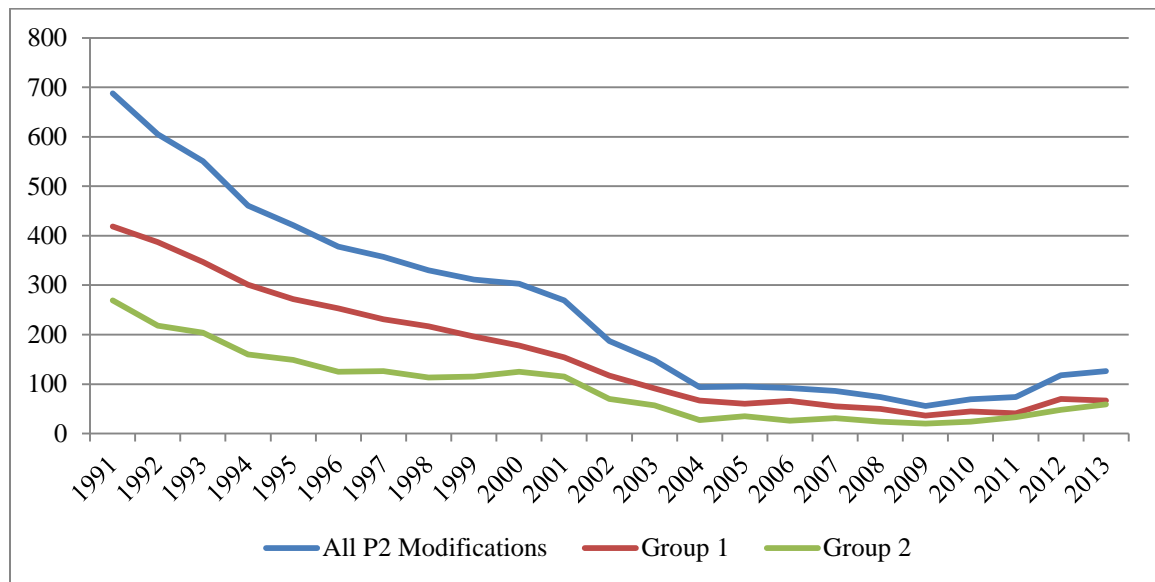


Figure 1.11. Number of New P2 Activities at Paper Manufacturing Facilities by Group (Source: TRI 2015)

Given this definition, policy instruments and financial assistance aimed at information sharing may be more effective at encouraging P2 adoptions. The effect, however, may not be the same across different groups of P2 activities, with information sharing having greater effect on P2 activities related to management and logistical practices than on product and process modifications. Hence, I focus on the impact of the different P2 policy tools and grants on: (1) all P2 adoptions and (2) adoptions across different P2 categories.

1.9.The Three Essays, Summary

The first essay in Chapter 2 of this dissertation bridges two strands of literature on investments in capital-intensive industries, the one that follows the assumption of continuous capital adjustments and the other which adheres to the notions of lumpy investments in capital-intensive industries. To follow regional studies on capital investments, I use a first-differencing, limited probability and logit models to examine papermakers' investment decisions against a number of supply factors. The first group of factors hypothesized to influence the choice of investment location includes such 'traditional' factors of production as variable input costs – prices for materials, wages, energy, and land prices. In addition, I examine the impact of regulatory stringency of local/state environmental and tax policies.

The second essay in Chapter 3 of this dissertation examines the relationship between voluntary pollution abatement and prevention efforts at pulp and paper mills and regulatory stringency they face. Using facility level data on U.S. pulp and paper mills for 1989-2002, I estimate the negative binomial model to test the hypotheses of responsive regulation and whether regulators are driven by numerical pollution targets or budgetary constraints. I find that voluntary pollution abatement has greater impact on regulatory stringency than government expenditures. Additionally, state political pressure, pollution prevention legislation, and firm and mill characteristics are found to be significant predictors of regulatory behavior.

The third and final essay in Chapter 4 analyzes the relationship between P2 policy instruments and adoption of P2 modifications at individual plants. Using facility level data on U.S. pulp and paper mills for 1991-2002, I estimate the negative binomial model

to test the hypotheses of whether P2 state legislation and policies on target setting, reporting requirement, mandatory planning, and P2 state grants have positive impact on P2 adoptions. In addition, I examine the effects of regulatory and political threats, P2 firm spillovers and prior mill experience with P2 modifications, firm and mill size, and type of mill product.

CHAPTER 2

ESSAY 1: ENVIRONMENTAL COMPLIANCE AND INVESTMENT BEHAVIOR OF CAPITAL-INTENSIVE INDUSTRIES

Abstract

This study extends the existing literature on location choice in two ways. First, in contrast to the traditional location choice literature, which focuses only on the location of new plants and on re-location of production, this paper examines capacity investments in the existing pulp and paper mills as implicit ‘stay-put’ location decisions. Second, it bridges two strands of literature on investments in capital-intensive industries, one that follows the assumption of continuous capital adjustments and the other, which adheres to the notions of lumpy investments. I use first-differencing for the continuous capital adjustments and limited probability and logit methodologies for lumpy investments to analyze papermakers’ ‘stay-put’ decisions against a number of supply-side factors. The first group of factors hypothesized to influence the investment decision includes variable input costs – prices for materials, labor, energy and land. The second group includes regulatory stringency of state environmental and tax policies. The findings suggest that short-term capacity changes are sensitive only to energy and land prices while larger inflows of investments respond to the fluctuations in the availability of recycled pulp and land prices. Finally, whether I am looking at a continuous flow of investments or its spikes, I find that state environmental stringency has a negative impact on investments, but it is statistically insignificant through all the models and higher taxes do not deter investments in the pulp and paper industry, contrary to the expectations.

2.1.Introduction

The main purpose of this study is to frame the discussion of choice of location in capital-intensive industries in terms of a ‘stay-put’ investment decisions. Earlier research on new branch plant location decisions for all manufacturing industries in general found limited support that location characteristics had significant impacts on the choice of new plant locations (Carlton 1983, Bartik, 1985).³⁸ Later studies, however, find that such local characteristics as environmental regulations affect behavior of pollution-intensive industries (Gray and Shadbegian 1993, Henderson 1996, Levinson 1996, Gray 1997, List 2001, List et al. 2004, Gray and Shadbegian 2005b, Condliffe and Morgan 2008). Further, works that narrowly focused on the pulp and paper industry examined the investment decisions of existing plants (Bergman and Johansson 2002, Gray and Shadbegian 1998, 2002, 2003, 2004, Lundmark 2001, Lundmark and Nilsson 2001, and Lundmark 2003). These studies recognize that local and regional factors play a role in a firm’s investment planning. Principally, these studies find that wage rates and such agglomeration factors as the size of existing pulp and paper capacity as well as the size of the consumer market are significant determinants of investment flows.

Building on the theory of short-run profit maximization, I articulate two broad hypotheses: (1) increases in regulatory stringency will decrease capacity levels, and (2) decreases in variable input costs will increase capacity levels. I use first-differencing for

³⁸ More specifically, Carlton (1983) found that energy costs, existing concentrations of employment had strong impact on new plant openings; Bartik (1985) showed that differences in unionization across states had major effect on business location, while state taxes did not.

small capacity changes and linear probability and logit methodologies for large capacity changes to test the two main hypotheses. The findings from this work contribute to the previous literature in two main ways. First, I explicitly reframe the discussion of the choice of location as a ‘stay-put’ decision, arguing that building a greenfield at a new location for such capital-intensive industries as pulp and paper is prohibitively expensive and induces firms to invest in existing locations. Second, to bridge various strands in the previous literature, this paper empirically tests two alternative theoretical models of capital investment – continuous vs. lumpy capital outlays. More practical implications of this work will inform (1) policy-makers and industry analysts about the state and regulatory characteristics to which traditional manufacturing employers respond most sensitively, and (2) managers, investment analysts and regional planners about those combinations of location-specific factors and regulatory stimuli that attract further investments into capital-intensive industries under profit maximization.

The findings in this paper suggest that the two models of capital adjustments inform different behavioral choices considered by papermakers. When facing increases in variable input costs, specifically energy and land prices, papermakers respond by decreasing levels of investments. In contrast, when considering larger inflows of investments, availability of recycled pulp and land prices become more important determinants in pulp and paper investments. Additionally, whether the ‘stay-put’ decision is viewed as a continuous flow of investments or its spikes, state environmental stringency has a negative impact on investments, yet it is statistically insignificant through all the models. Finally and contrary to the expectations, higher taxes do not deter either continuous or lumpy investments in the pulp and paper industry.

2.2.Literature Review

The Pulp and Paper Industry in Economic Geography Literature

Historically, the U.S. paper industry has located its operations in areas that economized on one or more major inputs (e.g. fiber, water). In one of the earliest studies of papermakers' location choices Lindberg (1953) used a location theoretic framework to analyze transportation costs of a number of Swedish paper and pulp mills for 1830-1939 and found that distances to raw materials matter less than distances for product delivery and/or export. Barr and Fairbairn (1975) conducted interviews with managers in a number of newly established mills in western Canada in the 1960s and concluded that corporate behavior, rather than government incentives, cost and demand conditions, determine success and viability of location choices made by paper companies. Hayter (1978) conducted interviews with corporate executives in the same geographical area and time period as Barr and Fairbairn (1975) and outlined the executives' decision-making model of the choice of location that consisted of: (1) selecting a forest-rich region, (2) identifying a number of sites which provide the least of both input and output shipment costs, and (3) comparing and selecting the sites. The author concluded that at the regional level corporate decision-making is centered around raw material factors.³⁹ Table 2.1 summarized of key locational studies.

³⁹ Hayter (1978) outlines the following specific cost factors: timber accessibility, quality, species mix and tenurial conditions; cost of adequate power, supply of fresh water for processing, suitable waterways for effluent disposal and minimal effect of air pollution on residential areas, and availability of housing or provision for building new housing.

Table 2.1. Previous Literature

Author (Year)	Investigation	Country	Period	Main Findings
Lindberg (1953)	Transportation costs of Swedish paper and pulp mills	Sweden	1830-1939	Distances to raw materials matter less than distances for product delivery/export
Barr and Fairbairn (1974)	Interviews of managers of newly established mills	Canada	1960s	Corporate behavior (versus government incentives) and cost/demand conditions determine location choices
Hayter (1978)	Interviews of corporate executives	Canada	1960s	Corporate decision-making is centered around raw material factors
Hunter (1955)	Descriptive U.S. Census data analysis	U.S.	1880-1940	Sunk costs dictate location choices; papermakers take 40-50 years to respond to locational pressures
Gray and Shadbegian (1998)	Econometric: MNL	U.S.	1972-1990	Mills located in states with stricter environmental regulations install “cleaner” technology
Lundmark (2001)	Econometric: Conditional logit	16 EU countries	1985-1995	Local market size and agglomeration effects are significant location determinants, prices for raw materials are not
Lundmark and Nilsson (2001)	Econometric: Conditional logit	13 Western European countries	1985-1995	More standardized grades (newsprint and wrapping papers) are more sensitive to changes in cost and market conditions
Bergman and Johansson (2002)	Econometric: Poisson ML, CMLE, GMM	15 EU countries	1988-1997	Most important factors for the count of investment projects are wage rates and agglomeration economies, measured as already installed pulp and paper capacity

Table 2.1. Continued

Author (Year)	Investigation	Country	Period	Main Findings
Gray and Shadbegian (2002)	Econometric: Conditional logit	U.S.	1967- 2002	Firms allocate smaller shares of production to states with stricter environmental regulations; low compliance firms avoid states with higher regulatory stringency
Lundmark (2003)	Econometric: OLS, fixed and random effects models	10 EU countries	1978- 1995	Wages, wastepaper availability, market size and agglomeration economies have the strongest impact on papermakers' investment decisions; prices for raw materials exhibit ambiguous effects

In her extensive survey of regional composition and movements of the U.S. papermakers during 1880-1940, Hunter (1955) points out that technological characteristics of papermaking process have played a principal role in directing papermakers' locational choices. Prior to the advent of papermaking technology that relies primarily on woodpulp kraft process, paper companies tended to cluster in most populous and urban Northeastern states where straw, rags, wastepaper, and manila stock were readily available. Introduction of woodpulp technology shifted production towards areas plentiful with wood fiber resources. Hunter (1955), without explicitly saying it, documents the path dependent behavior of the mills during the 'formative' years of the industry or from around 1880 to 1940. According to her analysis, given the high capital costs, the industry had been more reluctant to rapidly relocate its operations in response to the introduction of woodpulp technology and fluctuating stocks of pulpwood which at

the time were affected by the booming lumber and housing markets. The two factors had put pressures on pulp and paper mills to relocate first from urban areas abundant with rag and waste input sources to more rural areas plentiful with forest stands to then even more rural areas rich with self-replenishing forest stands. The author depicts the slow process of managerial learning from experience, gradual but persistent growth in overcapacity, and continual acquiescence to produce paper products in less than optimal production sites, all of which are symptomatic to the situation that the U.S. pulp and paper mills face today. Hunter's (1955) analysis of the industry between 1880 and 1940 suggested that such highly capital-intensive industries as pulp and paper are able to respond to locational pressures in no less than 40-50 years and that sunk costs constrain many of the choices available to such firms.⁴⁰

Location Choices and Paper Industry in Literature, Environmental Factors

Few econometric studies exist on locational choices of papermakers. Gray and Shadbegian (1998) studied the impact of environmental regulations across different states on new plant location decisions of the U.S. papermaking companies over 1972-1990. The authors analyzed the location choices by specific types of pulping technologies installed at new mills as well as annual investment spending at existing mills. The authors concluded that mills choosing to locate in states with stricter environmental regulations

⁴⁰ The author documents the dramatically increased scale of production, vertical integration to internalize procurement costs, and higher responsiveness, reflected in firms' restructuring and relocations, to market and geographic cost conditions among producers of more standardized paper-grades, namely newsprint and wrapping papers, which also demonstrated higher growth rates in consumption.

ended up installing cleaner technology. Additionally, the study found abatement and productive investments tended to be scheduled together and high abatement costs tended to be associated with lower productive capital expenditures.⁴¹

In their subsequent work, Gray and Shadbegian (2002) focused on the impact of environmental regulations on the pulp and paper firms' decision to re-allocate productive capacity across states. Using Census' Longitudinal Research Database for 1967-2002 at five-year intervals the authors found that, controlling for other state characteristics, firms allocated smaller shares of production to states with stricter regulations. The results also differed by the firm level of environmental compliance – low compliance firms appeared to avoid states with higher regulatory stringency, while high compliance firms deemed unnecessary to do so.

Lundmark (2001) studied the effect of wastepaper availability and its prices on location decisions of paper producers in 16 European countries over 1985-1995. The study tested the hypothesis that increases in the importance of wastepaper as a raw material for the industry may have contributed to a structural locational shift/movement of paper companies from forest-endowed areas to regions with high levels of aggregate paper consumption and effective paper recycling programs. The author found that local

⁴¹ Gray and Shadbegian (1998) specifically note that high abatement costs over the studied period reflected that environmental investment 'crowded out' productive investment and that "...firms shifted investments towards plants facing less stringent abatement requirements," p. 235. The authors also look at the impact of environmental policies on firm productivity, effects of productive vs. pollution abatement capital, choice of technology, co-relationship with plant vintage, firm structure and managerial expertise and spatial effects on plants' environmental performance.

market size and agglomeration effects were significant location determinants of pulp and paper investments, while prices for raw materials were not.

Lundmark and Nilsson (2001) analyzed the effects of recycling rates and investments in paper recovery infrastructure on location choices of newsprint capacity investments. Country-specific newsprint investment project counts were regressed against four cost factors – tonnage of wastepaper recovered, volume of standing forest, electricity price, and wage; two demand factors – per capita GDP and paper consumption; and income tax for 13 Western European countries over 1985-1995. The two raw material factors and energy input prices were found to be significant and with the expected signs indicating that Western European newsprint industry is resource-oriented while wages were found insignificant. Demand variables were also found to be insignificant. The findings suggest that more standardized grades (such as newsprint and wrapping papers) respond differently to changes in cost and market conditions.

Bergman and Johansson (2002) studied the impact of regional cost factors on investment propensities of the pulp and paper companies in 15 European countries over 1988-1997. The authors found that the most important determinants of European pulp and paper firms' decisions to invest in pulp lines and paper machines were wage rates, installed production capacity, price of the final product and the USD/ECU exchange rate.⁴²

⁴² European Currency Unit.

Lundmark (2003) looked at three continuous investment models for the pulp and paper industry in ten European countries over 1978-1995. His fixed and random effects models of continuous investment flows indicated that wages, wastepaper availability, market size and agglomeration economies have the strongest impact on papermakers' investment decisions, while prices for raw materials exhibited ambiguous effects.⁴³ The author concluded that the choice of country to invest was related to time-specific effects that stemmed possibly from market cyclicalities, introduction of new technologies, and adjustments in competition patterns due to changes in regional and common policies.

Location Choices and Paper Industry in Literature, Agglomeration and Innovative Activities

Agglomeration forces attract productive investments towards already well-established paper-producing regional markets even if technological advancements and/or requirements may call for geographic relocations (Hunter 1955, Lundmark 2001, Bergman and Johansson 2002). Firms tend to enter regional markets through either vertical integration (Ohanian 1994, Melendez 2002) or horizontal expansion via mergers and acquisitions (Pesendorfer 2003). Greater reliance on recycled raw materials and decreased usage of virgin pulp in the 1990s discouraged vertical integration with timber producers and encouraged gradual relocation towards large metropolitan areas with sufficient supply of waste paper (McNutt 2002). Expectations that biotechnology would

⁴³ More specifically, Lundmark (2003) found that wages, wastepaper recovery rate, GDP and agglomeration had the expected signs and high statistical significance, while energy and raw material prices exhibited statistically and substantively ambiguous results.

provide the industry with the next radical technological boost (Laestadius 1998, 2000) lead to the forecasts that industry clusters would shift even further towards large metropolitan areas with high research capacity. The main limitation of the enumerated location choice studies is the narrow focus on the establishment of new plants or greenfields and, in the case of the EU studies, the use of country-level aggregates.

Pulp and Paper Industry in Industrial Organization Studies

In addition to the above stream of the Economic Geography studies, there are a few Industrial Organization (IO) papers that have analyzed the industry's regional capital investments and market restructuring. Ohanian (1994) used individual mill level data for years 1900 to 1940 to analyze regional patterns of vertical integration. Studying the period of industry relocation from the Northeast and Great Lakes to South and Pacific Coast, the author found that vertical integration of the U.S. pulp and paper industry is consistent with the transactions cost model of consolidation and positively associated with regional concentration, paper-mill capacity, and production of standardized grades of paper. Consistent with Hunter's (1955) observations of slow reactions of industry to changing technology and cost incentives, Ohanian (1994) documented that the model of vertical integration fitted the cohorts of new entrants much better than the cohort of the established mills. Once mills were built, her analysis showed, they were unlikely to alter their integrated status despite changes in the regional market environment. The author also stated that major adjustments to industry trends occurred through entry and exit, not through changes in integrated status.

Extending Ohanian's (1994) work to cover 1975-1995, Melendez (2002) expanded the definition of vertical integration to include pulp and paper mills that belonged to multi-plant firms and that were located within 350-400 miles away from each other. Melendez's (2002) confirmed Ohanian's (1994) findings that vertical integration was positively associated with mill size, measured in daily capacity, and production of newsprint, or standardized paper grades. In contrast to Ohanian's (1994) results, Melendez (2002) found that the measures of regional concentration were negatively associated with vertical integration. At the same time, lagged concentration measures gave positive and significant results, signaling that vertical integration, as a response to increasing market concentration (or decreasing number of buyers and sellers in the market) during the studied period was not instantaneous.⁴⁴ Melendez suggested that the difference in the effects of concentration between these and Ohanian's (1994) findings stemmed from the difference in periods studied.⁴⁵

Documenting the effect of the horizontal merger wave on the welfare of paper and paperboard companies during 1972-1992, Pesendorfer (2003) found that increased capacity and larger number of merged firms generally reduced marginal costs while having little effect on consumer surplus and increasing producer surplus – findings that were consistent with competitive pricing environment and overall increased profits for

⁴⁴ Melendez (2002, p. 28) reported that the current period concentration measure was negative and significant while lagged concentration measure was found positive and strongly significant. Such results, the author pointed out, demonstrated that mills responded with a lag to market concentration in terms of making decisions about their integration status.

⁴⁵ According to the authors, 1900-1940 marked a period of gradual yet massive relocation of the industry to the Southern and Pacific regions of the country, while the years of 1975-1995 did not observe extensive capital relocations.

merging firms.⁴⁶ Additionally, the author documented that over 40% of the total capacity expansions for all years combined were achieved through horizontal acquisitions while only 7.29% are achieved through building new plants. Companies affected by mergers tended to be the largest within the industry – acquiring firms were among top 15% largest producers, while acquired firms among 25% top producers. Other findings included evidence of increased likelihood of merged companies to lose their market share and scrap excess capacity.

Following the works of Lieberman (1987a, 1987b, 1987c), Christensen and Caves (1997) analyzed abandonment of previously announced capacity expansion projects in 11 North-American pulp and paper industry segments for 1978-1991. In their analysis, the authors focused on the determinants of firms' decisions to abandon projects that they have previously announced. Such determinants included attributes of the announced project and of the firm sponsoring it, the amount of resources already committed to it, and the fresh news arriving about the project's expected payout. Having found that likelihood of abandonment increased if, during the same year, there were other competing projects announced, the authors suggested that there was some sort of continual auction within the market. According to the authors, the pulp and paper industry "comfortably fitted" into "a two-stage game, in which suppliers first chose their capacities and then competed in the short run within those capacity constraints."⁴⁷ The authors found empirical evidence that companies operating in more competitive paper market segments and with few or no financial commitment to the announced projects were more likely to

⁴⁶ According to the author, the merger wave followed 1984 revision of merger guidelines.

⁴⁷ Christensen and Caves (1997), p.48.

abandon those projects. Further, firms operating in less competitive paper grades were less likely to abandon previously announced capacity expansions and were more likely to complete when similar projects were announced by other/rivaling firms.

To summarize, this brief literature review depicts an old highly capital-intensive industry which has been reluctant to carry out quick adjustments to changes in regional markets (Hunter 1955). Proximity to forest stands, rivers, and transportation links (Linberg, 1953, Barr and Fairbairn 1974, Hayter 1978) appear to be prerequisites for the initial papermakers' choices of location. However, once the producers are located in those areas, regional fluctuations in prices for raw materials have significant effects only for the producers of standardized paper grades (Lundmark and Nilsson 2001, Lundmark 2003). Wages (Bergman and Johansson 2002) and environmental regulations (Gray and Shadbegian 1998, 2002) are found to be significant determinants of choice of the optimal location for continuous investments. Agglomeration forces attract productive investments towards already well-established paper-producing regional markets even if technological advancements and/or requirements may call for geographic relocations (Hunter 1955, Lundmark 2001, Bergman and Johansson 2002). Firms are expected to enter regional markets through either vertical integration (Ohanian 1994, Melendez 2002) or horizontal expansion via mergers and acquisitions (Pesendorfer 2003). Finally, firms' strategic expansion and investment plans are announced and contested, as in auctions, in industry publications (Christensen and Caves 1997).

2.3. Methodology and Hypotheses

Theoretical Motivation

The early models of firm locational choices, developed by Carlton (1983) and Bartik (1985), rise from the theory of dual relationships between firms' production, cost and profit functions. Under this framework, the profit maximization conjectures allow one to infer information on the optimal choice of variable and fixed inputs associated with chosen locations. McFadden (1971) proved one-to-one correspondence between given sets of concave production and respective convex profit functions.⁴⁸ The dual relationship of the production and profit functions allows one to estimate parameters of an indirect restricted profit function without having to separately specify the corresponding production function. Under the assumptions of (i) a concave production function in variable inputs, (ii) profit maximizing and (ii) firms' output and variable input price-taking, an indirect restricted profit function expresses the maximized profit of a firm as the function of prices of output and variable inputs and the quantities of the fixed factors of production for a given set of technologies and endowment of fixed factors of production.

Consider a short run (restricted) production function with all the usual neoclassical properties:

$$(1) \quad Q_{is} = F(X_{is1}, \dots, X_{ism}; \bar{K}_{is}, Z_{s1}, \dots, Z_{sn}),$$

⁴⁸ Following McFadden (1971) and Lau (1971), Lau and Yotopoulos (1972, p.11) observe that "almost all continuous production functions in current use which are concave will give rise to a well-behaved profit function."

where Q_{is} is firm i 's output in a state s , X_i 's are quantities of a firm's m variable inputs such as labor, materials, energy, \bar{K}_{is} is installed capital in state s , and the Z 's are the levels of n conditional factors such as environmental regulations, transportation infrastructure, proximity to an urban area, regional market size, and other agglomeration factors associated with a given state s . Given the inputs, the associated short-run profit function for a firm i in a state s is:

$$(2) \quad \pi_{is} = p_i F(X_{is1}, \dots, X_{ism}; Z_{s1}, \dots, Z_{sn}) - \sum c_{sm} X_{ism} - r_{is} \bar{K}_{is},$$

where π_{is} is short-run profit, p_i is the unit price of firm output, and c_{sm} is the unit price of the m variable input X , r_{is} is the user cost of capital, and \bar{K}_{is} is the quasi-fixed level of the firm's capital or installed capacity in state s . Maximizing (2) with respect to X gives optimal quantities of variable inputs, denoted X^* 's, as functions of output price, m variable inputs costs c_{is} , installed capital \bar{K}_{is} and quantities of n fixed inputs Z_{sn} :

$$(3) \quad X_k^* = f_k(p, c, Z, \bar{K}), k = 1, \dots, m,$$

where non-subscripted p , c , Z , and \bar{K} denote vectors. Substituting X^* 's back into (2) gives the following indirect profit function:

$$(4) \quad \pi_{is}^* = p_i (F(X_{s1}^*, \dots, X_{sm}^*; Z_{s1}, \dots, Z_{sn}) - \sum c_{sm} X_{ism}^* - r_{is} \bar{K}_{is}), \text{ or}$$

$$(5) \quad \pi_{is}^* = \pi_{is}^*(p_i, c_{is1}, \dots, c_{ism}, r_{is}; Z_{is1}, \dots, Z_{isn}, \bar{K}_{is}).$$

which is a function of installed capacity or the quasi-fixed factor of production. Of importance, the partial derivative of the indirect profit function with respect to the quasi-

fixed factor gives the shadow value of a unit increase in installed capacity. And if the shadow value of installed capacity is greater than the cost of capital (i.e. the user cost of capital which, in general, includes interest, depreciation and obsolescence), then the firm has a profit incentive to increase capacity and invest in additional capacity. Without loss of generality, the profit function can be written as:

$$(6) \quad \pi_{is}^* = E(\pi_{is}^*),$$

where $E(\pi_{is}^*)$ is expected profit and u_{is} is a random term with mean 0.

Empirical Methodology

The first step of the empirical analysis is to carry out the first-differenced (FD) estimation by using the logarithm of the changes in the state's annual paper, board, and pulp capacity:

$$(7) \quad \ln C_{st} - \ln C_{st-1} = \sum_{s=1}^S \beta (\ln x_{st} - \ln x_{st-1}),$$

where C is the state's s operating capacity in year t measured in thousand short tons.

Given installed capital, each firm in time t will invest in capacity in state s if the expected profit from the investment exceeds the expected profit without the investment, that is $E(\pi_{is}^*/\text{given investment}) > E(\pi_{is}^*/\text{without investment})$. Yet since I do not observe all of the determining factors, this occurs with some probability. In particular, $Pr(\text{invest in state } s) = Pr(\pi_{is}^*/\text{given investment} > \pi_{is}^*/\text{without investment})$

$$= \Pr(E(\pi_{is}^*/\text{given investment}) + u_{is,\text{investment}} > E(\pi_{is}^*/\text{without investment}) + u_{is,\text{no investment}}),$$

or:

$$(8) \quad \Pr(y_{ist} = 1) = \Pr(\pi_{ist1} > \pi_{ist0}) = \Pr(u_{ist1} - u_{ist0} > V_{ist1} - V_{ist0}),$$

where π_{ist} is profit π_{ist}^* of firm i at time t in state s and the vector of observed characteristics of an investment choice V_{ist} and chosen state s at time t .

Further, to replicate the earlier studies on the location choice, I estimate the LPM and logit models of the following basic functional form:

$$(9) \quad I_{st} = \beta x_{st} + e_{st},$$

where I equals 1 when there is an increase in annual capacity by more than 10 thousand short tons (10K) in a state s in year t and x is the set of state characteristics under consideration. The 10K-tons threshold captures both large investments, associated with the installment of new production lines, and small capital investments, such as those geared towards productive efficiency and environmental compliance.⁴⁹ I estimate

⁴⁹ Berman and Johanson (2002) defined investment spikes as 50K and 100K tons increases for newly installed papermaking and pulping lines/facilities, respectively. Lundmark (2001) and Lundmark and Nilsson (2001), on the other hand, focused on all capacity increases while discarding investments that resulted in less than 10K tons capacity increases. For the purposes of this analysis, I have estimated models for 10K, 50K, and 100K capacity increases and have chosen the 10K threshold of as the larger capacity increases were far fewer and did not result in substantively or statistically significant estimates.

equation (9) using the ordinary least squares (OLS) and logistic regressions with 2-year lags of the natural logarithm of x variables with and without state and year fixed effects.⁵⁰

To carry out the analyses, first, I expand the definition of the dependent variable and use the continuous measure of capacity changes to arrive at the first-differenced estimators as in equation (7). This allows me to utilize all of the information contained in the annual capacity data. Further, to compare the results of the current work with the previous findings, I redefine the dependent variable as in the previous literature – a binary variable with a non-negative value for mills that have been upgraded within the given time frame – and apply it in the limited dependent variable models given in equation (9).

Hypotheses

To test whether environmental regulatory stringency has deterring effect on capacity investments, I follow Gray and Shadbegian (1998, 2002) and include ‘non-traditional’ costs associated with environmental regulations such as the degree of stringency of local/state environmental regulations. In addition, following the previous literature on the choice of location in the initial cross-industry studies (Carlton, 1983; Bartik, 1985) and in paper industry in particular (Lundmark and Nilsson, 2001; Bergman and Johansson, 2002; Lundmark, 2001, 2003), in the second group of factors

⁵⁰ In addition to state-level, I estimate mill-level FD for the continuous investments and LPM and logit models with and without fixed effects for lumpy investments. The mill-level results are reported in Appendix A in Tables A.3 and A.4 and specific estimates are reviewed in the section on the overall results.

hypothesized to influence the choice of location for continuous and lumpy ‘stay put’ investment decision, I include the ‘traditional’ factors of production – variable input costs: availability of recycled pulp, labor and energy prices. Given that pulp and paper mills represent the input-oriented sectors of the paper manufacturing industry which produce intermediate goods (as opposed to final goods), I focus on the input cost structure.⁵¹ More specifically, the hypothesized investment and direct and indirect cost factor relationships are, all else constant:

H1: An increase in the level of stringency of environmental state regulations will decrease the probability of continued investments in a given state, and

H2: A decrease in the prices of variable inputs is expected to increase the probability of an investment at a given state.

Consistent with the previous literature, we expect that variable operating costs will have negative impact on the firm/mill profitability and are likely to divert the investments away from the location with high input prices (Carlton 1983, Bartik 1985, Gray and Shadbegian 1998, 2002, Lundmark and Nilsson 2001, Bergman and Johansson 2002, Lundmark 2001, 2003). Availability of recycled pulp will attract capital investments (Gray and Shadbegian 1998, 2002, Lundmark and Nilsson 2001, Bergman

⁵¹ Material inputs for pulp and paper industry include virgin and recycled pulp and, according to McCarthy and Urmanbetova (2009), comprise about 20% of total short-run variable input costs. In order to proxy virgin pulp availability, I have examined a number of measures from the U.S. Department of Agriculture Forest Service inventory. Specifically, I tried the area of forest land, area of timberland, number of growing-stock trees on forest land, and number of live trees on forest land. However, the estimated coefficients for virgin pulp were statistically and substantively insignificant and were omitted from the final analyses.

and Johansson 2002, Lundmark 2001, 2003). Tax and environmental policies, on the other hand, impose indirect production costs and higher taxes and more frequent environmental monitoring and enforcement actions will divert the infusion of productive capital (Carlton 1983, Bartik 1985, Gray 1997, Gray and Shadbegian 1998, 2002).

2.4.Data and Variables

Dependent Variable: Lockwood-Post's Capacity

To measure changes in capital investments, I use the data on productive mill capacity collected from the annual editions of Lockwood-Post's Directory of the Pulp, Paper, and Allied Trades (LW), which is a unique source on historical equipment and production processes registry on all U.S. pulp and paper mills since 1873. The annual editions of LW cover all the U.S. territories providing the list of all headquarters and mills for pulp and paper companies by state and city.⁵² For this chapter, annual editions for 1979-2002 were surveyed to collect data on all listed mills, annual capacity and product information, zip codes, availability of pulping facilities on the premises of the

⁵² Specifically, each mill is listed with its site or local facility name, parent company and owner (if either are different from the site or local facility name), street address and zip code, mill phone number and indication of the neighboring transport link used by the mill (railroad or highway), and names and job titles of the management team, and the total number of the employees. In addition, more technical and in-depth details are provided on itemized equipment for the following production facilities: wood-handling and preparation, pulp mill, paper mill, steam and power generation, water treatment and effluent treatment. Each mill entry is closed with the list of products, their associated product capacities, and year of establishment (distinguished separately for pulp and paper mills).

mills (to ensure identification of vertically integrated mills), ownership information, and the timing of idling and dismantling of the mills.

In this work, I equate the choice of location with the choice to invest additional capital in an existing/operating production site. Traditional economic geography studies examine the choice of location for new branch plants (greenfields), or plant entries (Carlton 1983, Bartik 1985). The rationale for such definition of the dependent variable is that firms choose to build new plants in areas that managers view as ‘geographic profit centers.’ In addition, works that study the effects of policy variables, such as environmental regulations (Gray and Shadbegian 1993, Henderson 1996, Levinson 1996, Gray 1997, List 2001, List et al. 2004, Gray and Shadbegian 2005b, Condliffe and Morgan 2008), argue that many of the environmental requirements are not imposed on older plants (‘grandfathering’ rules), hence environmental costs are not appropriately allocated among older establishments.

A number of reviewed works focusing on the pulp and paper industry re-define the choice of location as the choice of optimal location for both continuous and new investments (Bergman and Johansson 2002, Gray and Shadbegian 1998, 2002, Lundmark 2001, Lundmark and Nilsson 2001, Lundmark 2003).⁵³ There is an intuitive reasoning for such definition of the location choice measure. Given the high capital intensity of the industry as well as the number of locational production requirements (closeness to forest stands, running water, and transportation networks), it is reasonable to suggest that

⁵³ Lieberman (1987a, 1987b, 1987c) studies the effect of both new plant entries as well as incremental capital adjustments made by incumbents on the market structure and barriers to entry for the chemical industries.

papermakers' choices of manufacturing sites is limited by financial and resource prerequisites. Thus, the decision to upgrade existing equipment, whether to increase existing productive capacity, or expand into new product lines, or to comply with the environmental regulations, at any one given site is indicative of the managers' perception that the selected site has superior production characteristics when compared to other sites.⁵⁴ Hence, choosing to invest in an existing location becomes a decision to 'stay put' as opposed to try to relocate. And in a sense, the high capital investment is not only a barrier to greenfield by other firms, it is also a barrier to its own greenfield decisions.

Explanatory Variables

To test H1 on whether environmental stringency has impact on pulp and paper capital investments by increasing abatement, thereby total, costs, I supplement the plant-level LW capacity estimates with the EPA's facility-level Enforcement and Compliance History Online (ECHO) records. The ECHO data base includes information on facility characteristics, its environmental permits and compliance history. The EPA data collections do not report any capacity or production- and/or technology-related information, but I match facility-level compliance with LW production data and obtain mill- and state-level measures of environmental stringency and noncompliance. Environmental stringency is measured by the total number of regulatory monitoring and enforcement actions in air and water pollution media, and mill noncompliance by the

⁵⁴ By similar logic, the decision not to invest into an existing plant may signal the managerial decision to divest the operation with a subsequent exit from the market.

number of non-compliant quarters, respectively, and both variables are scaled by state capacity.⁵⁵ Unlike other studies that use statewide and all-industry measures of environmental stringency, we match the mill level capacity with the EPA's ECHO data to calculate the total number of inspections and enforcements specific to the mills in the sample.⁵⁶ This allows me to use a direct measure of environmental regulatory stringency faced by the pulp and paper mills in the sample. Gray (1997) and Gray and Shadbegian (1998, 2002) found that air and water regulations, as measures of environmental stringency, had negative (yet statistically insignificant) impact on the choice of location and paper-making technology.

The hypotheses under H2 include the following state price and other state control variables: real hourly wages, real electricity prices, availability of wood and waste, tax index for paper manufacturing and land prices. Previous studies found input costs – wages, energy, materials, and land prices – to negatively impact location and investment decisions in pulp and paper and other industries (Carlton 1983, Bartik 1985, Levinson 1996, Gray 1997, Gray and Shadbegian 1998, 2002, Lundmark and Nilsson 2001, Bergman and Johansson 2002, Condliffe and Morgan 2008, Lundmark 2001, 2003, Bergman and Johansson 2002).⁵⁷ As in these studies, I propose that increases in production input prices will increase variable costs, thereby making the location as less

⁵⁵ Air and water inspections and enforcements were collected from the Air Facility System (AFS) and National Pollutant Discharge Elimination System (NPDES), respectively.

⁵⁶ In addition to facility-specific air and water inspections, Gray (1997) and Gray and Shadbegian (2002) include Green Policies Index, state environmental spending, and manufacturing pollution abatement costs, adjusted for industry mix.

⁵⁷ Table A.1 in Appendix A lists signs and statistical significance of explanatory variables included in the previous works relevant to this work.

desirable for continued investments. In addition to the input price variables, Bartik (1985), Levinson (1996), Gray (1997), and Gray and Shadbegian (2002) found corporate and/or property taxes to have a negative impact on the plant location decision. Similar to the impact of input costs, increased tax rates are likely to deter further increases in investments into productive capacity. For measures of the above variables, I obtain wages from the BEA's Annual Personal Income Employment, energy prices and availability of recycled pulp data from the Energy Information Administration (EIA), land prices from the National Agricultural Statistics Service (NASS) of the U.S. Department of Agriculture, and annual state tax index on production for paper and allied industries from the BEA's Regional Economic Accounts.⁵⁸ Tables 2.2 and 2.3 present descriptive statistics for all the variables involved in this analysis.⁵⁹

Table 2.2. Descriptive Statistics for Variables in the First-differencing Models

Variable (Expected Sign)	Definition	Source	Mean	SD
Dep.Var.: Δ Investment (N/A)	State LW annual capacity in thousand short tons calculated using 350 operating days	FPL, LW, MOL	0.02	0.08
Δ Environmental Stringency (-)	Number of facility actions in state, ECHO, per million short tons of LW capacity	EPA, ECHO	0.04	0.66

⁵⁸ The hourly wage was estimated by dividing the total annual paper manufacturing compensation by the sector employment and then by the total number of work hours in 350 working days. All other variables included in the analysis did not require additional calculations, except for either converting into real 1990 dollars or to the base of 1990 in the case of the tax index.

⁵⁹ In addition, Tables A.2-A.3 in Appendix A present correlation matrices for the continuous and discrete investment models.

Table 2.2. Continued

Variable (Expected Sign)	Definition	Source	Mean	SD
Δ Environmental Noncompliance (-)	Number of facility noncompliance quarters in state, NPDES system water, per million short tons of LW capacity	EPA, ECHO	0.06	0.47
Δ Wage (-)	Paper and allied state hourly wage converted into real using regional 1990 CPI for urban workers in average US city	BEA	0.01	0.14
Δ Energy Price (-)	Real price for electricity in the industrial sector in 1990 dollars per million BTU	EIA, SEDS	-0.01	0.06
Δ Recycled Pulp (+)	Wood and waste consumed in the industrial sector at a cost in billion BTU	EIA, SEDS	0.02	0.40
Δ Taxes (-)	Tax index on production and imports less subsidies for paper and allied, 1990 = 100	BEA	0.06	0.07
Δ Land Price (-)	State farm real estate: average value per acre in 1990 dollars	NASS	0.39	1.60

Note: N = 684, all variables are in the log form and explanatory variables are lagged by two years.

Table 2.3. Descriptive Statistics for the LPM and Logit Models

Variable (Expected Sign)	Definition	Source	Mean	SD
Dep. Var.: Investment (N/A)	1 if more than 10k increase in state LW capacity	FPL, LW, MOL	0.50	0.50
Environmental Stringency (-)	Number of facility actions in state, ECHO, per million short tons of LW capacity	EPA, ECHO	2.33	1.01
Environmental Noncompliance (-)	Number of facility noncompliance quarters in state, NPDES system water, per million short tons of LW capacity	EPA, ECHO	0.33	0.80
Wage (-)	Paper and allied state hourly wage converted into real using regional 1990 CPI for urban workers in average US city	BEA	3.01	0.28

Table 2.3. Continued

Variable (Expected Sign)	Definition	Source	Mean	SD
Energy Price (-)	Real price for electricity in the industrial sector in 1990 dollars per million BTU	EIA, SEDS	-1.99	0.31
Recycled Pulp, (+)	Wood and waste consumed in the industrial sector at a cost in billion BTU	EIA, SEDS	9.19	1.56
Taxes, (-)	Tax index on production and imports less subsidies for paper and allied, 1990 = 100	BEA	3.62	1.83
Land Price, (-)	State farm real estate: average value per acre in 1990 dollars	NASS	5.75	2.93
Environmental Stringency, (-)	Number of facility actions in state, ECHO, per million short tons of LW capacity	EPA, ECHO	2.33	1.01

Note: N = 720, all variables are in the log form and explanatory variables are lagged by two years

2.5. Results

First-differenced Results

Table 2.4 presents the state-level first-differencing results for the one-year change in capacity with environmental and input price variables. Model I includes both environmental variables – stringency and noncompliance. No input prices are significant except energy, which has the expected sign. Environmental stringency and noncompliance have expected signs, yet both are statistically insignificant. R-squared explains only 3% of the variation in the dependent variable. Heteroskedasticity-robust standard errors are reported in parentheses and the White (1980) test statistic fails to reject the null hypothesis of no heteroskedasticity. The calculated F-value rejects the null

of joint insignificance of all the variables at the 5%-level. The Durbin-Watson test statistic fails to reject the null hypothesis that errors are serially uncorrelated.⁶⁰

Table 2.4. First-differenced Models

Dependent variable: Δ state capacity	Model I
Intercept	0.0124*** (0.003)
Δ Environmental Stringency	-0.0040 (0.012)
Δ Environmental Noncompliance	0.0218 (0.022)
Δ Taxes	0.0869* (0.050)
Δ Wage	0.0136 (0.023)
Δ Energy Prices	-0.0819*** (0.031)
Δ Recycled Pulp	0.0064 (0.005)
Δ Land Price	-0.0020** (0.001)
Number of Observations	684
R-Square	0.03
Adj R-Sq	0.020

Note: All variables are in the two-year lagged and log form. Heteroskedasticity-consistent standard errors for the OLS estimates were obtained using White (1980) procedure and are reported in brackets. Significance levels are indicated as follows: * significant at the $\alpha = .10$ level, ** significant at the $\alpha = .05$ level, and *** significant at the $\alpha = .01$ level.

Changes in state environmental stringency, measured by the natural logarithm of facility actions reported in ECHO, have a statistically insignificant negative effect on the changes in the level of state capacity. The 10% increase in the number of facility actions

⁶⁰ Durbin-Watson statistic is 2.08, F-value is 2.93 and the White heteroskedasticity Lagrange Multiplier (LM) value is 20.6 with p-value of 0.98.

decreases state capacity by 0.04%. Similarly, environmental noncompliance has positive yet substantively and statistically insignificant effect. Given these results, the first hypothesis (H1) of environmental stringency having a negative impact on the continuous capital adjustments can be rejected.

With respect to the second hypothesis (H2) within the framework of the continuous capital adjustments, wages and state taxes have the ‘wrong’ sign -- both are expected to be negatively related to the changes in the state paper capacity, yet have a positive sign. In addition, taxes are statistically significant at 10% level. And in terms of marginal effects, all else constant, a 10% increase in taxes increases state annual capacity by 0.87%.

In contrast to wages and taxes, energy, land prices and availability of recycled pulp have the expected signs and energy and land prices are statistically significant at 1% and 5% levels, respectively. In terms of marginal effects, a 10% increase in state energy prices decreases state pulp and paper capacity by 0.82%, and a 10% increase in land prices decreases state pulp and paper capacity by 0.02%, all else the same. Finally, the availability of recycled pulp, approximated by changes in wood and waste consumption in the industrial sector, is positively related to the changes in the state paper capacity. A 10% increase in the availability of recycled pulp increases paper capacity by 0.06%, but is statistically insignificant.

LPM Results

To replicate the results from some of the previous studies, I also ran the linear probability models (LPM) with and without the fixed effects (Table 2.5) as well as the

logit models with and without the fixed effects (Table 2.6). The dependent variable in these two sets of models is defined as 1 if there is at least a 10K-ton increase in state capacity and 0 if there are no, smaller than 10K tons or negative changes. Table 2.5 presents the state-level LPM results for the same model reported in Table 2.4. Column I of Table 2.5 reports LPM estimates with heteroskedasticity-consistent standard errors, and Column II presents the same model but with state and year fixed effects (FE).⁶¹

The LPM results differ substantially from the results of the first-differenced model. Environmental stringency and noncompliance are highly statistically significant in Model I with no FE and have negative impact on the probability of capacity investments, yet both variables become statistically insignificant when FE are included and environmental noncompliance changes its sign from negative to positive (Table 2.5, Model II). Further, wages have now the expected negative sign and are significant at the 5% level in the FE model. Energy prices are still negatively related to the capacity investments in the estimation with the FE (Table 2.5, Model II), but are statistically insignificant, and they are positive and statistically insignificant in the model with no FE (Table 2.5, Model I). Availability of recycled pulp, measured by the industrial wood and waste consumption, is highly significant (at 1% level) in both models, but paradoxically changes sign from positive to negative when going from the LPM with no FE to the LPM with FE. Similarly, taxes are positively associated with the 10K tons increases in state capacity in the model with no FE and are statistically significant at 1% level, but change sign and become insignificant in Model II (Table 2.5). Likewise, land prices change sign

⁶¹ In the LPM and logit models, ‘FE’ refers to 2-way (year and state) fixed effects.

from positive to negative when FE are included, and in both cases they are statistically insignificant.

Table 2.5. Linear Probability Models

Dependent variable: 1 if at least 10K capacity increase			
	Model I		Model II
Intercept	0.1161		2.7176***
	(0.229)		(0.747)
Environmental Stringency	-0.0467**		-0.0283
	(0.018)		(0.028)
Environmental Compliance	-0.0760***		0.0332
	(0.024)		(0.029)
Taxes	0.0528***		-0.1075
	(0.014)		(0.089)
Wage	-0.0384		-0.1525**
	(0.069)		(0.074)
Energy Prices	0.0075		-0.0498
	(0.071)		(0.167)
Recycled Pulp	0.0465***		-0.0789***
	(0.015)		(0.030)
Land Price	0.0059		-0.0563
	(0.007)		(0.072)
Number of Observations	720	DFE	658
R-Square	0.11	R-Square	0.36
F Value	11.11	F Value	4.74

Note: All variables are in the two-year lagged and log form. Significance levels are indicated as follows: * significant at the $\alpha = .10$ level, ** significant at the $\alpha = .05$ level, and *** significant at the $\alpha = .01$ level. For the LPM results in Column I and II, Heteroskedasticity-consistent standard errors for the OLS estimates were obtained using White (1980) procedure and are reported in brackets.

Finally, the fit statistics for both models suggest that they are only marginally better than the first-differenced model. R-squared explains 11% of variation in the dependent variable in Model I and 36% in Model II and F-values associated with all four

models fail to reject the null of joint insignificance of all the variables in the models at 1% critical value (Table 2.5).

Logit Results

Logit results, reported in Tables 2.6 and 2.7, are similar to the LPM results in Table 2.5. As in the LPM results, parameter estimates for the environmental variables are negative and statistically significant for logit, yet, as is the case with the LPM, the statistical significance of the environmental variables dissipates when fixed effects are included. In general, both environmental stringency and noncompliance have negative impact on the probability of 10K capacity investments. Environmental stringency is statistically significant at 5% level, and environmental noncompliance is statistically significant at 1% level (Table 2.6, Model I). Specifically, for 1% increase in the number of regulatory actions at pulp and paper mills (environmental compliance), decreases the odds of 10 thousand tons capacity investments by a factor of 0.81 and 0.84 in logit models without and with FE, holding all else constant (Table 2.7, Models I and II). Similarly, under *ceteris paribus*, 1% increase in the number of noncompliant facility-quarters (environmental noncompliance), decreases the odds of 10K ton capacity investments by a factor of 0.73 and 0.83 (Table 2.7, Models I and II). As in the LPM models, I find negative but statistically insignificant wage parameter estimates. Energy prices are positively associated with the probability of 10K capacity investments, but are statistically insignificant in the model with no FE (Table 2.6, Model I).

Once the FE are included however, the energy prices become negative yet still statistically insignificant. Taxes are positive and statistically significant at 1% level

Table 2.6. Logit Models

Dependent variable: 1 if at least 10K state capacity increase	I	II: State/Year FE
Intercept	-1.6898 (1.043)	
Environmental Stringency	-0.2103** (0.090)	-0.1701 (0.163)
Environmental Noncompliance	-0.3203*** (0.107)	-0.1814 (0.134)
Taxes	0.2303*** (0.066)	-0.4350 (0.387)
Wage	-0.1728 (0.293)	-0.6445 (0.427)
Energy Prices	0.0725 (0.326)	-0.6324 (0.919)
Recycled Pulp	0.2143*** (0.074)	-0.4255*** (0.151)
Land Price	0.0254 (0.031)	0.1237*** (0.048)
N	720	720
-2 Log L	915.3	671.3
Pseudo R-squared	0.083	0.033

Note: All variables are in the two-year lagged and log form. Significance levels are indicated as follows: * significant at the $\alpha = .10$ level, ** significant at the $\alpha = .05$ level, and *** significant at the $\alpha = .01$ level.

Table 2.7. Odds Ratio Estimates of Logit Models

Explanatory Variables	I	II: State/Year FE
Environmental Stringency	0.810	0.844
Environmental Noncompliance	0.726	0.834
Taxes	1.259	0.647
Wage	0.841	0.525
Energy Prices	1.075	0.531
Recycled Pulp	1.239	0.653
Land Price	1.026	1.132

(Table 2.6, Model I), but become negative and statistically insignificant in the model with the FE (Table 2.6, Model II). In 2-way FE logit, the availability of recycled pulp and land

prices are statistically significant at 1% level (Table 2.6, Model II), but both have the unexpected sign – availability of recycled pulp is expected to have impact on 10K capacity increases, while land prices negative. Finally, the goodness-of-fit measure McFadden's (1974) Pseudo R-squared is low.

2.6.Discussion

Table 2.8 presents the signs and significance of all the estimated models. The difference in results and their inconclusive performance from the continuous first-differencing to limited probability and logit models found in this study is not surprising, given the previous literature. Assuming that investments are made in a continuous flow of adjustments to achieve an optimal capital stock, these results suggest that the environmental regulatory variables – environmental stringency and noncompliance – are not as important as input price variables and among the number of the input costs, energy and land have statistical weight while others are statistically insignificant. In addition, taxes have a positive sign and are statistically significant at 10% level.

Unlike most of the surveyed literature on the investments in pulp and paper industry, this study examines the direct impact of disciplinary actions conducted by the environmental regulatory agencies on the investment flows in the pulp and paper sector. Whether I am looking at a continuous flow of investments or its spikes, I find that state environmental stringency has a negative impact on investments, but it is statistically insignificant through all the models that take into account fixed effects. Firm environmental noncompliance renders even more inconclusive results changing from

positive in the continuous and LPM to negative in the logit model, but in all cases with FE, it is statistically insignificant. Using a less direct measure for regulatory stringency, specifically pro-environment Congressional voting, Gray and Shadbegian (2002) found a statistically strong negative impact on papermaking firms' state production shares. Interacting pro-environment Congressional voting with firm compliance, Gray and Shadbegian (2002) conclude that the impact of stringency is concentrated on low-compliance firms.⁶² It is possible that interacting my more direct measure of state environmental stringency with firm environmental compliance may change results for one or both of these variables, yet the statistically weak stand-alone effect of the environmental stringency suggests that papermakers' investment decisions are not affected by direct disciplinary actions of environmental regulators.

Table 2.8. Summary Results

	Continuous FD	Discrete			
		Without FE LPM	Logit	State/Year FE LPM	Logit
Environmental Stringency	-	_ ^{**}	_ ^{**}	-	-
Environmental Noncompliance	+	_ ^{***}	_ ^{***}	+	-
Tax Rates	+ [*]	+ ^{***}	+ ^{***}	-	-
Wage	+	-	-	_ ^{**}	-
Energy Prices	_ ^{***}	+	+	-	-
Recycled Pulp	+	+ ^{***}	+ ^{***}	_ ^{***}	_ ^{***}
Land Price	_ ^{**}	+	+	-	+ ^{***}

⁶² This suggests interacting environmental stringency and compliance for this study also to see if results change significantly.

Regarding the effects of taxes on pulp and paper investment flows, the continuous and LPM and logit model results without the FE suggest that taxes have a surprisingly positive effect and are statistically significant. However, in the discrete models with state and year FE, taxes have negative and statistically insignificant coefficients. On the surface, this finding is inconclusive and may render little value, however other studies also found inconclusive and unexpected results. Specifically, Carlton (1983) found mixed results, Gray (1997) found negative but only marginally significant results. On the contrary, Bartik (1985) and Gray and Shadbegian (2002) found corporate tax rates to be positive and statistically significant, and Levinson (1996) and Lundmark and Nilsson (2001) found positive but statistically weak relationship between taxes and investment projects. However, Gray (1997), Lundmark and Nilsson (2001) and Gray and Shadbegian (2002) focused on pulp and paper industry and their findings that pulp and paper investments are not deterred by higher taxes are confirmed by the results in this work. Overall, the parameter estimates of the policy variables – environmental stringency and noncompliance and taxes – reject the hypothesis H1 that more stringent policies deter pulp and paper continuous and lumpy investments.

The performance of the input price variables in both the continuous and spike-like investment models confirms findings in some but not other studies. Wages appear to be one of the more robust variables in the literature. With the exception of Lundmark and Nilsson (2001), the rest of the studies have found wages to be negatively correlated with the investment and production shifting decisions of the European and U.S. papermakers. My findings suggest that wages have no significant effect on the continuous flow of investments, but a negative and statistically significant effect on the discrete increases in

capacity levels (in the case with the LPM 2-way FE model). This finding is consistent with Lundmark (2001, 2003),⁶³ Bergman and Johansson (2002), and Gray and Shadbegian (2002) and suggests that more expensive labor negatively affects bigger investments in pulp and paper industry.

Availability of recycled pulp, which has been analyzed only in the European studies, has an insignificant positive effect on the continuous investment adjustments and a strong negative effect on the discrete investment increases in the models that control for FE. The strong negative result contradicts the hypothesis that firms are attracted to states with large supplies of recycled paper. Another interpretation of the negative effect is that processing of secondary pulp is expensive and amount of wood and waste consumed – the measure that is used in this study to proxy for the availability of recycled pulp – is picking up the costs associated with wastepaper processing. In addition, Lundmark and Nilsson's (2001) strong positive relationship of rate of recycling and newsprint investment projects suggests that producers of more standardized grades of paper, such as newsprint, are more interested in the availability of recycled pulp (vs. the consumer product paper producers such as tissue). Hence, in order to determine whether the availability of recycled paper is a determining factor for larger paper investments within specific paper product lines, one needs to differentiate specific pulping and/or papermaking technologies and final products.

Further, I find that land prices are, as expected, negative and statistically significant for the continuous investments in pulp and paper industry. However, they

⁶³ Lundmark (2003) uses a continuous model.

change sign to positive in the discrete models and are highly statistically significant for the logit model with 2-way FE. Gray and Shadbegian (2002) arrived at a similar outcome — they found the effect of land prices to be positive but statistically inconclusive given that this variable’s statistical significance changed from insignificant to significant through different models.⁶⁴ Finally, scholars specializing in the European paper markets omit land prices altogether, making the findings in this and Gray and Shadbegian’s (2002) works distinctive and mutually reinforcing. The unexpected positive and statistically significant result of land prices in the state discrete models suggests that this variable is picking up influences other than of a conventional cost variable. At the mill level however, land prices are negative and statistically significant for logit regressions with 2-way (i) state and year and (ii) mill and year effects (Appendix Table A.4). This suggests that analyses aggregated to the state level contain other omitted influences and disaggregated analyses are preferred.

Finally, changes in energy prices have the strongest effect on the continuous flow of investments – the results are negative and statistically significant. The negative sign persists through the models, yet its statistical power dissipates when moving from the model of continuous capital adjustments to discrete inflows of investments. This result suggests that energy price is the most important cost variable for the continuous investment adjustments in the pulp and paper industry. Also, the performance of the energy variable from model to model is more consistent than the cumulative findings

⁶⁴ In addition to land prices, Gray and Shadbegian (2002) included state area as a scale control variable. However, when including state FE, land area was dropped from the analysis and the coefficient of land price was still positive and statistically insignificant.

from the previous literature: Lundmark and Nilsson (2001) and Gray and Shadbegian (2002) found energy prices to be negatively related to the number of newsprint investments and firm production shares, respectively, Lundmark (2001) and Shadbegian (1998) cite positive correlation, and Lundmark (2003) and Bergman and Johansson (2002) report inconclusive results.

To summarize, the H1 hypotheses on the impact of regulatory climates on the choice of pulp and paper investments fail to be accepted for both continuous and lumpy models of investment. Input prices or hypotheses under H2, on the other hand, have mixed results in the two different models of investments. In the continuous or incremental investments adjustments, energy and land prices deter short-term capacity increases. Larger investments are sensitive to change in wages, availability of recycled pulp and land prices. While wages and recycled pulp reflect increases in respective costs, land prices give mixed and inconclusive results at the state level.

Robustness Checks

In addition to the state-level models, I also estimated a number of preliminary mill-level models. The results for these estimations are reporting in Appendix A, Tables A.4 and A.5. In the mill-level FD model, environmental noncompliance is found to be negative and statistically significant at 5% level. Energy and land prices, on the other hand, become statistically insignificant. Most importantly, with the exception of environmental stringency, all variables exhibit the expected signs (Table A.4). When examining hypotheses H1 and H2 at the mill level in the lumpy investments context, or in

logit estimations with 2-way state/year and mill/year effects, all variables also exhibit the expected signs with the exception of environmental stringency in the model with state and year FE, where it is positive and statistically significant at 5% level. Interestingly, the land variable is negative and statistically significant at 1% level in both state/year and mill/year models (Appendix, Table A.5).

Additionally, to check for potential endogeneity of the environmental stringency and noncompliance I ran the endogeneity tests for all FD, LPM, and logit models at state and mill levels.⁶⁵ Both state and mill FD models showed no endogeneity, while the tests within the LPM and logit estimation methods at the state and mill levels showed significant endogeneity – the statistical significance of the individual and joint endogeneity test parameters of environmental stringency and noncompliance strongly rejected the null of exogeneity.⁶⁶ To address the issue of endogeneity in the next step of this research, I first plan to test the existing instrumental variables (IVs) for their validity using the overidentification test. Also, while controlling for endogeneity is straightforward within the linear panel models, it is more complicated in nonlinear panel

⁶⁵ To instrument for state environmental stringency and compliance, I used the 2-year lagged logarithms of the number of landfills in a state and total amount of waste generated. The logic behind these instruments is that dirtier states are likely to have more stringent monitoring and enforcement and the two variables will be correlated with the state's environmental stringency, but not the error term of the unrestricted model.

⁶⁶ In order to run the endogeneity tests for the logit models at the mill level, I had to exclude non-compliance as it was correlated with the binary dependent variable and including the 2-way fixed effects in the logit regression resulted in model failing to converge. Once environmental compliance was excluded, however, I failed to reject the null of exogeneity of environmental stringency.

data analyses.⁶⁷ Finally, all estimations in the future analyses should be done at the mill level.

2.7. Conclusion

The main contribution of this work is to analyze and bridge two strands of literature on investments in the pulp and paper industry, the one that follows the assumption of continuous capital adjustments and the other which adheres to the notions of lumpy investments in capital-intensive industries. The current findings suggest that two models inform different behavioral choices considered by papermakers. When facing increases in variable costs, specifically energy prices, papermakers respond by decreasing levels of investments. However, in day-to-day capital adjustments, regulatory stringency, whether tax or environmental, availability of secondary pulp sources, wages and land prices have little or no effect. In contrast, when considering larger inflows of investments, wages, land prices, and availability of recycled pulp become more important determinants in pulp and paper investments. Finally, whether I am looking at a continuous flow of investments or its spikes, I find that state environmental stringency has a negative impact on investments, but it is statistically insignificant through all the models and higher taxes do not deter investments in the pulp and paper industry, contrary to my expectations.

⁶⁷ Preliminary examination indicates that the analyses may need to use the Correlated Random Effects (CRE) probit estimation methodology.

For future work, I plan to disaggregate the analyses to the mill level and include ten additional years of data extending the study period up to 2013. The preliminary mill-level analyses demonstrate significantly more robust and consistent results across different models and estimations (Appendix Tables A.4 and A.5). Moreover, including political variables as in Gray and Shadbegian (1998, 2002) will inform on the extent to which political pressure has significant impact on the choice of investments in environmentally-sensitive segments of manufacturing such as pulp and paper mills. Similarly, given the previous literature we anticipate that differentiating investments by the type of the pulping and papermaking technology, type of final product, and accounting for local demand factors will provide more comprehensive and theoretically sound findings.

CHAPTER 3

ESSAY 2: RESPONSIVE REGULATION: TARGET- VS. BUDGET-DRIVEN REGULATION

Abstract

The main purpose of this study is to examine the relationship between voluntary pollution abatement and prevention efforts at pulp and paper mills and regulatory stringency they face. Using facility level data on U.S. pulp and paper mills for 1989-2002, I estimate the fixed effects negative binomial model to test the hypotheses of responsive regulation and whether regulators are driven by numerical pollution targets or budgetary constraints. I find that voluntary pollution abatement has greater impact on regulatory stringency than government expenditures. Additionally, state political pressure, pollution prevention legislation, firm and mill characteristics are found to be significant predictors of regulatory behavior.

3.1.Introduction

Most previous literature on environmental regulation focuses on firms' compliance. Since the late 1990s, there has been a growing body of work studying how firms' environmental decisions and performance, in turn, affect the behavior of regulators. Building upon and expanding Decker (2005, 2007) and Maxwell and Decker (2006), I test the hypothesis of 'responsive regulation' first advanced by Hemphill (1993-1994) and Cothran (1993).⁶⁸ Maxwell, Lyon, et al. (2000) tested strategic self-regulation that preempted political action and their empirical results confirmed that increased threat of regulation, measured by membership in conservation groups, induced firms to reduce toxic releases. Building the first formal models of responsive regulation, Maxwell and Decker (2006) and Decker (2007) corroborated theoretically that profit-maximizing firms, under responsive regulation, overinvest in environmental compliance. They proposed a two-stage game with the outcome of firms voluntarily overinvesting in pollution abatement because of responsive regulation.

Confirming theoretical propositions of responsive regulation, Arguedas (2013) points out that such regulatory behavior is documented not only in growing empirical literature, but also in the regulations themselves. For example, under the EPA's Audit Policy, fines for non-compliance can be reduced up to from 75% to 100% if firms promptly disclose and correct violations.⁶⁹ Building on the previous theoretical works, Heyes and Kapur (2009) addressed the type of regulatory missions and formally

⁶⁸ Decker (2005) identifies Hemphill (1993-1994) and Cothran (1993) as the first works using the term 'responsive regulation,' p. 180.

⁶⁹ Arguedas (2013) cites EPA (December 22, 1995), Incentives for Self-Policing: Discovery, Disclosure, Correction and Prevention of Violations – Final Policy Statement, 60 Fed. Reg. 66, 706, p 157.

modelled two regulatory regimes/climates – target- and budget-driven. Under the target regime, firms’ compliance decisions are viewed as strategic substitutes and there are positive spillovers to enforcement and under the budget regime firms’ compliance decisions are modelled as strategic complements and result in negative enforcement spillovers.

The main purpose of this study is to empirically test Heyes and Kapur’s (2009) hypothesis of ‘responsive regulation’ and gauge the extent to which the regulatory climate, in which pulp and paper mills operate, can be called a target- vs. budget-regime or both. This has not been done before. The analyses use firms’ pollution abatement and voluntary prevention efforts, measured by the EPA’s Toxic Release Inventory (TRI) and pollution prevention (P2) facility-level data, and local and state budgetary expenditures on protective inspection and regulation from the Census’ Rex-Dac data base. I use the fixed effects negative binomial model to regress the number of EPA inspections and enforcements for 200 pulp and paper mills during 1984-2002, across all pollution media and separately for air, water, and land against the measures of TRI (by media), P2, local and state government expenditures. The EPA facility-level data were merged to the plant capacity data from the Forest Product Laboratory⁷⁰ (FPL) and annual editions of Lockwood-Post’s Directory of the Pulp, Paper, and Allied Trades⁷¹ (LW). In addition, I test the impact of state political pressure, P2 legislation, firm and mill characteristics and find them to be important factors in predicting regulators’ behavior.

⁷⁰ For the full description of the FPL data, see:
<http://www.fpl.fs.fed.us/documnts/fplrp/fplrp602.pdf>.

⁷¹ For the latest description of Lockwood’s Post Directory, see:
<http://www.risiinfo.com/risi-store/do/product/detail/lockwood-post-plus-contact-database.html>.

3.2.Literature Review

Deterrence Model

Gray and Shimshack (2011) reviewed empirical literature on effectiveness of environmental monitoring and enforcement. According to them, the existing empirical enforcement models measure firm deterrence, or how plants respond to enforcement activities. There are a number of studies on pulp and paper industry that find evidence for effectiveness of enforcement on facility compliance (Nadeau 1997, Gray and Shadbegian 2007, Shimshack and Ward 2005, 2008). Shimshack and Ward (2005, 2008) found that an additional fine induced state-wide compliance. Shimshack and Ward (2008) found that fines at violating facilities induced facilities that were operating within the permitted level of discharges, were induced to discharge even less, or go beyond compliance. Gray and Shadbegian (2007) found that inspections at one plant tended to increase compliance at both the inspected and nearby facilities.

Reviewing the empirical literature on effectiveness of environmental monitoring and enforcement, Gray and Shimshack (2011) point out that plant's choice of its abatement effort is "a function of: (i) its perceived probability of a violation given its chosen abatement level; (ii) its perceived probability of detection by the regulator if it violates; (iii) its perceived probability of a penalty if a violation is detected; and (iv) its perception about the likely magnitude of the penalty if it is levied."⁷² These appear strategic in nature and are included in the discussion of the hypotheses that I propose below.

⁷² Gray and Shimshack (2011), p. 10.

More specifically on pulp and paper industry, Shadbegian and Gray (2003) found that air pollution emissions at 68 paper plants in 1985 were significantly lower in plants with a larger air pollution abatement capital stock, greater local regulatory stringency, and higher productive efficiency. Further, Gray and Shadbegian (2007) found that a typical regulatory measure, both inspection and enforcement mechanisms, induced a 10% increase in air pollution compliance among 116 paper mills over 1979-1990.

Shimshack and Ward (2005) found that in the sample of 217 pulp and paper mills over 1988-1996, an additional fine was associated with a two-thirds reduction in the statewide water pollution violation rate in the year following the fine. Shimshack and Ward (2008) extended the analysis to 251 pulp and paper mills over 1990-2004 and found a 7% decrease in statewide water pollution discharges in the year following a fine being imposed at any plant in the state. They also showed that EPA enforcement actions increased overcompliance confirming the theoretical arguments of Maxwell and Decker (2006), and Decker (2007), and Arguedas (2013), all of which I review next.

Voluntary Pollution Abatement Discussion

Maxwell et al. (2000) tested strategic self-regulation that preempted political action and their empirical results confirmed that increased threat of regulation, measured by membership in conservation groups, induced firms to reduce toxic releases. Maxwell and Decker (2006) and Decker (2007) corroborated theoretically that profit-maximizing firms, under responsive regulation, overinvest in environmental compliance; hence regulatory fines are likely to be an overkill and must be lowered. They proposed a two-stage game with an outcome of firms voluntarily overinvesting in pollution abatement

because of responsive regulation. Arguedas (2013) documents ‘responsive regulation’ within the EPA and Spanish environmental legislation.⁷³

Decker (2005) tested the responsiveness of regulation to voluntary environmental abatement and found mixed results. In two out of four frequently inspected industries, regulators conduct fewer inspections at the facilities that report lower per unit output of toxic release inventory. In pulp and paper industry, mills with larger share of state employment are inspected less frequently. Maxwell and Decker (2006) ran two regressions: one predicting the threat of regulation measured by green membership, and another using these estimated values for green membership in the regression of toxic releases (as a measure of voluntary abatement) against estimated green membership and other control variables.

In 2013, Arguedas (2013) critiqued Maxwell and Decker (2006) and Decker (2007), arguing that self-reporting/policing efforts are already built-into the regulations, hence it is not necessary to model a hierarchical model of regulation with regulators worrying over their reputation costs. The simpler model of Arguedas (2013) arrives at the same outcome that fines should be reduced, but due to excessive administrative costs of regulations. Hence, according to the author, fines (enforcements) should be negatively related to the abatement investment efforts.

To contrast, Heyes and Kapur (2009) addressed the type or nature of regulatory mission. They distinguished a target-driven vs. a budget-driven regulatory policy. Under the target-driven regulatory policy, firms’ compliance decisions are strategic substitutes and there are positive spillovers to enforcement – greater number of inspections will

⁷³ Arguedas (2013), p. 157.

reduce non-compliance. In contrast, the budget-driven regime is characterized by firms' compliance decisions as being strategic complements, thus resulting in negative enforcement spillovers. I next turn to the specific hypotheses.

3.3.Hypotheses

Responsive Regulation

Hypothesis 1: Increases in voluntary pollution abatement, measured as the number of all P2 activities at mills, are expected to decrease the expected count of regulatory inspections and enforcements.

Following Maxwell et al. (2000), Maxwell and Decker (2006), Decker (2005, 2007), and Arguedas (2013), I hypothesize that when deciding whether to inspect and/or enforce, regulators take into account mills' efforts to reduce pollution by implementing P2 activities. If a mill reports that it has implemented successfully a greater number of P2 measures than in the previous period, the regulators may exercise greater leniency towards this mill as opposed to the mills that may have not implemented any P2 and are in need of greater regulatory pressure. To illustrate, Arguedas (2013) documents instances within the current environmental regulation when the regulations explicitly include provisions for "good behavior". Specifically, she points out the EPA's audit policy, which stipulates 75% and 100% fine reduction for gravity- and non-gravity-based

components, respectively, if firms quickly disclose and correct any discovered violations as a result of self-audit procedure.⁷⁴

Target-driven Regulatory Regime

Hypothesis 2: Lower TRI levels will reduce the probability of inspections and/or enforcements, or increases in TRI will increase the expected count of inspections and/or enforcements.

Similarly to P2 activities and as proposed by Maxwell et al. (2000), Maxwell and Decker (2006), Decker (2005, 2007), I expect mills' lower TRI levels to signal to the regulators that mills are acting in good faith to decrease their emissions, thereby potentially decreasing regulatory scrupulousness. In contrast to the measure of P2 activities, mills are encouraged not to exceed given levels of TRI for specific chemicals. In cases when a mill does not exceed permitted level of emissions, it can file a shortened Form A to the regulatory authorities, which does not require it to specify the actual number of emissions. These reports are credible as those employees who are responsible for filing the forms bear civil responsibility for potential misreporting or misrepresentation (Gray and Shimshack, 2011).

Because of the numerical TRI goal that mills can strive to attain, I can follow Heyes and Kapur (2009) to hypothesize that TRI represents a target-driven regulatory regime. To do so, I assume that there are V number of polluters, with M being the maximum target of pollution. Each firm emits 1 unit of pollution, hence M is also the

⁷⁴ Incentives for Self-Policing: Discovery, Disclosure, Correction and Prevention of Violations – Final Policy Statements, 60 Fed. Reg. 66,706 (Dec. 22, 1995) cited in Arguedas (2013), p. 157.

number of firms allowed to pollute. Under these assumptions, Heyes and Kapur (2009) find that the probability that a firm will be caught is equal to $\frac{(V-M)}{V}$ – or the greater number of firms that choose to violate, the greater the probability that the firms will be inspected (positive enforcement spillovers). Conversely, a smaller number of firms that choose to violate, the smaller the probability that the firms will be inspected. This result leads to the conclusion that firms' compliance decisions are strategic substitutes and there are positive spillovers to enforcement – greater number of inspections will reduce non-compliance. Hence, I can hypothesize that lower TRI levels will reduce the probability of inspections and/or enforcements.

Budget-driven Regulatory Regime

Hypothesis 3, 4: H3: Larger state budget will increase the expected count of inspections and enforcements. H4: Larger local budget will increase the probability of inspections and enforcements.⁷⁵

Continuing with the theoretical argument of Heyes and Kapur (2009), I hypothesize that regulators are driven by their budget constraints. Under this regime, environmental inspectors will continue to inspect and enforce until they run out of budget. Hence, one firm's decision to violate decreases the probability of another firm's violation being detected, thereby making firms' compliance decisions strategic

⁷⁵ I estimated the models combining the state and local budget data and chose to keep the two separate for the following reasons: (i) for air and water, state and local budgets have opposite signs (in those cases when both are statistically significant with about the same magnitude in coefficients, combining the two into one renders the result insignificant), and (ii) when doing the formal test, the null that the two betas are equal is rejected.

complements and leading to negative compliance spillovers. Here, I expect that the bigger sizes of local and state budgets will increase the probability of inspections and enforcements. Given the data, I am able to separate the effects of state vs. local inspection and enforcement effort. I expect that both state and local budgets will have a positive relationship with the probability of inspection and enforcement, with local budget having potentially greater impact than the state budget. Finally, among the empirical works focused on pulp and paper industry, Gray and Shadbegian (1998) found that their time-invariant measure of state government environmental spending was positively correlated with the plant birth rates, but was not significant.⁷⁶

Responsive Regulation: Budget vs. Target Regimes

Hypothesis 5: Increases in budget are a function of decreases in pollution abatement efforts, measured in TRI and P2 activities, and will increase the expected count of inspections and enforcements.

Building on the previous hypotheses, I also include the interaction terms between TRI, P2 on the one hand, and local and state budgetary expenditures, on the other. In the world of constrained budgetary realities, one can stipulate that state and local budgets are determined in light of the most recent pollution trends within the local communities. Mills that appear to have consistently fallen short in their pollution abatement efforts in previous years may attract additional scrutiny from the regulatory authorities who, in

⁷⁶ However, the authors also note that such result could be due to endogeneity of government spending – state agencies in growing states would have larger resources to spend.

response, would allocate greater resources to inspect and, if necessary, enforce mills in question.

Political Pressure

Hypothesis 6: Increases in the number of members in environmental organizations will increase the expected of regulatory inspections/enforcements.

Maxwell et al. (2000), Maxwell and Decker (2006), Khanna et al. (2009), Harrington (2012) hypothesize that membership in environmental conservation groups is an effective measure of political pressure that influences the stringency of regulatory oversight and enforcement. More recently, Matisoff and Edwards (2014) find state's environmental group membership, namely Sierra Club membership, to be important determinants for state adoption of energy and climate-change policies.

P2 Legislature

Hypothesis 7: Legislated P2 programs for toxic waste reduction will lead to decrease in toxic releases and increase in firm compliance, thereby decreasing the expected count of inspections/enforcements.

Khanna et al. (2009) and Harrington (2012, 2013) continued the empirical discourse by examining the role of regulatory threat on the voluntary pollution abatement efforts. The authors argue that legislated programs can promote abatement technology adoption and reduction in pollution through: (i) information-sharing and technical assistance and (ii) increased visibility of regulatory agencies and environmental stewardship of regulated firms. This, in turn, leads to decreased regulatory scrutiny (Harrington 2013).

Willingness to Pay

Hypothesis 8: Increases in income per capita, measuring willingness to pay for higher environmental quality of life, are expected to increase the expected count of inspections/enforcements.

To follow Maxwell et al. (2000), Decker (2005), and Harrington (2012, 2013), I include state income per capita to measure citizens' willingness to pay for higher environmental quality of life, resulting in greater scrutiny of regulators. Maxwell et al. (2000) include income per capita and educational attainment with the expectation that both capture increased demand for pollution abatement. Decker (2005) included county median income measuring local affluence and hypothesizing that wealthier neighborhoods have higher demand for cleaner environment, hence exhibit political pressure for stricter environmental regulations. Similarly, Harrington (2012, 2013) used median income of households to proxy for community-related benefits from stricter environmental regulations.

Firm Characteristics

Hypothesis 9: Increases in firms' market share/power are expected to decrease the probability of regulatory inspections and enforcements.

Decker and Wohar (2006), Delmas and Toffel (2004, 2008), Khanna et al. (2009), and Minatti Ferreira (2014) suggested that oligopolies and market leaders have the ability to deter political actions, thereby decreasing regulatory monitoring. Additionally, Decker and Wohar (2006) suggested that firms that represent strategically important employers and producers are less frequently examined.

Mill Characteristics

Hypotheses 10-12: H10: Increases in mill annual capacity will increase the expected count of regulatory inspections and enforcements. H11: Increases in the number of products produced at a mill will increase the expected count of regulatory inspections and enforcements. H12: Pulp and paper mills are expected to have higher expected count of inspections and enforcements than paperboard mills.

Although larger corporations with significant market power can deter political action, Nadeau (1997) and Decker (2005) found that larger producers face greater number of inspections due to the scale of production and, therefore, releases. Similarly, greater number of final products produced increases the number of potential pollution, hence environmental scrutiny. Nadeau (1997) found that pulp mills are likely to get more inspections (mills involving kraft and bleaching technology are expected to get more inspections but less enforcement activities). Minatti Ferreira et al. (2014) also argued that mills with pulping technology face greater stringency.

3.4. Empirical Model and Data

The main goal for this study is to test whether there is a relationship between voluntary mill pollution abatement efforts and the level of regulatory scrutiny they face. If such relationship is found, it could suggest that when considering the level of monitoring and enforcement, regulators take into account mills' actions, thereby confirming the propositions of responsive regulation. In addition, I am interested in examining the impact of two main motivators for regulators' decision-making – environmental target of decreasing pollution and their budgetary constraints.

To assess such relationship, as the measure of regulatory scrutiny I choose two variables – the count of inspections and enforcements for each environmental media j , at mill i , at time t . The following two equations are the functional forms for inspections and enforcements:

$$\begin{aligned}
 (1) \text{ Inspections}_{jit} &= \beta_1 TRI_{jit-1} + \beta_2 P2_{it-1} + \beta_3 LocGov_{st-1} + \beta_4 StateGov_{st-1} + \beta_5 Sierra_{st-1} + \\
 &+ \beta_6 YrP2Adopt_{st-1} + \beta_7 PerCapInc_{st-1} + \beta_8 FirmMS_{it-1} + \beta_9 MillCap_{it-1} + \beta_{10} NumGrades_{it-1} + \\
 &+ \beta_{11} PulpMill_{s,t} + \beta_{12} PaperMill_{s,t} + \delta_i + \rho_t + e_{jit}, \text{ and} \\
 (2) \text{ Enforcements}_{jit} &= \beta_1 TRI_{jit-1} + \beta_2 P2_{it-1} + \beta_3 LocGov_{st-1} + \beta_4 StateGov_{st-1} + \beta_5 Sierra_{st-1} + \\
 &+ \beta_6 YrP2Adopt_{st-1} + \beta_7 PerCapInc_{st-1} + \beta_8 FirmMS_{it-1} + \beta_9 MillCap_{it-1} + \beta_{10} NumGrades_{it-1} + \\
 &+ \beta_{11} PulpMill_{s,t} + \beta_{12} PaperMill_{s,t} + \delta_i + \rho_t + e_{jit}.
 \end{aligned}$$

In addition to the time and mill vectors, the two dependent variables and TRI vary by three environmental media – air, water, land – and their total or $j = 1, 2, 3, 4$.

Voluntary abatement technology adoption variable is the count of all P2 activities at the mill level. Other mill-level variables are firm's market share, annual mill capacity in thousand short tons, number of grades manufactured at the mill, and whether the mill produces pulp, paper, or paperboard. State variables include annual local and state budget expenditures for protective inspection and regulation, the Sierra Club membership measuring the state environmental political activism and pressure, year of adoption of P2 legislation, and income per capita gauging citizens' willingness to pay for environmental quality of life. Table 3.1 provides descriptive statistics for each of the variables.⁷⁷

⁷⁷ For correlations, see Table B.1 in Appendix B.

Table 3.1. Descriptive Statistics

Dependent Variables	Expected Sign	Mean	SD
Air Inspections, Number	N/A	1.29	2.14
Air Enforcements, Number	N/A	0.12	0.48
Water Inspections, Number	N/A	1.34	1.64
Water Enforcements, Number	N/A	0.23	1.04
Land Inspections, Number	N/A	0.28	0.71
Land Enforcements, Number	N/A	0.10	0.39
All Inspections, Number	N/A	2.90	3.02
All Enforcements, Number	N/A	0.45	1.24
Independent Variables			
Air TRI in pounds	+	9.30	5.68
Water TRI in pounds	+	6.11	4.99
Land TRI in pounds	+	3.51	4.85
Total TRI in pounds	+	9.97	5.38
Number of P2	-	0.10	0.33
Local Government Expenditures on Protective Inspection and Regulation, Thousand 1990 Dollars	+	10.24	1.16
State Government Expenditures on Protective Inspection and Regulation, Thousand 1990 Dollars	+	11.04	0.72
Sierra Membership, Number of Members	+	9.04	0.90
State Per Capita Income, Thousand 1990 Dollars	+	1.50	1.03
Annual Mill Capacity, Thousand Short Tons	+	4.52	2.11
Firm Market Share	-	-4.14	2.02
Number of Paper Grades Mill Produces	+	0.27	0.41
Dummy Variables			
Year P2 Adopted, 1 if Adopted	-	0.73	0.44
Board Mill, Reference Category	N/A	0.38	0.49
Pulp Mill	+	0.15	0.36
Paper Mill	+	0.59	0.49

Note: N = 2,922. All continuous explanatory variables are in log form and lagged one year.

EPA Facility-level Variables

The count of inspections and enforcements at the mill level and for the three environmental media come from the EPA's Environmental Compliance History Online (ECHO). I use the Integrated Data for Enforcement Analysis (IDEA) system and Facility Registry System (FRS) to merge the facility-level data from the: (1) Air Facility System

(AFS), (2) Permit Compliance System (PCS), (3) Integrated Compliance Information System National Pollutant Discharge Elimination System (ICIS-NPDES), and (4) Resource Conservation and Recovery Act Information (RCRAInfo) System.⁷⁸ The data are further matched with the TRI facility records to calculate (i) total annual TRI by each media,⁷⁹ and (ii) counts of facility-level of new P2 activities.⁸⁰

P2 measure is the sum of all new P2 activities at the mill level.⁸¹ They are everyday procedural and operational measures taken at individual production facilities and aimed at reducing pollution by minimizing waste, spills, and leaks. In contrast to end-of-pipe pollution abatement measures, they are less costly in terms of capital, technological, and personnel investments.⁸² P2s arose in response to the National Pollution Prevention Act of 1990 which called on industry to prevent pollution ‘whenever feasible’ and included 43 types of pollution prevention activities subdivided into eight broader categories: (i) operating practices, (ii) inventory control, (iii) spill and leak prevention, (iv) raw-material modifications, (v) process modifications, (vi) cleaning and degreasing

⁷⁸ For more information about ECHO and IDEA and data downloads, please refer to <http://echo.epa.gov/> and <http://echo.epa.gov/resources/echo-data/data-downloads#downloads>.

⁷⁹ Facility-level TRI data can be downloaded from <http://www2.epa.gov/toxics-release-inventory-tri-program/tri-data-and-tools>.

⁸⁰ I used the TRI EZ search tool to download the list of facilities reporting P2 activities: <http://www.epa.gov/enviro/facts/tri/ez.html>.

⁸¹ The TRI states that each facility is allowed to report no more than four P2 activities within one of the 43 categories. To investigate if there is an empirical issue associated with the maximum number of P2 activities allowed to be reported in one year, I follow Harrington (2012) and examine if the current sample for any facilities that reported the maximum allowable number of P2 activities for a number of consecutive years and did not find them.

⁸² The U.S. Environmental Protection Agency (EPA) defines pollution prevention (P2) as “reducing or eliminating waste at the source by modifying production, the use of less-toxic substances, better conservation techniques, and re-use of materials” (EPA, Pollution Prevention, Basic Information: <http://www.epa.gov/p2/pubs/basic.htm>).

modifications, (vii) surface preparations and finishing modifications, and (viii) product modifications.

Mill-level Production Variables

To supplement facility-level monitoring and technology abatement data, I use the mill-level data from the Forest Product Laboratory (FPL) and annual editions of Lockwood-Post's Directory of the Pulp, Paper, and Allied Trades (LW).^{83,84} The two, FPL and LW, contain detailed information on all of the U.S. pulp and paper mills from 1970 to the present. The FPL comprised detailed information on the type of pulping processes and capacities for all the mills, their names and locations over 1970-2000. I used LW to verify the capacities, number of products, whether the mill was listed as vertically integrated, and extended the data to 2002. Additionally, using LW as well as other trade publications I added the name of the parent company and corporate owner/s in case the two were different, which helped identify a more accurate estimate of firm market share.

The FPL and LW collectively contain data on more than 900 mills that have operated at any one point over 1970 to 2002. During 1988 and 2002 that number was 893 mills. Both the FPL and LW collected data on the paper and pulp facilities that produced final products reported within the three primary paper SIC codes – 2611 for pulp, 2621 for paper, and 2631 for paperboard mills. The EPA's ECHO and TRI have records for

⁸³ For the full description of the FPL data, see:
<http://www.fpl.fs.fed.us/documnts/fplrp/fplrp602.pdf>.

⁸⁴ For the latest description of Lockwood's Post Directory, see:
<http://www.risiinfo.com/risi-store/do/product/detail/lockwood-post-plus-contact-database.html>.

almost 520 pulp and paper facilities listed under SIC2611, SIC2621, and SIC2631 for pulp, paper and paperboard facilities.⁸⁵ Matching the EPA with mill data, I was able to find 201 one-to-one clean matches. The FPL and LW data provide firm-level market share, mill-level measure of capacity or its annual output, number of paper products produced at the mill, and whether the mill produces pulp, paper or board as its final products.

State-level Data

State and local budget data come from the Census' Rex-Dac data base, or more specifically, from the Data Base on Historical Finances of Federal, State and Local Governments: State Aggregates, Fiscal Year 1978-2008.⁸⁶ The budget line item that captures state and local expenditures on government protective and inspection services comes from the Direct Expenditures and is called Protective Inspection and Regulation, NEC, and is defined as: "Regulation and inspection of private establishments for the protection of the public or to prevent hazardous conditions..." (U.S. Bureau of the Census, 2006).⁸⁷ The budget numbers are aggregated to the state level for both local and

⁸⁵ Corresponding NAICS codes for the three sectors are: NAICS322110 for pulp facilities, NAICS322121 for paper and NAICS322122 for newsprint facilities, and NAICS322130 for paperboard facilities. To arrive at the total values for paper facilities equivalent to SIC2621, one would need to combine NAICS322121 for paper and NAICS322122 for newsprint facilities. For more information on NAICS definition for paper manufacturing, see: <http://www.bls.gov/iag/tgs/iag322.htm>.

⁸⁶ The link (<http://www2.census.gov/pub/outgoing/govs/special60/>) to the data base was provided by the Census's govs.cms.inquiry@census.gov upon request with the indication that the link will be available for a limited time only.

⁸⁷ The U.S. Census provides the full definition at: http://www2.census.gov/govs/pubs/classification/2006_classification_manual.pdf: "Definition: Regulation and inspection of private establishments for the protection of the

state expenditures on protective inspection and regulation.⁸⁸ To measure the state environmental political clout I use the annual membership of the Sierra Club, the largest grassroots environmental organization in the U.S.⁸⁹ The year of P2 legislation adoption across states comes from Harrington (2013).⁹⁰ According to Harrington (2013), since 1988 36 state have legislated P2 programs emphasizing the need to implement pollution source reduction technologies. Finally, state income per capita comes from the Bureau of Economic Analysis' (BEA) Regional Economic Accounts.⁹¹

public or to prevent hazardous conditions NOT classified under another Census Bureau function, and the regulation of professional occupational licensing. Includes: Inspection of plans, permits, construction, or installations related to buildings, housing, plumbing, electrical systems, gas, air conditioning, boilers, elevators, electric power plant sites, nuclear facilities, weights and measures, etc.; regulation of financial institutions, taxicabs, public service corporations, insurance companies, private utilities (telephone, electric, etc.), and other corporations; licensing, examination, and regulation of professional occupations, including health-related ones like doctors, nurses, etc.; inspection and regulation or working conditions and occupational hazards; motor vehicle inspection and weighing unless handled by a police agency; regulation and enforcement of liquor laws and sale of alcoholic beverages unless handled by a police department. Excludes: Distinctive license revenue collection activities (report at Financial Administration, code *23); regulatory or inspection activities related to food establishments or to environmental health (report at Health, code *32); motor vehicle inspection, liquor law enforcement, and other regulatory type activities of police agencies (report at Police Protection, code *62); regulatory and inspection activities related to other major functions, such as fire inspections, health permits, water permits, and the like (report at function involved),” p.180.

⁸⁸ The budget expenditures are in thousand 1990 dollars converted to real using the regional consumer price index for urban consumers, which can be found at: <http://www.bls.gov/cpi/>.

⁸⁹ The membership data were obtained directly from the Sierra Club; more information about the organization can be found at: <http://www.sierraclub.org/about>.

⁹⁰ Specifically, Harrington (2013), p. 258.

⁹¹ The data can be downloaded at: <http://www.bea.gov/regional/index.htm>. Per capital income is measured in thousands of 1990 converted to real similarly to the state budget expenditures, or using the regional consumer price index for urban consumers, which can be found at: <http://www.bls.gov/cpi/>.

3.5.Econometric Methodology

The count data models are usually estimated using the Poisson regression method.

The density function of the Poisson distribution can be written as:

$$(2) \quad f(y_i / \theta_i) = \frac{\exp(-\theta_i) \theta_i^{y_i}}{y_i!},$$

where y_i is the number of inspections or enforcements at mill i , and θ_i is the conditional mean and variance. The main property of the Poisson model is that the variance and mean of the dependent variable are equal. This is not the case in my data. The difference between the mean and the standard deviation in the number of inspections and enforcements reported in Table 3.1 informs that the Poisson model would be an inappropriate choice in this case.⁹²

According to Cameron and Trivedi (1998), the case when the variance of the count variable exceeds its mean, referred to as over-dispersion, is common due to the unobserved heterogeneity. Using the Poisson regression in such cases, however, may lead to biased and inefficient estimates. The negative binomial model, on the other hand, allows for the variable mean to be not perfectly observable and the unobservable heterogeneity is assumed to follow a gamma distribution. Hence, the density of the negative binomial model is given by:

⁹² Building on the previous literature on inspections, Decker (2005) suggests using both the OLS and count regression analyses. I have ran both the OLS and negative-binomial models and found the results of the two estimation methods to be consistent with each other with the negative-binomial estimates having greater statistical significance. In addition, Decker (2005) has used the Poisson model for Chemicals and Iron and Steel industries, and negative binomial for Pulp and Paper and Petroleum Refining industries given the results of the over-dispersion tests for the four industries.

$$(3) \quad f(y_i / \theta_i, \alpha) = \frac{\Gamma(y_i + \alpha^{-1})}{\Gamma(y_i + 1)\Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1} + \theta_i} \right)^{\alpha^{-1}} \left(\frac{\theta_i}{\alpha^{-1} + \theta_i} \right)^{y_i},$$

where α and Γ represent the dispersion parameter and gamma function, respectively.

Applying the negative binomial model to the functional forms (1) and (2) provides a straightforward interpretation of the parameters, i.e. a 1 unit increase in independent variables leads to a $\beta\%$ change in θ . The expected inspections and enforcement frequencies are assumed to be in a log linear form. The use of panel data allows us to control for changes in unobserved time and state heterogeneity. In my models (1) and (2), the unobserved heterogeneity specific to state and year fixed effects is captured by δ_i and ρ_t .

3.6.Results

Inspections Models

I estimate eight model specifications for the count of inspections and eight models for the count of enforcements; the results are presented in Tables 3.2 and 3.3. Each media has two models (with and without the interaction terms), all independent non-dummy variables are in the log form and lagged one year. The TRI measure varies by the environmental media also. Table 3.4 gives marginal effects for the interactions terms in Models 5-8 in Table 3.2 and Models 12-16 in Table 3.3. Finally, Table 3.5 gives the overall picture of model performance by providing direction and significance of the estimated coefficients.

The high significance of the over-dispersion variable through all sixteen models confirms the correct choice of negative binomial estimation method over the Poisson

regression. Most of the models have high log likelihood values and provide a reasonable basis for concluding that these models fit well.

I start by looking at the basic inspection models for all media without the interaction terms (Table 3.2, Models 1 through 4). In Model 1, the two measures of voluntary abatement efforts, TRI and P2, are positive, with TRI statistically significant at 1% level. Increases in annual TRI and P2 activities in the previous year increase the expected count of current period inspections. While the positive sign on TRI is expected, it is surprising for P2. In terms of marginal effects, 1% increase in last year's all media TRI increases the estimated count of inspections across all media by 0.04%, all else constant.

Going across the three media for the basic model (Table 3.2, Models 2 through 4), the TRI variable is positive and highly significant for both air and water, and is negative and statistically insignificant for land, and P2 variable is negative, confirming the expectation, for water and land yet statistically insignificant (Table 3.2, Models 3, 4). P2 for the air model (Table 3.2, Model 2) is positive and statistically significant at 5% level – 1% increase in the number of P2 activities at the mill during the previous year increases the expected count of air inspections by 0.16%, all else constant.

Local budget on protective inspection and regulation expenditure is positive for all media, water and land with a coefficient statistically significant at 10% level for the land model (Table 3.2, Model 4). In terms of the marginal effects, 1% increase in previous year's local budget increases the expected number of land inspections 0.42%, *ceteris paribus*. Surprisingly, state budget on protective inspection and regulation, on the

Table 3.2. Negative-binomial: Determinants of Inspections

	All Media Model 1	Air Model 2	Water Model 3	Land Model 4	All Media Model 5	Air Model 6	Water Model 7	Land Model 8
Intercept	3.0544* (1.702)	10.6023*** (2.404)	-3.5676 (2.288)	-3.1829 (4.954)	5.6510*** (1.282)	10.1378*** (2.492)	-1.6791 (2.303)	-3.3838 (4.985)
TRI, t-1	0.0400*** (0.004)	0.0317*** (0.006)	0.0769*** (0.005)	-0.0135 (0.010)	-0.2876*** (0.041)	-0.0835 (0.076)	-0.4229*** (0.076)	-0.3770** (0.164)
P2, t-1	0.0447 (0.048)	0.1611** (0.064)	-0.0908 (0.062)	-0.0835 (0.140)	2.1885*** (0.698)	0.8592 (1.286)	3.0789** (1.244)	0.7778 (2.654)
Loc Gov Exp, t-1	0.0264 (0.083)	-0.1561 (0.120)	0.1357 (0.106)	0.4238* (0.235)	0.1376* (0.073)	0.0645 (0.138)	0.2526** (0.118)	0.4085* (0.240)
State Gov Exp, t-1	-0.2985*** (0.113)	-0.6370*** (0.166)	-0.1190 (0.144)	0.0264 (0.322)	-0.6204*** (0.094)	-0.8114*** (0.178)	-0.3819** (0.151)	0.0067 (0.330)
Sierra Club, t-1	0.0133 (0.091)	-0.2181* (0.113)	0.2586* (0.142)	-0.5198 (0.362)	-0.0081 (0.061)	-0.2120* (0.112)	0.2426* (0.138)	-0.4618 (0.364)
Year P2 Adopted	-0.0042 (0.070)	-0.1669* (0.097)	0.1736** (0.088)	0.0894 (0.200)	0.0346 (0.050)	-0.1563 (0.097)	0.1745** (0.087)	0.0961 (0.200)
State Per Cap Inc, t-1	0.0478 (0.031)	0.0922** (0.044)	-0.0066 (0.040)	0.0326 (0.091)	0.0666*** (0.023)	0.1050** (0.044)	0.0097 (0.039)	0.0352 (0.091)
Annual Mill Capacity, t-1	0.0467*** (0.010)	0.0436*** (0.014)	0.0185 (0.013)	0.1112*** (0.030)	0.0479*** (0.008)	0.0456*** (0.014)	0.0162 (0.013)	0.1095*** (0.030)
Firm Market Share, t-1	0.0131 (0.009)	0.0388*** (0.013)	-0.0479*** (0.012)	0.1447*** (0.025)	0.0152** (0.007)	0.0409*** (0.013)	-0.0469*** (0.012)	0.1460*** (0.025)
# of Paper Grades, t-1	0.0717 (0.047)	-0.0084 (0.065)	0.0837 (0.061)	0.2891** (0.128)	0.0988*** (0.033)	0.0033 (0.065)	0.1239** (0.062)	0.2590** (0.129)
Pulp Mill	-0.0821 (0.050)	0.0577 (0.067)	-0.1150* (0.065)	-0.5318*** (0.145)	-0.0540 (0.036)	0.0597 (0.067)	-0.0914 (0.065)	-0.5133*** (0.146)
Paper Mill	0.1594*** (0.040)	0.0883 (0.055)	0.1147** (0.052)	0.7200*** (0.112)	0.1501*** (0.029)	0.0881 (0.055)	0.0950* (0.052)	0.7145*** (0.113)
P2 * Loc Gov Exp, t-1					0.2141*** (0.052)	0.2090** (0.097)	0.1466 (0.094)	0.2774 (0.210)

Table 3.2. Continued

	All Media Model 1	Air Model 2	Water Model 3	Land Model 4	All Media Model 5	Air Model 6	Water Model 7	Land Model 8
P2 * State					-0.3924***	-0.2558	-0.4242**	-0.3327
Gov Exp, t-1					(0.095)	(0.175)	(0.167)	(0.350)
TRI * Loc					-0.0189***	-0.0232***	-0.0178**	0.0008
Gov Exp, t-1					(0.004)	(0.007)	(0.007)	(0.015)
TRI * State					0.0469***	0.0320***	0.0610***	0.0323
Gov Exp, t-1					(0.005)	(0.010)	(0.011)	(0.023)
Over- dispersion	0.2795*** (0.018)	0.3665*** (0.029)	0.2681*** (0.028)	0.8942*** (0.147)	0.0000*** (.)	0.3575*** (0.028)	0.2512*** (0.027)	0.8776*** (0.146)
AIC	11,976.0	8,280.5	8,589.5	3,500.7	12,611.0	8,272.3	8,549.9	3,501.8
LL	-5,927.1	-4,079.2	-4,233.8	-1,691.4	-6,240.7	-4,071.2	-4,209.9	-1,687.9
N	2,922	2,922	2,922	2,894	2,922	2,922	2,922	2,894

Note: All variables, except for dummy variables, are in the log form; standard errors are reported in parentheses and ***, **, * indicate 1%, 5%, and 10% statistical significance levels, respectively.

Table 3.3. Negative-binomial: Determinants of Enforcements

	All Media Model 9	Air Model 10	Water Model 11	Land Model 12	All Media Model 13	Air Model 14	Water Model 15	Land Model 16
Intercept	-6.2793 (4.711)	3.6891 (7.615)	-13.2885 (9.983)	-7.8529 (7.606)	-6.2927 (4.956)	8.0144 (8.319)	-12.0790 (10.103)	-9.8065 (7.591)
TRI, t-1	0.0631*** (0.013)	0.1547*** (0.030)	0.0738*** (0.022)	-0.0162 (0.016)	-0.2236 (0.166)	-0.3596 (0.361)	-0.2811 (0.291)	-0.3155 (0.248)
P2, t-1	0.1911 (0.128)	0.1416 (0.200)	0.2763 (0.227)	0.0604 (0.212)	5.9302** (2.556)	4.8820 (4.237)	7.6805* (4.371)	2.3936 (3.863)
Loc Gov Exp, t-1	0.2695 (0.237)	0.2383 (0.387)	0.4417 (0.448)	0.8309** (0.376)	0.4926* (0.294)	-0.0404 (0.549)	0.3902 (0.503)	0.6772* (0.382)
State Gov Exp, t-1	0.0445 (0.318)	-0.8363 (0.562)	0.8251 (0.557)	-0.1943 (0.498)	-0.1969 (0.357)	-0.9817 (0.636)	0.7428 (0.589)	0.0259 (0.517)
Sierra Club, t-1	-0.0841 (0.251)	-0.1789 (0.308)	-0.6974 (0.730)	-0.5008 (0.547)	-0.0472 (0.254)	-0.1585 (0.305)	-0.6764 (0.728)	-0.3997 (0.546)
Year P2 Adopted	-0.0924 (0.192)	0.3361 (0.371)	-0.1894 (0.315)	0.2558 (0.310)	-0.0875 (0.191)	0.3652 (0.372)	-0.1989 (0.315)	0.2731 (0.307)
State Per Cap Inc, t-1	-0.0743 (0.089)	-0.4097*** (0.152)	0.1725 (0.156)	0.0655 (0.154)	-0.0569 (0.089)	-0.3928*** (0.152)	0.1718 (0.156)	0.0947 (0.154)
Annual Mill Capacity, t-1	0.0969*** (0.031)	0.1683*** (0.059)	0.0173 (0.051)	0.1454*** (0.052)	0.1003*** (0.031)	0.1702*** (0.059)	0.0218 (0.052)	0.1565*** (0.052)
Firm Market Share, t-1	-0.0228 (0.029)	-0.0495 (0.054)	-0.0883* (0.050)	0.1362*** (0.044)	-0.0197 (0.029)	-0.0464 (0.055)	-0.0861* (0.050)	0.1456*** (0.045)
# of Paper Grades, t-1	0.1585 (0.131)	0.1437 (0.227)	-0.0496 (0.225)	0.2299 (0.198)	0.1467 (0.132)	0.1279 (0.229)	-0.0334 (0.226)	0.1460 (0.198)
Pulp Mill	-0.0994 (0.135)	0.5915*** (0.214)	-0.3003 (0.231)	-0.4278** (0.214)	-0.1089 (0.135)	0.5786*** (0.214)	-0.3053 (0.230)	-0.4264** (0.214)
Paper Mill	-0.0861 (0.118)	-0.2162 (0.212)	-0.3795* (0.202)	0.8337*** (0.187)	-0.0921 (0.118)	-0.2153 (0.211)	-0.3862* (0.202)	0.8619*** (0.188)
P2 * Loc Gov Exp, t-1					0.5840*** (0.217)	0.4198 (0.373)	0.7183* (0.408)	0.5731* (0.312)

Table 3.3. Continued

	All Media Model 9	Air Model 10	Water Model 11	Land Model 12	All Media Model 13	Air Model 14	Water Model 15	Land Model 16
P2 * State					-1.0606***	-0.8201	-1.3256**	-0.7363
Gov Exp, t-1					(0.365)	(0.599)	(0.663)	(0.533)
TRI * Loc					-0.0225	0.0159	0.0039	0.0290
Gov Exp, t-1					(0.015)	(0.034)	(0.031)	(0.023)
TRI * State					0.0463**	0.0306	0.0280	0.0002
Gov Exp, t-1					(0.022)	(0.042)	(0.043)	(0.036)
Over- dispersion	1.8812*** (0.169)	2.3276*** (0.445)	4.0696*** (0.474)	1.3941*** (0.344)	1.8402*** (0.167)	2.2670*** (0.441)	4.0064*** (0.470)	1.2632*** (0.328)
AIC	4,424.9	1,824.5	2,326.0	1,728.0	4,421.3	1,828.7	2,328.8	1,727.2
LL	-2,152.5	-856.3	-1,108.0	-808.0	-2,146.6	-854.3	-1,105.4	-803.6
N	2,908	2,771	2,771	2,810	2,908	2,771	2,771	2,810

Note: All variables, except for dummy variables, are in the log form; standard errors are reported in parentheses and ***, **, * indicate 1%, 5%, and 10% statistical significance levels, respectively.

Table 3.4. Marginal Effects of Interaction Terms

Interaction terms marginal effects	Inspections				Enforcements			
	All Media Model 5	Air Model 6	Water Model 7	Land Model 8	All Media Model 13	Air Model 14	Water Model 15	Land Model 16
TRI, t-1	0.07***	0.03**	0.07	-0.01	0.06***	0.14	0.07*	-0.02*
P2, t-1	0.05***	0.18	-0.10**	-0.06	0.20***	0.13	0.40**	0.13
Loc Gov Exp, t-1	-0.03***	-0.13***	0.16**	0.44	0.33	0.15	0.49	0.84
State Gov Exp, t-1	-0.19***	-0.54***	-0.05***	0.09	0.16**	-0.78	0.78	-0.05

Table 3.5. Models Overview: Signs and Significance

	Inspections							
	All Media Model 1	Air Model 2	Water Model 3	Land Model 4	All Media Model 5	Air Model 6	Water Model 7	Land Model 8
TRI, t-1	+ ***	+ ***	+ ***	-	- ***	-	- ***	- **
P2, t-1	+	+ **	-	-	+ ***	+	+ **	+
Local Gov Exp, t-1	+	-	+	+ *	+ *	+	+ **	+ *
State Gov Exp, t-1	- ***	- ***	-	+	- ***	- ***	- **	+
Sierra Membership, t-1	+	- *	+ *	-	-	- *	+ *	-
Year P2 Adopted	-	- *	+ **	+	+	-	+ **	+
State Per Capita Inc, t-1	+	+ **	-	+	+ ***	+ **	+	+
Annual Mill Capacity, t-1	+ ***	+ ***	+	+ ***	+ ***	+ ***	+	+ ***
Firm Market Share, t-1	+	+ ***	- ***	+ ***	+ **	+ ***	- ***	+ ***
Number of Paper Grades Produced, t-1	+	-	+	+ **	+ ***	+	+ **	+ **
Pulp Mill	-	+	- *	- ***	-	+	-	- ***
Paper Mill	+ ***	+	+ **	+ ***	+ ***	+	+ *	+ ***
P2 * Local Gov Exp, t-1					+ ***	+ **	+	+
P2 * State Gov Exp, t-1					- ***	-	- **	-
TRI * Local Gov Exp, t-1					- ***	- ***	- **	+
TRI * State Gov Exp, t-1					+ ***	+ ***	+ ***	+
Over-dispersion Parameter	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***

	Enforcements							
	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
TRI, t-1	+ ***	+ ***	+ ***	-	-	-	-	-
P2, t-1	+	+	+	+	+ **	+	+ *	+
Local Gov Expenditure, t-1	+	+	+	+ **	+ *	-	+	+ *
State Gov Expenditure, t-1	+	-	+	-	-	-	+	+
Sierra Membership, t-1	-	-	-	-	-	-	-	-

Table 3.5. Continued

	Enforcements							
	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
Year P2 Adopted	-	+	-	+	-	+	-	+
State Per Capita Inc, t-1	-	- ***	+	+	-	- ***	+	+
Annual Mill Capacity, t-1	+ ***	+ ***	+	+ ***	+ ***	+ ***	+	+ ***
Firm Market Share, t-1	-	-	- *	+ ***	-	-	- *	+ ***
Number of Paper Grades Produced, t-1	+	+	-	+	+	+	-	+
Pulp Mill	-	+ ***	-	- **	-	+ ***	-	- **
Paper Mill	-	-	- *	+ ***	-	-	- *	+ ***
P2 * Local Gov Expenditure, t-1					+ ***	+	+ *	+ *
P2 * State Gov Expenditure, t-1					- ***	-	- **	-
TRI * Local Gov Expenditure, t-1					-	+	+	+
TRI * State Gov Expenditure, t-1					+ **	+	+	+
Over-dispersion Parameter	***	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***

Note: ***, **, * indicate 1%, 5%, and 10% statistical significance levels, respectively.

other hand, is negative and statistically significant for all media and air models (Table 3.2, Models 1, 2) – 1% increase in last year’s budget on protective inspection and regulation decreases the expected count of all media and air inspections by 0.29% and 0.64%, respectively.

Moving to the other state-level variables, the Sierra Club membership and the year of P2 legislation adoption are statistically significant at 5-10% level for air and water models (Table 3.2, Models 2, 3). Both variables have the expected signs for the water model – increases in the number of people belonging to the Sierra Club and adopting P2 legislation increase the expected count of water inspections. In contrast, the two have a negative sign and are statistically significant at 10% level. Per-capita income is positive in three models – all media, air and land – and is statistically significant at 5% for air inspections – 1% increase in last year’s state per-capita income increases the expected number of air inspections by 0.09%, all else the same.

Mill’s annual capacity is positive, as expected, in all four models and highly significant (at 1% level) in all media, air and land models (Table 3.2, Models 1, 2, 4). Firm market share, on the other hand, gives statistically strong coefficients for air, water and land models, all at 1% level, but is positive in the air and land model (Table 3.2, Models 1, 4) and negative in the water model (Table 3.2, Model 3). Number of paper grades produced at a mill has statistical significance only in the land model (Table 3.2, Model 4) and is positively related to the expected count of mill inspections. Finally, whether the mill produces pulp or paper, as opposed to paperboard, makes a statistical difference only for the water and land inspections (Table 3.2, Model 3 and 4). To be more specific, producing pulp as a final product decreases the expectation of water discharged

being frequently inspected (Table 3.2, Model 3), while producing paper as a final product, increases the expected number of inspections across all media, and in water and land (Table 3.2, Model 1, 3, 4).

The introduction of the interaction terms of TRI and P2 with the local and state budgets, reverses the signs on the TRI from positive to negative in all four models and P2 from negative in the water and land models (Table 3.2, Model 3, 4) to positive (Table 3.2, Models 7, 8). Local and state budgets remained with the same signs, yet gained in statistical significance in all media and water models (Table 3.2, Models 1, 3 vs. 5, 7). The marginal effects of all media TRI at mean state and local government expenditures is 0.07%, i.e. 1% increase in mills' last year's all media TRI at mean state and local government expenditures increases the estimated count of all media inspections by 0.07% (Table 3.4, Model 5), all else constant. 1% increase in last year's P2 activities decreases this year's inspections at a mill across all media by 0.05%, *ceteris paribus* (Table 3.4, Model 5). 1% increases in last year's local and state government expenditures increase the expected count of mill inspections by -0.03% and -0.19%, respectively, *ceteris paribus* (Table 3.4, Model 5).

The signs and significance levels of the rest of the variables are not substantially affected by the addition of the interaction terms. Holding all other variables constant for each of the variables discussed below: the Sierra Club membership has a statistically significant positive effect on expected count of water inspections but significant negative effect on air inspections. State adoptions of P2 legislation increases the incidence of inspections and are statistically significant for the water model (Table 3.2, Model 7). Higher income per capita is positively related to the expected number of inspections and

in case of all media and air inspections the effect is statistically significant at 1% and 10% levels, respectively (Table 3.2, Model 5, 6). Increases in the size of mill capacity are statistically strong and positive predictors of the expected count of inspections for all media, air and land models (Table 3.2, Model 6, 8). Firm market share is statistically significant for all four models with the interacted effects and is positive for all media, air and land models (Table 3.2, Models 5, 6, 8) and negative for the water model (Table 3.2, Model 7). The number of paper products produced at a mill have positive signs and are statistically significant for all but the air inspections (Table 3.2, Model 6). Surprisingly, pulp mills have lower expected count of inspections than paperboard mills, yet this effect is statistically insignificant (except for the land model, Table 3.2, Models 5, 6, 7 vs. Model 8). And as expected, mills that produce paper, as opposed to paperboard products, are expected to be inspected more frequently at statistically significant levels, 1% and 10% levels in all media, water and land models (Table 3.2, Models 5, 7, 8).

Enforcements Models

Looking at models results that predict the expected number of regulatory enforcements (Table 3.3), I notice in general the same pattern of signs yet much lower statistical significance than that for inspections. First, the TRI variable in the four basic models (Table 3.3, Models 9 through 12), is statistically highly significant for all media, air and water models and negative and statistically insignificant for the land model. The P2 variable is statistically insignificant across all models. Local spending on protection and inspection is positive across all four models and statistically significant at 5% and 10% levels for the land models (Table 3.3, Models 12, 16, respectively). State budget, on the other hand, is positive for all media and water and negative for air and land models.

The Sierra Club membership and P2 coefficients are statistically insignificant for all four basic models. Per-capita income is negative for all media and air and statistically significant at 1% level for the air model – 1% increase in last year’s state per-capita income decreases the expected count of enforcements by 0.41%, *ceteris paribus* (Table 3.3, Models 10, 14). Mill capacity is statistically significant for all media, air, and land enforcements, while firm market share keeps its statistical power only in the water and land enforcements model while being negative for water (Table 3.3, Models 11, 15) and positive for land models (Table 3.3, Models 12, 16). The number of paper grades produced is positive for all but water models, yet insignificant across all eight model specifications of enforcements. Finally, pulp mills face higher expected frequencies of air enforcements (Table 3.3, Models 10, 14) and lower land enforcements (Table 3.3, Models 12, 16), while paper mills have lower expected counts of water inspections (Table 3.3, Models 11, 15) and higher number of land inspections (Table 3.3, Models 12, 16).

3.7.Discussion

In both sets of models, inspections and enforcements, it is clear that combining the three pollution source media together into one category obscures a number of prominent differences within the models results. When looking at the three media models separately, I find that, on the one hand, the parameter estimates for air and water are statistically more significant than for the land models, suggesting that the two media enjoy greater political and regulatory salience. On the other hand, the signs appear to be more consistent between the air and land models in opposition to the water models.

Pollution abatement measured by the TRI demonstrates expected and consistent performance through all the models, confirming Hypothesis 2. While anticipated to be negatively related to the expected number of inspections, as stated in Hypothesis 1, P2 is positive and significant. The result suggests that implementing P2 activities at mills does not necessarily signal to the regulators that the mill is in full compliance and, in effect, may suggest that the mill is a high polluter and/or that that P2 activities are not a sufficient measure of the voluntary abatement efforts at mills. In this light, the TRI is a stronger determinant of regulatory actions, both inspections and enforcements, while P2 is a statistically significant factor for air and water enforcements. The results confirm the Hypothesis 1, but not Hypothesis 2, that regulators respond to the voluntary abatement performance of the mills in determining the level of scrutiny to levy on the mills. Additionally, the hypothesis that regulators are driven by numerical targets is strongly supported by the TRI coefficients.⁹³

State government expenditures, in contrast, surprise with negative coefficients through most of the models with the exception of the land models, where they are positively related to the number of inspections and enforcements (Hypotheses 3 and 4). This counter-intuitive result is further confirmed with the introduction of the interactive terms (Hypothesis 5) – given the average levels of TRI and P2, state government

⁹³ To test if TRI and P2 are endogenous due to the omitted quality of mill management, I ran preliminary endogeneity tests. The general results are reported in Appendix B under section B1. Preliminary Endogeneity Checks. In general, I fail to reject the null of exogeneity for the joint hypothesis for TRI and P2 in both inspections and enforcement models. When testing both variables individually, I fail to reject the null of no endogeneity for P2 in both inspections and enforcements, but not for TRI. This suggests that P2 activities present as a more robust measure of voluntary environmental stewardship, hence management, than the TRI.

expenditures are consistently negatively associated with the regulatory inspections (except for land, Table 3.2, Model 8 and water and land, Table 3.3, Models 15 and 16, respectively). Increases in local government expenditures, on the other hand, increase the expected count of water and land inspections, but decrease for air inspections, assuming average TRI and P2 (Models 3, 4 in Table 3.2 and Models 7 and 8 in Table 3.4). Further, examining the direction and statistical power of the interacted coefficients (Hypothesis 5), it is noted that P2 interacted with the local budget has a positive and statistically strong effect, while when interacted with the state budget it is negative and statistically strong. Same can be said about the TRI measure interacted with the state and local budget – it is negative when interacted with the local government expenditure and positive when interacted with the state government expenditure. These two directly opposite results suggest that the two budgets may constrain regulatory scrutiny along different abatement efforts, as represented by TRI and P2 activities.

Political activism, articulated in Hypothesis 6 and measured by the Sierra Club membership, has a statistically significant positive effect in the water models and a statistically significant negative effect in air models. The year of adoption of P2 legislation (Hypothesis 7) follows the same pattern – negative for air, positive for water and both statistically significant. These inconsistent, yet significant results suggest that the Sierra Club membership and adoption of P2 legislation could be picking up some other influences which impact air and water regulations in the opposite ways. It is possible that the direct costs of air vs. water monitoring and enforcement differ due to the nature of emissions in the two media. One could hypothesize that water effluents are easier to monitor and enforce, hence are associated with lower enforcement costs, and

that water pollution resulting from pulping and papermaking facilities is politically more salient because the affected waterways are directly used as sources of drinking water.⁹⁴

On the other hand, air pollution monitoring and enforcement could be more costly because of the nature of ambient air pollution and because the associated health risks are more difficult to quantify due to the hard-to-measure actual pollutant exposure. Finally, air pollutant immediate exposure depends not only proximate location, but also on people's age and associated activities, such as commuting patterns.^{95,96}

Income per capita (Hypothesis 8) is positive and statistically significant for the models across all pollution media and air inspections, but negative and highly statistically significant for air enforcements. The change in signs in the income measure from inspections to enforcements for the air models further points to the possibility of bias associated with the omitted costs related to enforcement efforts, which one would expect to be substantially higher than monitoring/inspection costs.

⁹⁴ Pulp and paper mills generate large volumes of wastewater, which can contain chlorinated and sulfur compounds, volatile organic and other chemicals. In response to the 1981 EPA finding confirming that dioxin was one of the most potent carcinogens, litigious concerns arose around paper mills' discharge of chlorinated organic compounds such as dioxins and furans, often referred to as adsorbable organic halides (Powell 1997).

⁹⁵ Air pollution from pulp and paper mills is not as politically salient as water pollution due to lower concentrations and potentially less direct health risks associated with the air pollutants from pulping and papermaking processes. The largest part of air emissions from paper mills are water vapors that are the result of the paper drying process (UN 1996). In the recent years, however, the air emissions from the mills that employ kraft manufacturing processes and generate a lot of their own energy have been attracting more media attention due to their greenhouse gas emissions (Schlossberg 2012).

⁹⁶ There is large literature analyzing the risks associated with pollution as well as unequal distribution of environmental regulation across different neighborhoods and population groups. More recently, a number of articles estimate the differences in risks associated with different air pollution concentrations and hot spots (Logue et al. 2011; Turaga et al. 2011).

Bigger mills attract regulatory attention through all the media sources (Hypothesis 10). Market leaders are inspected routinely more than followers within the air and land media and significantly less in water medium (Hypothesis 9). Additionally, the negative sign of the pulp dummy variable in the water and land models is perplexing given the expectation that pulp production process is chemically ‘dirtier’ and involves extensive water treatment (Hypothesis 12). On the other hand, this result is consistent with Levinson (1996) and Gray and Shadbegian (1998) who find that due to their age many pulp mills are unable to drastically reduce their emissions and discharges and enjoy grandfathering rules that allow them to stay in business.

3.8. Conclusion

The purpose of this analysis was to investigate the impact of (i) voluntary pollution abatement and prevention efforts at the U.S. pulp and paper mills and (ii) local and state protective and inspection government expenditures on the level of scrutiny levied by the regulators. More specifically, I tested the hypotheses of ‘responsive regulation,’ first advanced by Maxwell and Decker (2006) and Decker (2007), and further examined whether the regulation climate could be characterized, as suggested by Heyes and Kapur (2009), as being motivated by numerical pollution targets or size of regulators’ budgets. In addition, I have explored the role of political and consumer pressure, measured by the Sierra Club membership and state per capital income, and mill and firm heterogeneity on the number of regulatory inspections and enforcements.

This paper contributes to the empirical body of literature on ‘responsive regulation’ by testing if regulatory actions are determined by environmental firm

performance and/or regulatory budget expenditures. While the pioneering works analyzed the effect of TRI on the count of regulatory inspections, I included regulatory inspections and enforcements and in addition to the TRI, I integrated the number of mill-level P2 activities as the second measure of voluntary pollution abatement efforts. I also included two measures of government expenditures, at local and state levels. To contribute to the studies on the pulp and paper industry, which focus on either air or water pollution, I include all three pollution vectors – air, water, and land – as well as the combined category. The disaggregated results display better model performance than when the three media are combined together. Finally, P2 legislation also has not been examined in this context previously.

Informing relevant policy implications, the main findings suggest that regulators are driven by numerical pollution targets and not budgetary constraints. Grass-roots environmental activism has greater impact for water inspections, while state residents' willingness to pay affects the expected count of air inspections. Finally, bigger mills attract regulatory attention through all the media sources and market leaders are inspected more frequently than followers within the air and land media.

CHAPTER 4

ESSAY 3: POLICY INSTRUMENTS AND ADOPTION OF POLLUTION PREVENTION

ACTIVITIES

Abstract

The main purpose of this study is to analyze the relationship between pollution prevention (P2) policy instruments and adoption of P2 modifications. Using facility level data on U.S. pulp and paper mills for 1991-2002, I estimate the fixed effects negative binomial model to test the hypotheses of whether P2 state legislation and policies on target setting, reporting requirement, mandatory planning, and grants have positive impact on P2 adoptions: (1) when they are grouped together and (2) when combined in two categories: (a) management and logistical modifications or (b) product and process. In addition, I examine the effects of regulatory and political threats, P2 firm spillovers and prior mill experience with P2 modifications, firm and mill size, and type of mill product. I find that: (1) policy instruments have different effects on the two groups of P2 modifications, (2) mandatory planning and grants have perverse results, (3) regulatory and political threats, firm spillover and prior mill experience are strong predictors of P2 adoptions, and (4) there are substantial diseconomies of scale associated with P2 modifications. To contribute to previous research, I examine the impact of each P2 policy instrument individually and include state P2 grants.

4.1.Introduction: What Are P2 Activities and Why Are They Interesting?

Pollution prevention activities, or P2s, are every-day procedural and operational measures taken at individual production facilities and aimed at reducing pollution by minimizing waste, spills, and leaks. In contrast to end-of-pipe pollution abatement measures, they are less costly in terms of capital, technological, and personnel investments.⁹⁷ P2s arose in response to the National Pollution Prevention Act of 1990 which called on industry to prevent pollution ‘whenever feasible’ and included 43 types of pollution prevention activities subdivided into eight broader categories: (1) operating practices, (2) inventory control, (3) spill and leak prevention, (4) raw-material modifications, (5) process modifications, (6) cleaning and degreasing modifications, (7) surface preparations and finishing modifications, and (8) product modifications. Table 4.1 reports the detailed list of P2 activity codes and descriptions.

Table 4.1. P2 Codes and Activity Descriptions

Operating Practices
Improved maintenance scheduling recordkeeping or procedures
Changed production schedule to minimize equipment and feedstock changeovers
Introduced an in-line product quality monitoring or other process analysis system
Other changes in operating practices

⁹⁷ The U.S. Environmental Protection Agency (EPA) defines pollution prevention (P2) as “reducing or eliminating waste at the source by modifying production, the use of less-toxic substances, better conservation techniques, and re-use of materials” (EPA, Pollution Prevention, Basic Information: <http://www.epa.gov/p2/pubs/basic.htm>).

Table 4.1. Continued

Inventory Control
Instituted procedures to ensure that materials do not stay in inventory beyond
Began to test outdated material - continue to use if still effective
Eliminated shelf-life requirements for stable materials
Instituted better labeling procedures
Instituted clearinghouse to exchange materials that would otherwise be discarded
Other changes in inventory control
Spill and Leak Prevention
Improved storage or stacking procedures
Improved procedures for loading unloading and transfer operations
Installed overflow alarms or automatic shutoff valves
Installed vapor recovery systems
Implemented inspection or monitoring program of potential spill or leak sources
Other spill or leak prevention
Raw-material Modifications
Increased purity or raw materials
Substituted raw materials
Substituted a feedstock or reagent chemical with a different chemical
Other raw material modifications
Process Modifications
Optimized reaction conditions or otherwise increased efficiency of synthesis
Instituted recirculation within a process
Modified equipment layout or piping
Use of a different process catalyst
Instituted better controls on operating bulk containers to minimize discarding
Changed from small volume containers to bulk containers to minimize discarding
Reduced or eliminated use of an organic solvent
Used biotechnology in manufacturing process
Other process modifications

Table 4.1. Continued

Cleaning and Degreasing Modifications
Modified stripping/cleaning equipment
Changed to mechanical stripping/cleaning devices (from solvents or other
Changed to aqueous cleaners (from solvents or other materials)
Modified containment procedures for cleaning units
Improved draining procedures
Redesigned parts racks to reduce dragout
Modified or installed rinse systems
Improved rinse equipment design
Improved rinse equipment operation
Other cleaning and degreasing modifications
Surface Preparation and Finishing Modifications
Modified spray systems or equipment
Substituted coating materials used
Improved application techniques
Changed from spray to other system
Other surface preparation and finishing modifications
Product Modifications
Changed product specifications
Modified design or composition of product
Modified packaging
Developed a new chemical product to replace previous chemical product
Other product modifications
<i>Source: EPA (2015): http://www.epa.gov/p2/pubs/basic.htm.</i>

Encouraged by P2 Legislation

Pollution prevention programs are, by definition, voluntary or quasi-regulatory programs that do not require a change in polluting behavior, but may require other types of actions, such as submitting reports under Toxic Release Inventory (TRI) disclosure

requirements.⁹⁸ As such, the P2 policies represent the newer form of environmental policies, which have evolved from top-down command regulations, to market-based incentives, to voluntary pollution and waste prevention and reduction programs that are more broadly termed as voluntary environmental programs (VEPs).

In contrast to command-and-control policies, P2 legislation is characterized as a soft policy that encourages information sharing, numerical targeting, and mandatory planning, all of which are designed to appeal to the wide scope of the P2 activities. Since 1990, 36 states adopted P2 programs, prescribing varying combinations of regulatory-, information-, and management-based policies (Harrington 2013). Table 4.2 lists the history of state adoptions of P2 and complementary policies to P2 policies, specifically: (1) numerical goal of specific percentage reduction (adopted in 12 out of 36 states), (2)

⁹⁸ P2 activities are voluntary to adopt, yet facilities are mandated to file reports of any pollution prevention modifications for chemicals reported under the TRI and to submit plans to implement new P2s for hazardous waste. More specifically, paragraph 13106 of Pollution Prevention Act of 1990, entitled "Source reduction and recycling data collection," defines reporting requirement as: "Each owner or operator of a facility required to file an annual toxic chemical release form under section 11023 of this title for any toxic chemical shall include with each such annual filing a toxic chemical source reduction and recycling report for the proceeding (FOOTNOTE 1) calendar year. The toxic chemical source reduction and recycling report shall cover each toxic chemical required to be reported in the annual toxic chemical release form filed by the owner or operator under section 11023(c) of this title. This section shall take effect with the annual report filed under section 11023 of this title for the first full calendar year beginning after November 5, 1990. (FOOTNOTE 1) The copy of Pollution Prevention Act of 1990 can be found at: <http://www.epa.gov/p2/pubs/p2policy/act1990.htm>. In relation to mandatory planning, the report prepared by Research Triangle Institute for EPA, Office of Air Quality emphasizes that many states have introduced the requirement that specific industries prepare facility P2 plans. These plans, however, are not required to be implemented. The motivation for this rule is that when firms are forced to evaluate as many of P2 options as possible, they are a lot more likely to discover potential money-saving and waste-reducing opportunities and will be more open to implementing them. The report can be downloaded from: <http://www.epa.gov/airquality/permits/memoranda/permits.pdf>.

required reporting of environmental performance measures (adopted in 18 states), and (3) management-based regulations that require facilities to develop P2 plans identifying problems, targets and solutions to their pollution concerns (adopted in 14 states).

Table 4.2. History of P2 Program Legislation and Policy Instruments

State	Year of P2 Legislation	Regulatory Policy: Numerical Goal	Information-Based Policy: Reporting Requirement	Management-Based Regulation: Mandatory Planning
AK	1990			
AL				
AR	1993			
AZ	1991	√ (1993)	√	√
CA	1989	√ (1993)	√	√ (2007)
CO	1992			
CT	1991			
DC				
DE	1990	√ (1992)		
FL	1991			
GA	1990		√	√ (1993)
HI				
IA	1989	√ (1994)		
ID				
IL	1989		√ (1992)	
IN	1990			
KS				
KY	1988	√ (1997)		
LA	1992		√	
MA	1989	√ (1997)	√ (1991)	√ (1994)
MD				
ME	1990	√ (1994)	√ (2000)	√ (2000)
MI	1994			
MN	1990		√ (1992)	√ (1991)
MO	1990	√ (1998)		
MS	1990	√	√	√
MT	1995			
NC				
ND				
NE	1992			

Table 4.2. Continued

State	Year of P2 Legislation	Regulatory Policy: Numerical Goal	Information-Based Policy: Reporting Requirement	Management-Based Regulation: Mandatory Planning
NH	1996			
NJ	1991	√ (1996)	√	√
NM				
NV				
NY	1990	√ (2000)	√	√
OH	1992		√	
OK	1994			
OR	1989		√	√
PA				
RI				
SC				
SD	1992		√	
TN	1991		√	√
TX	1991		√	√
UT				
VA	1994			
VT	1990		√ (1992)	√ (1992)
WA	1988	√ (1995)	√	√
WI	1989			
WV	1998			
WY				

Source: Policy adoption years can be found in Ramirez Harrington, D. (2013). "Effectiveness of State Pollution Prevention Programs and Policies." *Contemporary Economic Policy* 31(2): p. 258.

P2s as Soft Technologies

It is not clear how P2 activities should be classified within the mainstream literature on technology innovation. The typical taxonomy characterizes technology innovations as: (1) product and/or service innovations, (2) process innovations, including new practices or delivery, (3) organizational innovations such as changes in management structure, methods and information management, and (4) marketing innovations (Youtie et al. 2006, OECD 1997). P2s are clearly not new products, hardware technologies or machines, and

they are not new management or marketing methods. However, the application of P2s spans across all stages of modern industrial systems, from inventory control and administrative book-keeping to equipment maintenance, and production process and product modifications. Given that P2s are a set of every-day hands-on managerial and production practices, they can be classified as active experiential knowledge, or applied know-how. And in spite of being spread out across all administrative and manufacturing operations, P2 activities fit into a narrow niche of technology innovations referred to as soft technologies.

P2s Are Also Strategic Tools

The progression of environmental policies from command-and-control regimes to voluntary corporate self-regulation became possible with the recognition on the part of the regulated industries that voluntary programs can help reduce long-term compliance costs, rebrand their public image, and enhance their long-term competitiveness. This recognition is first marked by the establishment of the World Business Council for Sustainable Development at the 1992 Rio Earth Summit and subsequent emergence of the ISO 14001 environmental management system (EMS) leading the way to the bigger movement towards programs aimed at voluntary environmental self-regulation (Koehler 2007). The movement has been corroborated by numerous researchers who examined the nature and dynamics of corporate self-regulation, both theoretically and empirically (Maxwell et al. 2000; Decker 2005; Maxwell and Decker 2006; Decker 2007; Koehler 2007; Khanna et al. 2009; Harrington 2012; Harrington 2013).

Contribution of This Paper

The contribution of this study is to shed further light on the effectiveness of policy and policy tools that encourage the adoption of P2 activities as well as other determinants identified in the previous literature. P2 activities present an interesting subject of investigation because they are voluntary to adopt and because they are accompanied by narrowly-defined state legislation and by a number of policy tools encouraging adoption of as many P2 activities as possible across entire production systems. I am interested in looking at whether the given policy instruments and financial assistance in the form of state P2 grants are effective: (1) for all P2 activities as well as (2) for specific P2 activity groups related to either (a) management and logistical modifications or (b) product and process.

Because of their unique definition as soft technologies, or applied knowledge skills directed at reducing and preventing production-related pollution, P2s exhibit the characteristics of knowledge-based technology innovations and are influenced by prior experience and knowledge spillovers. Given this definition, policy instruments and financial assistance aimed at information sharing may be more effective at encouraging P2 adoptions. The effect, however, may not be the same across different groups of P2 activities, with information sharing having greater effect on P2 activities related to management and logistical practices than on product and process modifications. Hence, this study focuses on the impact of the different P2 policy tools and grants on: (1) all P2 adoptions and (2) adoptions across different P2 categories.

In the previous literature, Khanna et al. 2009 have focused only on the mandatory component of P2 policy combining them in one variable⁹⁹. Harrington (2013) studied the effect of P2 legislation and three P2 policy tools – numerical goal, reporting requirement and mandatory planning – but, both Khanna et al. (2009) and Harrington (2013) focused on adoption of all P2 activities. In contrast, Harrington (2012) examined the impact of P2 policy and other variables on P2 activities disaggregated into three groups, but included only one policy instrument – mandatory planning. All the three works presented cross-industry examinations. The impact of awarded P2 grants has not yet been studied.

4.2.Literature and Hypotheses

Environmental Policy and Technology Innovations

Jaffe et al. (2002) and Koehler (2007) reviewed the literature on the dynamic relationship between: (1) environmental policy and firm environmental innovations and (2) environmental policy and firms' participation in voluntary environmental programs. Despite the fact that the two articles summarize the literature within two different methodological paradigms – environmental economics and policy program evaluation and analysis – both raise a number of the same unanswered research questions. The key question, at which the two authors arrive is, more broadly how environmental policy instruments affect the adoption and diffusion of environmental technologies.¹⁰⁰ This

⁹⁹ The authors do not specify whether they used the year of adoption of P2 legislation or if they used specific policy instruments.

¹⁰⁰ Jaffe et al. (2002): "How do environmental policy instruments that implicitly or explicitly increase the economic incentive to reduce emissions affect the diffusion rate of those technologies?" p. 48. Similarly, Koehler (2007): "With the exception of theoretical work (Lyon & Maxwell, 2004), very little is known about the interplay between market

study examines the impact of environmental policy directed at voluntary pollution prevention practices and other market pressures, and the effectiveness of individual policy instruments resulting in the number of pollution prevention activities undertaken at pulp and paper mills.

Corporate Environmentalism and Voluntary Pollution Abatement

Building on Becker (1983), Stigler (1971), and Peltzman (1976), Maxwell et al. (2000) formalized firms' strategic self-regulation that preempted political and government action. Following Becker's (1983) proposition that regulation is a result of political pressure between consumers and producers, and assuming organization and policy influencing costs on the part of the lobbying parties, the authors built a three-stage game theoretic model, in which when faced with increased threat of political pressure and regulation, firms choose to preemptively decrease their pollution levels and over-comply. The authors tested the proposition of corporate self-regulation with empirical analyses confirming the hypothesis that increased threat of regulation, measured by membership in conservation groups, induced firms to reduce toxic releases.

Khanna et al. (2009) and Harrington (2012, 2013) continued the empirical discourse by examining the role of regulatory and political threats on voluntary pollution abatement efforts. Specifically, Khanna et al. (2009) found that the threat of anticipated regulations is important in adoption of voluntary pollution prevention, or P2, programs.

and regulatory pressures on adoption and action under a VEP. For example, if regulation is anticipated, does firm resistance increase or decrease after joining the associated VEP? Even less is known about the actual effectiveness of various program design elements intended to motivate participation and action," p. 690.

Examining the role of previous inspections and penalties on the adoption of P2 programs, Harrington (2012, 2013) found mixed results. In the earlier article, the author found that the facilities that are exposed to greater threat of enforcement action find a limited scope for P2 in achieving environmental compliance objectives; in her later article Harrington (2013) found past inspections to be a credible threat to firms and a good predictor of the P2 adoptions. In addition, Harrington (2012) tested whether P2 legislation and other market factors had varying impact across different P2 groups, yet out of all P2 policy tools, she included only mandatory planning. Following Harrington (2012, 2013) and using the data on state P2 program legislation and policy instruments provided in Harrington (2013), the set of hypotheses is proposed in the following section.

Hypotheses

The main purpose of this study is to examine the extent to which (1) P2 legislation and policy instruments, (2) threat of regulatory action and political pressure, and (3) previous experience with P2 technologies and external P2 spillovers – impact mill behavior in relation to its choice to adopt pollution prevention technologies and if the three groups of factors have different effects across different P2 categories. More broadly, I hypothesize that environmental policy instruments that are focused on practical day-to-day technology recommendations and that can be easily implemented at individual plants without extensive training and other resource expenditure can be as effective as mandated regulations in impacting a firm's pollution abatement technology adoption.¹⁰¹

¹⁰¹ For a more detailed discussion of the literature of relative effectiveness of regulatory command-and-control vs. market-based approaches, see Jaffe et al (2002).

P2 Legislation, Policy Instruments, and Grants

Hypothesis 1: The following P2 policy instruments are hypothesized to have a positive effect on P2 adoptions: (1) year of state adoption of P2 legislation, (2) year of state adoption of the numerical goal for pollution reduction, (3) year of state adoption of the mandatory information disclosure policy as a reporting requirement, (4) year of state adoption of management-based policy as mandatory P2 activity planning, and (5) P2 grant amounts.

In addition to these hypotheses, I expect that (3.a) year of state adoption of the reporting requirement will have greater positive impact on the expected count of input and procedural P2 modifications, which are aimed at administrative operations such as inventory and raw materials management, than on product and process modifications. Similarly, I expect that (4.a) year of state adoption of mandatory planning may have different effects on the two groups of P2 modifications. Finally, I expect that (5.a) the annual P2 grants awarded to state and local government agencies, private businesses, nonprofits and universities and geared towards information- and expertise-sharing, or towards generating positive external information spillovers, will have a positive effect on the P2 adoptions among pulp and paper mills.

According to Harrington (2013), state legislated environmental programs help mills adopt environmental technology and reduce pollution through: (1) information sharing, thus decreased transaction costs of technology adoption and (2) increased public visibility and credibility of the regulating agencies. Studies on the effectiveness of using numerical targets, such as numerical goal for pollution reduction, in environmental enforcement are inconclusive. On one hand, Jaffe and Stavins (1995) find that legislating state mandatory building codes did not improve building practices on energy efficiency.

On the other hand, Lanoie et al. (1998) found that more facility-specific, thus more stringent, emission level requirements can be effective in lowering effluent emissions at Ontario pulp and paper mills.

The effectiveness of information disclosure mandates, that are similar to mandatory P2 reporting requirements, has been extensively documented in the empirical literature. Many studies discuss the impact of information disclosure policy under the TRI regulations on reducing emissions directly as well as indirectly by means of increasing pressure of grass-root organizations and stock market reactions (Khanna et al. 1998, Khanna and Damon 1999, and Decker 2005). Similarly, Delmas et al. (2010) find that mandating disclosure of fuel mix in the electricity industry resulted in lowered use of fossil fuels and increases the use in clean fuels.

A number of recent studies, as reviewed by Harrington (2013), document the effectiveness of management-based programs, comparable to management-based P2 planning, at improving firms' environmental performance (Khanna et al. 2009, Arimura et al. 2008, Khanna and Anton 2002, Dasgupta et al. 2000, Henriques and Sadorsky, 1996). Anton et al. (2004) found that more comprehensive environmental management systems (EMS) lead to lower toxic emissions per unit output and decrease offsite transfers and onsite releases. Bannear (2007) found that in states with mandatory planning programs, referred to as management-based regulations or MBRs, facilities engaged in greater number of source-reduction activities and lowered their TRI. Further, Khanna et al. (2009) demonstrated that Total Quality Environmental Management promoted P2 adoptions. Finally, as suggested in Anton et al. (2004), financial assistance for state technical know-how programs is hypothesized to reduce the aforementioned

transaction costs associated with P2 program knowledge acquisition and technological adaptation of it to specific facilities and their production processes.

Regulatory Threat and Political Pressure

Hypothesis 2: Increases in annual TRI will increase the expected count of P2 adoptions at pulp and paper mills. Increases in regulatory stringency, measured by the total number of inspections and enforcements, will increase the expected count of P2 adoptions at pulp and paper mills. Increases in the number of members in environmental organizations will increase the expected count of P2 adoptions at pulp and paper mills. Finally, increases in income per capita, measuring willingness to pay for higher environmental quality, are expected to increase the expected count of P2 adoptions at pulp and paper mills.

With higher levels of TRI, mills are expected to face higher threat of regulation and will have greater incentives to adopt P2 activities. Examining the role of previous inspections and penalties on the adoption of P2 programs, Harrington (2012, 2013) found mixed results. Harrington (2012) found that those facilities that are exposed to greater threat of enforcement action find a limited scope for P2 in achieving environmental compliance objectives. In her later article Harrington (2013) found past inspections to be a credible threat to firms and good predictors of P2 adoptions. In addition, Harrington (2012) corroborated the previous literature that regulatory pressure: (1) reduces facility pollution levels (Khanna and Damon 1999, Vidovic and Khanna 2007, and Brouhle et al. 2009), (2) encourages participation in voluntary environmental programs (Brouhle and Harrington 2010, Brouhle et al. 2009, Sam et al. 2009, Innes and Sam 2008, Vidovic and Khanna 2007, King and Lenox 2000, Khanna and Damon 1999, Arora and Cason 1995),

and (3) promotes environmental technology innovations (Khanna et al. 2009, Brunnermeier and Cohen 2003, Gray and Shadbegian 1998, Jaffe and Palmer 1997).

The game-theoretical works of Maxwell and Decker (2006) and Decker (2007) emphasized the importance of regulators' reputation and credibility, or credible regulatory threats, in decision to comply or over-comply in order to signal their progressive environmental performance and, as a result, face reduced regulatory stringency. Khanna et al. (2009) found that the threat of anticipated regulations is important in adopting of voluntary pollution prevention programs, thereby supporting Maxwell's et al. (2000) propositions of corporate self-regulation in which voluntary abatement is explained by increases in threat of state and/or government regulations.

In relation to political pressure, Maxwell et al. (2000), Maxwell and Decker (2006), Khanna et al. (2009), Harrington (2012) demonstrate that membership in environmental conservation groups, or "green" membership, is an effective measure of political pressure that increases the threat of regulatory oversight and enforcement. Recently, Matisoff and Edwards (2014) show that a state's environmental group membership, namely the Sierra Club membership, is an important determinant of state adoption of energy and climate-change policies. I hypothesize that political pressure will increase the expected count of mill-level P2 adoptions.

Finally, to gauge how state political climate affects firms' decisions to implement P2 activities and following the theoretical propositions of Maxwell et al. (2000), Decker (2005), and Harrington (2012, 2013), I hypothesize that environmental quality is a normal good and increases in income will increase the demand for higher quality of environment. More specifically, Maxwell et al. (2000) include income per capita with

the expectation that it will capture increased demand for pollution abatement. Decker (2005) includes county median income to measure local affluence and positing that wealthier areas will demand higher quality environment and will exhibit political pressure for stricter environmental monitoring. Finally, Harrington (2012, 2013) employed median household income to approximate localized benefits from stricter environmental regulations. Following these works, I hypothesize that political attitudes are expected to influence environmental mill performance and the incidence of P2 adoptions.

Internal Mill Experience and Firm P2 Spillovers

Hypothesis 3: Mills with greater previous experience with P2 technology adoptions face lower costs of such technology adoptions and are expected to have a greater number of new P2 counts. Similarly, cumulative experience with P2 technology adoptions at sister mills of the same parent firm are hypothesized to increase the expected count of mill's new P2 adoptions.

Jaffe et al. (2002) provide extensive review of theoretical and empirical literature examining the relationship of environmental policy and technological change. Increasing returns in the form of learning effects and reduction in the pollution abatement costs via learning-by-doing, according to Goulder and Mathai (2000), affect policy-induced innovation and resultant pollution abatement. Additionally, Jaffe (1986), Griliches (1992), and Jaffe (1998) discuss the importance of external information and knowledge spillovers, be it within firm or intra-firm know-how.

Firm and Mill Characteristics

Hypothesis 4: Changes in the number of mills per firm are expected to impact the expected count of P2 adoptions at pulp and paper mills. Increases in mill annual capacity will increase the expected count of P2 adoptions at pulp and paper mills. Finally, pulp and paper mills are expected to have higher expected count of P2 adoptions than paperboard mills.

Decker and Wohar (2006), Delmas and Toffel (2008), Khanna et al. (2009), and Minatti Ferreira et al. (2014) proposed that large corporations and market leaders have greater ability to adjust to the changes in the regulatory climate, create legal and environmental stewardship departments, and institute environmental programs with permanent and well-trained technical personnel to oversee the environmental performance at their firms and decrease compliance and liability costs. On the other hand, size of firm could mean higher transactions costs associated with disseminating P2 knowledge and experience. In light of these stipulations, I do not provide hypotheses on the direction of the effect of the size of the parent firm.

In connection to Nadeau's (1997) and Decker's (2005) argument that larger production facilities face greater number of inspections due to the scale of production and, therefore, releases, I expect that larger mills will have a higher rate of P2 adoptions than smaller mills. Finally, Nadeau (1997) and Minatti Ferreira et al. (2014) found that mills involving kraft and bleaching technology, or those with pulping technologies, face greater regulatory scrutiny and have greater incentive to implement P2 activities.

4.3. Empirical Model and Data

The empirical framework discussed in this section examines the relationship between the measure of voluntary pollution prevention technology adoption at mill level, state P2 program legislation and its policy instruments, regulatory threat and threat of political action, mill's previous experience with P2 technology adoption, and spillovers of within-firm P2 experience. Following is the functional form of the empirical model of this study with the dependent variable as the counts of new P2 activities at mill i in state s at time t :

$$(1) \ P2_{it} = \beta_1 P2_{st-1} + \beta_2 P2NGoal_{it-1} + \beta_3 P2reporting_{it-1} + \\ + \beta_4 P2Planning_{it-1} + \beta_5 P2Grants_{st-1} + \beta_6 TRI_{it-1} + \beta_7 Inspections_{it-1} \\ + \beta_8 Enforcements_{it-1} + \beta_9 Sierra_{st-1} + \beta_{10} PerCapInc_{st-1} + \\ + \beta_{11} FirmP2Spillover_{it-1} + \beta_{12} CumulativeP2_{it-1} + \beta_{13} MillsPerFirm_{it-1} + \\ + \beta_{14} MillCap_{it-1} + \beta_{15} PulpMill_{st} + \beta_{16} PaperMill_{st} + \delta_i + \rho_t + e_{it}.$$

Other state variables include annual state P2 grants, the Sierra Club membership approximating the state environmental political engagement, and income per capita measuring citizens' ability to pay for environmental quality of life. Other mill-level variables are number of mills per firm, annual mill capacity in thousand short tons, and whether the mill produces pulp, paper or paperboard. Table 4.3 provides the descriptive statistics for all variables.

EPA Data: P2 Activities, Cumulative P2, Spillovers, and Regulatory Threat

The dependent variables – the new P2 counts and regulatory threat variables: (1) TRI, (2) ECHO inspections, and (3) ECHO enforcements – come from the EPA. The data for this

study consist of the sample of 9,441 pulp, paper, and paperboard facilities that have reported at least one P2 activity during 1988-2002 and have been downloaded using TRI.EZ search tool from the TRI database Envirofacts.¹⁰² The dependent variable is the sum of all new P2 activities reported at the mill level. The TRI stipulates that each facility is allowed to report no more than four P2 activities within one of the 43

Table 4.3. Descriptive Statistics

Variable	Expected Sign	MEAN	SD
Number of New P2 Activities	N/A	0.49	1.11
Group 1 P2: Number of New Input and Procedural Modifications	N/A	0.32	0.82
Group 2 P2: Number of New Process, Equipment, and Product Modifications	N/A	0.16	0.51
Year P2 Adopted, 1 if Adopted	+	0.76	0.43
Year P2 Adopted, Numerical Goal, 1 if Adopted	+	0.10	0.30
Year P2 Adopted, Reporting Requirement, 1 if Adopted	+	0.41	0.49
Year P2 Adopted, Mandatory Planning, 1 if Adopted	+	0.34	0.47
P2 State Grant Budget, 1990 Dollars	+	8.72	5.02
Mill TRI, Pounds	+/-	10.04	5.34
Mill Inspections, Number	+	0.79	0.73
Mill Enforcements, Number	+	0.11	0.36
Sierra Membership, Number	+	9.07	0.86
State Per Capita Income, Thousand 1990 Dollars	+	1.44	1.01
Firm Spillover P2, Number of Firm P2	+	0.64	0.81
Mill Cumulative P2, Number	+	0.74	0.98
Mill Cumulative Group 1 P2, Number	+	0.51	0.82
Mill Cumulative Group 2 P2, Number	+	0.32	0.60
Number of Mills per Firm, Number	+	1.85	1.15
Annual Mill Capacity, Thousand Short Tons	+/-	4.56	2.09
Board Mill, 1 if Board Mill, Reference Category	N/A	0.38	0.48
Pulp Mill, 1 if Pulp Mill	+	0.15	0.36
Paper Mill, 1 if Paper Mill	+	0.59	0.49

Note: N = 2,409. All variables, except for dummy, are in the log form and lagged one year.

¹⁰² The TRI.EZ search tool is available at: <http://www.epa.gov/enviro/facts/tri/ez.html>.

categories (Table 4.1).¹⁰³ To disaggregate all P2 activities into categories, I have grouped the total eight categories into two. The first one consists of: (1) operating practices, (2) inventory control, (3) spill and leak prevention, (4) raw-material modifications; and rest of them – 5 through 8 – form the second group: (5) process modifications, (6) cleaning and degreasing modifications, (7) surface preparations and finishing modifications, and (8) product modifications.¹⁰⁴ Mill-level cumulative P2 activities and firm-level P2 spillovers are calculated for both all P2s as well as two P2 groups.¹⁰⁵

The data are further matched with the TRI facility records to calculate (1) total annual TRI¹⁰⁶ and (2) number of inspections and enforcements at facilities across all three media: air, water, and land. I use the Integrated Data for Enforcement Analysis (IDEA) system and Facility Registry System (FRS) to merge the facility-level data from

¹⁰³ To investigate if there is an empirical issue associated with the maximum number of P2 activities allowed to be reported in one year and following Harrington (2012), I examine the current sample for any facilities that reported the maximum allowable number of P2 activities for a number of consecutive years and did not find them.

¹⁰⁴ Running estimations for all eight original P2 categories is not feasible given the data, resulting in most of the models not converging. Harrington (2012) used three groups combined in the following way: first group: (1), (2), (3), and (6); second group: (4) and (7); and third group: (5) and (8). I have combined P2s into a number of varying groupings, including the one used in Harrington (2012), and ran into the same issue – one out of three models did not converge. Table 4.1 shows that the eight original P2 categories are grouped according to the stage of production process and combining the consecutive P2 activities, as done in this study, may make better intuitive sense.

¹⁰⁵ It is important to note that P2 as a measure of cumulative voluntary abatement efforts can suffer from measurement error given that P2 activities that are no longer implemented at mills may not be reported as discontinued. The EPA Office of Information Analysis and Access (OIAA), Office of Environmental Information (OEI) confirmed that facilities are not required to report discontinued P2 activities. In the next step of research I plan to investigate if the measurement error associated with the cumulative P2 activities is nonrandom and biases the estimates.

¹⁰⁶ Facility-level TRI data can be downloaded from <http://www2.epa.gov/toxics-release-inventory-tri-program/tri-data-and-tools>.

the: (1) Air Facility System (AFS), (2) Permit Compliance System (PCS), (3) Integrated Compliance Information System National Pollutant Discharge Elimination System (ICIS-NPDES), and (4) Resource Conservation and Recovery Act Information (RCRAInfo) System.¹⁰⁷ The TRI and P2 data starts at 1988.

Political Threat

To measure the state environmental political clout I use the annual membership of the Sierra Club, the largest grassroots environmental organization in the U.S.¹⁰⁸ Finally, state income per capita comes from the Bureau of Economic Analysis' (BEA) Regional Economic Accounts.¹⁰⁹

Variables Measuring P2 Policy Tools

The year of P2 legislation adoption across states comes from Harrington (2013).¹¹⁰ According to Harrington (2013), since 1988, 36 state have legislated P2 programs emphasizing the need to implement pollution source reduction technologies. The P2 legislation measure enters the model as a dummy variable taking the value of 0 for all the years prior to the year of P2 adoption in a state, and 1 afterwards. A number of

¹⁰⁷ For more information about ECHO and IDEA and data downloads, please refer to <http://echo.epa.gov/> and <http://echo.epa.gov/resources/echo-data/data-downloads#downloads>.

¹⁰⁸ The membership data were obtained directly from the Sierra Club; more information about the organization can be found at: <http://www.sierraclub.org/about>.

¹⁰⁹ The data can be downloaded at: <http://www.bea.gov/regional/index.htm>. Per capital income is measured in thousands of 1990 converted to real using the regional consumer price index for urban consumers, which can be found at: <http://www.bls.gov/cpi/>.

¹¹⁰ Specifically, Harrington (2013), p. 258. The author collected data from National Pollution Prevention Roundtable, http://www.p2.org/inforesources/nppr_leg.html, but the data are no longer available.

states have not adopted P2 legislation and have zero values for the P2 legislation variable across all years. Similarly, the three policy instruments – numerical goal, reporting requirement, and mandatory planning – are dummy variables with 0 for years prior to states' adoption and 1 subsequently to adoption.¹¹¹ In addition to P2 legislation and policy instruments variables, I include the amounts of P2 grants awarded to state and tribal technical assistance programs from 1988.¹¹²

Mill-level Production Variables

To supplement facility-level monitoring and technology abatement data, I use the mill-level data from the Forest Product Laboratory (FPL) and annual editions of Lockwood-Post's Directory of the Pulp, Paper, and Allied Trades (LW).^{113,114} The two, FPL and LW, contain detailed information on all of the U.S. pulp and paper mills from 1970 to the present. The FPL comprised detailed information on the type of pulping processes and capacities for all the mills, their names and locations over 1970-2000. I used LW to verify the capacities, number of products, whether the mill was listed as

¹¹¹ In states where the year of adoption of a specific policy instrument is not known, I assume it was adopted during the same year as the P2 legislation for that state.

¹¹² The Pollution Prevention Incentives for States (PPIS) grant summaries were manually collected from: <http://www.epa.gov/p2/pubs/archive/index.htm#p2grant> and aggregated to the state level. For more information on the P2 Grants Program and its effectiveness, see:

<https://www.cfda.gov/index?s=program&mode=form&tab=step1&id=68f347ac81af17195e58709ef6e7ad59> and <http://www.epa.gov/p2/pubs/rep1.pdf>. The current grant dollars were converted to 1990 using the regional consumer price index for urban consumers, which can be found at: <http://www.bls.gov/cpi/>.

¹¹³ For the full description of the FPL data, see: <http://www.fpl.fs.fed.us/documnts/fplrp/fplrp602.pdf>.

¹¹⁴ For the latest description of Lockwood's Post Directory, see: <http://www.risiinfo.com/risi-store/do/product/detail/lockwood-post-plus-contact-database.html>.

vertically integrated, and extended the data to 2002. Additionally, using LW as well as other trade publications I added the name of the parent company and corporate owner/s in case the two were different, which helped identify an accurate estimate of number of mills per firm.

The FPL and LW collectively contain data on more than 900 mills that have operated at any one point over 1970 to 2002. During 1991 and 2002 that number was 717 mills.¹¹⁵ Both the FPL and LW collected data on the paper and pulp facilities that produced final products reported within the three primary paper SIC codes – 2611 for pulp, 2621 for paper, and 2631 for paperboard mills. The EPA’s ECHO and TRI have records for almost 520 pulp and paper facilities listed under SIC2611, SIC2621, and SIC2631.¹¹⁶ Matching the EPA with mill capacity data, I was able to find and include in my final sample 200 one-to-one clean matches. The FPL and LW data provide firm-level number of plants, mill-level measure of capacity or its annual output, and whether the mill produces pulp, paper, or board as its final products.

4.4.Econometric Methodology

Traditionally, the count data models are estimated using the Poisson regression method. The density function of the Poisson distribution is written as follows:

¹¹⁵ The total number of mills for 1991-2002 is 809, but only 717 of them had non-zero capacity.

¹¹⁶ Corresponding NAICS codes for the three sectors are: NAICS322110 for pulp facilities, NAICS322121 for paper and NAICS322122 for newsprint facilities, and NAICS322130 for paperboard facilities. To arrive at the total values for paper facilities equivalent to SIC2621, one would need to combine NAICS322121 for paper and NAICS322122 for newsprint facilities. For more information on NAICS definition for paper manufacturing, see: <http://www.bls.gov/iag/tgs/iag322.htm>.

$$(2) \quad f(y_i / \theta_i) = \frac{\exp(-\theta_i) \theta_i^{y_i}}{y_i!},$$

where y_i is the number of P2 activities at mill i , and θ_i is the conditional mean and variance. The main assumption of the Poisson model is that the variance and mean of the dependent variable are equal. This is not the case in my data. Following the previous literature and Harrington (2013), and looking at the difference between the mean and the standard deviation in the number of P2 activities reported in Table 4.3 of descriptive statistics, I conclude that using the Poisson model is inappropriate and estimate the functional form in equation (1) using the negative binomial regression analysis.

Cameron and Trivedi (1998) suggested that over-dispersion, or when the variance of the dependent variable exceeds its mean, is common in count regression models because of nonobserved heterogeneity. Hence, using the Poisson model in such cases leads to biased and inefficient parameter estimates. Instead, Camron and Trivedi (1991) propose using the negative binomial regression technique, which assumes the variable mean to be imperfectly unobserved and the unobservable heterogeneity to follow the gamma distribution. The resultant density function of the negative binomial model is given by:

$$(3) \quad f(y_i / \theta_i, \alpha) = \frac{\Gamma(y_i + \alpha^{-1})}{\Gamma(y_i + 1) \Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1} + \theta_i} \right)^{\alpha^{-1}} \left(\frac{\theta_i}{\alpha^{-1} + \theta_i} \right)^{y_i}.$$

Here in equation (3), α denotes the dispersion parameter and Γ represents the gamma function. Applying the negative binomial estimation to the functional form in (1) provides a straightforward interpretation of the parameters, i.e. a 1 unit increase in independent variables leads to a $\beta\%$ change in θ . The expected counts of new P2 activities are assumed to be in a log linear form. The use of panel data allows one to

control for changes in unobserved time and state heterogeneity. In the current models, the unobserved heterogeneity specific to state and year fixed effects are captured by δ_i and ρ_t , respectively.¹¹⁷

4.5.Results

Table 4.4 reports the results for the fixed effects negative binomial models. The models are grouped into three categories with the following dependent variables: (1) counts of all new P2 activities (Models 1-3), (2) counts of new input and procedural modifications (Models 4-6), and (3) counts of new process, equipment, and product modifications (Models 7-9). Each of the three groups includes three models adding consecutively, first, firm P2 spillover variable, and second, cumulative mill P2 activities. It is important to note that both P2 spillover and cumulative P2 variables are calculated for all three groupings: (1) all P2, (2) input and procedural, and (3) process, equipment, and product modifications. The high significance of the over-dispersion parameter through all nine models confirms the correct choice of negative binomial methodology over the Poisson regression. And most of the models have high log likelihood values and provide a reasonable basis for concluding that the models fit well.

I start with the policy variables. The results for the first two variables – the year of state adoption of P2 legislation and the year of adoption of numerical goal – are inconclusive and statistically insignificant across all nine models. While this is expected

¹¹⁷ The sample includes mills in Alabama, Arkansas, Connecticut, Florida, Georgia, Indiana, Iowa, Kentucky, Louisiana, Maine, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, New Hampshire, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Vermont, Virginia, and Washington during 1991-2002.

for the numerical goal, in light of the previous literature, the results for the year of P2 legislation adoption are surprising. In contrast, reporting requirement, mandatory planning and P2 grants are highly statistically significant for all new P2 adoptions, but they have different signs. Reporting requirement is positive confirming the hypothesized relationship, while mandatory planning and P2 grants are negative and raise interesting questions (Models 1-3).

In terms of marginal effects, adoption of the reporting requirement in the previous year increases the estimated count of all P2 activities by 1.07%, all else constant (Model 1). In contrast, *ceteris paribus*, adoption of mandatory planning and 1% increase in the amount of P2 grants in the previous year decrease the expected count of all P2 activities by 0.68% and 0.03%, respectively (Model 1). Further, in states where in addition to the general P2 legislation, all three P2 policy instruments are adopted, the marginal effects all of four policy instruments are 0.75%, 1.06%, and 0.37% for (1) all P2 adoptions, (2) input and procedural, and (3) process, equipment, and product modifications, respectively (Models 3, 6, and 9). Finally, the computed ratios of the conditional mean of P2 counts for the above magnitudes are: 2.12, 2.88, and 1.45, respectively, indicating that mills in states that have adopted all four P2 policies have as much as 2.12, 2.88, and 1.45 counts of (1) all P2 adoptions, (2) input and procedural, and (3) process, equipment, and product modifications, respectively.

The results for two different P2 groups present an interesting picture – the three variables still show statistically strong results, but only for one group of P2 activities at a time. Specifically, reporting requirement is positive and statistically highly significant for the first group of P2 activities – input and procedural modifications (Models 4-6), and

statistically insignificant for the second group – process, equipment, and product modifications (Models 7-9). Going in the other direction, mandatory planning and P2 grants are negative and statistically insignificant for input and procedural modifications (Models 4-6) and negative and highly statistically significant for process, equipment, and product adoptions (Models 7-9). Coefficients for the three variables are also higher for the two separate P2 groups than for all P2 activities pooled together. Specifically, adoption of the reporting requirement in the previous year increases the expected count of input and procedural modifications by 1.38% (Model 4) as opposed to 1.07% for all P2 counts (Model 1), all else the same. Similarly, adoption of mandatory planning and 1% increase in P2 grants in the previous year decreases the estimated count of process, equipment and product modifications by 1.05% and 0.05% (Model 7), respectively, vs. 0.68% and 0.02% for all P2 activities (Model 1), *ceteris paribus*.

Moving on to regulatory and political threat variables, previous year's TRI, inspections and enforcements are all positive, as expected, with TRI and enforcements being highly statistically significant across all nine models. Inspections are statistically significant at 5% significant level for process, equipment and product modifications (Model 7). In terms of the magnitude of the estimated coefficients for the regulatory threat variables, enforcements have the highest estimates – 1% increase of inspections in the previous year increases the expected count of process, equipment, and product modifications by 0.38%, all else constant (Model 8). 1% increase in mill's TRI during the previous year increases the expected count of all P2 activities by 0.16%, *ceteris paribus* (Model 1) and the TRI coefficients are higher for the process, equipment and product (Models 7-9) than for input and procedural modifications (Models 4-6).

Political pressure, measured by the Sierra Club membership and per capita income, have positive and negative signs, respectively. While the positive sign for the Sierra Club membership is expected, the negative coefficient of per capita income is unanticipated. The Sierra membership is significant at 10% significance levels in two models (Models 1 and 4). Holding all else constant, 1% increase in last year's Sierra membership in the state increases the expected count of all P2 and input and procedural modifications by 0.73% and 0.86%, respectively. State per capita income, measuring willingness to pay for higher environmental quality, is negative in all nine models, but statistically significant for all P2s and process, equipment, and product modifications. *Ceteris paribus*, 1% increase in last year's state per capita income decreases the expected count of all P2 activities and process, equipment, and product modifications by 0.21% and 0.43%, respectively.

Technology variables – firm P2 spillover and mill cumulative P2 activities – are positive and statistically significant at 1% level across the three groups. All else constant, 1% increase in last year's firms P2 activities increases the expected count of all P2 and input and process modifications by 0.84% (Models 2 and 5), and process, equipment, and product modifications by 0.77% (Model 8). Similarly, *ceteris paribus*, 1% increase in the mill cumulative P2 activities in last year increases the expected all P2, input and process, and process, equipment, and product activities by 0.80%, 0.95%, and 0.77%, respectively (Models 3, 6, and 9).

Further, mill annual capacity and number of mills per firm have negative sign through all nine models, but are statistically significant for all P2 and input and

Table 4.4. Two-way Fixed Effects Negative Binomial Results

Dep Var: # of New P2 Activities	All P2s			Group 1			Group 2		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Intercept	-9.84** (3.969)	-8.56** (3.753)	-7.27** (3.515)	-11.12** (4.535)	-9.89** (4.311)	-10.31** (4.027)	-7.99 (5.458)	-7.05 (5.444)	-4.70 (5.306)
Year P2 Adopted, <i>s</i>	-0.053 (0.246)	0.158 (0.229)	0.314 (0.206)	-0.227 (0.283)	-0.016 (0.266)	0.230 (0.238)	0.358 (0.317)	0.416 (0.307)	0.412 (0.296)
Numerical Goal, <i>s</i>	0.172 (0.268)	-0.008 (0.255)	0.019 (0.240)	0.148 (0.299)	-0.051 (0.286)	-0.071 (0.269)	0.263 (0.382)	0.129 (0.374)	0.225 (0.366)
Reporting Requirement, <i>s</i>	1.066*** (0.333)	0.779** (0.316)	0.852*** (0.285)	1.380*** (0.408)	1.105*** (0.387)	1.185*** (0.340)	0.667 (0.426)	0.545 (0.416)	0.577 (0.398)
Mandatory Planning, <i>s</i>	-0.683** (0.285)	-0.509* (0.271)	-0.435* (0.247)	-0.534 (0.340)	-0.344 (0.326)	-0.285 (0.291)	-1.05*** (0.368)	-0.91** (0.362)	-0.89** (0.346)
P2 State Grant Budget, <i>s</i>	-0.026** (0.013)	-0.027** (0.012)	-0.03*** (0.011)	-0.014 (0.015)	-0.014 (0.014)	-0.019 (0.013)	-0.05*** (0.017)	-0.05*** (0.017)	-0.06*** (0.016)
TRI, <i>i</i>	0.16*** (0.016)	0.15*** (0.016)	0.10*** (0.015)	0.15*** (0.018)	0.13*** (0.018)	0.09*** (0.017)	0.17*** (0.024)	0.16*** (0.025)	0.14*** (0.024)
Inspections, <i>i</i>	0.140* (0.073)	0.090 (0.069)	0.071 (0.064)	0.110 (0.082)	0.058 (0.078)	0.110 (0.072)	0.206** (0.095)	0.145 (0.094)	0.117 (0.092)
Enforcements, <i>i</i>	0.285** (0.129)	0.32*** (0.123)	0.31*** (0.113)	0.287* (0.153)	0.318** (0.147)	0.36*** (0.134)	0.368** (0.157)	0.376** (0.153)	0.282* (0.148)
Sierra Club, <i>s</i>	0.726* (0.412)	0.575 (0.389)	0.295 (0.365)	0.860* (0.472)	0.718 (0.448)	0.576 (0.417)	0.334 (0.564)	0.231 (0.563)	-0.065 (0.550)
State Per Capita Income, <i>s</i>	-0.21*** (0.082)	-0.190** (0.078)	-0.173** (0.072)	-0.098 (0.093)	-0.074 (0.089)	-0.016 (0.082)	-0.43*** (0.114)	-0.40*** (0.110)	-0.44*** (0.109)
Firm Spillover P2, <i>i</i>		0.84*** (0.067)	0.42*** (0.066)		0.84*** (0.076)	0.41*** (0.073)		0.77*** (0.092)	0.55*** (0.093)
Mill Cumulative P2, <i>i, j</i>			0.80*** (0.055)			0.95*** (0.065)			0.77*** (0.099)
Annual Mill Capacity, <i>i</i>	-0.12*** (0.027)	-0.09*** (0.025)	-0.06*** (0.023)	-0.14*** (0.029)	-0.11*** (0.027)	-0.08*** (0.025)	-0.036 (0.036)	-0.023 (0.035)	-0.015 (0.034)

Table 4.4. Continued

Dep Var: # of New P2 Activities	All P2s			Group 1			Group 2		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Number of Mills per Firm, <i>i</i>	-0.097** (0.048)	-0.38*** (0.051)	-0.17*** (0.048)	-0.090* (0.054)	-0.37*** (0.057)	-0.18*** (0.054)	-0.102 (0.066)	-0.36*** (0.072)	-0.23*** (0.071)
Pulp Mill, <i>i</i>	0.63*** (0.138)	0.55*** (0.129)	0.225* (0.119)	0.72*** (0.154)	0.64*** (0.145)	0.252* (0.135)	0.287* (0.171)	0.257 (0.167)	0.269 (0.163)
Paper Mill, <i>i</i>	0.67*** (0.121)	0.45*** (0.117)	0.260** (0.110)	0.62*** (0.138)	0.40*** (0.134)	0.318** (0.127)	0.72*** (0.163)	0.49*** (0.163)	0.363** (0.160)
Over-dispersion	1.64*** (0.155)	1.17*** (0.126)	0.66*** (0.093)	1.70*** (0.200)	1.16*** (0.162)	0.50*** (0.106)	0.99*** (0.231)	0.71*** (0.194)	0.44*** (0.162)
N	2,409	2,409	2,409	2,409	2,409	2,409	2,409	2,409	2,409
LL	-1,941.1	-1,864.6	-1,755.9	-1,524.6	-1,465.1	-1,351.5	-959.7	-923.7	-893.7
AIC	3,998.3	3,847.2	3,631.8	3,165.2	3,048.1	2,823.1	2,035.4	1,965.5	1,907.5

Note: All variables, except for dummy, are in the log form; all but product dummy variables are lagged one year; standard errors are reported in parentheses and ***, **, * indicate 1%, 5%, and 10% statistical significance levels, respectively. Italicized *i* and *s* denote mill and state. Group $j = 1$ includes input and procedural modifications and group $j = 2$ includes process, equipment, and product modifications. To save space, state and year fixed effects are not reported; the reference group is Wisconsin board mills in 2002.

procedural modifications and less so for process, equipment, and product modifications. Specifically, 1% increase in last year's mill capacity decreases the expected count of all P2 and input and procedural modifications by 0.11% and 0.14%, respectively, all else constant (Models 1 and 4). Similarly, 1% increase in the number of mills per firm during the previous year decreases the expected counts of all P2 and input and procedural activities by 0.38%, and process, equipment, and product modifications by 0.36%, all else the same.

Finally, both pulp and paper mill dummy variables have the expected positive coefficients and are statistically highly significant at 1-5% significance levels in most models. The highest coefficient for the pulp mill is in the model with input and procedural modifications – operating a pulp mill increases the expected count of input and procedural P2 activities by 0.72%, holding all else constant (Model 4). And the highest coefficient for the paper mill is found in the model for process, equipment, and product modifications – operating a paper mill increases the expected count of process, equipment and product P2 activities by 0.72%, *ceteris paribus*.

4.6.Discussion

The current results for Hypothesis 1 confirm some of the findings in the previous research on the impact of policy instruments on voluntary participation in environmental programs. The results confirm that assigning numerical goals as environmental policy tools can produce ambiguous results. For all P2 modifications, conditional on the adoption of P2 legislation, the impact of adopting P2 numerical goal is inconclusive and statistically insignificant (Models 1-3). When disaggregated into different P2 activity

groups and conditional on adopting P2 legislation, the sign of the numerical goal is positive for the input and procedural and negative for process, equipment, and product modifications. In both cases, however, the coefficients are statistically insignificant. Harrington (2013) reports a negative, but statistically insignificant coefficient for the numerical target policy instrument on the adoption of all P2 activities. Similarly, Jaffe and Stavins (1995) found that building codes were not effective in increasing building energy efficiency.

In contrast to the inconclusive results on the numerical goal, reporting requirement and mandatory planning have much more robust and statistically stronger results, yet the two go in different directions and exhibit even higher coefficients and statistical significance in models with disaggregated P2 modifications. Reporting requirement, conditional on adopting P2 legislation, has a strong positive impact on the adoptions of all and input and procedural P2 activities, in particular. This overall result is consistent with the findings in Harrington (2013) and earlier studies that find policies aimed at information disclosure directly and indirectly decrease emissions (Khanna et al. 1998, Khanna and Damon 1999, and Decker 2005), and lowered the use of fossil fuels while increasing the use of cleaner fuels (Delmas et al. 2010).

The stronger effect for the input and procedural modifications may be a reflection of either one or both of the following factors. First, the input and procedural modifications characterize the managerial side of the manufacturing process, or operations management and, as such, are more likely to be affected by information sharing policies. The second, and potentially more plausible, explanation is that the input and procedural modifications dominate other modifications in the pulp and paper

industry, in general, and in my sample, in particular. The 2002 EPA report on pollution prevention opportunities at the pulp and paper mills documents that most of the P2 activities are completed mainly in three areas: (1) source reduction and material substitution, (2) water use and effluent releases, and (3) use of recycled materials,¹¹⁸ all of which fall into the category of input and procedural modifications. And in my sample, there are twice as many of input and procedural modifications than process, equipment, and product P2s (Table 4.3).

Mandatory planning shows similarly strong statistical results but with a negative effect on P2 adoptions, conditional on adopting P2 legislation. This finding contradicts the earlier results of strong positive effect of mandatory planning on all P2 adoptions (Harrington, 2013) and on P2 adoptions differentiated by groups (Harrington, 2012). It is not clear why the mandatory P2 planning requirement has the negative effect on all P2 adoptions and especially on process, equipment, and product modifications in my sample. It is possible that the non-binding nature of P2 plans, whereby companies are mandated to submit P2 plans but are not required to follow up on them, signals that many of the proposed P2 modifications are too costly for firms to implement. Another facet of the non-binding nature of P2 plans bearing import on policy implications is that they are not available to the public. The private nature, or lack of public disclosure, provides an additional incentive for facilities to delay the implementation of potential P2 modifications.

¹¹⁸ The report is available at: <http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp/pasn.pdf>; for the discussion of P2 opportunities at pulp and paper mills, refer to pages 62-67.

Given that the effect is stronger for process, equipment, and product modifications, the interpretation of delayed cost expenditures appears to be even more plausible in light of the above-mentioned EPA evaluation of pollution prevention opportunities at pulp and paper mills. According to the EPA, the nature of long equipment lifetimes of the paper-producing technologies precludes the industry from easily undertaking major process-changing pollution prevention measures, which are viewed as expensive and requiring long time periods of operational downtime.

This result corroborates the concern documented in Lyon and Maxwell (2001) that some government reports criticize the public voluntary programs that do not institute monitoring and reporting requirements.¹¹⁹ This, to quote the authors, “damages the credibility of the voluntary agreements since it does not allow for accountability, and makes ex post evaluation of the effectiveness of the agreements difficult” (Lyon and Maxwell, 2001, p. 2).

The most controversial findings are those of P2 state grant budgets. As defined earlier, P2 grants are grants given to state and local governments, private businesses, nonprofits and universities to develop programs on establishing information networks and tools for implementing P2s.¹²⁰ Naturally, one would expect the grants to generate positive

¹¹⁹ More specifically, the European Environmental Agency (1997) report entitled “Environmental Agreements: Environmental Effectiveness,” which can be found here: <http://www.eea.europa.eu/publications/92-9167-052-9/page002.html>.

¹²⁰ The Catalogue of Federal Domestic Assistance (CFDA) defines P2 grants as “grants and cooperative agreements that provide pollution prevention technical assistance services and/or training to businesses” and “the P2 grant program supports P2 approaches and methodologies that focus on: institutionalizing P2 as an environmental management method, helping businesses establish prevention goals, providing on-site technical assistance or training to businesses, supporting outreach and research endeavors, and

externalities or spillover effects for and be positively related with the counts of P2 adoptions. However, the direction and statistical significance of P2 state grants display the similar pattern as mandatory P2 planning, i.e. they have robust negative and statistically significant coefficients for the models with all P2 modifications and, even higher and statistically stronger estimates in models with process, equipment, and product modifications. However, it is much more difficult to understand the potential underlying reasons for this perverse result than in the case of mandatory planning. One possible explanation could be that P2 grants generate positive spillovers, but not for all industries. The pulp and paper industry, in particular, appears to experience the negative spillover effects of the P2 grants.¹²¹ However difficult to envision, this is the only plausible explanation I can conjecture given my data and results and suggest that more research needs to be done across other industries and possibly over a longer time span.¹²²

In contrast to the P2 policy instruments, the variables measuring regulatory and political pressure (Hypothesis 2) display expected direction and are, in general, well-behaved. Confirming the propositions voluntary pre-emption (Maxwell et al. 2000, Maxwell and Decker 2006, Decker 2007) and corroborating earlier empirical results

supporting data collection and analysis to curb environmental inefficiencies while increasing awareness of P2.” The discussion can be found at: <https://www.cfda.gov/index?s=program&mode=form&tab=core&id=2598bcba855346b5a45c84107499fbc3>.

¹²¹ The 1996 EPA Pollution Prevention Incentives for States (PPIS) Grant Program Assessment Study identifies the automotive (with auto body repair and vehicle maintenance) and printing industries as the top receivers of the number of grants each receiving 21% percent of total grants; the pulp and paper received 3% of total grants. The full text of the report can be downloaded from: <http://www.epa.gov/p2/pubs/rep1.pdf>.

¹²² It is possible that the perverse results of both the year of adoption of mandatory planning and P2 grants is indicative of having omitted other important influences, such as P2 adoption costs, that have a strong negative impact on all P2 adoptions in general, but especially for process, equipment and product P2 modifications.

(Harrington 2012, Brouhle and Harrington 2010, Brouhle et al. 2009, Sam et al. 2009, Innes and Sam 2008, Vidovic and Khanna 2007, King and Lenox 2000, Khanna and Damon 1999, Arora and Cason 1995), I find that: (1) a higher level of pollution, measured by mill-level TRI amounts, and (2) higher level of regulatory scrutiny, measured by mill inspections and enforcements, are good predictors of mills' efforts to adopt all P2 modifications and modifications categorized into two groups. More specifically, the effect of the TRI measure is robust across all nine models and enforcements appear to have more credibility as regulatory threats for adoption of P2 modifications than inspections.

Variables measuring political pressure present mixed results, however. The two variables, the Sierra Club membership and state income per capita, measure the two potentially different political forces – environmental group interests and increased pressure from groups with greater incomes who are willing to pay for and demand higher environmental quality. The Sierra Club membership has positive impact on the expected counts of P2 adoptions corroborating the previous literature (Maxwell et al. 2000, Maxwell and Decker 2006, Khanna et al. 2009, Harrington 2012, Matisoff and Edwards 2014). In contrast, the negative sign of state per-capita is unexpected yet is consistent with some of the earlier findings. Specifically, Maxwell et al. (2000) found state per capita income also negative but insignificant; Decker (2005) found county median family income to be negative and statistically highly significant; finally, Harrington (2012, 2013) found mixed results of county median household income. In light of these previous findings, the current result is less surprising and suggests it is picking up some other

influences.¹²³ Finally, the coefficients of the Sierra Club and income differ in their statistical significance, with the Sierra Club showing a strong statistical result in only two out of nine models and income per capita having a high statistical significance in six out of nine models. The interesting nuance is that when looking at disaggregated P2 modifications, one sees that the effect of the Sierra Club membership is driven by input and procedural modifications, while income per capita results are driven by process, equipment, and product modifications.

The results on the impact of firm-level P2 spillovers and role of mill-level P2 experience (Hypothesis 3), measured by cumulative P2 support arguments and evidence presented in the previous literature (Jaffe 1986, Griliches 1992, Jaffe 1998, Goulder and Mathai 2000, and Jaffe et al. 2002). The results unequivocally suggest that both firm spillovers and mills' prior experience capture the effects of increasing returns in the form of learning effects and reduce pollution abatement costs via learning-by-doing. This is true for all P2 modifications and for the two groups separately with similarly large coefficients across all the six models.

Finally, for Hypothesis 4, following the line of reasoning that market leaders and large firms are superior innovators and technology adopters (Schumpeter 1942, Scherer 1967, Mansfield 1968) and where I am hoping to find positive firm and mill economies of scales for P2 technologies as in Khanna et al. (2009), I do not. Moreover, the findings exhibit substantive and statistically strong diseconomies of scale at both levels – firm and

¹²³ The cost of regulation could be one of the omitted variables influencing the results. It is suggested that costs of regulation for low income states may drive P2 adoptions as a strategy to substitute for other more costly monitoring and enforcement. Consequently, as income and state revenues rise, the need for P2 adoptions drops.

mill. The result is strong for all P2 and especially input and procedural modifications; firm effect is strong for process, equipment, and product innovations as well. The result confirms some of the earlier studies which supported the hypotheses that market concentration has, in fact, negative effect on innovations (Geroski 1990, Williamson 1965) in part because once monopolistic rents are secured, firms have lower incentives to innovate. Yet, it is important to note, that this result could be different for end-of-pipe technologies, whereby there are increasing economies of scale with firm and/or mill size. This could also be different under different market conditions – more competitive markets could be forced to substitute pollution control for cheaper pollution prevention technologies, or forego all environmental improvements altogether if not regulated.

4.7. Conclusion

The main research question posed at the beginning of this paper was how environmental policy instruments affect the adoption and diffusion of environmental technologies. I examined this question looking at a narrow set of state P2 policy instruments that represent the wave of newer types of policies, namely voluntary environmental programs, and their impact on a narrow set of environmental technologies – P2 modifications. The P2 state programs prescribe varying combinations of regulatory-, information-, and management-based policies. In addition, the states receive P2 grants that are designed to help develop programs on establishing information networks and tools for implementing P2s.

My results confirm some of the findings in the previous research on the impact of policy instruments on voluntary participation in environmental programs and environmental technology innovations. For instance, like others, I find that assigning

numerical goals as environmental policy tools can produce ambiguous results. Similarly, reporting requirement, regulatory and political threats as well as firm P2 spillover and prior P2 experience are all strong predictors of the increases in P2 adoptions at pulp and paper facilities.

Mandatory planning and P2 grants, however, produced quite surprising, if not perverse, results and, while I was able to explore and offer a couple of plausible explanations for the unexpected effect of the mandatory planning policy instrument, I could not uncover why P2 grants had a robust negative effect on P2 modifications. I also found substantive diseconomies of P2 modifications associated with the firm and mill size, confirming most of the previous empirical literature that did not find much support for economies of scale for innovative activities. Another interesting finding is that the effects of most of the policy instruments and other factors differ by groups of P2 modifications. These differences stem from the nature of the paper-making technology and P2 modifications associated with different stages of production, which then affects their cost and feasibility of implementation.

The perverse results of the impact of P2 mandatory planning and P2 grants inform an important policy challenge and opportunity. To explain the effect of the P2 mandatory planning, I suggest that both nonbinding and private characteristics of P2 mandatory plans create an incentive for delaying more costly modifications. It would be wise, on the part of policy-makers, to consider potential ways to modify the policy in order to reverse this incentive.

The explanation for the negative effect of state P2 grants does not appear as easily, however. After considerable research within the data as well as P2 grant program

descriptions, I conclude that, even though pulp and paper mills get little attention from the federal and state government in comparison to other sectors, this should not justify the negative spillovers that I find in my sample. Consequently, policy-makers must look into the planning and all stages of implementation of the P2 grant programs. It would not hurt to improve the data and other information tools available on the EPA site related to P2 grants.

Another important policy implication derived from my results is that policy instruments affect different P2 modifications in different ways. For P2 modifications that heavily rely on improved management tools (like more improved maintenance, scheduling, or record-keeping), information-sharing policies, such as reporting requirement, have strong positive policy impact. This would not be true, as my results confirm, for P2 modifications related to process or product modifications.

Future research would benefit from amassing more facility level data to look deeper at all eight categories of P2 modifications. Examining all policy instruments and P2 grants for each P2 category might shed more light on the effectiveness of the policies. It would be insightful to investigate the effects of P2 grants on a different set of industries or all manufacturing, data permitting. Additionally, case study analyses would complement the empirical models, completing the picture of what kind of decision-making goes into planning and implementing P2 modifications as well as the type of management and oversight carried out by P2 grant administrators and grant recipients.

CHAPTER 5

CONCLUSION

5.1.Review of Findings

This dissertation provides a broad view of and contributes to the current theoretical and empirical discourse on the effectiveness of the environmental policies and regulations. Chapter 1 documents the history of environmental regulations that apply to one of the larger manufacturing polluters in the U.S. – pulp and paper industry. The industry presents a good case for the analysis of the gradual progression in the character of policies – from the rigid command-and-control regulations of the Clean Air and Clean Water Acts in the early 1970s to the more flexible and accommodating Cluster Rules and voluntary, or quasi-voluntary, pollution prevention programs under the Pollution Prevention Act during the early-to-mid 1990s. While the Clean Air, Clean Water, and the Pollution Prevention Acts, along with other regulations reviewed in Chapter 1, apply to a wide set of industrial producers, the Cluster Rules was designed specifically for the pulp and paper mills making it a good case for a variety of empirical analyses.

Essay1: Environmental Compliance and Investment Behavior of Capital-intensive Industries

The first essay in Chapter 2 examines the impact of the regulatory stringency on the industry investment decisions. The previous literature found that increases in environmental stringency, realized through higher pollution abatement and compliance costs, had impact on the papermakers' choice of technology and timing (Gray and

Shadbegian 1998) and caused firms to shift production from more environmentally stringent to less stringent states (Gray and Shadbegian 2002). This essay contributes to the previous work by testing the hypotheses of non-zero impact of environmental stringency, as a proxy of compliance costs, within both the continuous and discrete choice regression analyses, thereby bridging the two literatures that view industrial investments as continuous capital adjustments or as lumpy outlays. The environmental stringency is measured by the total number of monitoring and enforcement actions undertaken by the regulators and as such, presents as a suitable measure of command-and-control policy climate. In addition to the environmental regulatory stringency, I study the effect of other cost factors – prices for materials, labor, energy, land, and corporate taxes.

The findings from this inquiry suggest that the two models inform different behavioral choices considered by papermakers. Confirming the results in Gray and Shadbegian (1998, 2002) and whether I am looking at a continuous flow of investments or its spikes, I find that state environmental stringency has a negative impact on investments, but it is statistically insignificant through all models. When facing increases in variable costs, specifically energy prices, papermakers respond by decreasing levels of investments, thereby confirming the findings of Lundmark and Nilsson (2001) and Gray and Shadbegian (2002). However, in day-to-day capital adjustments, regulatory stringency, availability of virgin or secondary pulp sources, wages and land prices have little or no effect. In contrast, when considering larger inflows of investments and reinforcing the findings in Bergman and Johansson (2002), Gray and Shadbegian (1998, 2002), Lundmark (2001, 2003) and Lundmark and Nilsson (2001), my results suggest

that papermakers' view wages, land prices, and availability of recycled pulp as important inputs when planning larger investments.

Essay 2: Responsive Regulation: Target- vs. Budget-Driven Regulation

The statistically weak impact of monitoring and enforcement actions on capital investments found in Essay 1 suggests, first, that inspections and enforcements measure other than command-and-control regulatory policy. Second, the results also suggest that pulp and paper mills may be employing a number of successful market adjustment strategies, cumulatively termed in the literature as corporate environmentalism, in order to lessen future regulatory scrutiny and, hence, decrease resultant compliance costs. To investigate if mills' compliance behavior had significant impact on regulatory stringency they face, Essay 2 and Chapter 3 examines the hypotheses of 'responsive regulation.' Maxwell and Decker (2006) and Decker (2007) first advanced the theory of 'responsive regulation' and proposed that regulators acted in response to the compliance behavior of the regulated industries. As such, regulatory policies get characterized as more flexible, or responsive, while mills ensure compliance in order to preempt future regulatory stringency. Further, building on these theoretical propositions, I extend the empirical analysis to investigate if the environmental regulation regime could be characterized, as suggested by Heyes and Kapur (2009), as being motivated by numerical pollution targets or the size of regulators' budgets. In short, I evaluate the impact of (1) voluntary pollution abatement and prevention efforts at the U.S. pulp and paper mills and (2) local and state protective and inspection government expenditures on the level of scrutiny levied by the regulators. In addition, I explore the role of political and consumer pressure,

measured by the Sierra Club membership and state per capita income, as well as mill and firm heterogeneity on the number of regulatory inspections and enforcements.

The paper contributes to the positive theory and empirical body of work on ‘responsive regulation’ by testing if regulatory actions are determined by environmental firm performance and/or regulatory budget expenditures. While the pioneering works analyzed the effect of TRI on the count of regulatory inspections (Maxwell et al. 2000), in addition to inspections I include the number of enforcements, and in addition to the TRI, I use the number of mill-level P2 activities as the second measure of voluntary pollution abatement efforts. I also included two measures of government spending on inspection and protection, at local and state levels. To contribute to the studies on the pulp and paper industry, which focus on either air or water pollution (Nadeau 1997, Gray and Shadbegian 2007, Shimshack and Ward 2005, 2008), I include all three pollution vectors – air, water, and land – as well as the combined category. The disaggregated results display better model performance than when the three media are combined together. Finally, neither P2 activities, nor state and local budgets had been examined in this context previously.

Essay 3: Policy Instruments and P2 Adoptions

In the Essay 2 I find that regulators take into account mills’ compliance behavior measured by the TRI for each specific pollution media and the total number of new P2 activities. Both indicators had positive, and in most models, statistically significant results. While the positive relationship of the TRI coefficients is expected and consistent with the previous works, the same direction and similar statistical magnitude found for the P2 activities is unexpected and raises interesting empirical questions. More

specifically, according to the hypotheses proposed by Maxwell and Decker (2006) and Decker (2007), the voluntary adoption of P2 activities at mills should serve as a positive signal of environmental stewardship to the regulators, hence should be associated with reduced regulatory scrutiny and less frequent inspections and enforcements. Yet, this was not what I find.

In order to understand the nature of P2 activities and the effectiveness of policy instruments aimed at voluntary environmental programs (VEP), such as P2 programs, I examine a number of models of adoption of new P2 activities, and factors influencing P2 adoptions, in the Essay 3 in Chapter 4. More specifically, I study if: (1) P2 policy instruments – regulatory-, information-, and management-based – designed to encourage P2 adoption, (2) threat of regulatory action and political pressure, and (3) previous experience with P2 technologies and external firm-level P2 spillovers, have impact on all P2 adoptions and when grouped in two more general categories. I define the first P2 category as consisting of operating practices, inventory control, spill and leak prevention, and raw-material modifications. Process modifications, cleaning and degreasing modifications, surface preparations and finishing modifications, and product modifications form the second P2 group. For the purposes of this analysis, I term the first group as management and logistical, and second as process and product modifications.

The results of the third analysis confirm some of the findings in the previous research on the impact of policy instruments on voluntary participation in environmental programs. For instance, like Jaffe and Stavins (1995) and Harrington (2013), I find that assigning numerical goals as environmental policy tools can produce ambiguous results. Similarly, I confirm the previous findings that reporting requirement (Khanna et al. 1998,

Khanna and Damon 1999, Decker 2005, Delmas et al. 2010), regulatory and political threats (Arora and Cason 1995, Khanna et al. 1998, Khanna and Damon 1999, King and Lenox 2000, Maxwell et al. 2000, Decker 2005, Maxwell and Decker 2006, Decker 2007, Vidovic and Khanna 2007, Innes and Sam 2008, Brouhle et al. 2009, Sam et al. 2009, Brouhle and Harrington 2010, Delmas et al. 2010, Harrington 2012, 2013) as well as firm P2 spillover and prior P2 experience (Jaffe 1986, Griliches 1992, Jaffer 1998, Goulder and Mathai 2000, and Jaffe et al. 2002) are all strong predictors of the increases in P2 adoptions at pulp and paper facilities.

5.2.Implications

In light of the EPA (2014) findings that compliance costs associated with the Cluster Rules were significantly over-estimated by the regulators as well as the industry, the results of weak or no impact of environmental stringency on investment patterns documented in Essay 1 of this thesis are not surprising. The main lesson of these results is that, *ceteris paribus*, pollution abatement costs do not change the usual investment behavior of such capital intensive industries as the pulp and paper. And more specifically, the environmental costs do not have drastic impacts on the papermakers' profit maximization. These findings are consistent regardless if the analyses are done for short-term capacity fluctuations or longer term lumpy investments. The EPA (2014) report suggested that the over-estimated costs did not account for the substitution of mandatory abatement requirements by more flexible compliance procedures adopted by the regulators and mills, suggesting that these more flexible pollution abatement strategies

provide substantial cost-savings and are preferred by mills.¹²⁴ On the other hand, the only costs that are found to significantly affect short-term investment decisions are energy prices, emphasizing the need of corporate strategists to analyze local energy markets. And when looking at longer-term investments pulp and paper managers take into account wages, land prices, and availability of recycled pulp.

The analyses on whether mills adjust their pollution behavior in order to pre-empt regulatory stringency in Essay 2 suggest that voluntary P2 activities is a better measure of such behavior than the mill TRI, which are required to be reported to the EPA. The preliminary endogeneity tests further suggest that P2 is a robust measure of environmental management and is not a greenwash. In addition, the analyses showed that regulators are more driven by environmental targets than by their budgets. Also, environmental political activism has greater impact for water inspections, and state residents' willingness to pay for better environmental quality increases the expected count of air inspections. Finally, larger facilities as well as firm market leaders are found to draw more regulatory attention on average.

Finally, the findings in Essay 3 inform policy on the effectiveness of P2 legislation and its individual policy tools – numeric goal, reporting requirement and mandatory planning. While the findings are ambiguous on whether the adoption of the legislation and numeric goal have any impact on P2 adoptions at pulp and paper mills,

¹²⁴ EPA (2014): “Among the reasons for EPA’s overestimates of these capital costs are the mills’ use of the clean condensate alternative (CCA), flexible compliance options, extended compliance schedules, site specific rules, use of equivalent-by-permit, and equipment/mill shutdowns and consolidations. However, the lack of detail in the available data means we can only speculate on which reason(s) is primarily responsible for EPA’s overestimate,” p. 52.

results for reporting requirement and mandatory planning policy instruments are more conclusive. The adoption of the reporting requirement appears to have a strong positive impact on the expected count of P2 adoptions at mill, on the one hand. Mandatory planning and P2 grants, however, produce quite surprising, if not perverse, results and, while I am able to offer a couple of plausible explanations for the unexpected effect of the mandatory planning policy instrument, I cannot uncover why P2 grants have a robust negative spillover effect on P2 modifications. To explain the effect of the P2 mandatory planning, I suggest that both nonbinding and private characteristics of P2 mandatory plans created an incentive for delaying more costly modifications. It would be wise, on the part of policy-makers, to consider potential ways to modify the policy in order to reverse this incentive. The explanation for the negative effect of state P2 grants do not appear as easily, however. After having done considerable research within the data as well as P2 grant program descriptions, I concluded that, even though pulp and paper mills get little attention from the federal and state government in comparison to other sectors, this should not justify the negative spillovers that I find in my sample. Consequently, policy-makers must look into the planning and all stages of implementation of the P2 grant programs.

Another interesting finding bearing import on policy is that the impact of most of the policy instruments and other factors varied for different groups of P2 modifications. I find that these distinctions result from the nature of the paper-making technology and P2 modifications associated with different stages of production, which then affect their cost and feasibility of implementation. For P2 modifications that heavily rely on improved management tools (like improved maintenance, scheduling, or record-keeping),

information-sharing policies, such as reporting requirement, have strong positive impact. The result is opposite for P2 modifications related to process or product modifications.

5.3.Future Research and Empirical Implications

Putting the results from the three essays back together within a bigger picture of how changes in regulatory policies interact with and shape industry response and compliance, a few theoretical and empirical implications emerge. The current literature on environmental compliance is focused on how markets adjust to the evolving regulatory climates. To extend this work further, I propose to pursue the next three prominent lines of inquiry: (1) impact of different regulatory climates and policies on industry structure and interaction between corporate restructuring strategies and regulations, (2) role of strategic firm communications/interactions in preempting regulatory action under different policy climates/regimes, and (3) whether firms, in the effort to minimize costs, move pollution across different media. From the perspective of the literature focused on regulatory effectiveness, my findings suggest two directions for subsequent research: (1) examining monitoring and enforcement activities separately, and (2) analyzing the role of public scrutiny in the effectiveness of voluntary environmental programs. I next discuss each of these themes in greater detail and conclude with necessary empirical and data improvements.

Market Adjustments to Regulatory Climate

Compliance Costs and Industry Restructuring

I start with the discussion of the current state of the literature and findings on the types of restructuring strategies used by industries in their efforts to adjust to

environmental compliance costs. While earlier research documented that compliance costs had significant impact on mill behavior, more evidence is emerging that these effects are not always big and/or unidirectional. Gray and Shadbegian (1998, 2002) found that compliance costs had significant impacts on the choice of pulping technology and shifting production shares across states in favor of less stringent regulatory climates. Similarly, Keller and Levinson (2002) find that compliance costs have moderate deterrent effects on foreign direct investment flows in the U.S.

More recently, in their working paper Gray et al. (2011a) found that plants that underwent restructuring in the previous couple of years had better environmental compliance. Their econometric analyses looked at how three types of restructuring events – downsizing, re-engineering, and outsourcing – influenced air and water compliance and toxic releases at 454 pulp and paper mills during 1985-1996.¹²⁵ Similarly, in another analysis, Gray et al. (2011b) examined if environmental compliance associated with the Cluster Rules caused decreases in total employment at 458 pulp and paper mills during 1993-2007. Contrary to the expectations, the authors find that having to comply with the Cluster Rules caused only small decreases in labor demand at the affected mills.

¹²⁵ While downsizing and outsourcing are self-explanatory, the notion of restructuring via re-engineering requires additional definition. According to Hammer and Champy (1993) cited in Gray et al. (2011a), re-engineering is “the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures such as cost, quality, service, and speed.” The authors further expand by adding that “the strategy consists of such actions as eliminating functions, hierarchical levels, groups, divisions, or products; redesigning work tasks; and consolidating or merging units” (Gray et al. 2011a,p. 3).

Further, documenting the abatement and compliance costs associated with the Cluster Rule, the 2014 EPA report found that the actual compliance costs were much lower than predicted by both the regulators and the industry.¹²⁶

Finding that compliance costs may have more complex effects on manufacturing investments, I propose that it is important to examine next the impact of different policies and policy regimes within a broader, if not the full, set of restructuring strategies available to the industries. To do so, I propose to expand the list of restructuring strategies included in Gray et al. (2011a) to include: (a) vertical and horizontal mergers and acquisitions, and (b) greenfields, closures and/or bankruptcies. Earlier work on the corporate restructuring within the pulp and paper sector suggests that most of the restructuring occurs through mergers and acquisitions. Specifically, Pesendorfer (2003) documented that 40% of capacity expansions were achieved through horizontal acquisitions, with only 7.29% through building new plants. Both Ohanian (1994) and Melendez (2002) find that vertical integration of pulping and paper-making operations was consistent with the transactions costs model and was associated with larger mill size. Ohanian (1994) also found that major adjustments to industry trends occurred through entry and exit, not through changes in integrated status. Finally, Ho et al. (2013) examined market exits through bankruptcies and found very few firms in the industry went bankrupt, yet the choice of bankruptcy filing as an exit strategy decreased with firm size, and bankruptcy filing resulted in a negative market reaction.

¹²⁶ For review, see Chapter 1 of the thesis. For detailed discussion, see EPA, 2014, Retrospective Study of the Costs of EPA Regulations: A Report of Four Case Studies, in Environmental Protection Agency National Center for Environmental Economics, Office of the Administrator: [http://yosemite.epa.gov/ee/epa/erm.nsf/vwAN/EE-0575.pdf/\\$file/EE-0575.pdf](http://yosemite.epa.gov/ee/epa/erm.nsf/vwAN/EE-0575.pdf/$file/EE-0575.pdf).

Strategic Interactions under Different Regulatory Climates

In Chapter 1 I introduced the findings of Gray and Shimshack (2011) of decreasing amounts of money allotted to the regulatory oversight.¹²⁷ Results in Chapter 3 show that regulatory actions are motivated more by environmental targets than by budgetary constraints, while at average levels of both TRI and P2, state and local budgets have different effects on different media. This confirms the expectations that while monitoring and enforcement are effective at attaining pollution targets, decreases in budgets do not automatically signal reduced effectiveness of the oversight. These findings invite further empirical analyses of the effectiveness of target vs. budget motivations within the theoretical framework of responsive regulation. Building on Maxwell and Decker (2006), Decker (2007), and Heyes and Kapur (2009), Colson and Menapace (2012) theoretically demonstrate that even under a budget-driven mission regulators can use multiple measures of ambient pollution to create strategic interaction among firms, thereby generating positive compliance spillovers. Under such conditions, the authors argue, the budget-driven mission can be more effective than a target-driven mission.

The use of multiple measures of ambient pollution appears to reflect the reality of the regulators relying not only on plant-level pollution releases, but on the general measures of ambient pollution collected directly by the environmental agencies at their regional collection stations. Further, emphasizing the strategic nature of mill compliance,

¹²⁷ For a more detailed discussion, see Chapter 1, Introduction, 7. Responsive Regulation, Essay 2, Budget-driven Regime: Role of Budgetary Constraints under and Figure 1.9 of the budget allotments for Office of Enforcement and Compliance Assurance (OECA).

Gray and Shadbegian (2009) found that inspections at one plant tended to increase compliance at both the inspected and nearby facilities. Finally, Christensen and Caves (1997) empirically tested and documented the importance of strategic interactions within the pulp and paper industry in their bids for future capacity projects. Incorporating such strategic communications among mills empirically is an important next step in understanding the dynamics of preemptive corporate environmentalism.

Cross-Media Pollution: Complements or Substitutes?

The final strategy which manufacturers may be using in order to adjust to abatement and compliance costs and which I suggest for further research is the strategy of moving pollution from one pollution media to another. I propose to test empirically whether and to what extent different media pollution releases are complements or substitutes. The literature on cross-media substitution is limited to Sigman (1996) and Alberini (2001). Sigman (1996) finds that increases in hazardous waste management costs raised air emissions, suggesting that facilities substitute between releases into different environmental media. Similarly, Alberini (2001) found that the enactment of regulations was associated with the change in the nature of the relationship between underground and aboveground pollutant disposals from one of complementarity to substitution. Anecdotally, the Commission for Environmental Cooperation (CEC) noted that during 1995-1999 North American 25% decreases in air releases were offset by 25% increases in on-site land releases, 35% landfill releases, and 26% effluent releases.¹²⁸

¹²⁸ More specifically, the CEC notes that “The North American manufacturing sector's 25-percent (153,000 tonnes) reduction in releases to air was largely offset by a 25-percent

Further, when examining the residuals from the three environmental performance models of a given mill across air and water compliance, and toxic releases, Gray et al. (2011a) found weak positive correlations between (1) air and water, and (2) air and toxics, suggesting that a mill with good air pollution performance was likely to perform better on water and toxics. Finally, potentially similar to the theoretical model in Colson and Menapace (2011), the use of cross media monitoring and enforcement creates cross-media compliance spillovers. Given the availability of the data and in order to expand the limited literature, I propose in-depth analyses investigating the nature of the relationship between different pollution media at the mills.

Regulatory Effectiveness

Monitoring vs. Enforcement, Environmental Recidivism and Chronic Non-compliance

From the perspective of the literature focused on regulatory effectiveness, my findings suggest that monitoring and enforcement actions may be driven by different factors. This can be seen anecdotally in Chapter 1 in Figures 1.5 and 1.6, which depict dramatically different graphs for the number of inspections and enforcements at pulp and paper mills during 1973-2013. First, I suspect that monitoring inspections are regularly scheduled events and their primary role is to communicate the importance of consistent

(33,000 tonnes) increase in on-site releases to land and a 35-percent (58,000 tonnes) increase in off-site releases (mostly to landfills). Releases to lakes, rivers and streams also increased during this period by 26 percent (24,000 tonnes)”
(<http://www.cec.org/Page.asp?PageID=122&ContentID=1945&SiteNodeID=361>).

compliance during the current and future periods. Enforcement actions, such as levied fines and judicial actions, on the other hand, are targeted at ex-post and repeat offenders with the emphasis on past performance. To put in other words – while both compliant and non-compliant firms need to be inspected, only offenders need to be punished.

Further, in their 2007 report, the EPA explicitly states that, while there is ample literature on the deterrence effect of monitoring and enforcement on non-compliance, the empirical literature on repeat offenders, or recidivists, is limited and “represents a promising area of future empirical research.”¹²⁹ The report cites the single work of Miller (2005), which analyzed both civil and administrative penalties and found that both were associated with reduced repeat offenses. Also, the author found some evidence that criminal fines that increased with the number of offenses were especially effective for reducing recidivism and chronic non-compliance. Given the differences exhibited in the number of monitoring and enforcement actions and lack of literature differentiating the two types of activities and factors that drive them, this presents an interesting area for empirical investigation.

Role of Public Scrutiny in Voluntary Environmental Programs

I next move to the question of evaluating the effectiveness of the voluntary environmental programs. According to the taxonomy developed by Lyon and Maxwell (2001) and updated by Lyon (2013), policies geared towards firms’ self-regulation fall under Public Voluntary Schemes (PVS) and Public Voluntary Programs (PVP).

¹²⁹ EPA (2007), "Monitoring, Enforcement, & Environmental Compliance: Understanding Specific & General Deterrence, State-of-Science White Paper," p. 13.

Reviewing the existing literature, the authors emphasize that the PVS' and PVPs can be effective in complementing more traditional regulations and help raise public awareness of and stimulate public discourse over environmental initiatives. However, consistent with my findings, the authors indicate that some government reports criticize those PVS' and PVPs that do not institute monitoring and reporting requirements.¹³⁰ This, to quote the authors, “damages the credibility of the voluntary agreements since it does not allow for accountability, and makes ex post evaluation of the effectiveness of the agreements difficult” (Lyon and Maxwell, 2001, p. 2).

The assertion of the negative impact of damaged credibility of PVS' and PVPs due to the lack of public exposure and scrutiny is consistent with the findings in Essay 3 in Chapter 4 of this thesis on the determinants of new P2 activities at pulp and paper mills. Having found that the policy instrument associated with mandatory planning had a perverse effect on the expected number of new P2 counts, I suggest that both nonbinding and private characteristics of P2 mandatory plans create an incentive for delaying more costly modifications. Therefore, it is important to examine the role of public scrutiny in the effectiveness of the PVS' and PVPs, possibly extending the analysis to other voluntary programs that have a greater public exposure component.

¹³⁰ More specifically, the European Environmental Agency (1997) report entitled “Environmental Agreements: Environmental Effectiveness,” which can be found here: <http://www.eea.europa.eu/publications/92-9167-052-9/page002.html>.

To relate PVP discussions back to the rest of the literature on regulatory effectiveness and environmental compliance, one of the interesting findings using the case study methodology, Gray et al. (2011a) show that restructuring has little impact on compliance but affects voluntary activities. Specifically, their study showed that “as resources become scarce, companies might cut back on programs like establishing voluntary standards, consulting with environmental groups, or promoting EHS (environmental, human, safety) ‘culture’” (Gray et al. 2011a, p. 12).¹³¹ The authors suggest that EHS programs compete for scarce resources with other corporate functional departments and the impact of their programs is evaluated by the value-added or potential profits they would generate. From this perspective voluntary programs may not be viewed as ‘profit-generating’ and are likely to be cut from firms’ budgetary considerations. The survey results, as Gray et al. (2011a) state, showed that there was “little enthusiasm for ISO 14000 as a source of ‘additional value’ for the EHS departments in the Pulp and Paper industry” (Gray et al. 2011a, p. 12). This is consistent with the findings of Youtie et al. (2009), who found that only 3.3% of surveyed paper manufacturing firms in Georgia state indicated that they adopted ISO14000.¹³² Finally, the 1999 OECD report commented that regulators like VEPs potentially for two main reasons. On the one hand, the regulators may collude with the industry and speed up legislature in order to signal due diligence. On the other hand, the VEPs may serve as a

¹³¹ EHS stands for environmental, human and safety, and refers to the literature on corporate EHS risk management.

¹³² Youtie et al. (2009) enumerate the sustainability programs reported by the paper establishments in the GA manufacturing survey. The programs include: High Efficiency Lighting, Water Recycling, Energy Audits, Recycling Production Materials, ISO 14000, Life Cycle Costing, EPA Programs, Energy Star, and Sustainability Program for Environmental Stewardship.

mechanism to transfer at least part of the administrative cost of compliance to the industry. While undocumented, such claims would be consistent with the decreases in regulatory budgets found in Gray and Shimshack (2011) and more analyses need to be done to suggest any such relationships.

Empirical Improvements

Endogeneity of Preemptive/Strategic Behavior

Last, but far from least, in order to properly validate my empirical tests, it is important to address the issue of endogeneity persistent in all the models of preemptive and strategic interactions between the industry and the regulators. Confirming my expectations and when examining the residuals from the three environmental performance models of a given mill across air and water compliance, and toxic releases, Gray et al. (2011a) found that there were components of performance that were not explained by the models.¹³³ The weak positive correlations between (1) air and water, and (2) air and toxics, suggested that mills with good air pollution performance were likely to perform better on water and toxics. And while I did not examine errors estimated in my models, the parameter coefficients suggested similar relationships between (1) air and water and (2) air and land models (see Tables 4.2 and 4.3 in Essay 2, Chapter 3).

By my definition, the mill performance variables, namely the level of TRI and P2 count, are endogenous in the model of regulatory stringency. If the

¹³³ Such factors could include “better management ability or greater local pressure” as proposed by the authors (Gray et al. 2011a, p. 7).

unobserved component, for example, is the quality of mill management and good management is expected to decrease the number of regulatory actions, then the effect of effect of the omitted good management will generate lower than expected errors or will or will be associated with more regulatory stringency than expected from the included included independent variables. Good management will also be associated with better mill performance, leading to positive correlation between the estimated errors and TRI and P2 variables.

On the other hand, bad management is expected to generated greater environmental stringency and, if true, will generate higher than expected errors for the included explanatory variables. Yet, similar to the case with good management, bad management is likely to be associated with worse mill performance, resulting in the positive correlation between environmental performance and errors. In both cases, the correlation between the estimated errors and TRI/P2 is greater than zero, which leads to endogeneity caused by the omitted quality of management.

More Facility-level Data, Extension to Other Policies, Programs, and Sectors

Finally, my current analyses cover mid-1980s to 2002. Data availability allows me to extend the model estimations up to 2013-2014, once a number of data sets are merged together. In terms of additional variables, I can include the EPA facility-level data on the history of compliance. Additional years may provide sufficient basis for testing determinants of adoptions of all eight P2 categories. In relation to other PVPs, the pulp and paper industry take part in two certification programs – Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI) – both of which have not yet been empirically studied. Locational variables, such as per-capital income, can be merged

at a county level, which then can provide substantial basis for studying any spatial correlations and geographical spillovers in the data. Finally, extending the analyses to include other industries, regulatory policies and environmental programs will help broaden available research on the complex interrelationships between regulatory policy climates and industry responses.

Appendix A: Essay 1

Table A.1. Previous Findings

Variables	Levinson (1996)	Gray (1997)	Gray and Shadbegian (1998)	Bergman and Johanson (2002)	Lundmark and Nilsson (2001)	Lundmark (2001)	Gray and Shadbegian (2002)	Lundmark (2003)
Environmental Stringency		_*	_*					
Environmental Non-/Compliance								
Taxes	+, marginall y significant	-, marginall y significant			+		+	
Wages	-	-		-/+*	+	_*	_*	_*
Energy	-	+* in some specificatio ns	+	-	_*	+	_*	-
Land		Land price: -; Area: +*					Land price: +; land area: +*, takes away significance from polit var	
Virgin Pulp			+* for kraft, sulf, mech; - for deink	_*	+	+		_*

Table A.1. Continued

Variables	Levinson (1996)	Gray (1997)	Gray and Shadbegian (1998)	Bergman and Johanson (2002)	Lundmark and Nilsson (2001)	Lundmark (2001)	Gray and Shadbegian (2002)	Lundmark (2003)
Recycled Pulp				+	+	-		Waste paper price: -; recovery rate +
Transportation	+							
Employment	-	Unions: -; unemploy- ment: +					Unions: mixed insignificant; unemployment: -	
Income		Mixed			+	+	+	
Population		-	-	+	+	-	- , mixed	
Agglomeration				Real GDP growth: -		+	Paper demand: +; HHI: -; state paper production: +	+
Education		+					Mixed insignificant	
Cost of capital			+	+				
Exchange rate				+				
Time trend				-				
Political pressure	-	-	-				Vote: -	

Table A.1. Continued

Variables	Levinson (1996)	Gray (1997)	Gray and Shadbegian (1998)	Bergman and Johanson (2002)	Lundmark and Nilsson (2001)	Lundmark (2001)	Gray and Shadbegian (2002)	Lundmark (2003)
Plant age			_*					
Dirty industry		_*					+	
Political party (Democratic)		_*					+ mixed significance	

Note: '-/+' stand for negative and positive signs; '*' for statistical significance at, at least, 10% significance level; and HHI for Herfindahl Index measuring industry concentration. For space reasons did not include Carlton (1993), Bartik (1985), Herderson (1996), List (2001), List et al. (2004), and Condliffe and Morgan (2008).

Table A.2. Correlations for Variables in the First-differencing Models

	1	2	3	4	5	6	7
1 Dep.Var.: Δ Investment	1						
2 Δ Environmental Stringency	-0.03	1					
3 Δ Environmental Noncompliance	0.13	-0.07	1				
4 Δ Taxes	0.08	-0.01	-0.01	1			
5 Δ Wage	0.02	0.00	-0.03	0.05	1		
6 Δ Energy Price	-0.04	-0.05	0.04	-0.10	0.00	1	
7 Δ Recycled Pulp	0.04	-0.09	0.03	0.02	0.01	0.01	1
8 Δ Land Price	-0.04	0.06	-0.03	0.09	0.00	-0.04	-0.03

Table A.3. Correlations for the LPM and Logit Models

	1	2	3	4	5	6	7
1 Dep. Var.: Investment	1						
2 Environmental Stringency	-0.13	1					
3 Environmental Noncompliance	-0.09	0.11	1				
4 Tax Rates	0.25	-0.06	0.24	1			
5 Wage	0.06	-0.10	0.07	0.24	1		
6 Energy Price	-0.02	0.21	0.04	0.22	-0.15	1	
7 Recycled Pulp	0.27	-0.19	-0.04	0.54	0.22	-0.27	1
8 Land Price	0.02	0.30	0.25	0.21	0.17	-0.13	0.05

Table A.4. Mill-level First-differenced Models

Dependent variable: Δ Mill Capacity	I
Intercept	0.0618*** (0.020)
Δ Environmental Stringency	0.0021 (0.002)
Δ Environmental Noncompliance	-0.0073** (0.003)
Δ Taxes	-0.1735 (0.184)
Δ Wage	-0.0085 (0.054)
Δ Energy Prices	-0.0631 (0.290)
Δ Recycled Pulp	0.0149

Table A.4. Continued

Dependent variable: Δ Mill Capacity	I
	(0.027)
Δ Land Price	-0.3697
	(0.300)
N	2,988
R-Square	0.0008
F Value	0.36

Note: All variables are in the two-year lagged and log form. Heteroskedasticity-consistent standard errors for the OLS estimates were obtained using White (1980) procedure and are reported in brackets. Significance levels are indicated as follows: * significant at the $\alpha = .10$ level, ** significant at the $\alpha = .05$ level, and *** significant at the $\alpha = .01$ level.

Table A.5. Mill-Level Logit Models with State and Year FE

Dependent variable: 1 if at least 10K mill capacity increase	State/Year FE	Mill/Year FE
Environmental Stringency	0.0813** (0.033)	-0.0098 (0.035)
Environmental Noncompliance	-0.0912 (0.114)	-0.1850 (0.120)
Taxes	0.1346 (0.364)	0.0034 (0.370)
Wage	-0.5711 (0.394)	-0.6408 (0.392)
Energy Prices	-0.0074 (0.690)	-0.3116 (0.699)
Recycled Pulp	-0.1984 (0.149)	-0.1864 (0.150)
Land Price	-1.6646*** (0.480)	-1.6812*** (0.486)
N	3,190	3,190
-2 Log L	1,997.0	1,475.2
Pseudo R-squared	0.015	0.019

Note: All variables are in the two-year lagged and log form. Significance levels are indicated as follows: * significant at the $\alpha = .10$ level, ** significant at the $\alpha = .05$ level, and *** significant at the $\alpha = .01$ level.

Appendix B: Essay 2

B1. Preliminary Endogeneity Checks

To test for endogeneity due to the omitted quality of management, which is likely to be correlated with one or both measures of environmental performance – TRI and P2, I calculate ownership change and state paper manufacturing income. I expect the first variable to proxy improved management from the previous period in case there was a change in ownership, and the second variable to approximate industry profitability within a state. These are not be the best instrumental variables (IV) and further work, specifically examining IV validity using the overidentification test, will help identify better instruments for the quality of pulp and paper mill managers.

Since there are no endogeneity tests available for panel negative binomial methodology, I treated the two dependent variables – count of inspections and count of enforcements – first, as continuous, then as binary. However, when running the endogeneity tests using the discrete regressions with 2-way fixed effects, the models fail to converge. This could be the result of one or more explanatory variables having high correlation with the dependent variables. The quick look at the correlation matrices aggregated across all mills (see Appendix Table B.1) does not point to any one variable in particular, hence more disaggregated analysis is needed to complete this step. I intend to review the data mill-by-mill for the next stage of the research for this paper. Finally, to test and control for endogeneity in panel data and within the framework of the exponential regressions as the next step of this work, I will follow Wooldridge (2010) and will use the Correlated Random Effects (CRE) Poisson methodology.

For this thesis, to get a sense if there is an issue of endogeneity in the current analyses, I employ two-stage linear with 2-way FE using full information maximum

likelihood (FIML) estimation (PROC QLIM in SAS). The suspect endogenous variables are the mill-level TRI and number of P2 adoptions. The test of each of the variables independently as well as together for both inspections and enforcements, fails to reject the null of no endogeneity. The exception is TRI in the model of inspections with the p-value of 0.09, which rejects the null of exogeneity at 10% significance level. This result argues for P2 being a good measure of the quality of environmental management (vs. being a greenwash).

Table B.1. Correlation Matrix for Essay 2

#	Variable	1	2	3	4	5	6	7	8	9	10	11
1	All Inspections	1										
2	All Enforcements	0.16	1									
3	Air Inspections	0.8	0.06	1								
4	Air Enforcements	0.18	0.41	0.15	1							
5	Water Inspections	0.65	0.12	0.13	0.11	1						
6	Water Enforcements	0.05	0.86	0	0.02	0.08	1					
7	Land Inspections	0.33	0.21	0.09	0.06	0.05	0.02	1				
8	Land Enforcements	0.16	0.35	0.03	0.01	0.03	0.03	0.53	1			
9	ln(Air TRI, t-1)	0.25	0.16	0.17	0.14	0.17	0.08	0.15	0.11	1		
10	ln(Water TRI, t-1)	0.25	0.15	0.14	0.14	0.23	0.07	0.1	0.11	0.72	1	
11	ln(Land TRI, t-1)	0.16	0.12	0.14	0.12	0.1	0.07	0.04	0.04	0.51	0.55	1
12	ln(Total TRI, t-1)	0.25	0.15	0.17	0.14	0.16	0.07	0.15	0.11	0.95	0.74	0.5
13	ln(P2, t-1)	0.02	0.02	0.03	0.03	0	0	0	0.01	0.15	0.17	0.07
14	ln(Loc Gov Exp, t-1)	0	0.01	0	0.01	-0.01	0.01	0.03	-0.02	-0.06	-0.04	-0.05
15	ln(State Gov Exp, t-1)	0.01	0.04	-0.04	0	0.07	0.06	0	-0.02	-0.16	-0.13	-0.12
16	ln(Sierra Membership, t-1)	0	-0.01	0	0.01	0	0	0.01	-0.02	-0.2	-0.2	-0.21
17	Year P2 Adopted	-0.11	0.01	-0.13	0	-0.02	-0.01	0.01	0.04	-0.11	-0.06	-0.06
18	ln(State Per Capita Inc, t-1)	-0.02	-0.02	-0.04	-0.07	0.05	0	-0.05	0.01	0.14	0.17	0.09
19	ln(Annual Mill Capacity, t-1)	0.17	0.16	0.12	0.13	0.1	0.09	0.11	0.1	0.51	0.45	0.39
20	ln(Firm Market Share, t-1)	0.07	0.08	0.07	0.04	-0.01	0.05	0.11	0.08	0.33	0.31	0.24
21	ln(#Paper Grades Mill Produces, t-1)	0.12	0.11	0.09	0.07	0.05	0.05	0.12	0.11	0.34	0.33	0.25
22	Board Mill, Reference category	0.08	0.13	0.07	0.05	0.01	0.1	0.12	0.08	0.14	0.06	0.08
23	Pulp Mill	0.05	0.05	0.07	0.09	-0.02	0.01	0.04	0.03	0.2	0.2	0.26
24	Paper Mill	0.07	-0.03	0.01	-0.03	0.09	-0.04	0.04	0.03	0.12	0.16	0.03

Table B.1. Continued

	12	13	14	15	16	17	18	19	20	21	22	23
12 ln(Total TRI, t-1)	1											
13 ln(P2, t-1)	0.15	1										
14 ln(Loc Gov Exp, t-1)	-0.03	-0.07	1									
15 ln(State Gov Exp, t-1)	-0.12	-0.05	0.78	1								
16 ln(Sierra Membership, t-1)	-0.17	-0.07	0.81	0.8	1							
17 Year P2 Adopted	-0.09	0.02	0.05	0.1	0.14	1						
18 ln(State Per Cap Inc, t-1)	0.11	0.05	-0.62	-0.6	-0.63	-0.05	1					
19 ln(Ann Mill Capacity, t-1)	0.5	0.05	0	-0.11	-0.16	-0.1	0.07	1				
20 ln(Firm Market Share, t-1)	0.31	0.05	-0.13	-0.16	-0.23	-0.03	0.14	0.04	1			
21 ln(Number of Paper Grades Mill Produces, t-1)	0.32	0.08	-0.06	-0.11	-0.14	-0.06	0.12	0.4	0.08	1		
22 Board Mill, Reference category	0.11	-0.11	0.01	-0.08	-0.09	-0.09	-0.06	0.39	0.1	0.11	1	
23 Pulp Mill	0.2	0.08	-0.01	-0.06	-0.12	-0.1	0.02	0.25	0.06	0.38	-0.09	1
24 Paper Mill	0.13	0.12	0.01	0.04	0.06	0.06	0.1	0	-0.15	0.28	-0.63	0

Appendix C: Essay 3

C1. Preliminary Endogeneity Checks

Harrington (2012) suggested that the year of legislative adoption of P2 mandatory planning instrument may be endogenous in relation to state-level facility characteristics. She ran a state-level probit model with the year of adoption of P2 mandatory planning against a number of aggregated facility measures and did not find statistical significance among them. Following her suggestion, I test if the P2 legislation variables are endogenous individually as well as jointly. Given that there are no endogeneity tests available for panel negative binomial methodology, I ran linear and logit with two-way fixed effects treating the count of P2 adoptions as a continuous and binary variable. In the first case, the estimations ran smoothly, in the second (logit with 2-way FE) the models failed to converge.

For the purposes of providing preliminary estimations of endogeneity, I ran the linear regressions using the full information maximum likelihood (FIML) estimation (with PROC QLIM in SAS). The suspect endogenous variables are continuous and are: year of P2 adoption, year of adoption of numerical goal, year of adoption of reporting requirement, and year of adoption of mandatory planning. The tests of each variable independently fail to reject the null of no endogeneity. However, when testing for a joint null, the model fails to converge. This could be the result of one or more explanatory variables having high correlation with the dependent variables.

The quick look at the correlations mill-by-mill and the history of P2 legislation adoption (Table 4.2 of Essay 3, Chapter 4) show that the years of adoption of P2 reporting requirement and mandatory planning are correlated. This suggests that the two

variables should be combined into one. However, the main results presented in Table 4.4 indicated that the two variables have different impact on all P2 adoptions and especially when P2 modifications are disaggregated into two groups – (i) input and process and (ii) process, equipment, and product modifications. This further complicates the analysis and more research is needed to properly run the econometric estimations.

From Table 4.2 and the list of states in the current sample, there are two states which adopt one, but not the other policy instrument: LA and OH adopted the reporting requirement, but not mandatory planning. If including these two states from the sample does not change the overall results, then one would be able to say that the findings in relation to the negative sign on mandatory planning are robust. I ran Model I with additional LA and OH dummy variables, but it failed to converge. I then ran Model I on the sample without (1) LA and OH as well as (2) omitting the year of adoption of P2 legislation and year of adoption of P2 numerical goal, and the results were qualitatively the same – the coefficient on the reporting requirement is positive and on the mandatory planning is negative and both are highly significant.

To test for endogeneity due to omitted quality of state's environmental stewardship, I chose state and local monitoring and enforcement budgets to proxy for the state's ability to promote environmental programs. The budget variables are expected to be correlated with the years of adoption of state P2 policies and policy instruments, but uncorrelated with the error term in the unrestricted model. These may not be the best instrumental variables and further work will help identify better instruments for the quality of state environmental stewardship. Finally, to control for endogeneity in panel data and within the framework of the exponential regressions as the next step of this

work, I will follow Wooldridge (2010) and will use the Correlated Random Effects (CRE) Poisson methodology.”

Table C.1. Correlation Matrix for Essay 3

#	Variable	1	2	3	4	5	6	7	8	9	10	11
1	Number of New P2 Activities	1										
2	Group 1 P2: New Input and Procedural Modifications	0.9	1									
3	Group 2 P2: New Process, Equipment, and Product Modifications	0.72	0.35	1								
4	Year P2 Adopted, t-1	-0.03	-0.01	-0.07	1							
5	Year Adopted, Numerical Goal, t-1	-0.02	0.01	-0.06	0.19	1						
6	Year Adopted, Reporting Requirement, t-1	-0.01	0	-0.03	0.47	0.13	1					
7	Year Adopted, Mandatory Planning, t-1	-0.02	0.01	-0.06	0.4	0.18	0.84	1				
8	P2 State Grant Budget, t-1	-0.13	-0.09	-0.14	0.19	0.14	0.08	0.12	1			
9	Mill TRI, t-1	0.2	0.17	0.16	-0.1	-0.1	-0.03	-0.08	-0.06	1		
10	Mill Inspections, t-1	0.1	0.08	0.1	-0.13	0.01	-0.08	-0.14	-0.04	0.28	1	
11	Mill Enforcements, t-1	0.06	0.03	0.08	0.02	-0.07	0.1	0.02	-0.04	0.17	0.18	1
12	Sierra Membership, t-1	-0.09	-0.09	-0.06	0.12	-0.14	0.24	0.29	0.12	-0.21	-0.1	-0.03
13	State Per Capita Income, t-1	0.12	0.12	0.08	-0.03	0.17	-0.1	-0.05	-0.21	0.14	0.07	0
14	Firm Spillover P2, t-1	0.25	0.22	0.19	-0.04	-0.02	0.01	-0.06	-0.16	0.32	0.14	0.05
15	Mill Cumulative P2, t-1	0.32	0.32	0.18	0.09	0.05	0.04	0.07	0.17	0.3	0.11	0.02
16	Mill Cumulative Group 1 P2, t-1	0.32	0.37	0.12	0.1	0.08	0.02	0.06	0.15	0.25	0.05	-0.01
17	Mill Cumulative Group 2 P2, t-1	0.22	0.17	0.22	0.05	-0.02	0.07	0.07	0.14	0.24	0.1	0.06
18	Annual Mill Capacity, t-1	0.03	0	0.06	-0.11	-0.04	0.02	-0.04	-0.01	0.49	0.19	0.17
19	Number of Mills per Firm, t-1	0.04	0.02	0.06	-0.08	-0.09	-0.04	-0.11	-0.07	0.34	0.09	0.14
20	Board Mill, Reference Category	-0.15	-0.15	-0.08	-0.1	-0.14	0.01	-0.06	-0.03	0.11	0.07	0.14
21	Pulp Mill	0.08	0.07	0.06	-0.08	-0.03	0.02	0.03	-0.02	0.19	0.07	0.03
22	Paper Mill	0.16	0.14	0.11	0.04	0.11	0	0.03	0.01	0.1	0.07	-0.06

Table C.1. Continued

#	Variable	12	13	14	15	16	17	18	19	20	21	22
12	Sierra Membership, t-1	1										
13	State Per Capita Income, t-1	-0.63	1									
14	Firm Spillover P2, t-1	-0.19	0.16	1								
15	Mill Cumulative P2, t-1	-0.01	0.03	0.3	1							
16	Mill Cumulative Group 1 P2, t-1	-0.03	0.03	0.25	0.92	1						
17	Mill Cumulative Group 2 P2, t-1	0.02	0.02	0.23	0.78	0.57	1					
18	Annual Mill Capacity, t-1	-0.21	0.1	0.14	0.08	0.04	0.09	1				
19	Number of Mills per Firm, t-1	-0.2	0.15	0.49	0.07	0.05	0.07	0.31	1			
20	Board Mill, Reference Category	-0.13	-0.04	-0.07	-0.2	-0.18	-0.13	0.38	0.18	1		
21	Pulp Mill	-0.13	0.02	0.11	0.14	0.11	0.08	0.24	0.09	-0.09	1	
22	Paper Mill	0.05	0.11	0.17	0.23	0.19	0.18	-0.03	0	-0.66	-0.01	1

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