Policy Instruments and Adoption of Pollution Prevention Activities

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CPBIS Working Paper, CPBIS-WP-2015-01[c]

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, we 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, we 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. We 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. Robustness checks indicate that adopting mandatory P2 planning can lead to perverse results because of their non-public and non-binding nature. To contribute to previous research, we examine the impact of each P2 policy instrument individually and include state P2 grants.

Preliminary Version: September 15, 2015

JEL Classification: L67, M14, Q52, Q55, Q58
Keywords: Corporate Social Responsibility, Environmental Regulations, Industry Studies, Pulp and Paper, Pollution Control Adoption and Costs, Technological Innovation

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Introduction

Since 1981 when 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). Further 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).

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 (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 this paper, we 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.

To examine if the legislation aimed at voluntary compliance is effective in terms of encouraging facilities to adopt more VEPs, this study examines pollution prevention (P2) legislation and its impact, among other factors, on the adoption of P2 modifications at pulp and paper mills. 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 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

[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.

user among U.S. manufacturers.[2] The combination of its resistance to quick market adjustments due to its capital intensity and being one of the most regulated industries among heavy manufacturers makes the U.S. papermaking sector an interesting case study of how traditional manufacturers respond to the changing nature of environmental regulations.

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 in addition to 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. We are 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 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

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[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/pulppasn.pdf

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 variable[3]. 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.

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

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

environmental technologies.[4] This 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. Examining the role of previous

[4] 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 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.

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, we 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.[5]

P2 Legislation, Policy Instruments, and Grants

[5] 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).

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, we 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, we expect that (4.a) year of state adoption of mandatory planning may have different effects on the two groups of P2 modifications. Finally, we 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 at 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. We 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), we 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, we 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, we 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, we 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.

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*:

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

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 1 provides the descriptive statistics for all variables.

[Table 1]

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.[6] 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 categories.[7,8] To disaggregate all P2 activities into categories, we 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

[6] The TRI.EZ search tool is available at: http://www.epa.gov/enviro/facts/tri/ez.html.
[7] For detailed discussion of P2 categories, see Urmanbetova (2015).
[8] 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), we 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.

modifications.[9] Mill-level cumulative P2 activities and firm-level P2 spillovers are calculated for both all P2s as well as two P2 groups.[10]

The data are further matched with the TRI facility records to calculate (1) total annual TRI[11] and (2) number of inspections and enforcements at facilities across all three media: air, water, and land. We 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.[12] The TRI and P2 data starts at 1988.

Political Threat

To measure the state environmental political clout we use the annual membership of the Sierra Club, the largest grassroots environmental organization in the U.S.[13] Finally, state income

[9] 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). We 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. 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.

[10] 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 we plan to investigate if the measurement error associated with the cumulative P2 activities is nonrandom and biases the estimates.

[11] Facility-level TRI data can be downloaded from http://www2.epa.gov/toxics-release-inventory-tri-program/tri-data-and-tools.

[12] 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.

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

per capita comes from the Bureau of Economic Analysis' (BEA) Regional Economic Accounts.[14]

Variables Measuring P2 Policy Tools

The year of P2 legislation adoption across states comes from Harrington (2013).[15] 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 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.[16] In addition to P2 legislation and policy instruments variables, we include the amounts of P2 grants awarded to state and tribal technical assistance programs from 1988.[17]

Mill-level Production Variables

[14] 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/.

[15] 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.

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

[17] 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/.

To supplement facility-level monitoring and technology abatement data, we 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).[18,19] 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. We 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 we 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.[20] 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.[21] Matching the EPA with mill capacity data, we were able to find and include in the final sample 200 one-to-one clean matches. The

[18] For the full description of the FPL data, see: http://www.fpl.fs.fed.us/documnts/fplrp/fplrp602.pdf.

[19] 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.

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

[21] 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.

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.

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:

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

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 our 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 1 of descriptive statistics, we 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:

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

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 β% 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.[22]

Results

Table 2 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.

[Table 2]

[22] 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.

We 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 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 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.

Robustness Checks

After running preliminary tests of endogeniety,[23] we further tested if the P2 legislation variables are endogenous individually as well as jointly.[24,25] In the case of testing the P2

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[23] Following Harrington (2012), we ran a number of probit models regressing each of the P2 legislation variables against the state-level facility characteristics and found most of them to be statistically significant.

[24] Given that there are no endogeneity tests for the negative binomial methodology within the panel data, we ran linear and logit models with two-way fixed effects or treating the count of P2 adoptions as a continuous and binary variable.

[25] To test for endogeneity due to the omitted quality of state environmental stewardship, we chose state and local monitoring and enforcement budgets to proxy for the state 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. The budget data come from the Census' Data Base on Historical Finances of Federal, State and Local Governments: State Aggregates, Fiscal Year 1978-2008 (obtained directly from the Census through their inquiry services: govs.cms.inquiry@census.gov). The budget line item that captures state expenditures on government protective and inspection services comes from the Direct Expenditures and is called Protective Inspection and Regulation,

legislation variables individually, we failed to reject the null of no endogeneity; but when testing for a joint null, the model failed to converge. This could be the result of one or more explanatory variables having high correlation with the dependent variable or multicollinearity.

The correlation coefficients and the history of P2 legislation adoption (Harrington 2013) show that the years of adoption of P2 reporting requirement and mandatory planning are correlated (0.84). Yet, the coefficients of each of these variables have the opposite impact on all P2 adoptions – reporting requirement and positive, while mandatory planning is negative and both are statistically highly significant. The statistical effect is stronger when the P2 modifications are separated into the two groups: (i) input and process and (ii) process, equipment, and product modifications. Combining the two variables into one produced statistically insignificant results, as expected. However, including either reporting requirement or mandatory planning only (in both cases with and without year of adoption of P2 legislation and numerical goal), gave the same qualitative results as reported in Table 2 – the year of adoption of the reporting requirement as positive, mandatory planning as negative and both highly statistically significant, confirming the robustness of the initial results.

In addition, the current sample has two states, which adopted one, but not the other policy instrument: LA and OH adopted the reporting requirement, but did not adopt the mandatory planning. If excluding 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. We 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

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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: http://www2.census.gov/govs/pubs/classification/2006_classification_manual.pdf).

qualitatively the same – the coefficient on the reporting requirement was positive and on the mandatory planning was negative and both were highly significant.

Finally, to gauge if including time fixed effects obscure the results, we ran Model I (1) without time fixed effects and (2) with a time trend. In both of the cases, the year of adoption of P2 legislation became negative, but not significant at 0.05% level. We also tested and rejected the null hypothesis that the individual time effects were equal. As in the previous robustness checks, the coefficients for both the reporting requirement and mandatory planning maintained their original signs and high statistical significance.

Discussion and Policy Implications

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 this 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,[26] all of which fall into the category of input and procedural modifications. And in our sample, there are twice as many of input and procedural modifications than process, equipment, and product P2s (Table 1).

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

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 our 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.

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. [27] This, to quote the authors, "damages the credibility of the voluntary

[27] More specifically, the European Environmental Agency (1997) report entitled "Environmental

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.[28] Naturally, one would expect the grants to generate positive 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.[29] However difficult to envision, this is the only plausible

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Agreements: Environmental Effectiveness," which can be found here: http://www.eea.europa.eu/publications/92-9167-052-9/page002.html.

[28] 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 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.

[29] 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;

explanation we can conjecture given our data and results and suggest that more research needs to be done across other industries and possibly over a longer time span.[30]

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 (Harrington 2012, Brouhle and Harrington 2010, Brouhle at 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), we 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

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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.

[30] 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.

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.[31] 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 we are hoping to find positive firm and mill economies of scales for

[31] 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.

P2 technologies as in Khanna et al. (2009), we do not. Moreover, the findings exhibit substantive and statistically strong diseconomies of scale at both levels – firm and 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.

Finally, our findings 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, 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 we are able to offer a couple of plausible explanations for the unexpected effect of the mandatory planning policy instrument, we could not uncover why P2 grants have a robust negative spillover effect on P2 modifications. To explain the effect of the P2 mandatory planning, we 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, we 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 we find in the current 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. We 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.

Role of Public Scrutiny in 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). 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 our findings, the authors indicate that some government reports criticize those PVS' and PVPs that do not institute monitoring and reporting requirements. [32] 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 our findings 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, we 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.

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. (2011) 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. 2011, p. 12).[33] The authors suggest that EHS programs compete for scarce resources with other corporate

[32] 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.
[33] EHS stands for environmental, human and safety, and refers to the literature on corporate EHS risk management.

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. (2011) 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. 2011, 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.[34] 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 mechanism to transfer at least part of the administrative cost of compliance to the industry. While undocumented, such claims would be consistent with the aforementioned decreases in regulatory budgets found in Gray and Shimshack (2011) and more empirical analyses need to be done to suggest any such relationships.

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. We 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

[34] 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.

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.

The results of the 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), we find that assigning numerical goals as environmental policy tools can produce ambiguous results. Similarly, we 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 at 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.

Mandatory planning and P2 grants, however, produced quite surprising, if not perverse, results and, while we was able to explore and offer a couple of plausible explanations for the unexpected effect of the mandatory planning policy instrument, we could not uncover why P2 grants had a robust negative effect on P2 modifications. We 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, we 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, we 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 we find in our 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 our 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 our 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.

References

Anton W.R.Q., Deltas G., Khanna M. (2004) Incentives for Environmental Self-Regulation and Implications for Environmental Performance. Journal of Environmental Economics and Management 48:632-654. DOI: http://dx.doi.org/10.1016/j.jeem.2003.06.003.

Arimura T.H., Hibiki A., Katayama H. (2008) Is a Voluntary Approach an Effective Environmental Policy Instrument?: A Case for Environmental Management Systems. Journal of Environmental Economics and Management 55:281-295. DOI: http://dx.doi.org/10.1016/j.jeem.2007.09.002.

Arora S., Cason T.N. (1995) An Experiment in Voluntary Environmental Regulation: Participation in EPA′s 33/50 Program. Journal of Environmental Economics and Management 28:271-286. DOI: http://dx.doi.org/10.1006/jeem.1995.1018.

Brouhle K., Griffiths C., Wolverton A. (2004) The Use of Voluntary Approaches for Environmental Policymaking in the U.S., National Center for Environmental Economics, U.S. Environmental Protection Agency, Working Paper Series, Working Paper #04-05.

Brouhle K., Griffiths C., Wolverton A. (2009) Evaluating the Role of EPA Policy Levers: An Examination of a Voluntary Program and Regulatory Threat in the Metal-Finishing Industry. Journal of Environmental Economics and Management 57:166-181. DOI: http://dx.doi.org/10.1016/j.jeem.2008.07.006.

Brouhle K., Harrington D. (2010) GHG Registries: Participation and Performance under the Canadian Voluntary Climate Challenge Program. Environmental and Resource Economics 47:521-548. DOI: 10.1007/s10640-010-9391-4.

Brunnermeier S.B., Cohen M.A. (2003) Determinants of Environmental Innovation in Us Manufacturing Industries. Journal of Environmental Economics and Management 45:278-293. DOI: http://dx.doi.org/10.1016/S0095-0696(02)00058-X.

Cameron A.C. (1998) Regression Analysis of Count Data, in: P. K. Trivedi (Ed.), Econometric Society Monographs, Cambridge University Press, Cambridge, UK.

Dasgupta S., Hettige H., Wheeler D. (2000) What Improves Environmental Compliance? Evidence from Mexican Industry. Journal of Environmental Economics and Management 39:39-66. DOI: http://dx.doi.org/10.1006/jeem.1999.1090.

Decker C.S. (2005) Do Regulators Respond to Voluntary Pollution Control Efforts? A Count Data Analysis. Contemporary Economic Policy 23:180-194. DOI: 10.1093/cep/byi014.

Decker C.S. (2007) Flexible Enforcement and Fine Adjustment. Regulation & Governance 1:312-328. DOI: 10.1111/j.1748-5991.2007.00019.x.

Decker C.S., Wohar M.E. (2006) Environmental Accidents and Industry Structure. Journal of Economic Research 11:17-47.

Delmas M., Montes-Sancho M.J., Shimshack J.P. (2010) Information Disclosure Policies: Evidence from the Electric Industry. Economic Inquiry 48:483-498. DOI: 10.1111/j.1465-7295.2009.00227.x.

Delmas M.A., Toffel M.W. (2008) Organizational Responses to Environmental Demands: Opening the Black Box. Strategic Management Journal 29:1027-1055.

EEA. (1997) Environmental Agreements: Environmental Effectiveness, European Environmental Agency.

EPA. (2002) Profile of the Pulp and Paper Industry, EPA Office of Compliance Sector Notebook Project, EPA/310-R-02-002, Washington, DC 20460.

EPA. (2006) Pollution Prevention Incentives for States (PPIS) Grant Program Assessment Study, EPA Office of Pollution Prevention and Toxics, EPA742-R96-006, Washington, DC 20460.

Geroski P.A. (1990) Innovation, Technological Opportunity, and Market Structure. Oxford Economic Papers 42:586-602. DOI: 10.2307/2663063.

Goulder L.H., Mathai K. (2000) Optimal Co2 Abatement in the Presence of Induced Technological Change. Journal of Environmental Economics and Management 39:1-38. DOI: http://dx.doi.org/10.1006/jeem.1999.1089.

Gray W.B., Shadbegian R.J. (1998) Environmental Regulation, Investment Timing, and Technology Choice. Journal of Industrial Economics 46:235-256.

Gray W.B., Fatkin H., Golding D., Jiusto S., Sarkis J. (2011) Industrial Restructuring in the Pulp and Paper Industry: Relationships to Corporate Environmental, Health and Safety Risks, Working Paper.

Gray W.B., Shimshack J.P. (2011) The Effectiveness of Environmental Monitoring and Enforcement: A Review of the Empirical Evidence. Review of Environmental Economics and Policy 5:3-24. DOI: 10.1093/reep/req017.

Griliches Z. (1992) The Search for R&D Spillovers. The Scandinavian Journal of Economics 94:S29-S47. DOI: 10.2307/3440244.

Harrington D.R. (2012) Two-Stage Adoption of Different Types of Pollution Prevention (P2) Activities. Resource and Energy Economics 34:349-373. DOI: http://dx.doi.org/10.1016/j.reseneeco.2012.02.002.

Harrington D.R. (2013) Effectiveness of State Pollution Prevention Programs and Policies. Contemporary Economic Policy 31:255-278. DOI: 10.1111/j.1465-7287.2011.00312.x.

Hemphill T.A. (1993-1994) Corporate Environmentalism and Self-Regulation: Keeping Enforcement Agencies at Bay. Journal of Environmental Regulation:145-154.

Henderson J.V. (1996) Effects of Air Quality Regulation. The American Economic Review 86:789-813.

Henriques I., Sadorsky P. (1996) The Determinants of an Environmentally Responsive Firm: An Empirical Approach. Journal of Environmental Economics and Management 30:381-395. DOI: http://dx.doi.org/10.1006/jeem.1996.0026.

Innes R., Sam A. G. (2008) Voluntary Pollution Reductions and the Enforcement of Environmental Law: An Empirical Study of the 33/50 Program. Journal of Law and Economics 51:271-296. DOI: 10.1086/589659.

Jaffe A.B. (1986) Technological Opportunity and Spillovers of R & D: Evidence from Firms' Patents, Profits, and Market Value. The American Economic Review 76:984-1001. DOI: 10.2307/1816464.

Jaffe A.B. (1998) The Importance of “Spillovers” in the Policy Mission of the Advanced Technology Program. The Journal of Technology Transfer 23:11-19. DOI: 10.1007/bf02509888.

Jaffe A.B., Newell R.G., Stavins R.N. (2002) Environmental Policy and Technological Change. Environmental and Resource Economics 22:41-70. DOI: 10.1023/a:1015519401088.

Jaffe A.B., Palmer K. (1997) Environmental Regulation and Innovation: A Panel Data Study. The Review of Economics and Statistics 79:610-619. DOI: 10.2307/2951413.

Jaffe A.B., Stavins R.N. (1995) Dynamic Incentives of Environmental Regulations: The Effects of Alternative Policy Instruments on Technology Diffusion. Journal of Environmental Economics and Management 29:S43-S63. DOI: http://dx.doi.org/10.1006/jeem.1995.1060.

Khanna M., Anton W.R.Q. (2002) Corporate Environmental Management: Regulatory and Market-Based Incentives. Land Economics 78:539-558. DOI: 10.2307/3146852.

Khanna M., Damon L.A. (1999) EPA's Voluntary 33/50 Program: Impact on Toxic Releases and Economic Performance of Firms. Journal of Environmental Economics and Management 37:1-25. DOI: http://dx.doi.org/10.1006/jeem.1998.1057.

Khanna M., Deltas G., Harrington D. (2009) Adoption of Pollution Prevention Techniques: The Role of Management Systems and Regulatory Pressures. Environmental and Resource Economics 44:85-106. DOI: 10.1007/s10640-009-9263-y.

Khanna M., Quimio W.R.H., Bojilova D. (1998) Toxics Release Information: A Policy Tool for Environmental Protection. Journal of Environmental Economics and Management 36:243-266. DOI: http://dx.doi.org/10.1006/jeem.1998.1048.

King A.A., Lenox M.J. (2000) Industry Self-Regulation without Sanctions: The Chemical Industry's Responsible Care Program. The Academy of Management Journal 43:698-716. DOI: 10.2307/1556362.

Koehler D.A. (2007) The Effectiveness of Voluntary Environmental Programs—a Policy at a Crossroads? Policy Studies Journal 35:689-722. DOI: 10.1111/j.1541-0072.2007.00244.x.

Laestadius S. (1998) The Relevance of Science and Technology Indicators: The Case of Pulp and Paper. Research Policy 27:385.

Lanoie P., Thomas M., Fearnley J. (1998) Firms Responses to Effluent Regulations: Pulp and Paper in Ontario, 1985-1989. Journal of Regulatory Economics 13:103-120. DOI: 10.1023/a:1008022331188.

Lyon T.P., Maxwell J.W. (2001) “Voluntary” Approaches to Environmental Regulation: A Survey, in: A. N. Maurizio Franzini (Ed.), Economic Institutions and Environmental Policy, Ashgate Publishing Ltd., Aldershot, Hampshire.

Lyon T.P., Maxwell J.W. (2004) Corporate Environmentalism and Public Policy Cambridge University Press, Cambridge.

Lyon T.P. (2013) The Pros and Cons of Voluntary Approaches to Environmental Regulation, Reflections on Responsible Regulation Conference, Tulane University, New Orleans, LA.

Mansfield E. (1968) Industrial Research and Technological Innovation: An Econometric Analysis Norton Press, New York.

Matisoff D.C., Edwards J. (2014) Kindred Spirits or Intergovernmental Competition? The Innovation and Diffusion of Energy Policies in the American States (1990–2008). Environmental Politics 23:795-817. DOI: 10.1080/09644016.2014.923639.

Maxwell J., Lyon T., Hackett S. (2000) Self-Regulation and Social Welfare: The Political Economy of Corporate Environmentalism. The Journal of Law and Economics 43:583-618.

Maxwell J.W., Decker C.S. (2006) Voluntary Environmental Investment and Responsive Regulation. Environmental and Resource Economics 33:425-439.

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

Minatti Ferreira D.D., Borba J.A., Rover S., Dal-Ri Murcia F. (2014) Explaining Environmental Investments: A Study of Brazilian Companies. Environmental Quality Management 23:71-86. DOI: 10.1002/tqem.21374.

OECD. (1997) The Measurement of Scientific and Technological Activities. Proposed Guidelines for Collecting and Interpreting Technological Innovation Data (Oslo Manual) Second Edition, Eurostat, Luxembourg.

OECD. (1999) Voluntary Approaches for Environmental Policy OECD Publishing.

Ohanian N.K. (1994) Vertical Integration in the U.S. Pulp and Paper Industry, 1900-1940. Review of Economics and Statistics 76:202-07.

Parthasarathy P., Dowd S. (2000) Impact of the Cluster Rule on the Cost Competitiveness of U.S.

Peltzman S. (1976) Toward a More Generalized Theory of Regulation. Journal of Law and Economics 19:211-48.

Sam A.G., Khanna M., Innes R. (2009) Voluntary Pollution Reduction Programs, Environmental Management, and Environmental Performance: An Empirical Study. Land Economics 85:692-711. DOI: 10.2307/27759710.

Scherer F.M. (1967) Market Structure and the Employment of Scientists and Engineers. The American Economic Review 57:524-531. DOI: 10.2307/1812118.

Schumpeter J.A. (1942) Capitalism, Socialism and Democracy Harper Bothers, New York: Harper Bothers.

Stigler G.J. (1971) The Theory of Economic Regulation. The Bell Journal of Economics and Management Science 2:3-21. DOI: 10.2307/3003160.

USDOE. (2005) Energy and Environmental Profile of the U.S. Pulp and Paper Industry, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program, Prepared by Energetics, Inc.

Urmanbetova, A. (2015): "Pollution Prevention Activities: Background and Definitions," Center for Paper Business and Industry Studies, Center for Paper Business and Industry Studies (CPBIS), Working Paper CPBIS-WP-2015-04, Georgia Institute of Technology, Atlanta, GA.

Vidovic M., Khanna N. (2007) Can Voluntary Pollution Prevention Programs Fulfill Their Promises? Further Evidence from the EPA's 33/50 Program. Journal of Environmental Economics and Management 53:180-195. DOI: http://dx.doi.org/10.1016/j.jeem.2006.10.001.

Williamson O.E. (1965) Innovation and Market Structure. Journal of Political Economy 73:67-73. DOI: 10.2307/1828430.

Wooldridge J.M. (2010) Econometric Analysis of Cross Section and Panel Data. Second ed. The MIT Press, Cambridge, Massachusetts, 02142

Youtie J., Shapira P., Kay L. (2009) Practices and Plans for Sustainability in Georgia’s Pulp and Paper Sector: Results from the Georgia Manufacturing Survey 2008, CPBIS, Georgia Institute of Technology, Atlanta, GA, CPBIS Working Paper, CPBIS-FR-09-01.

Youtie J., Shapira P., Slanina J., Lamos E. (2006) Dimensions of Innovation in the Pulp and Paper Manufacturing Industry: Insights from the 2005 Georgia Manufacturing Survey, Paper prepared for the Annual Conference of the Technical Association of the Pulp and Paper Industry (TAPPI), April 24-27, 2006, Atlanta, Georgia.

Tables

Table 1. 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.

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

Table 2. 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*	-0.097**	-0.38***	-0.17***	-0.090*	-0.37***	-0.18***	-0.102	-0.36***	-0.23***
	(0.048)	(0.051)	(0.048)	(0.054)	(0.057)	(0.054)	(0.066)	(0.072)	(0.071)
Pulp Mill, *i*	0.63***	0.55***	0.225*	0.72***	0.64***	0.252*	0.287*	0.257	0.269
	(0.138)	(0.129)	(0.119)	(0.154)	(0.145)	(0.135)	(0.171)	(0.167)	(0.163)
Paper Mill, *i*	0.67***	0.45***	0.260**	0.62***	0.40***	0.318**	0.72***	0.49***	0.363**
	(0.121)	(0.117)	(0.110)	(0.138)	(0.134)	(0.127)	(0.163)	(0.163)	(0.160)
Over-dispersion	1.64***	1.17***	0.66***	1.70***	1.16***	0.50***	0.99***	0.71***	0.44***
	(0.155)	(0.126)	(0.093)	(0.200)	(0.162)	(0.106)	(0.231)	(0.194)	(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.