THE EFFECT OF REGULATORY ENFORCEMENT ON FACILITY-LEVEL EMPLOYMENT

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Abstract

This study examines the link from the stringency of environmental regulation, as captured by the extent which the regulation is enforced, to facility-level employment. This study contributes to the literature in three important ways by (1) examining the effects of the enforcement of environmental regulation, rather than the imposition of environmental regulation, (2) distinguishing workers based on their purpose – production workers versus environmental workers, and (3) identifying a causal mechanism linking environmental regulation to production workers based on a negative relationship between a facility's production level and its compliance with pollution limits. Our empirical analysis uses panel data from an original survey of chemical manufacturing facilities regulated under the Clean Water Act. The analysis first examines the effect of government interventions – regulatory monitoring inspections and enforcement actions (e.g., fines) – on overall employment. Then, the analysis jointly estimates a system of two equations: one for production workers and another for environmental workers. Overall, empirical results reveal that greater enforcement of environmental regulations reduces both production employment and environmental employment.

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1. Introduction

Economists and policy-makers debate whether or not jobs and environmental protection are mutually exclusive. The debate over the effects of environmental regulation on employment has proven especially fierce in today's political environment, where environmental protection budgets are widely being cut. The debate remains because the empirical literature on the labor effects of environmental regulation provides ambiguous conclusions. Almost all empirical studies find a statistically negligible effect (Morgenstern et al., 2002; Ferris et al., 2014; Gray et al, 2014) or a negative effect (Greenstone, 2002; Walker, 2011) on the total number of employees in an industry or at an individual facility. To contribute to this policy debate, this study examines the effects of environmental regulation, specifically its enforcement, on three facility-level labor outcomes: (1) overall employment, (2) employment related to activities supporting production including assembly, marketing, and accounting (hereafter "production employment"), and (3) employment dedicated to environmental management (hereafter "environmental employment").

Previous empirical studies of labor explore the imposition of environmental regulation. However, imposition is only the first step in protection of the environment through regulation. After an environmental regulation is imposed, continued effort in the form of enforcement is necessary to ensure facilities' compliance with any regulation (Helland, 1998a; Helland, 1998b; Earnhart, 2004a; Earnhart, 2004b; Gray and Shimshack, 2011). Environmental enforcement takes place in the form of various government interventions: monitoring inspections, informal enforcement (e.g., warnings), and formal enforcement (e.g., monetary penalties). Absent compliance, environmental regulation does not directly improve environmental protection. As important, as enforcement increases, the stringency of environmental regulation tightens. However, no previous study examines the effect of environmental enforcement on employment. Our study fills this void by examining the effect of Clean Water Act enforcement on employment at regulated facilities within the U.S. chemical manufacturing sector.

Within the economic literature linking environmental regulation to employment, most studies acknowledge that production labor is distinct from environmental labor (Morgenstern et al., 2002; Ferris, et al., 2014). However, these studies are unable to quantify separately the two types of labor, as data on environmental employment only exist in aggregate form at the industry level (Department of Commerce, 2010; Bureau of Labor Statistics, 2011).[1] Our study is able to examine two types of labor – production and environmental – using data from a unique survey that specifically instructs respondents to quantify separately these two labor types. Simply put, environmental employees engage in environmental management, which includes any method used by facilities to control pollution, e.g., environmental self-audits, internal monitoring protocols, end-of-pipe treatment technologies. In the studied sample, the presence of environmental employees is substantial, representing nearly 5 % of the average facility's workforce. In contrast to environmental workers, production workers engage in activities supporting production, including assembly, marketing, and accounting.

Our theoretical analysis constructs a two-input cost-minimizing framework to reveal the causal mechanisms linking environmental enforcement to production employment and environmental employment. Our analysis demonstrates that greater enforcement could spur more or less employment of production workers and environmental workers depending on whether the respective factor represents a "normal" or "inferior" input into the generation of compliance with environmental regulation. This exploration contributes to the literature since no previous study identifies a defensible causal mechanism linking environmental regulation, including its enforcement, to production employment. As important, all previous studies ignore environmental employment.

Our empirical analysis first estimates the effects of environmental enforcement on overall

[1] These aggregate data reflect estimates rather than actual measures of labor.

labor, which allows a comparison of our results with studies exploring the effects of environmental regulation on employment. Second, our analysis jointly estimates a system of equations with the two types of labor as separate dependent variables. This joint estimation incorporates facility-specific fixed effects to exploit the panel data structure and adjusts for facility-specific auto-correlation. Overall, our empirical results reveal that government interventions, almost exclusively, negatively affect overall employment as well as production and environmental employment. The joint estimation results reveal that reduced production is a desirable tool for complying with environmental restrictions, while environmental labor is an inferior input into the generation of environmental compliance, consistent with our theoretical framework. As one notable exception to the latter, inspections conducted by state agencies increase environmental employment; perhaps the technical assistance commonly offered by state inspectors prods the regulated facilities to employ more technically savvy environmental workers.

The rest of the paper proceeds as follows. Section 2 reviews the pertinent literatures. Section 3 describes Clean Water Act regulation of the chemical manufacturing sector. Section 4 constructs a theoretical framework, which generates empirically testable hypotheses. Section 5 describes the econometric framework. Section 6 discusses the data and provides summary statistics. Section 7 depicts the econometric analysis and reports the empirical results, while interpreting the results to test our hypotheses. Section 8 concludes and assesses briefly future research.

2. Literature Review

This study contributes to three distinct economic literatures. First and most important, this study contributes to the growing literature on the impact of environmental regulation on labor. Second, the study contributes to the literature on the public enforcement of environmental laws. Third, the study contributes to the literature on environmental management, of which environmental labor is one important form. The two latter literatures overlap since several studies examine the effects of various government interventions on environmental management decisions.

2.1. Impacts of Environmental Regulation on Labor

The economic literature examining the impacts of environmental regulation on labor is important, yet surprisingly thin. Our study examines the effect of environmental enforcement on labor, while all previous studies examine the labor impacts of the imposition of regulations. First, Morgenstern et al. (2002) examine the employment effects of greater environmental spending at the industry level of four key industries: pulp and paper mills, plastic manufacturers, petroleum refineries, and iron and steel mills. The authors find that increased environmental spending does not cause a significant change in employment. Walker (2011) examines the changes in employment as a result of the Clean Air Act Amendments of 1990. He finds that firms respond to the imposition of this environmental regulation by eliminating jobs. Greenstone (2002) finds that the Clean Air Act's designation of attainment vs. non-attainment counties has significant labor impacts in multiple manufacturing sectors. Berman and Bui (2001) examine the stringency of air quality regulation in the Los Angeles area. They find that regulatory stringency has no significant employment effects. Gray et al. (2014) study the impact of the Cluster Rule on employment in the pulp and paper industry. They find minimal effects on the number of employees at facilities subject to the rule. Sheriff et al. (2015) examine the employment effects of the Clean Air Act's Ozone National Ambient Air Quality Standards on the U.S. electric power sector. Finally, Ferris et al. (2014) find negligible employment effects when examining the effect of Phase I of the Title IV SO_2 trading program on fossil fuel-fired plants' employment.

2.2. Public Enforcement of Environmental Laws

A related literature explores the enforcement of environmental laws. As the seminal study, Becker (1968) provides the theoretical foundation for the public enforcement of laws including environmental laws. In this foundational study, the enforcement agency monitors the compliance of regulated facilities and deters non-compliance by threatening to impose sanctions in response to violations. Since this seminal work, a number of theoretical studies have expanded Becker's basic model; Polinsky and Shovell (2000) thoroughly review this theoretical literature. No previous theoretical study explores the effect of environmental enforcement on labor outcomes.

As important, numerous empirical studies explore the enforcement of public laws, which include environmental laws. This review focuses on the environmental studies. The majority of empirical environmental studies analyze the effect of environmental enforcement on facility- or firm-level environmental performance, e.g., compliance, or management, e.g., self-audits (Gray and Shadbegian, 2004; Shimshack and Ward, 2005; Gray and Deily, 1996; Laplante and Rhilstone, 1996; Earnhart, 2004a; Earnhart, 2004b; Earnhart and Segerson, 2012). Gray and Shimshack (2011) provide a comprehensive review of this empirical literature on environmental enforcement. No previous empirical study explores the effect of environmental enforcement on labor outcomes.

2.3. Environmental Management

A third literature examines the environmental management decisions of regulated facilities. Given the empirical thrust of the present study, this review focuses on previous empirical studies, of which none explore environmental labor. Several studies analyze specific types of environmental management. Khanna and Anton (2002), Anton et al. (2004), and Harrington et al. (2008) examine companies' decisions to implement various environmental management practices including pollution prevention practices, measured as a count. Khanna et al. (2007), Jones (2010), Ervin et al. (2012), Garcia et al. (2009), and Henriques and Sadorsky (1996) analyze companies' decisions to implement specific environmental management practices, each measured separately. Other studies focus on one particularly policy-relevant environmental management practice: environmental self-audits (Earnhart and Leonard, 2013; Evans et al., 2011; Earnhart and Harrington, 2014). And several studies examine a facility's decision to establish and possibly certify an environmental management system (EMS), such as certification based on the ISO 14001 commercial standard (Arimura et al., 2008; Nakamura et al., 2001; Dasgupta et al., 2000; Henriques and Sadorsky, 2007; Delmas and Toffel, 2008; Mori and Welch, 2008).

3. Clean Water Act Regulation of Wastewater from the Chemical Manufacturing Sector

3.1. National Pollutant Discharge Elimination System

This study examines facility behavior prompted by environmental regulation, specifically the Clean Water Act (CWA). The CWA's main purpose is to protect water quality. To this end, the CWA controls wastewater discharges from point sources.[2] The EPA created the National Pollutant Discharge Elimination System (NPDES) to control these point source discharges. The system's main form of control is the issuance of facility-specific permits, which identify the pollutant-specific discharge limits imposed on regulated facilities.

To establish discharge limits within individual facilities' permits, the issuing agency considers any relevant Effluent Limitation Guideline standard and water quality-based standard. The former is designed to require a minimum level of wastewater treatment for a given industry and the latter is designed to ensure that the water body receiving the discharges meets ambient surface water quality standards. After a potential discharge limit is calculated under each standard, the permitting agency writes the stricter of the two potential discharge limits into the permit.

The permitted discharge limit represents a performance-based standard. Compliance with this standard is based on a facility's own discharges. Thus, each facility is able to use any available abatement method to comply with its permitted limit. A number of abatement methods are available to facilities: end-of-pipe treatment technologies (i.e., capital), deployment of labor, and other methods.

NPDES-permitted facilities are required to monitor and self-report their discharges on a

[2] Point sources directly discharge into a waterbody, usually from a pipe or outfall, or indirectly discharge into a municipal wastewater collection system. In contrast, non-point sources generate discharges diffusely through run-off from agricultural fields, urban settings, or construction sites into a waterbody. This study focuses on point sources.

regular basis. Therefore, inspections are not needed to assess compliance with imposed discharge limits. More important, inspections cannot measure this type of compliance since limits constrain discharges measured over a period of time, e.g., entire month. Inspections can only measure the concentration of pollution in a discharge stream at a moment in time.

To ensure compliance with permits, the EPA and authorized state agencies periodically inspect facilities and take enforcement actions when the facility is not in compliance. Agencies possess great discretion over monitoring and enforcement decisions. Thus, environmental enforcement activity can vary considerably over time and across administrations. In the NPDES program, authorized state agencies are the primary party responsible for monitoring and enforcement, even though the EPA retains authority to inspect and impose sanctions on facilities as well. Inspections represent the main monitoring activity. Regulatory agencies use inspections as a vehicle for gathering evidence for future enforcement actions (Wasserman, 1984). In addition, agencies oftentimes use inspections to offer compliance assistance. As needed, agencies use a mixture of informal enforcement actions, such as warning letters, and formal enforcement actions, including monetary penalties (i.e., fines).

The NPDES program distinguishes between major facilities and minor facilities. Generally, major facilities are larger and discharge more wastewater.[3] Federal guidelines prompt the EPA and state agencies to scrutinize major facilities much more greatly than minor facilities (Earnhart, 2009; Earnhart and Harrington, 2014; Earnhart and Segerson, 2013).

3.2. Chemical Manufacturing Sector

Point sources of wastewater fall into one of two main categories: municipal sources (i.e., municipal wastewater treatment facilities) and industrial sources. Our study focuses on a single

[3] For the classification of each regulated facility, the EPA calculates a major rating with points assigned on the basis of toxic pollution potential, flow type, conventional pollutant load, public health impact, and water quality impact; the EPA classifies any discharger with a point total of 80 or more as a "major facility".

sector, chemical manufacturing facilities, which falls into the industrial sources category. Figure 1 displays the location of all CWA-regulated chemical manufacturing facilities operating in the United States. The focus on a single industrial sector is consistent with other empirical studies of industrial pollution (e.g., Laplante and Rilstone, 1996; Barla, 2007; Earnhart, 2009; Earnhart and Harrington, 2014).

For many reasons, the chemical manufacturing sector serves as a good choice for analyzing the employment effects of government interventions. First, the EPA has shown a strong interest in this sector. The EPA and the Chemical Manufacturing Association (CMA) jointly authored a study on the causes of non-compliance in the chemical manufacturing sector (EPA, 1999). Further, the EPA solely studied the compliance history of facilities operating in this sector (EPA, 1997). Second, the EPA considered two sub-sectors in the industry (industrial organics and chemical preparations) as priority sectors during a portion of the study period. Third, the CMA (now known as the American Chemistry Council [ACC]) has demonstrated a strong interest in promoting pollution reduction and prevention with its Responsible Care initiative. Fourth, wastewater data disaggregated by 4-digit Standard Industrial Classification (SIC) code reveal that four of the 10 most polluting sub-sectors operated in the chemical manufacturing sector as of 2008 (EPA, 2011); this evidence demonstrates that the chemical manufacturing sector is very important in terms of total wastewater. Finally, the chemical manufacturing sector employs many environmental workers and even more production workers (Department of Commerce, 2010; Bureau of Labor Statistics, 2011).

4. Conceptual Framework

This section constructs a simple theoretical model. From this model, the study derives empirically testable hypotheses relating to the effects of enforcement, i.e., government interventions, on two specific types of labor – production and environmental. These hypotheses reflect whether regulated firms treat production reductions and environmental workers as either normal or inferior inputs into the production of compliance with environmental regulations. Briefly, if reduced production is a normal (inferior) input for generating compliance, then increased enforcement prompts a firm to employ fewer (more) production workers; similarly, if environmental labor is a normal (inferior) input for generating compliance, then increased enforcement prompts a firm to employ more (fewer) environmental workers.

An individual firm, running a single facility, operates in a perfectly competitive market setting. The firm generates a marketable product. The level of marketable production is denoted as Q. As a byproduct, the firm generates wastewater discharges, denoted as D. The firm faces a discharge limit of $\check{D}$, which is imposed by the environmental regulatory agency. The extent of compliance with this limit, denoted as K, reflects the difference between the limit and the discharge level: $K = \check{D} - D$. As discharges fall, the extent of compliance grows. In essence, the firm produces two types of product: a marketable product and compliance.

The regulatory agency monitors discharges and takes enforcement action whenever discharges lie above the limit. In practice, enforcement involves inspections, informal enforcement, and penalties, i.e., fines. To simplify the conceptual framework, we use the imposition of fines to capture all enforcement action taken in response to excessive discharges. Specifically, the regulatory agency imposes a per unit fine of F on all discharges lying above the limit. In this way, the level of the per unit fine, F, reflects the amount of enforcement activity in general. By extension, any increase in the fine level reflects greater enforcement in general. Given the agency's fine imposition, the amount of fines paid by the firm equals 0 if $K \geq 0$ and equals $-FK$ if $K < 0$. Since $F = 0$ if $K \geq 0$, the firm never overcomplies with the limit.

The firm's level of wastewater discharges depends on two factors: (1) marketable production quantity, Q, and (2) environmental management effort. Discharges rise as production increases, while discharges fall as environmental management effort expands. In order to focus on labor efforts, we assume that the firm's management efforts divide into two categories: (1) fixed factors, e.g., pollution treatment equipment, and (2) variable factors, captured exclusively by the amount of environmental labor employed, denoted as E. By focusing on the short run, we ignore the fixed factors and focus solely on environmental workers.

Given these relationships, the extent of compliance depends negatively on the production quantity, Q, and positively on environmental workers, E. We wish to construct a compliance function that depends positively on two inputs so that we can derive standard isoquant curves. To this end, we define an input reflecting negated production quantity: $Z = -Q$. Then we define this compliance function: $K = f(Z,E)$, where $\partial K/\partial Z > 0$ and $\partial K/\partial E > 0$.The two inputs in the compliance function carry costs. Let v denote the per unit cost of negated production, denoted as Z, which reflects the production-based profits sacrificed by lowering production. For the sake of simplicity, we assume v is constant over the relevant range of production. (Allowing v to rise as Z increases does not disrupt our conclusions.) The firm pays environmental workers the competitively determined wage of w.

To identify the role for production workers, we draw upon basic microeconomic theory to reveal that the firm's demand for production workers derives from the firm's chosen production level. Specifically, the firm's choice of production workers, denoted L, depends positively on the firm's production level, Q. Thus, any conclusion about the firm's choice of production quantity directly translates to the firm's choice of production workers. In this way, we indirectly identify the role of production labor by exploring the influence of the production level on discharges, and, thus, the extent of compliance. For example, if the firm reduces production in order to increase its compliance by decreasing discharges, the firm lays off production workers.

Given these relationships, the facility's input choices reflect a textbook case of constrained cost minimization regarding the creation of a product, in this case, "compliance". Our exposition follows the textbook depiction of Nicholson (1992).[4] In this framework of constrained cost minimization, the firm decides to generate a particular compliance level and then seeks to obtain this compliance level at minimum cost.[5] We assume the firm's decision depends on the per unit fine (F) charged against discharges lying above the discharge limit. Specifically, as F rises (i.e., enforcement expands), the firm decides to generate a higher level of compliance.

Initially the firm decides to generate a particular compliance level of K_o in response to a fine of F_o. The firm seeks to minimize total costs, $C = vZ + wE$, constrained by the compliance function: $K = f(Z,E)$. We assume concavity of the production function so that a unique solution exists. The relevant Lagrangian expression follows:

$$£ = vZ + wE + \lambda[K_o - f(Z,E)]. \quad (1)$$

The first-order conditions for the constrained minimum follow:

$$\partial £ / \partial Z = v - \lambda(\partial K/\partial Z) = 0 \text{ , and} \quad (2)$$

$$\partial £ / \partial E = w - \lambda(\partial K/\partial E) = 0 \text{ .} \quad (3)$$

Dividing the two equations generates this relationship:

$$v/w = (\partial K/\partial Z)/(\partial K/\partial E) = \text{rate of technical substitution of Z for E.} \quad (4)$$

This relationship reveals that the firm should equate the rate of technical substitution for the two inputs to the ratio of cost factors. We denote the cost-minimizing input choices as Z_o* and E_o*.

We also depict the cost-minimizing input choices graphically. See Figure 2. The compliance isoquant, labeled K_o, reflects all combinations of Z and E that generate the compliance level of K_o. The isocost line, labeled as C_o, reflects all combinations of Z and E that cost C_o dollars. The tangency point of the isocost line along the isoquant curve identifies the cost-minimizing input choices of Z_o* and E_o*.

[4] Walter Nicholson, *Microeconomic Theory: Basic Principles and Extension – Fifth Edition*, Dryden Press, Fort Worth, TX, 1992; see pages 332-337.

[5] Our framework does not require the particular compliance level to maximize overall profits, making the framework more broadly applicable.

Now imagine that the per unit fine rises from F_o to F_1 (i.e., enforcement grows). In response, the firm decides to generate a compliance level of K_1. The associated isoquant, labeled as K_1, lies above the initial isoquant of K_o, as shown in Figure 3. Similarly, the relevant isocost line, labeled as C_1, lies above the initial isocost line of C_o. The new cost-minimizing input choices, denoted as Z_1* and E_1*, depend on the rate of technical substitution reflected in the K_1 isoquant curve.

More important, the position of the new cost-minimizing input bundle (Z_1*, E_1*), relative to the position of the original cost-minimizing input bundle (Z_o*, E_o*), depends on the rates of technical substitution reflected in the two isoquant curves in the ranges where the isocost lines are tangent. We display the three possibilities. In Figure 3.a, the new cost-minimizing bundle lies above and to the left of the original cost-minimizing bundle; thus, $E_1^* > E_o^*$ but $Z_1^* < Z_o^*$. In Figure 3.b, the new cost-minimizing bundle lies below and to the right of the original cost-minimizing bundle; thus, $E_1^* < E_o^*$ yet $Z_1^* > Z_o^*$. In Figure 3.c, the new cost-minimizing bundle lies above and to the right of the original cost-minimizing bundle; thus, $E_1^* > E_o^*$ and $Z_1^* > Z_o^*$.

While one might expect increased compliance to prompt greater use of both inputs, *Z* and *E*, a firm may choose to use less of an input, which makes this input "inferior" (Nicholson, 1992, pg. 337).[6] We label the opposite type of input as "normal".

Given these possibilities, the effects of an increase in the fine from F_o to F_1 (i.e., greater enforcement) on the cost-minimizing choices of *Z** and *E** depends on whether the particular input is "normal" or "inferior". By extension, the effect on the firm's choice of production quantity, *Q*, and, thus, the firm's choice of production labor, *L*, depends on whether reduced production, as an input to compliance, is "normal" or "inferior". From this insight, we derive two pairs of testable hypotheses:

Hypothesis H1: If reduced production is a *normal* input for generating compliance, then increased enforcement (as reflected in a higher per unit fine) prompts a firm to employ fewer

[6] The possibility of an inferior input exists "even when isoquants have their usual convex shape" (Nicholson, 1992, pg. 337).

production workers (H1a). If reduced production is an *inferior* input for generating compliance, then increased enforcement prompts a firm to employ more production workers (H1b).

Hypothesis H2: If environmental labor is a *normal* input for generating compliance, then increased enforcement (as reflected in a higher per unit fine) prompts a firm to employ more environmental workers (H2a). If environmental labor is an *inferior* input for generating compliance, then increased enforcement prompts a firm to employ fewer environmental workers (H2b).

5. Econometric Framework

Our empirical analysis examines the effects of Clean Water Act enforcement, i.e., government interventions, on facility-level employment by separately estimating three types of labor outcomes. First, we estimate overall employment. Second, we estimate two types of labor – production and environmental – as separate outcomes. This section discusses the dependent variables, primary regressors, and control factors, and then constructs the regression equations, which capture the relationships between each dependent variable and a set of primary regressors and control factors.

5.1. Dependent Variables and Primary Regressors

In each year t, facility i chooses its level of production workers, denoted as L_{it}, and its level of environmental workers, denoted as E_{it}. Overall employment, W_{it}, is the sum of these two types of labor: $L_{it} + E_{it} = W_{it}$.

The primary regressors are government interventions, which divide between inspections and enforcement actions. Inspections divide between federal inspections and state inspections, while enforcement actions divide between informal actions and monetary penalties. Similar to some previous studies (Earnhart, 2009; Earnhart and Segerson, 2012), the analysis includes only federal enforcement actions, while excluding state actions, because the latter are small in magnitude and data are challenging to secure.

Further, the analysis splits government interventions into two categories: (1) government interventions against one's own facility and (2) government interventions against other facilities that are similar to one's own. Specific deterrence concerns the effect of increased monitoring or enforcement against an individual regulated facility on this same facility's subsequent environmental management decisions, while general deterrence concerns the effect of increased monitoring or enforcement against other regulated facilities on the individual facility's subsequent environmental management decisions.

These two deterrence categories influence how each facility forms expectations about enforcement before selecting its level of employment. Our empirical analysis assumes that each facility bases its expectations of future enforcement on the experiences of other similar facilities along with its own recent experiences (Shimshack and Ward, 2005; Earnhart, 2004a,b,c; Earnhart, 2009). General deterrence reflects the *ex ante* general "threat" of future punishment based on the recent experiences of other facilities with regulatory interventions (Sah, 1991; Cohen, 2000). Specific deterrence adjusts this general threat based on the specific enforcement experiences of particular facilities in the recent past (Cohen, 2000; Earnhart and Friesen, 2013).

With this insight in mind, our analysis constructs the government intervention regressors as follows. Consider first federal and state inspections. For the measures of specific deterrence, the analysis uses the number of federal or state inspections conducted in the 24 months preceding the current year at the individual facility, denoted as I_{it-1}^{EPAs} and I_{it-1}^{STs}, respectively, where "s" denotes specific deterrence. For the measures of general deterrence, the analysis uses the number of federal or state inspections conducted in the 12 months preceding the current year at other facilities of similar size (based on the distinction between NPDES major and minor facilities) operating in the same EPA region, in the case of federal inspections, and in the same state, in the case of state inspections, divided by the number of similarly sized facilities operating in the same EPA region or state (Earnhart and Leonard, 2013). Given the greater amount of time needed to respond to inspections conducted at other regulated facilities, we lag these general deterrence measures by one year, denoted as I_{it-2}^{EPAg} and I_{it-2}^{STg}, respectively, where "g" represents general deterrence.

The analysis constructs specific and general deterrence measures for informal enforcement actions in a manner identical to inspections. The resulting specific deterrence measure is denoted as A_{it-1}^{s}, while the general deterrence measure is denoted as A_{it-2}^{g}. For the penalty measures, the analysis uses the total monetary amount of penalties levied against the individual facility or other facilities rather than the count of penalties. The specific and general deterrence measures are denoted, respectively, as P_{it-1}^{s} and P_{it-2}^{g}. Similar to other studies, we focus on federal enforcement actions because data on state enforcement actions are poorly populated and difficult to secure (Earnhart and Segerson, 2012).

5.2. Control Factors

Our empirical analysis controls for variation in other factors that may influence employment. We derive these control factors from facility- and firm-level characteristics, as well as local community characteristics.

First, we include a control factor for firm ownership structure, as represented by the contrast between publicly held firms and other forms of ownership. This control factor captures many dimensions. Most prominently, facilities owned by publicly held firms may possess greater access to external financing for employment, including environmental employment. Facilities owned by publicly held firms are also held more accountable to stock holders. The analysis includes a publicly held firm indicator, with other ownership structures as the omitted category.

Second, our analysis includes facility age as a control factor since facility age may impact the amount of labor employed in either an environmental or production capacity. One can expect that the older a facility is, the more helpful are production employees at maintaining the older equipment. Similarly, as facility age rises, environmental employees become more helpful for keeping the facility compliant with its wastewater permits.

We collectively denote these facility- and firm-level measures as G_{it}.

Local community pressure may also influence environmental and production employment. We capture this pressure using local community characteristics as indirect proxies (Earnhart, 2004b). The first community characteristic is per capita personal income. Higher income communities are more likely to apply pressure on local facilities to practice better environmental management (e.g., by hiring more environmental workers) since environmental quality is a normal good (Earnhart, 2004c). Second, the analysis controls for local labor market conditions using two proxies: (1) unemployment rate, and (2) number of wage and salary jobs in the community. A local community is more likely to pressure facilities to provide better environmental quality when the unemployment rate is low or the number of individuals earning a salary or wages is high (Earnhart, 2009). Conversely, communities facing economically difficult times are more likely to focus on economic growth than environmental quality. Finally, population density is correlated with the local community pressure placed on a facility to improve local environmental quality by conducting better environmental management, e.g., employ more environmental workers. In a community where individuals are more densely populated around a polluting facility, the local community is more likely to urge the facility to generate less pollution. These community-level characteristics are collectively denoted as H_{it}.

Local community pressure plays a role similar to regulatory pressure applied through environmental enforcement. Thus, the expected effects of increased local community pressure depend on whether production labor reduction and environmental labor are normal or inferior inputs for generating compliance. See Hypotheses H1 and H2.

Finally, we control for variation in regulatory pressure not already reflected in government intervention measures by including year and facility fixed effects, denoted as N_t and R_i, respectively. The use of year-specific indicators controls for "un-measured" temporal variation, while use of facility-specific indicators controls for time-invariant factors unique to each facility.

5.3. Functional Relationships

The empirical analysis separately estimates the relationships between each labor type and the set of primary regressors and control factors. The analysis estimates a semi-log specification by log-transforming the dependent variable, as is standard with studies of employment. This specification facilitates easy interpretation of the coefficients: a one-unit increase in each regressor is associated with a percentage change in employment.

The first estimation treats overall employment, W_{it}, as the dependent variable, as represented by the following equation:

$$f(W_{it}) = \mu_0 + \mu_1 I_{it-1}^{EPAs} + \mu_2 I_{it-1}^{STs} + \mu_3 I_{it-2}^{EPAg} + \mu_4 I_{it-2}^{STg} + \mu_5 A_{it-1}^{s} + \mu_6 A_{it-2}^{g} + \mu_7 P_{it-1}^{s} + \mu_8 P_{it-2}^{g} +$$

$$\mu_9 G_{it} + \mu_{10} H_{it} + N_t + R_i + \varepsilon_{it} \,, \qquad (5)$$

where μ_1 through μ_8 are the coefficients of interest, μ_0 represents the intercept term, and ε_{it} represents the error term.

The second estimation treats both production and environmental employment as separate dependent variables. The following system of equations captures the functional relationships to estimate jointly:

$$f(L_{it}) = \alpha_0 + \alpha_1 I_{it-1}^{EPAs} + \alpha_2 I_{it-1}^{STs} + \alpha_3 I_{it-2}^{EPAg} + \alpha_4 I_{it-2}^{STg} + \alpha_5 A_{it-1}^{s} + \alpha_6 A_{it-2}^{g} + \alpha_7 P_{it-1}^{s} + \alpha_8 P_{it-2}^{g} + \alpha_9 G_{it} + \alpha_{10} H_{it} + N_t + R_i + \varepsilon_{Lit} \text{ , and} \qquad (6)$$

$$f(E_{it}) = \beta_0 + \beta_1 I_{it-1}^{EPAs} + \beta_2 I_{it-1}^{STs} + \beta_3 I_{it-2}^{EPAg} + \beta_4 I_{it-2}^{STg} + \beta_5 A_{it-1}^{s} + \beta_6 A_{it-2}^{g} + \beta_7 P_{it-1}^{s} + \beta_8 P_{it-2}^{g} + \beta_9 G_{it} + \beta_{10} H_{it} + N_t + R_i + \varepsilon_{Eit} \,, \qquad (7)$$

where α_1 through α_8 and β_1 through β_8 are the coefficients of interest, α_0 and β_0 represent the intercept terms, and ε_{Lit} and ε_{Eit} represent the equation-specific error terms, respectively.

6. Data

6.1. Sources

The study draws upon three main data sources to gather the information necessary to conduct the empirical analysis. First, the study draws upon a survey of regulated facilities in the chemical manufacturing industry; see Earnhart and Glicksman (2011) for details regarding the survey. Most important, the survey separately gathers information on the number of production and environmental employees at each facility.

Between April 2002 and March 2003, the survey was administered by phone to all chemical manufacturing facilities permitted within the NPDES program (as identified by the EPA Permit Compliance System database) as of September 2001, that met the following criteria: (1) faced restrictions on their wastewater discharges, (2) discharged regulated pollutants into surface water bodies, and (3) were operating as of 2002. These criteria identified 1,003 facilities to contact for the survey. Of these, 268 completed the survey, implying a 27 % response rate. This rate is comparable to previous large-scale surveys of industrial sectors (e.g., Arimura et al., 2008; Arimura et al., 2011; Nakamura et al., 2001) and lies above the average response rate of 21 % as identified by a review of 183 studies based on business surveys published in academic journals (Paxson, 1992).

The potential for sample selection bias affecting the survey data is a valid issue. We assess this concern in two ways. First, we compare the sample of 1,003 facilities contacted for the survey to the 268 facilities that completed the survey. Based on this comparison, we find no systematic state or regional bias in survey participation. Only the Midwest region is slightly over-represented in the response group. The other differences are trivially small. Moreover, across the states, the difference between representation in the original sample and representation in the response group averages less than 2 %. In contrast, our assessment reveals some difference in the participation of major facilities versus minor facilities. In the original sample, 69 % of facilities are minor facilities and 31 % are major facilities. In the group of survey respondents, major facilities are slightly over-represented at 39 %, a statistically significant difference.

Second, we assess whether any relevant factors appear to affect a facility's decision to complete our survey once the facility is contacted. We estimate the relationship between the (binary) decision to complete our survey and a set of relevant factors. The probit estimation results, displayed in Appendix Table A-1, reveal bias in a single dimension: major facilities were more likely to respond to the survey than were minor facilities. (Given this difference, we would need to interpret cautiously the coefficient on the major facility indicator if we included this indicator as a regressor. Fortunately, this concern is not relevant for our analysis because we use a fixed effects estimator, which ignores time-invariant factors, and the distinction between major and minor status does not vary over time for any given facility in our sample.)

For these reasons, our study does not correct for any potential sample selection bias. This lack of correction is consistent with recently published studies (e.g., Anton et al., 2004; Arimura et al., 2008).

In addition to these survey data, our study uses publicly available data. The EPA Permit Compliance System (PCS) database provides information on each facility's location and four-digit standard industrial classification (SIC) code, as well as inspections conducted by federal and state regulators. The PCS database and the EPA Docket database provide data on federal formal and informal enforcement actions. The Commerce Department Regional Economic Information System (REIS) database provides information on county-level community characteristics. All monetary measures are inflation-adjusted into 2002 dollars.

6.2. Statistical Summary

Table 1 provides summary statistics for the dependent variables, the primary regressors, and the control factors. As shown, the average facility employs roughly 260 employees, measured in full-time equivalent (FTE) terms. Additionally, the average facility employs 256 employees, measured in FTE, to work on production, and six FTE employees to work specifically on environmental management issues.

Table 1 also identifies key summary statistics for the primary regressors. As shown, state agencies conduct inspections much more frequently than EPA regional offices conduct inspections, as expected, since state agencies are primarily responsible for monitoring. The average facility is subjected to 1.5 state inspections over a 24-month period, yet only 0.07 federal inspections.[7] For enforcement actions, the more common action is the less severe of the two types. The average facility is subjected to 0.20 informal enforcement actions over a 24-month period, yet is fined only $ 127. (The latter figure reflects a highly skewed distribution of fines involving a few large penalties and many 24-month periods without a single fine.)[8] In order to display the meaningful variation in the primary regressors, Table 1 displays the coefficients of variation for the government intervention measures.

[7] Although federal inspections are conducted much less frequently than state inspections in the sample, the empirical analysis generates statistically significant results for federal inspections.

[8] Even though monetary fines occur infrequently in the sample, the empirical analysis generates statistically significant results for fines.

7. Econometric Analysis

7.1. Potential Endogeneity of Government Interventions

The decision by a regulating agency to inspect or levy enforcement actions on facilities may be endogenous. In particular, regulating agencies may target facilities with poor records of compliance. However, we claim that the constructed measures are exogenously determined with respect to environmental and production labor decisions. First, the general deterrence measures are surely exogenous, since these measures reflect government interventions prompted by the behavior and performance of other facilities. Second, the specific deterrence measures are exogenous due to the separation in time between lagged government interventions and current employment and environmental management decisions, consistent with all previous studies using lagged intervention measures (e.g., Earnhart, 2009; Helland, 1998a; Helland, 1998b; Earnhart and Leonard, 2013; Earnhart and Harrington, 2014). A comprehensive review of the environmental enforcement literature confirms that all previous empirical studies treat lagged interventions as exogenous (Gray and Shimshack, 2011). As such, the analysis proceeds treating all regressors as exogenous.

7.2. Regressor Sets

The analysis considers three regressor sets or "models" in order to assess the robustness of the estimated results with respect to the choice of regressor set. Model 1 includes only the eight primary regressors. Model 2 adds year-specific indicators, along with facility and firm characteristics, as control factors. Model 3 additionally includes the local community pressure factors as controls. All three models include facility fixed effects.

The eight primary regressors are potentially correlated since they all reflect environmental enforcement. To assess this potential multicollinearity, we calculate a Variance Inflation Factor (VIF) for each of the eight primary regressors (Studenmund, 2006, pg. 270-271). These calculations are specific to the estimation of each dependent variable and the chosen regressor set. Table 2 displays the VIFs for the parsimonious model (i.e., Model 1) for the estimation of overall employment in equation (5). As shown, none of the VIFs are higher than 3.17, which indicates that multicollinearity is not a problem for any of our primary regressors; the mean VIF of 1.94 further demonstrates that multicollinearity is not disrupting our coefficient estimates. VIFs calculated for other dependent variables and other models are extremely similar to those presented in Table 2 (and available upon request).

7.3. Estimation Techniques

This section discusses our choice of estimation techniques. This choice depends on two elements. First, we wish to exploit the panel structure of the data, which offers annual information over the three-year period between 1999 and 2001. To this end, we employ the standard panel data estimator of fixed effects estimation.

Second, we need to estimate multiple dependent variables. As the first dependent variable, we estimate overall employment as a single outcome using standard fixed effects estimation. However, the individual types of labor -- production and environmental – represent a pair of outcomes. We estimate these two outcomes individually and jointly. For the latter approach, we jointly estimate the system of equations using seemingly unrelated regression (SUR) (Zellner, 1962). SUR joint estimation generates efficiency gains by exploiting correlation between the error terms of the two individual regression equations (Hsiao, 2014). Collectively, we utilize two different estimation techniques: (1) fixed effects estimation, when examining the dependent variables individually, and (2) SUR fixed effects estimation, when jointly estimating production labor and environmental labor.

We implement the SUR fixed effects estimator following the approach of Blackwell (2005). Blackwell (2005) constructs two estimation methods. The panel corrected standard error (PCSE) estimator corrects for facility-specific auto-correlation. The Generalized Least Squares (GLS) estimator corrects for auto-correlation generally applicable to all facilities. Thus, the PCSE estimator allows more flexibility. Consequently, we focus on this estimator. Use of the two estimators generates identical coefficient p-values and extremely similar coefficient magnitudes. Thus, both sets of results support identical conclusions. Therefore, we report only the PCSE estimates. (The GLS estimates are available upon request.)[9]

Table 3 reports the overall labor estimates. Tables 4 and 5 report the individual equation fixed effects estimates for production and environmental labor, respectively. Table 6 reports the SUR fixed effects estimates for production and environmental labor, based on joint estimation of equations (6) and (7).

7.4. Results

7.4.1. Individual Labor Equation Estimation Results

This sub-section interprets the individual estimation results for three different labor outcomes: (1) overall employment, (2) production employment, and (3) environmental employment. For all three dependent variables, we focus on the broadest regressor set of Model 3 but assess the robustness of the primary regressors across the three models.

First, we interpret the estimates for overall employment, shown in Table 3. Based on Model 3, only three government interventions significantly affect overall employment. Informal enforcement-related specific deterrence and federal inspection-related general deterrence negatively affect overall employment. In contrast, penalty-related specific deterrence positively affects overall employment. These conclusions are nearly robust across the three models; in three cases, the statistical significance lies slightly above the 10 % level, with p-values between 0.104 and 0.115.

Collectively, these results reveal that some forms of environmental enforcement influence

[9] In addition to a fixed effects estimator, we employ a random effects estimator for both the equation-by-equation estimation and SUR estimation. Based on random effects estimation of the two equations separately, the Hausman Test of Random Effects statistics, which assess whether or not the random effects estimates are consistent, indicate that the random effects estimates do not appear consistent for both equations. The associated test p-values are 0.012 and 0.883 for the production employment and environmental employment equations, respectively. While the random effects estimates appear consistent for environmental labor, the random effects estimates for production labor appear inconsistent. Rather than examining only a single labor outcome, we neither report nor interpret the individual equation random effects estimates for both labor outcomes. The SUR random effects estimator does not facilitate the Hausman Test of Random Effects. Since the SUR random effects estimates are most likely inconsistent as well, we neither report nor interpret the SUR random effects estimates.

overall employment. However, most government intervention types (13 of 16) do not influence overall employment. As demonstrated in Section 4, greater environmental enforcement need not impact the two components of employment – production and environmental – in the same direction. The lack of statistically significant effects for most of the government intervention factors may reveal that the possibly countervailing forces on production and environmental labor are neutralizing the ultimate impact on overall labor. Moreover, the statistically significant effects on overall labor may merely reflect the net impact of potentially countervailing forces. As important, the estimated effects of government interventions on overall labor fail to decompose any reinforcing forces on production labor and environmental labor.

With these key points in mind, we next interpret the individual equation fixed effects estimates for production and environmental labor. Since the SUR fixed effects estimates are more efficient, we interpret the individual equation fixed effects estimates only briefly. As shown in Tables 4 and 5, the primary results are strongly similar across the three models.

Consider first the production labor estimates. As shown in Table 4, informal enforcement-related specific deterrence negatively affects production labor, yet penalty-related specific deterrence positively affects production labor. This contrast benefits from a broader context, so we tackle it when interpreting the more efficient SUR fixed effects estimates.

Consider next the environmental labor estimates. As shown in Table 5, three types of government interventions significantly influence the amount of environmental labor employed by regulated facilities. Federal inspection-related general deterrence, informal enforcement-related specific deterrence, and penalty-related specific deterrence all negatively affect environmental labor. For example, as the amount of penalties imposed on a specific facility over a preceding 24-month period rises, the regulated facility chooses to shed environmental workers. These results reveal that environmental labor is an inferior input into the generation of compliance with environmental restrictions.

7.4.2. Joint Estimation Results

More importantly, this sub-section assesses the SUR fixed effects estimates. As shown in Table 6, the primary regressor coefficient magnitudes and statistical significance levels are strongly similar across the three models. Consider first the production labor results. Five of the eight regressors prove statistically significant. Of the five significant regressors, three coefficients reveal that increases in certain government interventions prompt a reduction in production labor, consistent with Hypothesis H1a. Yet two regressors positively affect production labor, consistent with Hypothesis H1b. Specifically, increases in monetary penalties – in both specific and general deterrence form – prompt greater production labor. As with the individual equation fixed effects estimates, these results reveal a more nuanced relationship between government interventions and production labor and provide mixed support for the two competing hypotheses.

Consider next the environmental labor results. As shown in Table 6, six of the eight primary regressors prove statistically significant. Only federal inspection-related specific deterrence and state inspection-related general deterrence do not influence environmental labor. Of the six significant coefficients, five coefficients reveal that increases in government interventions prompt a reduction in environmental labor. As the exceptional result, greater state inspection-related specific deterrence prompts an increase in environmental labor. Disregarding the exceptional positive coefficient, these results convincingly reveal that environmental labor is an inferior input into the generation of compliance with environmental limits, consistent with Hypothesis H2b.

Our conclusions are strongly robust across the three models. Yet we note these differences. By adding facility/firm control factors to Model 1 (i.e., Model 2), we gain four significant effects but lose one. By further adding the local community pressure control factors (i.e., Model 3), we again lose the first lost significant effect, and lose one of the previously gained significant effects. Overall, we improve our statistical significance by adding control factors. Still, we acknowledge two points. First, one effect is not robust between the two models with controls. Second, one significant result is not revealed in the parsimonious model; most likely this significant effect stems from correlation with a control factor.

In order to explore the two labor outcomes more comprehensively, we assess the two outcomes – production labor and environmental labor – jointly for each government intervention type. We tackle each type in turn. (1) Federal inspection-related general deterrence negatively affects environmental labor but does not affect production labor. This pair of results demonstrates that an increase in federal inspection general deterrence prompts a shift away from environmental labor use without any corresponding change in production labor, which we label as a "partial shift". (2) State inspection-related general deterrence affects neither production labor nor environmental labor. (3) Federal inspection-related specific deterrence negatively affects production labor without any corresponding change in environmental labor. These results reveal a partial shift toward production labor reduction. (4) State inspection-related specific deterrence positively affects environmental labor but does not affect production labor. This pair of results shows a partial shift toward environmental labor use. (5) Informal enforcement-related general deterrence negatively affects both environmental and production labor. These results demonstrate a full shift toward production labor reduction and away from environmental labor use. (6) Informal enforcement-related specific deterrence negatively affects both environmental and production labor. These results demonstrate a full shift toward production labor reduction and away from environmental labor use. (7) Penalty-related general deterrence negatively affects environmental labor but positively affects production labor. (8) Penalty-related specific deterrence generates the same two effects. These two pairs of results are challenging to explain because they imply that ***both*** environmental labor and production labor are inferior inputs into the generation of environmental compliance, which is not possible in our two-input cost-minimizing framework. We could expand our conceptual framework to explore three inputs, allowing both environmental labor and production labor to serve as inferior inputs. However, this expansion still begs the question: why is penalty-related deterrence different from the other government intervention types? We tackle this point immediately below.

As a set, these results are internally consistent in that government interventions shift pollution control from environmental labor use to production labor reduction (i.e., production reduction), consistent with Hypotheses H1a and H2b. However, three results do not exhibit this consistency: (1) penalty-related specific deterrence, (2) penalty-related general deterrence, and (3) state inspection-related specific deterrence.

We offer two possible explanations for the penalty-related results. First, a robust literature demonstrates that increased enforcement of rules might crowd out prosocial motivations (Benabou and Tirole, 2006). If crowding out is possible, penalty-related specific and general deterrence are the government intervention types most likely to crowd out prosocial motivations since penalties are clearly the most harsh government intervention. As a second but arguably ad hoc explanation for specific deterrence, monetary resource extraction might prompt a facility to fire its environmental laborers and hire more production workers to generate more revenues in order to cover the penalty payment.

Regarding the exceptional result for state inspection specific deterrence, we speculate that the technical assistance provided by state inspections prompts facilities to employ more environmental labor. While we offer no theory to explain this connection, the explanation seems inherently intuitive.

7.4.3. Control Factors

This sub-section interprets the control factor coefficients, based on our preferred Model 3 and SUR fixed effects joint estimation of production and environmental labor, with results shown in Table 6.

First, we interpret the results for production labor. Facility age negatively affects production employment, contrary to our *a priori* expectation. Perhaps facilities use less production labor at older facilities because the marginal product of labor is lower when using older equipment. The local unemployment rate also negatively affects production employment. As long as *weaker* labor market conditions imply less local community pressure, this result indicates that production labor reduction is an inferior input for generating compliance. In contrast, population density positively affects production employment. As long as increased population density implies greater local community pressure, this result also indicates that production labor reduction is an inferior input. Thus, these two local community pressure results are consistent.

Second, we interpret the results for environmental labor. Facilities owned by publicly held firms employ more environmental labor, consistent with our *a priori* expectation. Older facilities employ less environmental labor, inconsistent with our *a priori* expectation. Increases in the number of wage and salary jobs in a community prompt more environmental employment. As local labor market conditions improve, local communities place more pressure on regulated facilities to adhere to environmental regulations (Earnhart, 2009). Consequently, this result reveals that environmental labor is a normal input for generating compliance. An increase in the local unemployment rate lowers environmental labor. As local labor market conditions degrade, local communities should pressure facilities less. This result also reveals that environmental labor is a normal input. Thus, our two labor market results support the same conclusion. Lastly, greater population density prompts more environmental labor. As long as greater density implies stronger local community pressure, this result reveals that environmental labor is a normal input. Uniformly, these local community pressure results identify environmental labor as a normal input.

Collectively, the effects of local community pressure on the two labor outcomes tell an interesting story. They reveal that production labor reduction is an inferior input for generating compliance yet environmental labor is a normal input. These two conclusions contradict the conclusions supported by the environmental enforcement results. Perhaps facilities adjust their resource allocation differently in response to regulatory pressure, in the form of environmental enforcement, and local community pressure. While regulatory agencies focus on compliance, accepting production labor as an effective means for achieving compliance, local communities expect a tangible investment in better environmental management, such as an expanded force of environmental engineers and technicians. Even more visible than new treatment equipment, local communities are able to engage personally and interactively with new environmental workers.

Our interpretation of these results is most certainly speculative. Given the strong contrast between regulatory and local community pressure, future research should explore this issue more thoroughly.

7.5. Cross-Equation Tests

This sub-section compares the effects of individual government intervention types on the two labor components – production and environmental – by conducting cross-equation tests based on the joint estimation of equations (6) and (7). In particular, we test whether or not a particular government intervention coefficient from one equation equals its counterpart from the other equation. In other words, we test the null hypothesis that the two slope coefficients in each pair of related coefficients are equal. Rejection of this null hypothesis reveals that the two effects differ between the two labor components. This testing is highly important because estimation of overall labor implicitly imposes the restriction of equal slope coefficients for each primary regressor. Thus, rejection of these equal slope null hypotheses reinforces the benefit of estimating production labor and environmental labor as separate outcomes, which no previous study explores. We test these equal slope null hypotheses using the SUR fixed effects joint estimation, which is critical since the SUR framework properly accounts for correlation between the two equation error terms (Wooldridge, 2002).

Table 7 displays the equal slope test statistics. These results reveal that several pairs of government intervention regressors involve slope coefficients that statistically differ. State inspections, informal enforcement actions, and monetary fines in specific deterrence form, and federal inspections and monetary fines in general deterrence form differently affect the two types of labor.[10] As one prominent example, penalty-related specific deterrence positively affects production employment yet negatively affects environmental employment and the difference proves significant. As a more subtle example, informal enforcement-related specific deterrence negatively affects both production and environmental labor yet the two magnitudes significantly differ, with the (negative) impact on production labor exceeding the (negative) impact on environmental labor. These significant differences highlight the misleading nature of the estimated effects of government interventions on overall labor, which mask the distinctive effects of government interventions on the two labor components.

7.6. Sensitivity Analysis

We next provide sensitivity analysis to assess further the robustness of our results by splitting the sample between facilities operating in the western half of the US and those operating in the eastern half. We divide the US using EPA regions. For this sensitivity analysis, we jointly re-estimate the production and environmental labor outcomes – equations (6) and (7) – using SUR fixed effects estimation on two separate sub-samples: (1) facilities in the eastern half of the US, and (2) facilities in the western half. This sub-section assesses the results generally. The appendix interprets in detail the sub-sample results displayed in Appendix Table A-2.

Collectively, the results paint an interesting picture. First, the results show that, to some extent, regulated facilities adjust their labor allocations differently in response to enforcement in different parts of the country. In particular, eastern and western facilities apparently treat production

[10] The difference in coefficients for federal inspections in specific deterrence form is almost statistically significant given a p-value of 0.117.

and environmental labor differently as a means for complying with wastewater discharge limits. Second, by splitting the sample, our analysis is able to isolate a meaningful effect for a number of government interventions in at least one part of the US. Third, results for some interventions, e.g., state-inspection related general deterrence, display a stark contrast in the link from enforcement to labor allocation between parts of the US. Finally, our sensitivity analysis reveals that eastern facilities generally decrease production labor as a result of government interventions, while western facilities generally decrease environmental labor as a result of the same government interventions.

7.7. Economic Importance

Finally, we assess the economic importance of our estimated coefficient magnitudes based on the SUR fixed effects joint estimation of production and environmental labor, drawing upon the baseline estimates shown in Table 6. We focus exclusively on the primary regressors, assessing only the significant regressors. We explore eight primary regressors and two labor outcomes, with a total of 16 primary coefficients to assess. Based on our preferred Model 3, 11 of the 16 primary regressor coefficients prove statistically significant. To assess the economic importance of each, we multiply each coefficient by the associated regressor's standard deviation, which is shown in Table 1. We interpret this product as the percent change in the dependent variable prompted by a one standard deviation increase in the relevant regressor. (Each coefficient in our semilog specification reflects the percent change in the dependent variable prompted by a one-unit increase in the relevant regressor.)

First, we examine the impacts on production labor. Consider the specific deterrence factors. A regulatory agency that increases federal inspections by one standard deviation prompts a 2.9 % decrease in production employment, reflecting an absolute reduction of 0.75 FTE employees at the average facility. For informal enforcement, this same increase prompts a 4.8 % decrease in production labor. An increase in the penalty amount by one standard deviation raises production employment by 1.4 %. Next consider general deterrence. An increase in informal enforcement by one standard deviation prompts a 2.7 % decrease in production labor. For penalties, this same increase raises production employment by 1.1 %.

Second, we examine the impacts on environmental labor. Consider the specific deterrence factors. An increase in state inspections by one standard deviation raises environmental employment by 3.5 %. The same increase in informal enforcement lowers environmental employment by 3.2 %. For penalties, a one standard deviation increase leads to a 1.1 % reduction. Next consider general deterrence factors, which all negatively affect environmental labor. An increase of one standard deviation in federal inspections lowers environmental employment by 2.3 %. The same increase in informal enforcement reduces environmental employment by 3.5 %. For penalties, this increase prompts a 1.5 % reduction in environmental employment.

Collectively, the magnitudes of these impacts demonstrate that increased enforcement does not strongly influence production and environmental labor allocations despite the associated statistical significance.

8. Conclusions

Our study examines the employment effects of environmental regulation, specifically its enforcement, on chemical manufacturing facilities regulated under the Clean Water Act over the years 1999 to 2001. An important and growing economic literature examines the employment effects stemming from the imposition of environmental regulation. However, this literature fails to account for the differences among employment types when examining these effects. To contribute to this literature, our study first estimates the effects of environmental enforcement on overall employment at regulated facilities. Our study then jointly estimates a system of equations to assess the effects of environmental regulation on environmental and production employees separately. Specifically, our study examines the enforcement of environmental regulation, which reflects one component of the regulation's stringency. The impacts of environmental enforcement on labor are especially important since environmental agencies allocate considerable resources to ensure adherence with regulations after they have been imposed on facilities.

Empirical results from the estimation of overall labor, as well as environmental labor and production labor as separate outcomes, reveal that government interventions mostly negatively affect facility-level employment, regardless of the form. As one notable exception, penalty-related specific deterrence positively affects overall employment. In general, the empirical results reveal that production labor reduction is a normal input for generating compliance with Clean Water Act discharge limits, yet environmental labor is an inferior input. As one notable exception to the latter conclusion, inspections conducted by state agencies prompt greater environmental labor; apparently the technical assistance provided by state inspectors leads regulated facilities to treat technically savvy environmental workers as a normal input.

These results offer policy implications. Greater environmental enforcement generally prompts facilities to substitute environmental workers for reduced production workers. As long as this substitution reflects privately optimal choices, environmental enforcement agencies should not expect or demand regulated facilities to expend greater environmental management in order to improve compliance with discharge limits. Empirical results show that facilities prefer to reduce their production levels rather than hire more environmental workers. This said, as noted above, state inspections appear to induce facilities to hire more environmental workers.

While this study contributes much to the debate over environmental enforcement policy and its effects on labor, the need for future research remains. Future research should examine the allocation of labor versus that of other inputs, specifically environmental treatment capital. In addition, future studies should explore more sectors and more types of environmental media (e.g., air, hazardous waste). Lastly, the contrast between regulatory pressure, as applied through environmental enforcement, and local community pressure proves important for identifying whether production labor reduction and environmental labor are normal or inferior inputs for generating compliance with environmental protection restrictions. Future research should scrutinize this issue more deeply.

Appendix: Sample Split between Western US and Eastern US

This appendix interprets in detail the results generated by splitting the sample between facilities operating in the western half of the US and those operating in the eastern half and then re-estimating the outcomes of production labor and environmental labor. Consider conclusions supported by the production labor results, beginning with the specific deterrence results. First, federal inspections negatively affect production labor in the eastern sub-sample, consistent with the full sample, however, positively affect production labor in the western sub-sample. Second, state inspections do not affect production labor in the eastern sub-sample, consistent with the full sample, but positively affect production labor in the western sub-sample. Third, informal enforcement positively affects production labor in the eastern sub-sample, however, negatively affects production labor in the western sub-sample, consistent with the full sample. Fourth, penalties positively affect production labor in the eastern sub-sample, consistent with the full sample, but do not affect production labor in the western sub-sample.

Consider next the general deterrence results. First, federal inspections do not affect production labor in either sub-sample, which is consistent with the full sample. Second, state inspections do not affect production employment using the full sample. This statistically insignificant effect stems from the conflicting signs in the two sub-samples: positive in the eastern sub-sample and negative in the western sub-sample. Third, more informal enforcement lowers production employment in the eastern US, consistent with the full sample, but generates no effect in the western US. Fourth, monetary penalties positively affect production labor in the full sample and the western sub-sample, yet negatively affects production labor in the eastern sub-sample.

We explore next the conclusions supported by the environmental labor results, beginning with the specific deterrence results. First, federal inspections do not affect environmental employment in either the full sample or the western sub-sample. Yet, in the eastern sub-sample, federal inspections negatively affect environmental employment. Second, results for state inspections in both sub-samples are consistent with those in the full sample: more state inspections increase environmental labor. Third, informal enforcement negatively affects environmental employment in the western sub-sample, consistent with the full sample, but positively affect environmental employment in the eastern sub-sample. Fourth, monetary penalties negatively affect environmental employment in the western sub-sample and full sample, yet do not affect environmental employment in the eastern sub-sample.

Consider finally the general deterrence results. First, federal inspections decrease environmental employment in both the eastern and western US, consistent with the full sample. Second, results for state inspections are identical to those for production labor: the insignificant effect in the full sample apparently stems from a positive effect in the eastern sub-sample yet a negative effect in the western sub-sample. Third, informal enforcement negatively affects environmental employment in the western sub-sample, consistent with the full sample, while no effect appears in the eastern sub-sample. Finally, greater monetary penalties decrease environmental employment in the full sample and western sub-sample, but generate no effect in the eastern sub-sample.

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Table 1: Sample Summary Statistics

Variable	Mean	Std. Dev.	Coef. of Variation [a]
Dependent Variables			
Overall employment (full-time equivalence)	259.9	480.9	1.850
Environmental employment (full-time equivalence)	6.23	14.91	2.373
Production employment (full-time equivalence)	256.82	486.92	1.900
Specific Deterrence Primary Regressors			
Federal inspections during preceding 24-month period (count)	0.068	0.330	4.825
State inspections during preceding 24-month period (count)	1.491	2.472	1.658
Informal enforcement actions during preceding 24-month period (count)	0.200	1.168	5.840
Penalty amount during preceding 24-month period (000 $)	0.128	3.571	28.01
General Deterrence Primary Regressors			
Federal inspections / other facilities per region, with 1-yr lag (#/facility)	0.029	0.050	1.754
State inspections / Other facilities per region, with 1-yr lag (#/facility)	0.674	0.966	1.433
Informal enforcement actions / Other facilities per region, with 1-yr lag (#/facility)	0.077	0.190	2.477
Penalty amount / Other facilities per region, with 1-yr lag (000 $/facility)	0.074	0.366	4.967
Facility / Firm Controls			
Facility age (years)	42.19	24.53	0.581
Facility owned by publicly held firm (vs. non-publicly held firm)	0.634	0.482	0.760
Local Community Pressure Controls			
Per capita personal income ($/person)	28,833.4	7518.7	0.261
Unemployment (rate)	4.650	1.418	0.305
Wage and salary employment (# of jobs)	291,208	560,671	1.925
Population density (persons/mile)	866.6	1548.0	1.786

Notes:
[a] The coefficient of variation is the ratio of the standard deviation to the mean.

Table 2: Variance Inflation Factors (VIF) for Primary Regressors

Primary Regressor	VIF
Specific Deterrence	
Federal inspections during preceding 24-month period	1.19
State inspections during preceding 24-month period	2.26
Informal enforcement actions during preceding 24-month period	1.18
Penalty amount during preceding 24-month period	1.14
General Deterrence	
Federal inspections / other facilities per region	2.78
State inspections / other facilities per region	2.41
Informal enforcement actions / other facilities per region	3.17
Penalty amount / other facilities per region	1.42
Mean VIF	1.94

Notes:
VIFs calculated from fixed effects estimation of logged overall employment using Model 1.

Table 3: Results from Fixed Effects Estimation of Logged Overall Employment

Independent Variable	Model 1	Model 2	Model 3
Specific Deterrence			
Federal inspections during preceding 24-month period	-0.063 (0.270)	-0.062 (0.271)	-0.063 (0.268)
State inspections during preceding 24-month period	0.002 (0.792)	0.003 (0.709)	0.003 (0.745)
Informal enforcement actions during preceding 24-month period	-0.031 (0.115)	-0.031 (0.113)	**-0.033** **(0.087)**
Penalty amount (000 $) during preceding 24-month period	**0.003** **(0.022)**	**0.003** **(0.017)**	**0.003** **(0.019)**
General Deterrence			
Federal inspections / other facilities per region	**-0.562** **(0.033)**	-0.439 (0.104)	**-0.539** **(0.039)**
State inspections / other facilities per region	-0.009 (0.534)	-0.009 (0.709)	-0.012 (0.441)
Informal enforcement actions / other facilities per region	-0.031 (0.115)	-0.024 (0.771)	-0.042 (0.657)
Penalty amount (000 $) / other facilities per region	**-0.040** **(0.002)**	-0.010 (0.498)	-0.020 (0.338)
Facility / Firm Controls			
Facility owned by publicly held firm		-0.057 (0.420)	-0.060 (0.612)
Facility age		-0.017 (0.483)	-0.017 (0.733)
Local Community Pressure Controls			
Per capita personal income			0.00002 (0.761)
Unemployment			-0.042 (0.633)
Wage and salary employment			-0.000001 (0.446)
Population density			0.001 (0.349)
Number of observations	803	779	773
Year indicators included	No	Yes	Yes

Notes:
p-values are shown in parentheses.
Bold text identifies coefficients significant at the 90% level or better ($p \leq 0.10$).
Standard errors are clustered at the facility level.

Table 4: Results from Individual Fixed Effects Estimation of Logged Production Employment

Independent Variable	Model 1	Model 2	Model 3
Specific Deterrence			
Federal inspections during preceding 24-month period	-0.073 (0.221)	-0.067 (0.213)	-0.070 (0.201)
State inspections during preceding 24-month period	0.003 (0.784)	0.006 (0.510)	0.005 (0.534)
Informal enforcement actions during preceding 24-month period	**-0.034 (0.081)**	**-0.034 (0.070)**	**-0.036 (0.048)**
Penalty amount (000 $) during preceding 24-month period	**0.004 (0.003)**	**0.004 (0.001)**	**0.004 (0.001)**
General Deterrence			
Federal inspections / other facilities per region	-0.414 (0.151)	0.077 (0.790)	-0.028 (0.923)
State inspections / other facilities per region	0.004 (0.848)	0.003 (0.897)	0.0007 (0.974)
Informal enforcement actions / other facilities per region	-0.037 (0.569)	-0.096 (0.245)	-0.124 (0.203)
Penalty amount (000 $) / other facilities per region	**-0.03 (0.029)**	**0.04 (0.094)**	0.03 (0.387)
Facility / Firm Controls			
Facility owned by publicly held firm		-0.028 (0.544)	-0.039 (0.742)
Facility age		**-0.068 (0.017)**	-0.057 (0.265)
Local Community Pressure Controls			
Per capita personal income			0.000008 (0.918)
Unemployment			-0.074 (0.398)
Wage and salary employment			-0.0000009 (0.667)
Population density			0.0008 (0.534)
Number of observations	803	779	773
Year indicators included	No	Yes	Yes

Notes:
p-values are shown in parentheses.
Bold text identifies coefficients significant at the 90% level or better ($p \leq 0.10$).
Standard errors are clustered at the facility level.

Table 5: **Results from Individual Fixed Effects Estimation of Logged Environmental Employment**

Independent Variable	Model 1	Model 2	Model 3
Specific Deterrence			
Federal inspections during preceding 24-month period	-0.029 (0.440)	-0.024 (0.527)	-0.033 (0.384)
State inspections during preceding 24-month period	0.016 (0.162)	0.016 (0.150)	0.016 (0.159)
Informal enforcement actions during preceding 24-month period	**-0.020 (0.026)**	**-0.021 (0.024)**	**-0.025 (0.017)**
Penalty amount (000 $) during preceding 24-month period	**-0.003 (0.008)**	**-0.003 (0.010)**	**-0.004 (0.000)**
General Deterrence			
Federal inspections / other facilities per region	**-0.556 (0.048)**	**-0.575 (0.081)**	**-0.580 (0.085)**
State inspections / other facilities per region	-0.002 (0.893)	-0.002 (0.913)	-0.003 (0.867)
Informal enforcement actions / other facilities per region	-0.002 (0.980)	-0.054 (0.572)	-0.110 (0.320)
Penalty amount (000 $) / other facilities per region	-0.030 (0.260)	-0.030 (0.485)	-0.040 (0.253)
Facility / Firm Controls			
Facility owned by publicly held firm		0.161 (0.132)	0.168 (0.346)
Facility age		0.002 (0.932)	0.011 (0.820)
Local Community Pressure Factors			
Per capita personal income			-0.00002 (0.768)
Unemployment			-0.065 (0.432)
Wage and salary employment			0.000002 (0.320)
Population density			0.001 (0.228)
Number of observations	803	779	773
Year indicators included	No	Yes	Yes

Notes:
p-values are shown in parentheses.
Bold text identifies coefficients significant at the 90% level or better ($p \leq 0.10$).
Standard errors are clustered at the facility level.

Table 6: Results from SUR Fixed Effects Estimation of Logged Production and Environmental Employment

	Model 1		Model 2		Model 3	
Independent Variable	Production	Environmental	Production	Environmental	Production	Environmental
Specific Deterrence						
Federal inspections during preceding 24-month period	**-0.082** **(0.000)**	-0.032 (0.275)	**-0.079** **(0.000)**	-0.028 (0.351)	**-0.087** **(0.000)**	-0.036 (0.304)
State inspections during preceding 24-month period	0.002 (0.637)	**0.014** **(0.002)**	**0.005** **(0.046)**	**0.015** **(0.000)**	0.005 (0.192)	**0.014** **(0.000)**
Informal enforcement actions during preceding 24-month period	**-0.036** **(0.000)**	**-0.021** **(0.000)**	**-0.036** **(0.000)**	**-0.021** **(0.000)**	**-0.041** **(0.000)**	**-0.027** **(0.000)**
Penalty amount (000$) during preceding 24-month period	**0.004** **(0.000)**	**-0.002** **(0.002)**	**0.004** **(0.000)**	**-0.002** **(0.004)**	**0.004** **(0.000)**	**-0.003** **(0.000)**
General Deterrence						
Federal inspections / other facilities per region	**-0.453** **(0.001)**	**-0.507** **(0.001)**	0.101 (0.313)	**-0.533** **(0.000)**	0.045 (0.622)	**-0.453** **(0.024)**
State inspections / other facilities per region	0.005 (0.451)	0.004 (0.595)	0.003 (0.344)	0.005 (0.481)	-0.0008 (0.881)	-0.001 (0.786)
Informal enforcement actions / other facilities per region	-0.030 (0.449)	-0.015 (0.648)	**-0.048** **(0.059)**	**-0.112** **(0.001)**	**-0.143** **(0.015)**	**-0.182** **(0.009)**
Penalty amount (000$) / other facilities per region	**-0.030** **(0.000)**	**-0.029** **(0.000)**	**0.030** **(0.055)**	**-0.014** **(0.000)**	**0.030** **(0.000)**	**-0.037** **(0.000)**
Facility / Firm Controls						
Facility owned by publicly held firm			**-0.048** **(0.000)**	**0.168** **(0.001)**	-0.057 (0.210)	**0.159** **(0.087)**
Facility age			**-0.068** **(0.002)**	**-0.044** **(0.000)**	**-0.054** **(0.000)**	**-0.053** **(0.000)**
Local Community Pressure Controls						
Per capita personal income					0.000003 (0.933)	-0.00003 (0.123)
Unemployment					**-0.085** **(0.000)**	**-0.098** **(0.000)**
Wage and salary employment					-0.0000007 (0.606)	**0.000002** **(0.001)**
Population density					**0.0008** **(0.001)**	**0.001** **(0.000)**
Number of Observations	803	803	779	779	773	773
Year indicators included	No	No	Yes	Yes	Yes	Yes

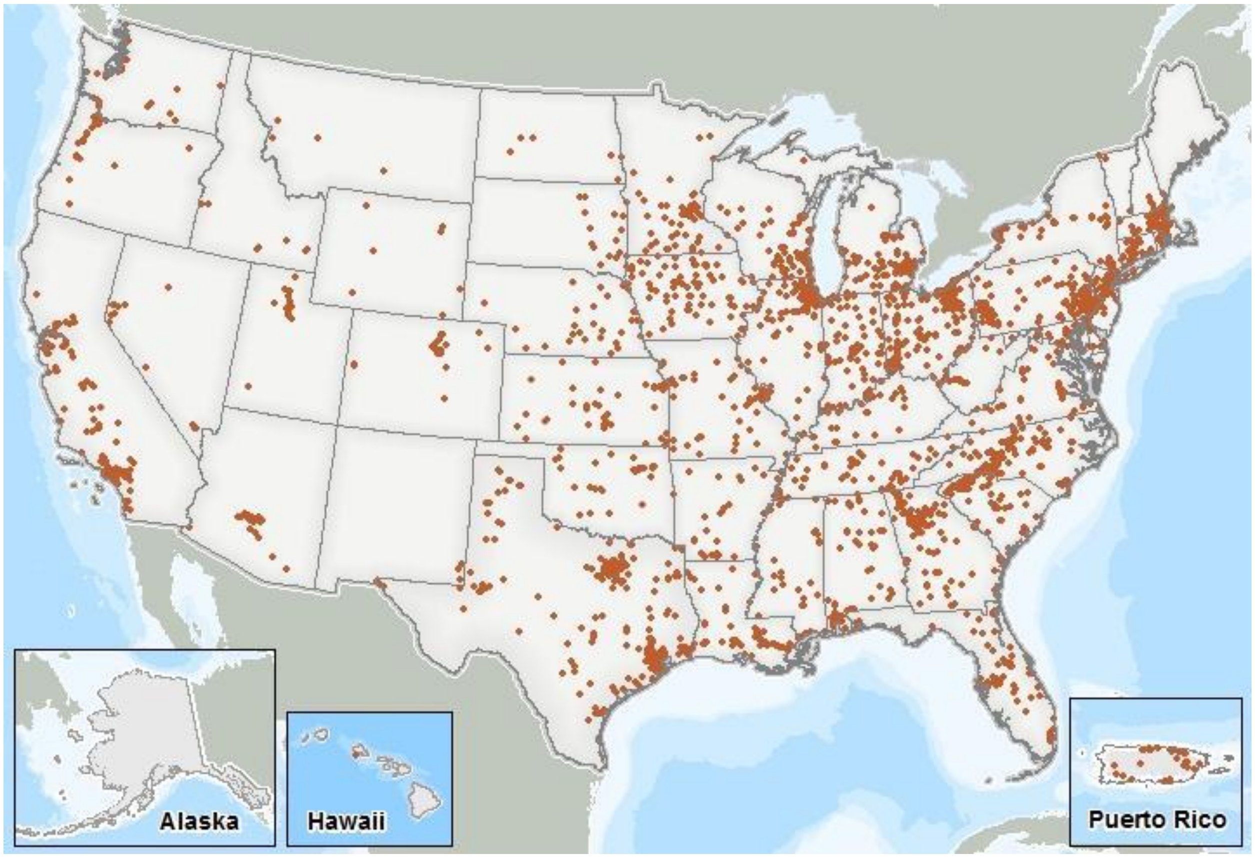
Notes:
p-values are shown in parentheses.
Bold text identifies coefficients that are significant at 90% level or better (p ≤ 0.10).

Table 7: Cross-Equation Testing of Equal Slopes

Government Intervention	χ^2	p-value
Specific Deterrence		
Federal inspections	2.45	0.117
State inspections	**4.45**	**0.035**
Informal enforcement actions	**16.06**	**0.000**
Penalties	**121.5**	**0.000**
General Deterrence		
Federal inspections	**5.01**	**0.025**
State inspections	0.06	0.802
Informal enforcement actions	1.06	0.302
Penalties	**87.28**	**0.000**

Notes:
Tests based on SUR fixed effects estimation of logged production and environmental employment using Model 3; results shown in Table 6.
Bold text identifies test statistics that significantly reject the null hypothesis at the 10 % level or better ($p \leq 0.10$).

Figure 1: Map of Chemical Manufacturing Facilities Operating in the United States



Source: U.S. EPA

Figure 2: Cost-Minimizing Input Choices

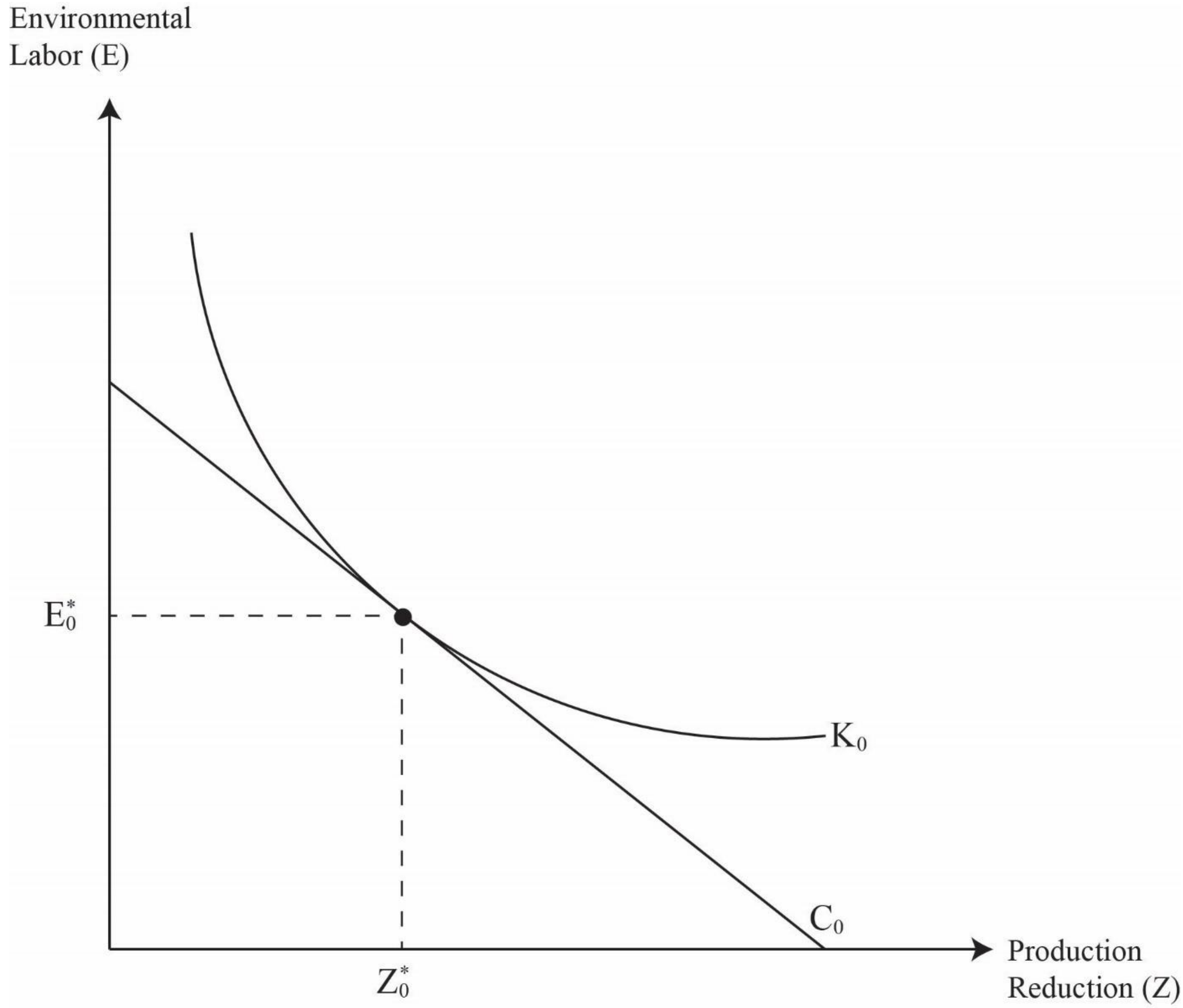


Figure 3: Cost-Minimizing Input Choices After Increased Enforcement

Figure 3.a. Increase in Environmental Labor and Increase in Production

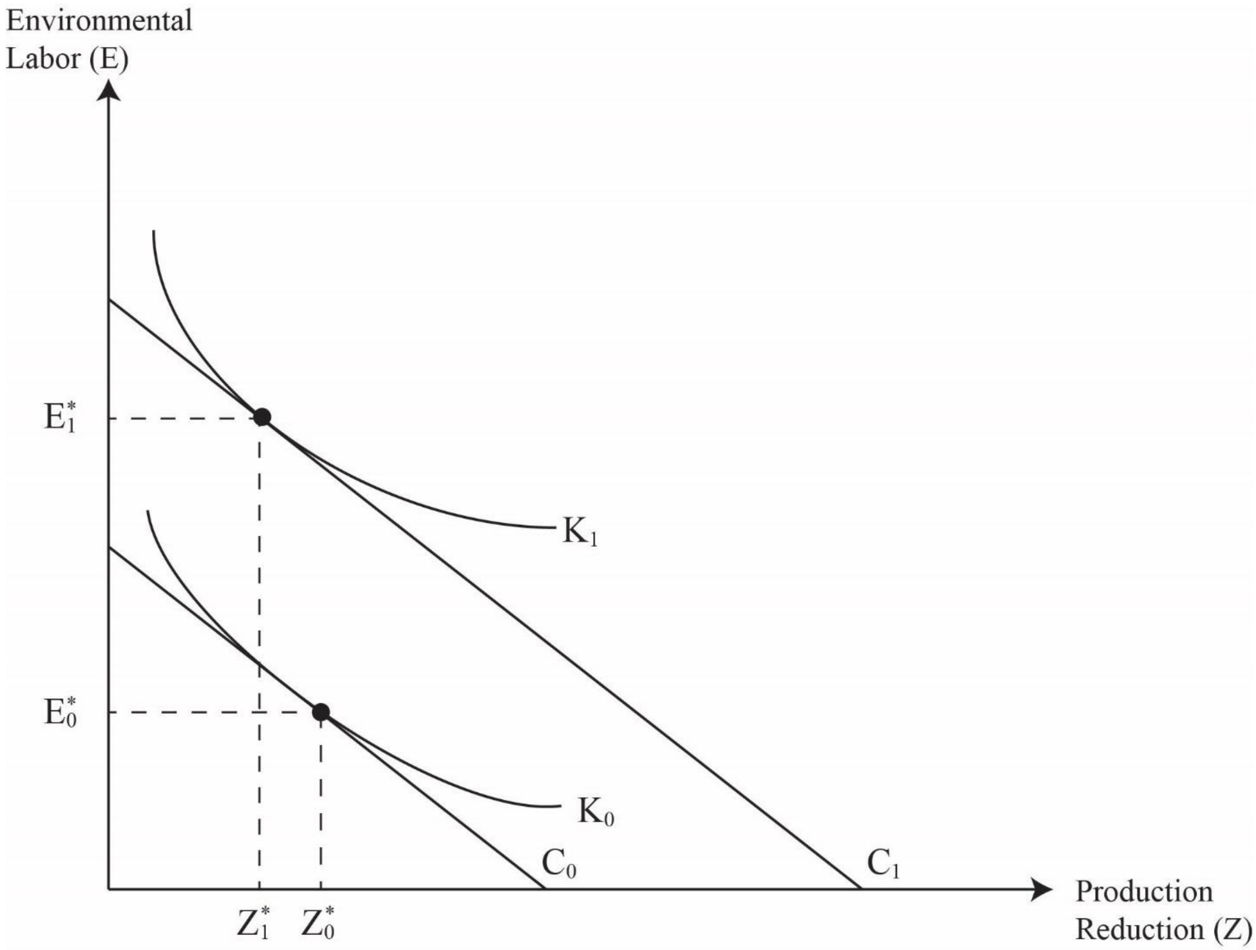


Figure 3.b. Decrease in Environmental Labor and Decrease in Production

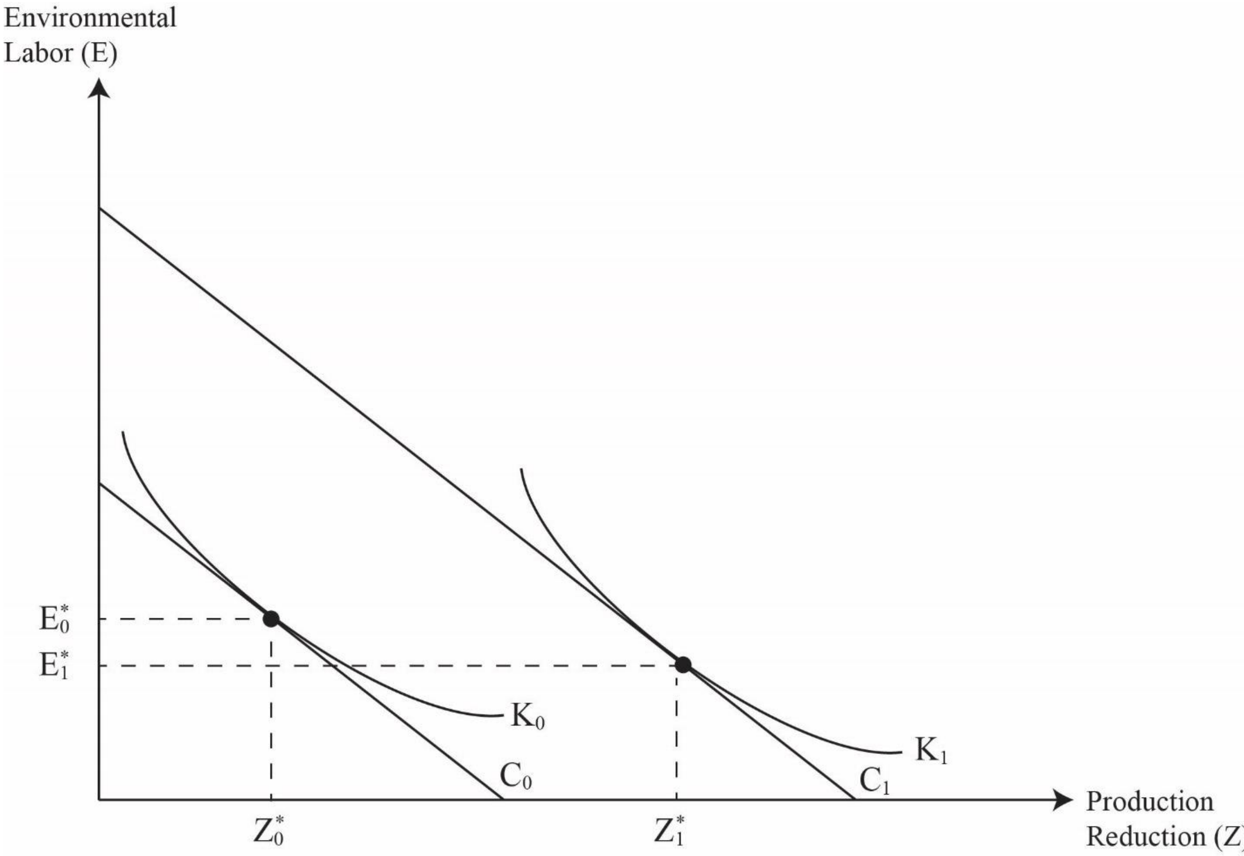
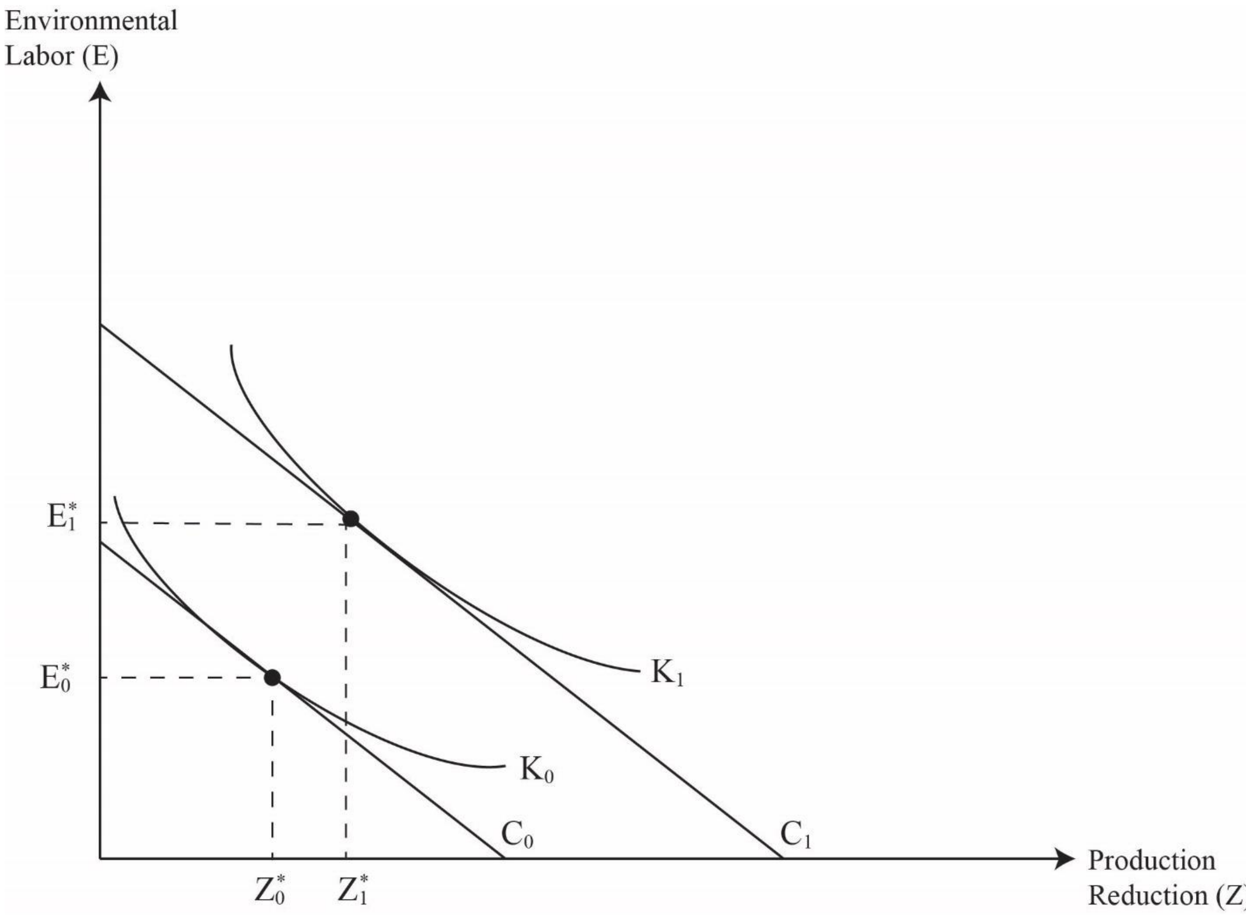


Figure 3.c. Increase in Environmental Labor and Decrease in Production



Appendix Table A-1: Probit Estimation of Survey Response Decision

Independent Variable	Coeff.
Federal inspections during preceding 12-month period at facility	-0.010 (0.973)
State inspections during preceding 12-month period at facility	-0.022 (0.484)
Informal enforcement actions during preceding 12-month period against facility	-0.020 (0.797)
Formal enforcement actions during preceding 12-month period against facility	-0.970 (0.999)
EPA Region 1 (1,0)	-0.092 (0.775)
EPA Region 2 (1,0)	-0.448 (0.171)
EPA Region 3 (1,0)	0.109 (0.660)
EPA Region 4 (1,0)	0.008 (0.971)
EPA Region 5 (1,0)	0.096 (0.691)
EPA Region 6 (1,0)	0.075 (0.748)
EPA Region 7 (1,0)	0.096 (0.691)
Sector: Organic Chemicals (vs. "other chemicals")	-0.063 (0.596)
Sector: Inorganic Chemicals (vs. "other chemicals")	-0.001 (0.998)
EPA Facility Status: Major (vs. minor)	**0.281** **(0.009)**
Number of observations	1003

Notes:
p-values are shown in parentheses.
Bold text identifies coefficients significant at the 90% level or better ($p \leq 0.10$).
Penalties are included in the count of formal enforcement action.
The omitted category for regions includes EPA Regions 8, 9, and 10.

Appendix Table A-2: Results from SUR Fixed Effects Estimation of Logged Production and Environmental Employment, by Part of the US – Western and Eastern

Independent Variable	East Production	East Environmental	West Production	West Environmental
Specific Deterrence				
Federal inspections during preceding 24-month period	**-0.295** **(0.000)**	**-0.162** **(0.000)**	**0.006** **(0.080)**	0.005 (0.934)
State inspections during preceding 24-month period	0.029 (0.154)	**0.055** **(0.000)**	**0.015** **(0.046)**	**0.012** **(0.000)**
Informal enforcement actions during preceding 24-month period	**0.079** **(0.090)**	**0.259** **(0.000)**	**-0.040** **(0.000)**	**-0.030** **(0.000)**
Penalty amount (000 $) during preceding 24-month period	**0.094** **(0.025)**	-0.052 (0.302)	0.0009 (0.206)	**-0.005** **(0.000)**
General Deterrence				
Federal inspections / other facilities per region	0.283 (0.275)	**-0.331** **(0.055)**	0.340 (0.269)	**-0.314** **(0.029)**
State inspections / other facilities per region	**0.029** **(0.000)**	**0.011** **(0.019)**	**-0.072** **(0.000)**	**-0.027** **(0.037)**
Informal enforcement actions / other facilities per region	**-0.396** **(0.001)**	-0.141 (0.386)	0.050 (0.423)	**-0.207** **(0.001)**
Penalty amount (000 $) / other facilities per region	**-9.790** **(0.000)**	**-3.530** **(0.048)**	**0.057** **(0.063)**	-0.004 (0.743)
Number of Observations	387	387	386	386
Year indicators included	Yes	Yes	Yes	Yes
Facility characteristics included	Yes	Yes	Yes	Yes
Community pressure factors included	Yes	Yes	Yes	Yes

Notes:
p-values are shown in parentheses.
Bold text identifies coefficients that are significant at 90% level or better (p ≤ 0.10).