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ENVIRONMENTAL REGULATORY POLICY: POLITICAL ECONOMY, INDUSTRIAL GEOGRAPHY, AND INTERGOVERNMENTAL FISCAL EFFECTS

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A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
Martin School of Public Policy & Administration
at the University of Kentucky

By
Douglas Alan Carr

Lexington, Kentucky

Director: Dr. David Wildasin, Endowed Professor of Public Finance
and Professor of Economics

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Environmental regulatory policy in the U.S. is a mixture of federal, state, and local activity and impacts. This is true of air quality regulations, which are governed at the federal level by the Clean Air Act. This dissertation analyzes both the political economy of federal environmental regulations and the empirical effects of ozone regulations under the Clean Air Act.

A political economy model is developed that offers a motivation for political support of national environmental policy that regulates strictly local pollution. Altering local environmental policies in other jurisdictions will cause capital migration, which may increase local welfare. Thus, individuals have an incentive to influence local policies in other jurisdictions. National environmental policy then becomes a potential tool for inter-jurisdictional competition.

The empirical impacts of ground-level ozone regulations under the Clean Air Act are also analyzed. The Clean Air Act established minimum air quality standards; localities failing to meet the established standards are classified as nonattainment areas and are subject to additional environmental regulations. These new regulations have a direct impact on polluting industries, and therefore also an indirect impact on the revenues and expenditures of local governments.

First, nonattainment status is seen to alter regional industrial geography. Overall economic activity declines in both nonattainment areas and the surrounding jurisdictions. Gaining attainment status partially mitigates these impacts, although to some extent the

economic impacts in both nonattainment areas and the surrounding jurisdictions do permanently persist. I also find evidence that manufacturing activity relocates from nonattainment areas to surrounding areas that face more lenient air quality regulations.

Ozone nonattainment status is also seen to produce fiscal effects for local governments as changes in industrial geography alter local tax bases. Revenues and expenditures decline in regulated population centers, while they increase in surrounding areas. These increases diminish with distance from the urban center. Also, the fiscal impacts persist even after attainment status has been gained.

Douglas Carr

7/5/07

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Dedicated to my family, for their steadfast support and encouragement.

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TABLE OF CONTENTS

Chapter 5: Conclusion

LIST OF TABLES

LIST OF FIGURES

Chapter 1

Introduction

Environmental regulatory policy in the U.S. is a mixture of federal, state, and local activity and impacts. This is true of air quality policies, which are governed at the federal level by the Clean Air Act. The analysis in this dissertation develops a political economy model explaining one motivation for the existence of federal environmental policies that have local policy targets. It also empirically tests the regulatory impacts of the Clean Air Act on regional industrial geography and on local government finance.

Theoretical Focus

While local jurisdictions are free to implement local environmental regulations, federal regulations are often developed that focus on local polluting activity. A common explanation for this is that local jurisdictions lack the legal or political capability to regulate pollution that crosses local jurisdictional boundaries. However, this does not explain ground-level ozone regulation under the Clean Air Act.

The Clean Air Act and its amendments establish national ambient air quality standards (NAAQS) for several criteria pollutants, including ground-level ozone. Counties failing to meet the NAAQS for a specific pollutant are classified as being in nonattainment for that pollutant. While nonattainment areas may include multiple counties, they are contained within state boundaries. Ground-level ozone pollution is primarily local in nature; local pollution sources are largely responsible for local ozone levels. Also, the Clean Air Act is not designed to primarily focus on the inter-jurisdictional pollution that contributes to local air quality, but instead focuses on local pollution sources that contribute to local air quality degradations. States could implement their own air quality regulations or create regional authorities for this purpose in areas with poor air quality; states, or regional authorities that could be created by counties or states, contain both the polluted air and the responsible pollution sources, and so could regulate local or regional polluting activity. However, we instead see the implementation of federal air quality regulations.

In this dissertation I develop a model offering an explanation for why federal environmental policies arise when the regulated pollution is local in nature. In the model, environmental policy increases the cost of production in regulated jurisdictions and reduces the national rate of return to capital. This causes capital to migrate, which in turn alters local wage rates throughout the national economy. The changes in local wage rates and national returns to capital will harm some localities, while it may benefit others. Thus, a situation arises when individuals may prefer environmental policies in other jurisdictions that differ from the policy preference of residents of those jurisdictions. National environmental policy is thus a potential tool for inter-jurisdictional competition.

The Clean Air Act

Before discussing the empirical analysis in this dissertation, it is important to understand how the Clean Air Act regulates local air quality. Prior to the 1970 Clean Air Act, air quality regulation was largely the responsibility of states. By creating the Clean Air Act, Congress greatly increased the stringency of air quality regulation. National ambient air quality standards (NAAQS) were established for several criteria pollutants. The nation was divided into air quality regions, and regions failing to meet the NAAQS were classified as being in nonattainment. States were required to submit a state implementation plan (SIP) designed to bring nonattainment regions into attainment.

In 1977, Congress passed the Clean Air Act Amendments. These amendments were in response to frustrations with the implementation of the 1970 Clean Air Act. States were considered to be making insufficient progress in implementing effective regulations and improving regional air quality. A variety of causes can be cited for this lack of progress, including a lack of technical expertise or resources on the part of states, confusion concerning how states were expected to implement the Clean Air Act regulations, and litigation on the part of both industrial and environmental groups.

The 1977 Clean Air Act Amendments replaced the air quality regions with county-level attainment classifications. Beginning in 1978, all counties or parts of counties were classified as either being in or out of attainment for each criteria pollutant. Federal penalties were also increased. Federal funding for states was tied to state compliance with the Clean Air Act, and new federal civil penalties were created for

polluters that ignored Clean Air Act requirements. The Clean Air Act was amended again in 1990, making changes to a number of specific regulatory requirements such as abatement technology requirements and permissible automobile emissions. The 1990 amendments did not make the same types of structural changes to implementation that the 1977 amendments made.

Attainment status for each county is determined by air quality measurements. If an area fails to meet the NAAQS for a particular pollutant for three consecutive years, it is subject to being declared in nonattainment. Nonattainment status is not automatic, but is an administrative decision within the EPA. Once an area is declared to be in nonattainment, the state containing the nonattainment area is required to submit a state implementation plan (SIP) to the EPA. The SIP details what actions will be taken to bring the area into compliance with the NAAQS.

While states are given some flexibility when developing SIPs, there are specific requirements each SIP must meet in order to be approved by the EPA. New facilities in nonattainment areas are required to use abatement technology leading to the lowest achievable emission rate; this requirement is not supposed to take cost into consideration. Existing facilities in nonattainment areas are required to use reasonably available control technology, which typically involves retrofitting.

Facilities in attainment areas are also subject to regulations; these regulations are aimed at the prevention of significant deterioration in air quality. Large new facilities are required to use the best available control technology. The specific technology requirements are negotiated on a case by case basis, and cost is taken into consideration. Thus, while new facilities in attainment areas may still be subject to emissions regulations, nonattainment status brings stricter regulations for polluting firms.

Once a nonattainment area has met the NAAQS, it can be reclassified as an attainment area. When this occurs, nonattainment regulations are no longer enforced. Instead, states are required to submit a maintenance plan for these areas describing what actions will be taken to maintain air quality compliance. The requirements for SIPs do not apply to maintenance plans; rather, states are given more flexibility in determining what regulations will be enforced to maintain attainment status.

Between 1978 and 2003, the years covered in this analysis, the Clean Air Act regulated 7 criteria pollutants: 1-hour ozone, carbon monoxide, lead, particulate matter smaller than 10 microns, nitrous oxide, sulfur dioxide, and total suspended particulates. Not all of these pollutants were regulated for the entirety of this 26-year period, although the 1-hour ozone standard was enforced during this whole period. The 1-hour ozone standard is so named because it limits the 1-hour average concentration of ground-level ozone. The 1-hour standard was revoked after 2004 for almost all areas; ground-level ozone is now regulated by an 8-hour standard.

While ozone is beneficial in the upper atmosphere, ground-level ozone is the main ingredient of smog and is harmful to both human health and vegetation. Ozone can cause respiratory health problems, and children and those with asthma are the most sensitive to ozone exposure. Ozone is not released directly into the atmosphere, but instead it is created by a chemical reaction between nitrous oxides (NO_x) and volatile organic compounds (VOCs) that is caused by sunlight. Roughly half of NO_x and VOC emissions are from automobiles; the rest come from various industrial sources such as electric power generation facilities.

Empirical Focus

The empirical chapters in this dissertation focus on the impacts of ground-level ozone nonattainment status. There is an existing literature concerning the impacts of ozone nonattainment on polluting industries; this literature provides the setting for the present research. Nonattainment regulations are designed to improve local air quality by targeting polluting facilities. This has been shown to significantly decrease not only pollution, but also economic activity in polluting industries in areas in nonattainment for the 1-hour ozone standard.

While much of the existing literature focuses on industry-level impacts of ozone nonattainment regulations, I take a more geographically oriented approach. As polluting activity declines in nonattainment areas, other industries may move into the area replacing the lost polluting economic activity. Alternatively, inter-industry ties may cause overall local declines in economic activity as industries with ties to polluting firms are

also affected. To capture these overall impacts, I analyze the relationship between ozone nonattainment regulations and aggregate local economic indicators.

Local economies do not exist in isolation. Instead, economic changes in one jurisdiction are expected to spill over into neighboring areas. Thus, focusing strictly on nonattainment areas fails to give a complete picture of the regional regulatory impacts. It is important to note that nonattainment regulations are only applied in nonattainment areas. The broader regional impacts of these regulations are caused by regional economic linkages, not regional application of air quality regulations. Polluting activity may relocate into surrounding areas where capital investments are less costly because these areas are not subject to nonattainment regulations. If this occurs, regulatory impact estimates based only on nonattainment areas will overestimate industrial impacts. It may also be the case that reductions in economic activity in nonattainment areas cause similar reductions in surrounding areas because of regional economic linkages. If this is the case, then analysis limited to nonattainment areas will underestimate the regional and national economic impacts of nonattainment regulations.

Not only are the impacts in nonattainment areas important, but so is the persistence of these impacts. Nonattainment regulations are intended to improve local air quality; once air quality standards have been met, these regulations are replaced by a maintenance plan that is focused on maintaining, rather than improving, local air quality. While nonattainment regulations are no longer implemented in areas that have gained attainment, it is not expected that the economic impacts of nonattainment status are immediately reversed. Some persistence is expected because of the nature of the nonattainment regulations; firms made investment decisions during the nonattainment period based on the stricter nonattainment regulations, and these decisions will have impacts for firms beyond the point when attainment status is gained. Also, regulations implemented to maintain attainment status are expected to have local and regional economic impacts. There is not, however, an a priori expectation of the extent to which economic impacts will persist after attainment status has been gained. These impacts may be transient, largely disappearing several years after attainment status has been gained, or the impacts could be permanent. Analyzing the nature of regulatory impact persistence is important for understanding the temporal effects of ozone nonattainment regulations.

Finally, the industrial impacts of nonattainment regulations are expected to affect local governments. Cities and counties are not responsible for implementing nonattainment regulations, but they are not isolated from regulatory impacts; industrial regulatory impacts will affect the tax bases of local governments. Thus, local governments are not expected to experience regulatory impacts because of direct compliance costs, which are paid by firms that invest in new abatement technology. Instead, nonattainment regulations are expected to indirectly affect the revenues and expenditures of local governments as industrial impacts alter local tax bases.

Chapter 2

A Political Economy Approach to Environmental Regulations in a Federated System

Central governments create a variety of national policies, including policies designed to correct problems that are contained within single jurisdictions. When the policy targets are strictly local in nature, local jurisdictions may have the ability to address the situations with local policies. Yet central governments often still create national policies that regulate strictly local activity.

For example, the Clean Air Act created national ambient air quality standards that apply to specific pollutants. These standards are applied at the local level, and localities failing to meet the standards over a three year period are declared to be non-attainment areas. The standards primarily focus on local air quality, not on trans-boundary pollution. Once an area is declared a non-attainment area, the state is required to submit a state implementation plan outlining what actions will be taken to achieve the ambient air quality standards. State implementation plans create additional regulations for industries that are located within non-attainment areas.

Another example is found in a 1996 European Union Council Directive. This Directive creates local air quality standards regulating several air pollutants. Similar to the Clean Air Act, the Directive includes regulations pertaining to local air pollution. Such regulatory decisions could have been left to individual member states.

In these examples, a central government has created a regulation that focuses on local environmental quality and not trans-boundary pollution externalities. Each jurisdiction where the central regulation is binding could have enacted a similar local regulation but chose not to do so. Why do central governments create such policies? The following model offers an explanation. Environmental policy causes capital to migrate in the model; national environmental policy then becomes a tool for inter-jurisdictional competition through which local capital stocks are altered, potentially producing local welfare benefits. Thus, jurisdictions have an incentive to influence national environmental policy.

Much of the environmental regulation literature considers competition for capital. For example, see Levinson (2003), Oates and Schwab (1988), Eerola (2004), and Fredriksson and Gaston (2000). A key question addressed both by this model and by the existing literature is whether outcomes are efficient when there is competition involving mobile capital.

Oates and Schwab (1988) develop a model including competition for capital with an environmental tax, and find that the decentralized median voter outcome is efficient because local workers receive the full benefit of pollution abatement and bear the full burden of capital relocation[1]. They also find that heterogeneous populations within a jurisdiction may lead to inefficient local policies because the majority in a locality may externalize policy outcomes onto a minority of local residents. The model in the present chapter finds that the decentralized environmental policy choices of homogeneous jurisdictions are not first-best optimal because each jurisdiction ignores the effects of capital migration on all other jurisdictions.

Markusen and Morey (1995) develop an interjurisdictional capital competition model that leads to decentralized outcomes that are inefficient. Levinson (1997) highlights that the source of the inefficiency does not directly arise from competition, but as the incidence of a local tax on production is exported to consumers in other jurisdictions. A key difference between this outcome and that of the model in the present chapter is that in the latter competition for local income and environmental quality, which are functions of local capital, directly creates an incentive to influence policies in other jurisdictions without considering the full welfare impacts of such policies.

The Model

This analysis models a closed economy where capital is freely mobile and labor is immobile. Pollution, which is produced in the production process, is strictly local in nature, not trans-boundary.

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[1] The model in this paper shares several key assumptions with the Oates and Schwab model. Both models assume capital is mobile, labor is immobile, pollution is not trans-boundary, and people work and live in the same jurisdiction.

Firms

All firms produce a single homogeneous product that is used as numéraire. Firms experience constant returns to scale, and there are many perfectly competitive firms of indeterminate size in each jurisdiction. Production f in jurisdiction j is a function of the fixed local labor supply $\bar{l}^j$ and local capital k^j; $f^j\left(\bar{l}^j, k^j\right)$. Production is concave with respect to labor and capital. Using subscripts to indicate partial derivatives, the marginal productivity of capital is given by $f_k^j > 0$ and the marginal productivity of labor is $f_{\bar{l}}^j > 0$. Capital and labor exhibit diminishing marginal returns; $f_{kk}^j < 0$ and $f_{\bar{l}\bar{l}}^j < 0$. Labor and capital are complements, so $f_{\bar{l}k}^j > 0$.

Firms emit pollution as part of the production process. This pollution is strictly local in nature, only affecting the local environment in the local jurisdiction. The local jurisdiction j sets a required environmental reclamation expenditure for firms. This expenditure equals a portion of total output and is given by α^j, where $0 \leq \alpha^j \leq 1$; $\alpha^j = 0$ corresponds with no local environmental reclamation expenditures.

Perfectly competitive local labor and national capital markets are assumed. Both r^*, the equilibrium rate of return to capital, and w^j, the equilibrium wage rate in jurisdiction j, are treated as exogenous by firms. Profits for firms in jurisdiction j are then given by

$$\pi^j = f^j - \left(r^* \cdot k^j\right) - \left(w^j \cdot \bar{l}^j\right) - \left(\alpha^j \cdot f^j\right). \tag{1}$$

Maximizing π^j with respect to k^j,

$$\frac{\partial \pi^j}{\partial k^j} = f_k^j - r^* - \alpha^j \cdot f_k^j = 0$$
$$\Rightarrow \left(1 - \alpha^j\right) f_k^j = r^*. \tag{2}$$

Similarly, maximizing π^j with respect to $\bar{l}^j$,

$$\frac{\partial \pi^j}{\partial \bar{l}^j} = f_{\bar{l}}^j - w^j - \alpha^j \cdot f_{\bar{l}}^j = 0$$
$$\Rightarrow \left(1 - \alpha^j\right) f_{\bar{l}}^j = w^j. \tag{3}$$

Thus, individual firms will employ the quantity of capital and labor that results in the rate of return to each factor equaling a portion of its marginal productivity as determined by α^j.

Because firms experience constant returns to scale, by Euler's theorem $f_k^j \cdot k^j + f_{\bar{l}}^j \cdot \bar{l}^j = f^j\left(\bar{l}^j, k^j\right)$. For firms, this means that

$$\left(\frac{r^*}{1-\alpha^j}\right) k^j + \left(\frac{w^j}{1-\alpha^j}\right) \bar{l}^j = f^j. \tag{4}$$

Applying this to the profit function in (1),

$$\pi^j = \left(\frac{r^*}{1-\alpha^j}\right) k^j + \left(\frac{w^j}{1-\alpha^j}\right) \bar{l}^j - r^* \cdot k^j - w^j \cdot \bar{l}^j - \alpha^j \left(\frac{r^*}{1-\alpha^j} \cdot k^j + \frac{w^j}{1-\alpha^j} \cdot \bar{l}^j\right)$$

$$= \frac{r^*}{1-\alpha^j} \cdot k^j + \frac{w^j}{1-\alpha^j} \cdot \bar{l}^j - \frac{r^*}{1-\alpha^j} \cdot k^j - \frac{w^j}{1-\alpha^j} \cdot \bar{l}^j = 0. \tag{5}$$

Thus, $\pi^j = 0$; firms do not earn pure profits in equilibrium.

Local Markets

The local labor supply in jurisdiction j is fixed at $\bar{l}^j$. Also, the total demand for capital in jurisdiction j is k^j. Firms within a jurisdiction use the same production technology, so each firm faces the same production function. Total local production in jurisdiction j aggregated across all local firms is then $f^j\left(\bar{l}^j, k^j\right)$. Note that the production function is allowed to vary across jurisdictions. Because both $f_k^j\left(\bar{l}^j, k^j\right)$ and $f_{\bar{l}}^j\left(\bar{l}^j, k^j\right)$, given r^* and the local policy α^j, the local capital stock k^j and the local wage rate w^j are determined by recursively solving the following set of equations taken from the firm profit maximization in (2) and (3). Specifically, the first equation is solved for k^j in terms of r^* and α^j, and then this result is used in the second equation to solve for w^j in terms of the same variables.

$$\begin{cases} \left(1-\alpha^j\right) f_k^j\left(\bar{l}^j, k^j\right) = r^* \\ \left(1-\alpha^j\right) f_{\bar{l}}^j\left(\bar{l}^j, k^j\right) = w^j \end{cases} \tag{6}$$

Thus the local capital stock is $k^j\left(\alpha^j, \bar{l}^j, r^*\right)$ and the equilibrium local wage rate is given by $w^j\left(\alpha^j, \bar{l}^j, k^j\right)$.

Consider the relationship between the local demand for capital and the local policy α^j. Recall the firm's profit maximization in (2). Since firms take r^* as exogenous,

$$\frac{\partial k^j}{\partial \alpha^j} = \frac{f_k^j}{\left(1-\alpha^j\right) f_{kk}^j} < 0 \tag{7}$$

by the implicit function theorem. Also,

$$\frac{\partial k^j}{\partial r^*} = \frac{1}{\left(1-\alpha^j\right) f_{kk}^j} < 0. \tag{8}$$

Turning to wage impacts, note that by Euler's theorem, $f_{\bar{l}}^j \cdot \bar{l}^j = f^j - k^j \cdot f_k^j$, or

$$w^j \cdot \bar{l}^j = \left(1 - \alpha^j\right) f^j - \left(1 - \alpha^j\right) k^j \cdot f_k^j. \tag{9}$$

Thus,

$$\frac{\partial w^j \cdot \bar{l}^j}{\partial \alpha^j} = -f^j + f_k^j k^j - \left(1 - \alpha^j\right) k^j f_{kk}^j \frac{\partial k^j}{\partial \alpha^j}. \tag{10}$$

Substituting from (7) yields

$$\frac{\partial w^j \cdot \bar{l}^j}{\partial \alpha^j} = -f^j < 0. \tag{11}$$

Similarly, ignoring the relationship between α^j and r^*,

$$\frac{\partial w^j \cdot \bar{l}^j}{\partial r^*} = -\left(1 - \alpha^j\right) f_{kk}^j \cdot k^j \left(\frac{\partial k^j}{\partial r^*}\right), \tag{12}$$

and substituting from (8) yields

$$\frac{\partial w^j \cdot \bar{l}^j}{\partial r^*} = -k^j < 0. \tag{13}$$

National Economy

There are n separate jurisdictions in the national economy. A nationally fixed capital stock is freely mobile between jurisdictions. The combined local demands for capital determine the national demand. Given a fixed national capital supply $\bar{K}$, the national demand for capital, $\sum_{i=1}^n k^i$, determines the national equilibrium rate of return to capital, r^*. Capital is mobile and will migrate until the local rate of return to capital equals the national equilibrium rate of return; $\left(1 - \alpha^i\right) f_k^i = r^*$ $\forall i$. The following system of equations simultaneously determines r^* and k^i $\forall i$.

$$\begin{cases} \sum_{i=1}^n k^i = \bar{K} \\ \left(1 - \alpha^i\right) f_k^i = r^* \ \forall i \end{cases} \tag{14}$$

Thus,

$$r^* \left(\alpha^1, \dots, \alpha^n\right). \tag{15}$$

While α^i is a local policy parameter, it affects the national capital market. Using the system of equations in (14), the value of $\partial r^* / \partial \alpha^i$ in equilibrium is derived; the proof is found in Proof 2.1.

$$\frac{\partial r^*}{\partial \alpha^i} = \frac{-f_k^i}{\left(1 - \alpha^i\right) f_{kk}^i \sum_{j=1}^n \frac{1}{\left(1 - \alpha^j\right) f_{kk}^j}} < 0 \tag{16}$$

Increasing the stringency of a local reclamation policy in one jurisdiction will increase the quantity of capital demanded in all other jurisdictions as it reduces the national equilibrium rate of return to capital. Formally,

$$\frac{\partial k^j}{\partial r^*}\frac{\partial r^*}{\partial \alpha^i} = \frac{\partial k^j}{\partial \alpha^i} > 0 \; \forall j \neq i. \tag{17}$$

Noting that a fixed national capital stock implies that an increase in the quantity of capital demanded in all jurisdictions must be offset by a decrease in demand for capital in the regulated jurisdiction, or formally

$$\sum_{j=1}^{n} k^j = \bar{K} \Rightarrow \sum_{j=1}^{n} \frac{dk^j}{d\alpha^i} = 0, \tag{18}$$

the following describes environmental policy impacts on local capital stocks.

$$\frac{dk^j}{d\alpha^i} = \begin{cases} \dfrac{\partial k^j}{\partial r^*}\dfrac{\partial r^*}{\partial \alpha^i} = \dfrac{1}{\left(1-\alpha^j\right)f_{kk}^j} \cdot \dfrac{-f_k^i}{\left(1-\alpha^i\right)f_{kk}^i \displaystyle\sum_{j=1}^{n}\dfrac{1}{\left(1-\alpha^j\right)f_{kk}^j}} > 0 & j \neq i \\[2em] -\sum_{j\neq i}\dfrac{\partial k^j}{\partial r^*}\dfrac{\partial r^*}{\partial \alpha^i} < 0 & j = i \end{cases} \tag{19}$$

This observation implies that a local reclamation policy reduces local production while increasing production in all other jurisdictions.

$$\frac{\partial f^j}{\partial k^j}\frac{dk^j}{d\alpha^i} = \frac{\partial f^j}{\partial \alpha^i}\begin{cases} < 0 & i = j \\ > 0 & i \neq j \end{cases} \tag{20}$$

Personal income is derived from wages and from capital income. A single representative household supplies $\bar{l}^j$ labor and is endowed with $\tilde{k}^j$ capital. Thus, wage income is $w^j \cdot \bar{l}^j$ and capital income is $r^* \cdot \tilde{k}^j$. The one private good produced by firms, x, is used as numéraire. Thus, the total income of the representative household in jurisdiction j is given by

$$x^j = w^j \cdot \bar{l}^j + r^* \cdot \tilde{k}^j. \tag{21}$$

Note that $\left(\alpha^1, \ldots, \alpha^n\right)$ uniquely determines x^j, as seen in (22).

$$\begin{aligned} x^j &= w^j\left(\alpha^j, \bar{l}^j, k^j\left[\alpha^j, \bar{l}^j, r^*\left(\alpha^1, \ldots, \alpha^n\right)\right]\right) \cdot \bar{l}^j + r^*\left(\alpha^1, \ldots, \alpha^n\right) \cdot \tilde{k}^j \\ &= w^j\left(\alpha^1, \ldots, \alpha^n\right) \cdot \bar{l}^j + r^*\left(\alpha^1, \ldots, \alpha^n\right) \cdot \tilde{k}^j \\ &\Rightarrow x^j\left(\alpha^1, \ldots, \alpha^n\right) \end{aligned} \tag{22}$$

Local Environmental Policy

Pollutants are produced in the production process and are measured by $\Gamma\left(f^j\right)$. The local policy α^j determines the end-of-pipe abatement expenditures per unit of output; these expenditures reduce pollution by a factor of $\beta\left(\alpha^j\right)$, where $\beta_\alpha > 0$. Thus, total pollution is given by

$$\Psi = \Gamma - \beta \cdot \Gamma. \tag{23}$$

The impact of the local policy α^j on pollution is

$$\frac{\partial \Psi}{\partial \alpha^j} = (1 - \beta) \frac{\partial \Gamma}{\partial f^j} \frac{\partial f^j}{\partial \alpha^j} - \Gamma \frac{\partial \beta}{\partial \alpha^j} < 0. \tag{24}$$

The policy α^j reduces local pollution. Local environmental quality is a function of local pollution; $e^j\left(\Psi\right)$ where $e^j_\Psi < 0$. Thus,

$$\frac{\partial e^j}{\partial \Psi} \frac{\partial \Psi}{\partial \alpha^j} = \frac{\partial e^j}{\partial \alpha^j} > 0. \tag{25}$$

The local policy α^j results in improved local environmental quality. Reclamation policy adjustments in other jurisdictions will result in local environmental quality changes as capital migrates.

$$\frac{\partial e^j}{\partial \Psi} (1 - \beta) \frac{\partial \Gamma}{\partial f^j} \frac{\partial f^j}{\partial k^j} \frac{dk^j}{d\alpha^i} = \frac{\partial e^j}{\partial \alpha^i} < 0 \ \forall j \neq i \tag{26}$$

Each jurisdiction sets its local environmental policy; $0 \leq \alpha^j \leq 1$. In the absence of a binding environmental policy $\alpha^j = 0$. Note that $\left(\alpha^1, \dots, \alpha^n\right)$ uniquely determine e^j.

$$e^j\left(\Psi\left(\Gamma\left(f^j\left(k^j\left(\alpha^j, r^*\left(\alpha^1, \dots, \alpha^n\right)\right)\right)\right), \beta\left(\alpha^j\right)\right)\right) = e^j\left(\alpha^1, \dots, \alpha^n\right) \tag{27}$$

The environmental policy modeled here does not directly regulate pollution emissions. Instead, the policy is tied to imposing a cost on total output and achieves improved environmental quality by increasing the cost of production and increasing pollution abatement expenditures. Note that from the firm's perspective, a stricter environmental quality standard only increases the cost of production via α^j and does not prohibit any given level of production or associated pollution.

Decentralized Policy Outcome

Individuals value personal consumption and local environmental quality; the utility of residents in jurisdiction j is given by $U^j\left(x^j, e^j\right)$. People are assumed to live and work in the same jurisdiction. Also, individual preferences are assumed to be convex,

implying that first order conditions are sufficient for maximizing utility or a corner solution exists.

When setting the local environmental policy α^j, jurisdictions take r^* and $\alpha^i \ \forall i \neq j$ as given and maximize local welfare. Thus,

$$V^j\left(\alpha^1,\ldots,\alpha^n\right) = U^j\left(x^j\left(\alpha^1,\ldots,\alpha^n\right), e^j\left(\alpha^1,\ldots,\alpha^n\right)\right) \tag{28}$$

and

$$\frac{\partial U^j}{\partial x^j}\frac{\partial x^j}{\partial \alpha^j} + \frac{\partial U^j}{\partial e^j}\frac{\partial e^j}{\partial \alpha^j} = \frac{\partial V^j}{\partial \alpha^j}. \tag{29}$$

Since jurisdictions are small and therefore take r^* as given, from an individual jurisdiction's perspective

$$\frac{\partial x^j}{\partial \alpha^j} = \frac{\partial w^j \cdot \bar{l}^j}{\partial \alpha^j} = -f^j + k^j \cdot f_k^j - \left(1-\alpha^j\right)k^j \cdot f_{kk}^j\frac{\partial k^j}{\partial \alpha^j} = -f^j; \tag{30}$$

this is seen by differentiating (9). The marginal impact on environmental quality is seen from (24) when r^* is taken as given;

$$\frac{\partial e^j}{\partial \alpha^j} = \frac{\partial e^j}{\partial \Psi}\left((1-\beta)\frac{\partial \Gamma}{\partial f^j}\frac{\partial f^j}{\partial k^j}\frac{\partial k^j}{\partial \alpha^j} - \Gamma\frac{\partial \beta}{\partial \alpha^j}\right) > 0. \tag{31}$$

Jurisdictions will balance the tradeoff between the reduction in wage earnings and the improvements in environmental quality that result from the local environmental policy α^j. The optimal value of α^j is characterized as follows.

$$\frac{\partial V^j}{\partial \alpha^j} = \frac{\partial U^j}{\partial x^j}\frac{\partial x^j}{\partial \alpha^j} + \frac{\partial U^j}{\partial e^j}\frac{\partial e^j}{\partial \alpha^j} = 0$$
$$\Rightarrow -\frac{\partial x^j}{\partial \alpha^j} = \frac{\partial U^j/\partial e^j}{\partial U^j/\partial x^j}\cdot\frac{\partial e^j}{\partial \alpha^j} \tag{32}$$

The marginal cost of an increase in α^j, incurred as income decreases, equals the marginal benefit of the environmental quality improvement resulting from an increase in α^j. Substituting from (30) and (31), (32) becomes

$$f^j = \frac{\partial U^j/\partial e^j}{\partial U^j/\partial x^j}\cdot\frac{\partial e^j}{\partial \Psi}\left((1-\beta)\frac{\partial \Gamma}{\partial f^j}\frac{\partial f^j}{\partial k^j}\frac{\partial k^j}{\partial \alpha^j} - \Gamma\frac{\partial \beta}{\partial \alpha^j}\right). \tag{33}$$

To understand the efficiency of this decentralized equilibrium, compare it with the first-best choice of α^j, k^j, and x^j by a central planner for all jurisdictions. The first-best resource distribution and policy choices are characterized in (34); the proof is found in Proof 2.2.

$$-\frac{\partial x^1}{\partial \alpha^1} = -\frac{\partial U^1\partial k^1}{\partial U^1/\partial x^1}\cdot\frac{\sum_{i\neq1}\partial U^i/\partial \alpha^1}{\sum_{i\neq1}\partial U^i/\partial k^1} + \frac{\partial U^1/\partial e^1}{\partial U^1/\partial x^1}\cdot\frac{\partial e^1}{\partial \alpha^1} \tag{34}$$

Since

$$-\frac{\partial U^1/\partial k^1}{\partial U^1/\partial x^1} \cdot \frac{\sum_{i \neq 1} \partial U^i/\partial \alpha^1}{\sum_{i \neq 1} \partial U^i/\partial k^1} \neq 0, \tag{35}$$

the characterization in (34) is different from the decentralized equilibrium

characterization in (32).

Proposition 1. *The decentralized equilibrium is not first-best efficient.*

$$-\frac{\partial x^j}{\partial \alpha^j} = \frac{\partial U^j/\partial e^j}{\partial U^j/\partial x^j} \cdot \frac{\partial e^j}{\partial \alpha^j} \ \forall j \Rightarrow W\left(U^1, \ldots, U^n\right) \text{ is not maximized} \tag{36}$$

National Policy Preferences

I now turn to preferences regarding a national environmental policy that tightens

the most lenient policies resulting from the decentralized equilibrium. First the case of

symmetric jurisdictions is considered, and then the general case is analyzed.

Symmetric Jurisdictions

Consider the case of symmetric jurisdictions. When jurisdictions are symmetric,

$\tilde{k}^j = \tilde{k}^i, \alpha^j = \alpha^i, f^j = f^i, \bar{l}^j = \bar{l}^i$, and $e^j = e^i \ \forall i$. Given r^*, $k^j = \left(1 - \alpha^j\right) f_k^j$. Because $f^j = f^i$

and $\alpha^j = \alpha^i \ \forall i$, $k^j = k^i \ \forall i$. Thus, $\tilde{k}^j = k^j = \bar{K}/n$ and $\tilde{k}^j - k^j = 0 \ \forall j$. In the decentralized

equilibrium, there is no capital migration.

Now consider a national policy, $\hat{\alpha}$, requiring that $\alpha^j \geq \hat{\alpha} \ \forall j$. Set $\hat{\alpha}$ at the lowest

decentralized equilibrium value of α^j and consider a marginal increase in $\hat{\alpha}$. Because

$\alpha^j = \alpha^i \ \forall i$, tightening this national policy will alter the local reclamation policy in all

jurisdictions. From (19), the change in demand for capital in each jurisdiction is

$$\frac{dk^j}{d\hat{\alpha}} = \sum_{i=1}^{n} \frac{dk^j}{d\alpha^i} = 0. \tag{37}$$

Differentiating (9), the marginal impact of the national policy on wage income is

seen.

$$\frac{\partial w^j \cdot \bar{l}^j}{\partial \hat{\alpha}} = -f^j + \left(1 - \alpha^j\right) f_k^j \frac{dk^j}{d\hat{\alpha}} + f_k^j \cdot k^j - \left(1 - \alpha^j\right) \left(f_k^j \frac{dk^j}{d\hat{\alpha}} + k^j \cdot f_{kk}^j \frac{dk^j}{d\hat{\alpha}}\right)$$

$$= -f^j + f_k^j \cdot k^j \tag{38}$$

While a marginal change in $\hat{\alpha}$ does not cause capital migration, returns to capital are affected as demand for capital decreases in all jurisdictions. This is seen formally from (16). Because $\alpha^j = \alpha^i$ and $f^j = f^i \; \forall j$,

$$\frac{\partial r^*}{\partial \hat{\alpha}} = \sum_{j=1}^{n} \frac{\partial r^*}{\partial \alpha^j} = \sum_{j=1}^{n} \frac{-f_k^j}{(1 - \alpha^j) f_{kk}^j \sum_{i=1}^{n} \frac{1}{(1 - \alpha^i) f_{kk}^i}}$$

$$= \frac{-n \cdot f_k^j}{n} = -f_k^j < 0. \tag{39}$$

Combining this with the previous observation of wage impacts, the affect on local income is seen by differentiating (21).

$$\frac{\partial x^j}{\partial \hat{\alpha}} = \frac{\partial w^j \cdot \bar{l}^j}{\partial \hat{\alpha}} + \frac{\partial r^* \cdot \tilde{k}^j}{\partial \hat{\alpha}} = -f^j + f_k^j \cdot k^j - f_k^j \cdot \tilde{k}^j. \tag{40}$$

Because $\tilde{k}^j = k^j$,

$$\frac{\partial x^j}{\partial \hat{\alpha}} = -f^j. \tag{41}$$

Turning to environmental quality, an increase in $\hat{\alpha}$ improves the local environmental quality in each jurisdiction. The following is seen from (24) and (25).

$$\frac{\partial e^j}{\partial \hat{\alpha}} = \sum_{i=1}^{n} \frac{\partial e^j}{\partial \alpha^i} = \sum_{i=1}^{n} \frac{\partial e^j}{\partial \Psi} \left((1 - \beta) \frac{\partial \Gamma}{\partial f^j} \frac{\partial f^j}{\partial k^j} \frac{dk^j}{d\alpha^i} - \Gamma \frac{\partial \beta}{\partial \alpha^i} \right)$$

$$= \frac{\partial e^j}{\partial \Psi} \left[\frac{dk^j}{d\hat{\alpha}} \sum_{i=1}^{n} \left((1 - \beta) \frac{\partial \Gamma}{\partial f^j} \frac{\partial f^j}{\partial k^j} \right) - \Gamma \frac{\partial \beta}{\partial \alpha^j} \right]$$

$$= -\Gamma \frac{\partial e^j}{\partial \Psi} \frac{\partial \beta}{\partial \alpha^j} > 0 \tag{42}$$

The local welfare impact of $\hat{\alpha}$ can now be understood. Starting from the decentralized equilibrium characterized in (33), consider the welfare impact of a marginal increase in $\hat{\alpha}$. The marginal cost of an increase in $\hat{\alpha}$ is given in (41), and the marginal benefit is given in (42). Comparing (41) with (30), it is seen that $\partial x^j / \partial \hat{\alpha} = \partial x^j / \partial \alpha^j$. Thus, the marginal cost to one jurisdiction of an increase in $\hat{\alpha}$ equals the marginal cost of an increase in α^j from its decentralized equilibrium value.

While there is no difference in the marginal cost of a change in α^j and $\hat{\alpha}$, there is a difference in the marginal benefit. It is seen that $\partial e^j / \partial \hat{\alpha} < \partial e^j / \partial \alpha^j$ from (42) and (31). This is because there are no capital stock adjustments when considering a national policy standard for symmetric jurisdictions. The marginal benefit of an increase in $\hat{\alpha}$ is then less than the marginal benefit of an increase in α^j from its decentralized equilibrium value.

16

$$\frac{\partial U^j / \partial e^j}{\partial U^j / \partial x^j} \cdot \frac{\partial e^j}{\partial \hat{\alpha}} < \frac{\partial U^j / \partial e^j}{\partial U^j / \partial x^j} \cdot \frac{\partial e^j}{\partial \alpha^j} \qquad (43)$$

Thus, from the decentralized equilibrium policy choice characterized in (32), an increase in $\hat{\alpha}$ reduces local welfare because the marginal benefit of improved environmental quality resulting from the policy increase is less than its marginal cost.

$$-\frac{\partial x^j}{\partial \hat{\alpha}} > \frac{\partial U^j / \partial e^j}{\partial U^j / \partial x^j} \cdot \frac{\partial e^j}{\partial \hat{\alpha}} \Rightarrow \frac{\partial U^j}{\partial \hat{\alpha}} < 0 \qquad (44)$$

Proposition 2. *In the case of symmetric jurisdictions, no jurisdiction has an incentive to increase the national minimum environmental policy. Instead, welfare in all jurisdictions would increase if the local environmental policy was simultaneously decreased in all jurisdictions.*

$$\frac{\partial U^j}{\partial \hat{\alpha}} < 0 \; \forall j \qquad (45)$$

In the decentralized equilibrium, each jurisdiction attempts to use local environmental policy to improve the local environmental quality in part by driving away capital. This creates a negative externality on the other jurisdictions, which receive the additional capital and resulting pollution. Because of this externality caused by capital migration, local regulations are too stringent in the decentralized equilibrium for symmetric jurisdictions. Even though there is no capital migration in equilibrium, the potential for such migration was considered by each jurisdiction when setting local environmental policy. A coordinated reduction of all local environmental policies would counter this externality, improving welfare in all jurisdictions.

This provides a normative basis for evaluating environmental policy when jurisdictions are symmetric. In the absence of capital migration in the symmetric case, decentralized environmental policies targeting strictly local pollution are too stringent in all jurisdictions. This inefficiency results from the environmental externality that occurs when jurisdictions attempt to chase polluting capital away and into other jurisdictions; the cost of local environmental improvement is partially externalized onto other jurisdictions.

Asymmetric Jurisdictions

Now consider an economy where jurisdictions are not symmetric. Also, let j now indicate the type of jurisdiction, where there are s^j symmetric individual jurisdictions of

each type $j = 1 \ldots n$. This means, for example, that x^j will now indicate the income in any one jurisdiction that is of type j. Order these types so that $\alpha^j < \alpha^{j+1}$.

Consider a national policy, $\hat{\alpha}^1$, that will increase the national minimum reclamation policy from the decentralized equilibrium. A marginal increase in $\hat{\alpha}^1$ will only have a direct regulatory impact in type 1 jurisdictions because $\alpha^j > \alpha^1 \; \forall j > 1$; the new national minimum value for α^j will only be binding in type 1 jurisdictions. Given the decentralized equilibrium stringency of local environmental policy in each jurisdiction, increasing $\hat{\alpha}^1$ may increase or decrease welfare in each jurisdiction.

Because a change in $\hat{\alpha}^1$ will alter the local environmental policy in all jurisdictions of type 1, from (19)

$$\frac{dk^j}{d\hat{\alpha}^1} = s^1 \frac{dk^j}{d\alpha^1} = \frac{s^1}{(1 - \alpha^j) f_{kk}^j} \cdot \frac{\partial r^*}{\partial \alpha^1} > 0 \quad \forall j \neq 1. \tag{46}$$

Because $dk^j / d\hat{\alpha}^1 > 0 \; \forall j \neq 1$, $dk^1 / d\hat{\alpha}^1 < 0$ for each symmetric jurisdiction of type 1. Also, $dk^1 / d\hat{\alpha}^1$ can be broken into two components: the change in demand for capital directly caused by the change in local environmental policy, and the change in local demand for capital caused by the change in r^* resulting from altering the local environmental policy in all type 1 jurisdictions. Thus,

$$\frac{dk^1}{d\hat{\alpha}^1} = \frac{\partial k^1}{\partial \alpha^1} + s^1 \frac{\partial k^1}{\partial r^*} \frac{\partial r^*}{\partial \alpha^1} < 0. \tag{47}$$

The national policy $\hat{\alpha}^1$ will affect the local environmental policy in many jurisdictions, all of which are of type 1. Because of this, jurisdictions will consider the impact on r^* of an increase in $\hat{\alpha}^1$. Thus, the wage impact for a change in $\hat{\alpha}^1$ is seen from the following derivation of (9).

$$
\begin{aligned}
\frac{\partial w^j \cdot \bar{l}^j}{\partial \hat{\alpha}^1} &= f^j \frac{\partial (1 - \alpha^j)}{\partial \hat{\alpha}^1} + (1 - \alpha^j) f_k^j \frac{dk^j}{d\hat{\alpha}^1} \\
&\quad - k^j \cdot f_k^j \frac{\partial (1 - \alpha^j)}{\partial \hat{\alpha}^1} - (1 - \alpha^j) \left(f_k^j \frac{dk^j}{d\hat{\alpha}^1} + k^j \cdot f_{kk}^j \frac{dk^j}{d\hat{\alpha}^1} \right) \\
&= \begin{cases} - (1 - \alpha^j) k^j f_{kk}^j \dfrac{s^1}{(1 - \alpha^j) f_{kk}^j} \cdot \dfrac{\partial r^*}{\partial \alpha^1} = -s^1 k^j \dfrac{\partial r^*}{\partial \alpha^1} & \forall j \neq 1 \\[4mm] -f^j + k^j f_k^j - (1 - \alpha^j) k^j f_{kk}^j \left(\dfrac{\partial k^1}{\partial \alpha^1} + s^1 \dfrac{\partial k^1}{\partial r^*} \dfrac{\partial r^*}{\partial \alpha^1} \right) & j = 1 \\[4mm] \quad = -f^1 - s^1 k^1 \dfrac{\partial r^*}{\partial \alpha^1} \end{cases}
\end{aligned} \tag{48}
$$

The impact on local income is then described by the following.

$$\frac{\partial x^j}{\partial \hat{\alpha}^1} = \frac{\partial w^j \cdot \bar{l}^j}{\partial \hat{\alpha}^1} + \frac{\partial r^* \cdot \tilde{k}^j}{\partial \hat{\alpha}^1}$$

$$= \begin{cases} -s^1 k^j \dfrac{\partial r^*}{\partial \alpha^1} + s^1 \tilde{k}^j \dfrac{\partial r^*}{\partial \alpha^1} = s^1 \dfrac{\partial r^*}{\partial \alpha^1} \left(\tilde{k}^j - k^j \right) & \forall j \neq 1 \\[3mm] -f^1 - s^1 k^1 \dfrac{\partial r^*}{\partial \alpha^1} + s^1 \dfrac{\partial r^*}{\partial \alpha^1} \tilde{k}^1 = -f^1 + s^1 \dfrac{\partial r^*}{\partial \alpha^1} \left(\tilde{k}^1 - k^1 \right) & j = 1 \end{cases} \tag{49}$$

Note that $\partial x^j / \partial \hat{\alpha}^1 > 0$ when $j \neq 1$ if $\tilde{k}^j < k^j$; income will increase in capital importing jurisdictions that are not of type 1.

The relationship between capital migration and $\partial x^j / \partial \hat{\alpha}^1$ where $j \neq 1$ is illustrated in Figure 2.1. A change in $\hat{\alpha}^j$ does not affect the local environmental policy in jurisdictions other than those of type 1, so the only impact on these jurisdictions comes through the impact of $\hat{\alpha}^1$ on r^*. The decrease in r^* caused by an increase in $\hat{\alpha}^1$ will result in a loss of capital income shown by the blue box and a gain in wage income shown by the hashed trapezoid. In Figure 2.1a, the jurisdiction is a capital importer, resulting in a net increase in local income. The jurisdiction in Figure 2.1b is a capital exporter; this jurisdiction experiences a net decrease in income from a decrease in r^*.

The impact of an increase in $\hat{\alpha}^1$ on environmental quality is derived from (23) and (25).

$$\frac{\partial e^j}{\partial \hat{\alpha}^1} = \frac{\partial e^j}{\partial \Psi} \left((1 - \beta) \frac{\partial \Gamma}{\partial f^j} \frac{\partial f^j}{\partial k^j} \frac{dk^j}{d\hat{\alpha}^1} - \Gamma \frac{\partial \beta}{\partial \hat{\alpha}^1} \right)$$

$$= \begin{cases} \dfrac{\partial e^j}{\partial \Psi} (1 - \beta) \dfrac{\partial \Gamma}{\partial f^j} \dfrac{\partial f^j}{\partial k^j} \dfrac{dk^j}{d\hat{\alpha}^1} < 0 & j \neq 1 \\[3mm] \dfrac{\partial e^j}{\partial \Psi} \left((1 - \beta) \dfrac{\partial \Gamma}{\partial f^j} \dfrac{\partial f^j}{\partial k^j} \dfrac{dk^j}{d\hat{\alpha}^1} - \Gamma \dfrac{\partial \beta}{\partial \hat{\alpha}^1} \right) > 0 & j = 1 \end{cases} \tag{50}$$

Even though individual jurisdictions of type 1 have maximized local welfare through their choice of local environmental policy, one may wonder if they would support a national policy that increases the stringency of environmental policy in all jurisdictions of type 1. Such a coordinated increase across all jurisdictions of type 1 may have different welfare effects than an increase in only the local jurisdiction. At the decentralized equilibrium value of α^1, from (30) and (49) it is seen that the marginal cost to jurisdiction 1 of an increase in $\hat{\alpha}^1$ is greater than the marginal cost of an increase in α^1 if $\tilde{k}^1 > k^1$; $-\partial x^1 / \partial \alpha^1 < -\partial x^1 / \partial \hat{\alpha}^1$ when jurisdictions of type 1 are capital exporters in the decentralized equilibrium. Also, using (47) to compare (31) and (50),

Figure 2.1: Capital Migration and Income Effects of a Change in r^*

(a) Capital importing jurisdiction
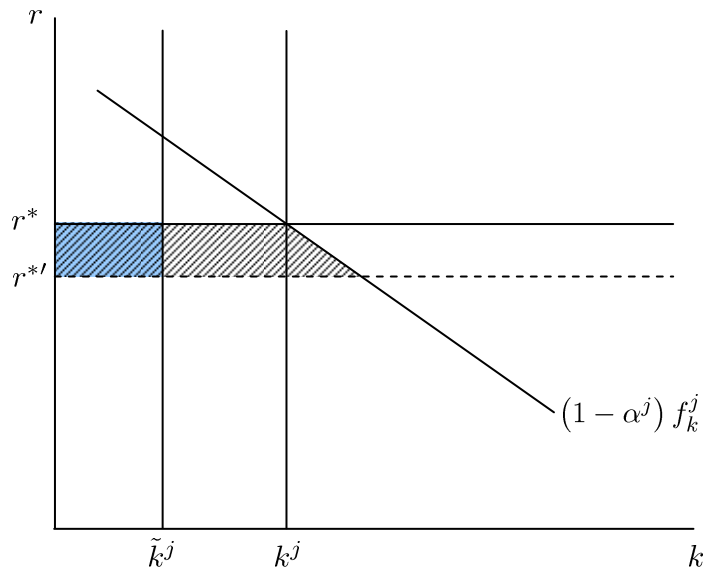
(b) Capital exporting jurisdiction
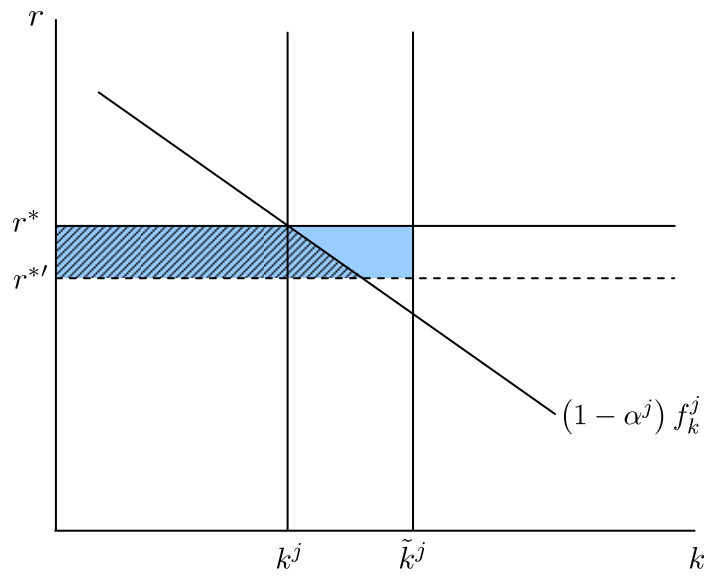
$$\left| \frac{dk^1}{d\hat{\alpha}^1} \right| < \left| \frac{\partial k^1}{\partial \alpha^1} \right| \Rightarrow \frac{\partial e^1}{\partial \alpha^1} > \frac{\partial e^1}{\partial \hat{\alpha}^1}. \tag{51}$$

The marginal benefit of improved environmental quality in jurisdiction 1 from an increase in $\hat{\alpha}^1$ is smaller than the marginal benefit of an increase in α^1. Thus, at the decentralized equilibrium policy choice characterized in (32), the marginal cost of an increase in $\hat{\alpha}^1$ exceeds its marginal benefit when jurisdictions of type 1 are capital exporters in the decentralized equilibrium. In this case, an increase in $\hat{\alpha}^1$ will reduce welfare in jurisdiction 1.

$$\tilde{k}^1 > k^1 \Rightarrow -\frac{\partial x^j}{\partial \hat{\alpha}^1} > \frac{\partial U^j / \partial e^j}{\partial U^j / \partial x^j} \cdot \frac{\partial e^j}{\partial \hat{\alpha}^1} \Rightarrow \frac{\partial U^1}{\partial \hat{\alpha}^1} < 0 \tag{52}$$

When type 1 jurisdictions are capital exporters, the decentralized choice of α^1 is too high from the collective perspective of type 1 jurisdictions, and these jurisdictions would benefit from a coordinated reduction in environmental policy across all type 1 jurisdictions. Such type 1 jurisdictions would not support a national policy that increased $\hat{\alpha}^1$. As was true in the symmetric case, capital exporting type 1 jurisdictions will make their local environmental policy too stringent because of the externality resulting from capital migration; local environmental policy in one type 1 jurisdiction will cause capital to migrate into all other type 1 jurisdictions, thus reducing their environmental quality.

If type 1 jurisdictions are capital importers, then both the marginal cost and marginal benefit from an increase in $\hat{\alpha}^1$ are lower than they are in (33) and it may be true that $\partial U^1 / \partial \hat{\alpha}^1 > 0$. If this is the case, then the decentralized choice of α^1 is too low. Each type 1 jurisdiction would then benefit from a coordinated tightening of environmental policy in all type 1 jurisdictions.

Lemma 1. *If type 1 jurisdictions are capital importers, they may prefer a national policy that strengthens environmental policy in all type 1 jurisdictions. If type 1 jurisdictions are capital exporters, they will always oppose such a policy.*

$$\begin{cases} \tilde{k}^1 < k^1 \text{ is a necessary condition for } \dfrac{\partial U^1}{\partial \hat{\alpha}^1} > 0 \\ \tilde{k}^1 > k^1 \Rightarrow \dfrac{\partial U^1}{\partial \hat{\alpha}^1} < 0 \end{cases} \tag{53}$$

Now consider the other jurisdiction types in the economy. At the decentralized equilibrium, jurisdiction $j \neq 1$ favors an increase in the national standard $\hat{\alpha}^1$ if the marginal benefit of the tightening exceeds its marginal cost. Because an increase in $\hat{\alpha}^1$

will decrease environmental quality in these jurisdictions, a tightening of the national policy will be supported if the welfare change from the income effect more than offsets the welfare lost from the environmental degradation. Otherwise, a tightening of the national policy would not be supported. Formally,

$$\begin{cases} \dfrac{\partial x^j}{\partial \hat{\alpha}^1} > -\dfrac{\partial U^j / \partial e^j}{\partial U^j / \partial x^j} \cdot \dfrac{\partial e^j}{\partial \hat{\alpha}^1} \Rightarrow \dfrac{\partial U^j}{\partial \hat{\alpha}^1} > 0 \\[4mm] \dfrac{\partial x^j}{\partial \hat{\alpha}^1} < -\dfrac{\partial U^j / \partial e^j}{\partial U^j / \partial x^j} \cdot \dfrac{\partial e^j}{\partial \hat{\alpha}^1} \Rightarrow \dfrac{\partial U^j}{\partial \hat{\alpha}^1} < 0 \end{cases} \tag{54}$$

Substituting from (49),

$$s^1 \frac{\partial r^*}{\partial \alpha^1} \left(\tilde{k}^j - k^j \right) > -\frac{\partial U^j / \partial e^j}{\partial U^j / \partial x^j} \cdot \frac{\partial e^j}{\partial \hat{\alpha}^1} \tag{55}$$

is necessary to satisfy (54) when $\partial U^j / \partial \hat{\alpha}^1 > 0$. Since the left hand side must be positive to satisfy the inequality, a necessary condition to satisfy (55) is then $\left(\tilde{k}^j - k^j \right) < 0$; as with type 1 jurisdictions, capital importing jurisdictions may favor an increase in $\hat{\alpha}^1$. Capital importing jurisdictions will favor an increase in the national standard $\hat{\alpha}^1$ from the decentralized equilibrium value of α^1 if the marginal benefit from the resulting increased income exceeds the marginal cost of the environmental degradation caused by the national policy change. Capital exporting jurisdictions will always favor a reduction in $\hat{\alpha}^1$; from (54), $\partial U^j / \partial \hat{\alpha}^1 < 0$ for such jurisdictions. Combining these observations when $j \neq 1$ with Lemma 1, the following is seen.

> **Proposition 3.** *Capital importing jurisdictions may prefer a national policy that strengthens the most lenient local policies, while capital exporting jurisdictions will always oppose such a policy.*
>
> $$\begin{cases} \tilde{k}^j < k^j \text{ is a necessary condition for } \dfrac{\partial U^j}{\partial \hat{\alpha}^1} > 0 \\[4mm] \tilde{k}^j > k^j \Rightarrow \dfrac{\partial U^j}{\partial \hat{\alpha}^1} < 0 \end{cases} \qquad \forall j \tag{56}$$

In the case of asymmetric jurisdictions, a tightening of the most lenient local environmental policies is not Pareto improving. Instead, welfare will likely increase in some jurisdictions, while it will decrease in others. Given the prior decentralized equilibrium value of local environmental policy in each jurisdiction, jurisdictions benefiting from the national policy will be capital importers, while capital exporting jurisdictions will be harmed by the national policy. If type 1 jurisdictions would benefit

from an increase in $\hat{\alpha}^1$, their welfare improvement would come from improved local environmental quality.

It is interesting to note that for jurisdictions not of type 1, a preference for a national policy increasing the minimum standard for local environmental regulation does not arise because of environmental quality improvements; rather, such a preference may arise because of the capital migration and the resulting rise in local income that the national policy would induce in these jurisdictions. Jurisdictions not of type 1 would experience a decline in environmental quality, but this decline would be more than offset by an increase in local income in jurisdictions that favor the national policy.

In general, when jurisdictions are asymmetric a national policy tightening the minimum standard for local environmental policy will have differing effects on the various types of jurisdictions. These differing welfare effects do not arise in the symmetric case because all jurisdictions experience symmetric policy impacts. When there are asymmetric policy impacts, individual jurisdictions may form coalitions to influence national environmental policy decisions. Such coalitions will attempt to improve welfare in some jurisdictions at the cost of other jurisdictions.

Empirical Expectations

For an empirical application, consider ground-level ozone regulations under the Clean Air Act. These regulations have been shown to affect firm location decisions in polluting industries; see Henderson (1996), Becker and Henderson (2000), and List and McHone (2000). The Clean Air Act influences location decisions because pollution abatement expenditures required by the Clean Air Act typically cost polluting facilities hundreds of thousands of dollars annually (Becker 2005). Thus, the Clean Air Act ground-level ozone regulations function similar to $\hat{\alpha}^1$ and provide an empirical context for this model.

One motivation for ground-level ozone regulations under the Clean Air Act is that by forcing some jurisdictions to tighten environmental regulations, capital will relocate to the benefit of certain jurisdictions. Using the Clean Air Act ground-level ozone regulations as an example, localities that may have an incentive to encourage more stringent federal environmental policy standards can be identified.

From Proposition 3, jurisdictions that benefit from a national environmental policy standard will be capital importers. Empirically, capital importing jurisdictions are likely those that, all else equal, are poor or are growing rapidly. Rapid growth is an indication that a jurisdiction is importing capital. Poor areas are expected to have a low capital endowment and receive most personal income through wage earnings. Areas with low capital endowments will likely import capital, even if they use a relatively small capital stock.

Figure 2.2 uses 1980 census data to divide counties according to per capital income. The poorer counties identified here are likely capital importers and may benefit from a national ground-level ozone policy standard.

Polluting firms that will migrate in response to nonattainment regulations are most likely in the manufacturing sector. Counties that are rapidly growing in response to the Clean Air Act are thus expected to experience rapid growth in manufacturing sector activity. Figure 2.3 identifies counties that grew by more than 20% in manufacturing sector employment between 1987 and 1992. These counties likely benefited from nonattainment regulations enforced in other jurisdictions.

Figures 2.2 and 2.3 identify many counties that may benefit from a national ground-level ozone policy standard. Such counties would be natural allies in supporting a national environmental policy standard for ground-level ozone.

Concluding Remarks

In the model presented in this chapter, local environmental policies affect the national capital market. A local policy in one jurisdiction causes capital to relocate, altering wage rates and capital income in all jurisdictions. Environmental quality in all jurisdictions is also affected by this capital migration. There will be an incentive to influence environmental policies in other jurisdictions in order to improve local welfare; national environmental policy provides a means through which this can be accomplished. In general, it is expected that welfare will decline in jurisdictions that are net exporters of capital in response to tightening the national environmental policy standard, while welfare may increase in jurisdictions that are net importers of capital.

Figure 2.2: Per Capita Income, 1979

County Per Capita Income (1979)

■ Poorest 1/3
▨ Middle 1/3
□ Wealthiest 1/3
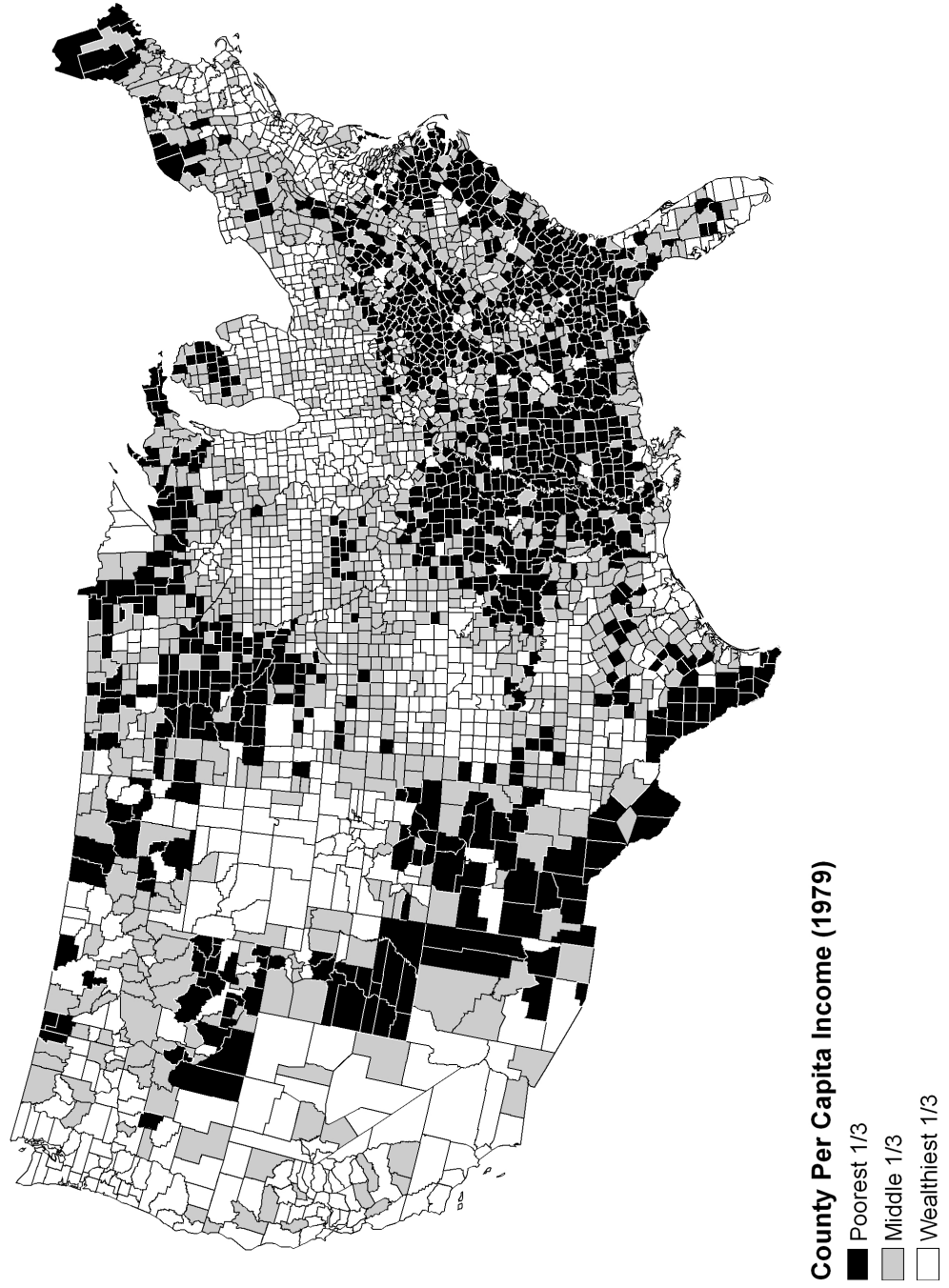
Figure 2.3: Manufacturing Sector Employment Growth, 1987-1992

Manufacturing Sector
Employment Growth > 20% (1987-1992)
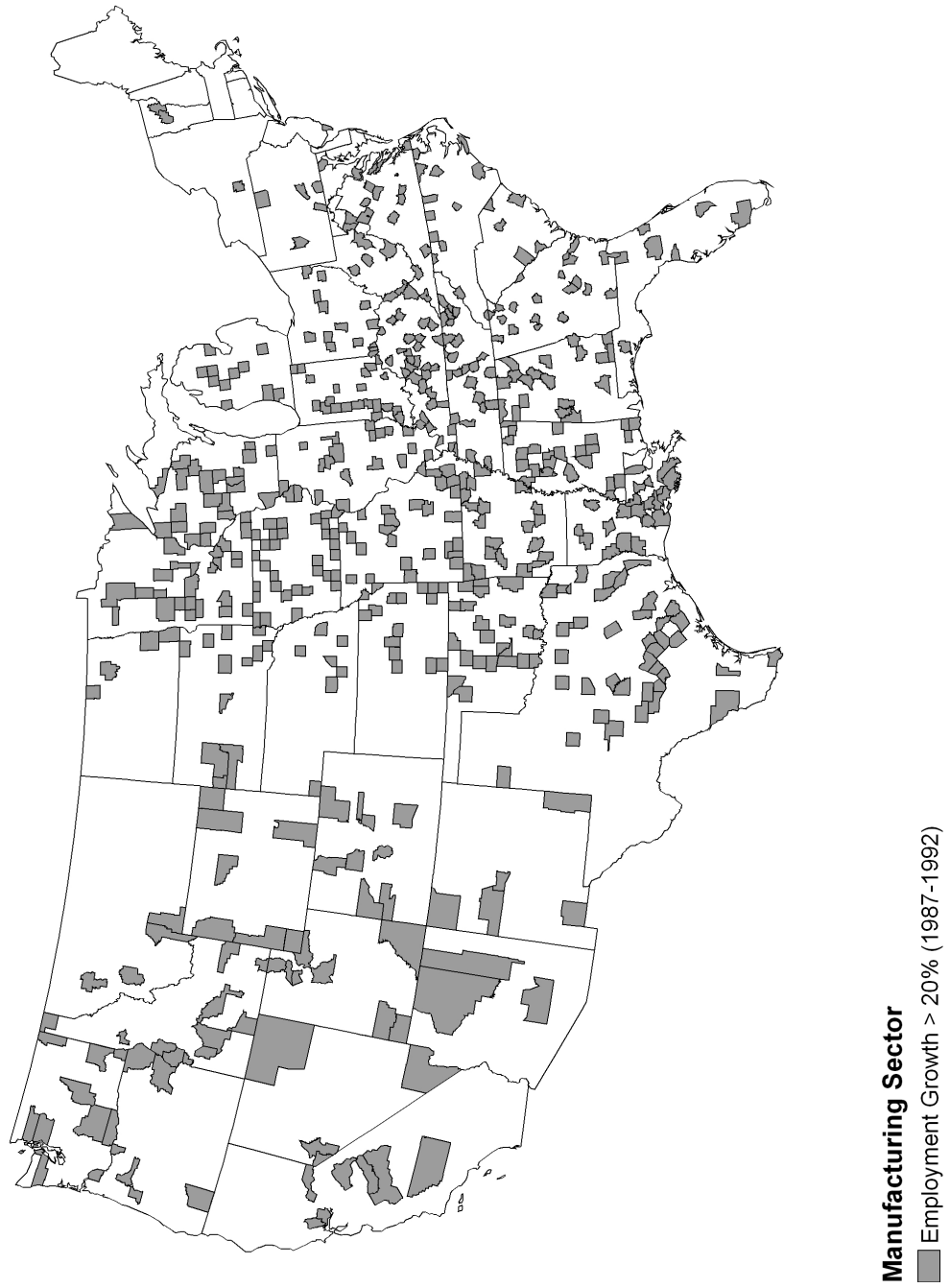
This result offers one explanation for why we observe central governments enacting environmental regulations with apparently purely local policy targets. The local environmental policy target has inter-jurisdictional implications; while the policy target is local, income and environmental effects are experienced in all jurisdictions as capital migrates in response to environmental policy. National environmental policy then becomes a tool for inter-jurisdictional competition.

This model could be extended to further the understanding of the efficiency of environmental policy preferences. The environmental tax competition literature examines tax harmonization as a potential solution to inefficiencies from decentralized outcomes; for example, see Cassing and Kuhn (2003) , Cremer and Gahvari (2004), and Duval and Hamilton (2002). The model in this chapter could be extended to compare the efficiency of decentralized equilibrium outcomes with that of a harmonized national policy when jurisdictions are not symmetric.

The relationship between capital migration in this model and vertical externalities could also be explored. As Keen and Kotsogiannis (2002) describe, local policies may not only horizontally affect other jurisdictions but also other levels of government. This could be explored by allowing the national government to tax production for the provision of a public good. The use of national policy for horizontal competition between local jurisdictions could then have interesting vertical efficiency implications.

Finally, the present analysis restricts the environmental policy instrument to a uniform requirement for all firms based on production. Varying the policy instrument may alter its effectiveness as a tool for competition, possibly leading to more efficient decentralized and national policy outcomes. Future research could focus on the relationship between policy instrument design and horizontal competition.

Proof 2.1: Proof of (16)

Let $F^i\left(\alpha^i, f^i_k\left(k^i\right), r^*\right) = \left(1 - \alpha^i\right) f^i_k - r^* = 0$ and $G\left(k^1, \ldots, k^n\right) = \sum_{i=1}^{n} k^i - \bar{K} = 0$. Also, recall that $k^i\left(\alpha^i, r^*\right)$ and $r^*\left(\alpha^1, \ldots, \alpha^n\right)$. First, take the total derivative of F^i, G, k^i, and r^*.

$$dF^i = \frac{\partial F^i}{\partial \alpha^i} d\alpha^i + \frac{\partial F^i}{\partial f^i_k} \frac{\partial f^i_k}{\partial k^i} dk^i + \frac{\partial F^i}{\partial r^*} dr^* = 0 \quad dG = \sum_{i=1}^{n} \frac{\partial G}{\partial k^i} dk^i = 0$$

$$dk^i = \frac{\partial k^i}{\partial \alpha^i} d\alpha^i + \frac{\partial k^i}{\partial r^*} dr^* \qquad\qquad dr^* = \sum_{i=1}^{n} \frac{\partial r^*}{\partial \alpha^i} d\alpha^i$$

(A.1)

Next substitute dk^i and dr^* into dF^i and dG.

$$dF^i = \frac{\partial F^i}{\partial \alpha^i} d\alpha^i + \frac{\partial F^i}{\partial f^i_k} \frac{\partial f^i_k}{\partial k^i} \left(\frac{\partial k^i}{\partial \alpha^i} d\alpha^i + \frac{\partial k^i}{\partial r^*} \left(\sum_{i=1}^{n} \frac{\partial r^*}{\partial \alpha^i} d\alpha^i \right) \right)$$

$$+ \frac{\partial F^i}{\partial r^*} \left(\sum_{i=1}^{n} \frac{\partial r^*}{\partial \alpha^i} d\alpha^i \right) = 0$$

$$= \left(\frac{\partial F^i}{\partial \alpha^i} + \frac{\partial F^i}{\partial f^i_k} \frac{\partial f^i_k}{\partial k^i} \frac{\partial k^i}{\partial \alpha^i} + \frac{\partial F^i}{\partial f^i_k} \frac{\partial f^i_k}{\partial k^i} \frac{\partial k^i}{\partial r^*} \frac{\partial r^*}{\partial \alpha^i} + \frac{\partial F^i}{\partial r^*} \frac{\partial r^*}{\partial \alpha^i} \right) d\alpha^i$$

$$+ \sum_{j \neq i} \left(\frac{\partial F^i}{\partial f^i_k} \frac{\partial f^i_k}{\partial k^i} \frac{\partial k^i}{\partial r^*} \frac{\partial r^*}{\partial \alpha^j} + \frac{\partial F^i}{\partial r^*} \frac{\partial r^*}{\partial \alpha^j} \right) d\alpha^j = 0$$

(A.2)

$$dG = \sum_{i=1}^{n} \frac{\partial G}{\partial k^i} \left(\frac{\partial k^i}{\partial \alpha^i} d\alpha^i + \frac{\partial k^i}{\partial r^*} \left(\sum_{i=1}^{n} \frac{\partial r^*}{\partial \alpha^i} d\alpha^i \right) \right) = 0$$

$$= \sum_{i=1}^{n} \left(\frac{\partial G}{\partial k^i} \frac{\partial k^i}{\partial \alpha^i} d\alpha^i + \sum_{j=1}^{n} \frac{\partial G}{\partial k^i} \frac{\partial k^i}{\partial r^*} \frac{\partial r^*}{\partial \alpha^j} d\alpha^j \right) = 0$$

Each α^i is chosen taking the value of α in all other jurisdictions as given. Once the economy is in equilibrium and the value of α has been optimized in each jurisdiction, the impact in jurisdiction i of a marginal change in α^i can be analyzed ignoring the subsequent adjustment in α^j $\forall j \neq i$ by the envelope theorem. Thus, in equilibrium $d\alpha^i$ can be treated as independent from $d\alpha^j$ $\forall j \neq i$ when considering the effects of a change in α^i, implying that the coefficient of $d\alpha^i$ must equal zero in the above equations. Factoring dF^i and dG and then using the coefficient for $d\alpha^i$ in each equation, the following is seen.

$$\frac{\partial F^i}{\partial f^i_k} \frac{\partial f^i_k}{\partial k^i} \frac{\partial k^i}{\partial \alpha^i} + \left(\frac{\partial F^i}{\partial f^i_k} \frac{\partial f^i_k}{\partial k^i} \frac{\partial k^i}{\partial r^*} + \frac{\partial F^i}{\partial r^*} \right) \frac{\partial r^*}{\partial \alpha^i} = -\frac{\partial F^i}{\partial \alpha^i}$$

$$\frac{\partial G}{\partial k^i} \frac{\partial k^i}{\partial \alpha^i} + \left(\sum_{j=1}^{n} \frac{\partial G}{\partial k^j} \frac{\partial k^j}{\partial r^*} \right) \frac{\partial r^*}{\partial \alpha^i} = 0 \tag{A.3}$$

Restating (A.3) in matrix notation,

$$\begin{bmatrix} \dfrac{\partial F^i}{\partial k^i} & \dfrac{\partial F^i}{\partial f^i_k} \dfrac{\partial f^i_k}{\partial k^i} \dfrac{\partial k^i}{\partial r^*} + \dfrac{\partial F^i}{\partial r^*} \\[2ex] \dfrac{\partial G}{\partial k^i} & \displaystyle\sum_{j=1}^{n} \dfrac{\partial G}{\partial k^j} \dfrac{\partial k^j}{\partial r^*} \end{bmatrix} \begin{bmatrix} \dfrac{\partial k^i}{\partial \alpha^i} \\[2ex] \dfrac{\partial r^*}{\partial \alpha^i} \end{bmatrix} = \begin{bmatrix} -\dfrac{\partial F^i}{\partial \alpha^i} \\[2ex] 0 \end{bmatrix}. \tag{A.4}$$

By Cramer's rule, $\partial r^* / \partial \alpha^i$ is then calculated as follows.

$$\frac{\partial r^*}{\partial \alpha^i} = \frac{\dfrac{\partial F^i}{\partial \alpha^i} \dfrac{\partial G}{\partial k^i}}{\dfrac{\partial F^i}{\partial f^i_k} \dfrac{\partial f^i_k}{\partial k^i} \displaystyle\sum_{j=1}^{n} \dfrac{\partial G}{\partial k^j} \dfrac{\partial k^j}{\partial r^*} - \dfrac{\partial G}{\partial k^i} \left(\dfrac{\partial F^i}{\partial f^i_k} \dfrac{\partial f^i_k}{\partial k^i} \dfrac{\partial k^i}{\partial r^*} + \dfrac{\partial F^i}{\partial r^*} \right)} \tag{A.5}$$

I now calculate the relevant partial derivatives.

$$\begin{aligned} \frac{\partial F^i}{\partial \alpha^i} &= -f^i_k & \frac{\partial G}{\partial k^i} &= 1 \\[1ex] \frac{\partial F^i}{\partial f^i_k} &= \left(1 - \alpha^i \right) & \frac{\partial k^i}{\partial r^*} &= \frac{1}{\left(1 - \alpha^i \right) f^i_{kk}} \\[1ex] \frac{\partial f^i_k}{\partial k^i} &= f^i_{kk} & \frac{\partial F^i}{\partial r^*} &= -1 \end{aligned} \tag{A.6}$$

Thus,

$$\frac{\partial r^*}{\partial \alpha^i} = \frac{-f^i_k}{\left(1 - \alpha^i \right) f^i_{kk} \displaystyle\sum_{j=1}^{n} \dfrac{1}{\left(1 - \alpha^j \right) f^j_{kk}}} < 0. \tag{A.7}$$

Proof 2.2: Proof of (34)

Let $W\left(U^1, \ldots, U^n\right)$ give the social welfare function for the economy. The first-best choice of α^j, x^j, and k^j for all jurisdictions will maximize W subject to $\sum_j k^j = \bar{K}$. Solving

$$\max U^1\left(x^1, e^1\right) \text{ s.t. } U^i\left(x^i, e^i\right) \geq \bar{U}^i \ \forall i \neq 1 \text{ and } \sum_{i=1}^{n} k^i = \bar{K} \tag{B.1}$$

using the Lagrangian method produces

$$\mathcal{L} = U^1 + \sum_{i \neq 1} \lambda^i \left(\bar{U}^i - U^i\right) + \mu \cdot g\left(\sum_{i=1}^{n} k^i - \bar{K}\right) \tag{B.2}$$

and the following first order conditions.

$$\frac{\partial \mathcal{L}}{\partial \alpha^j} = \frac{\partial U^1}{\partial \alpha^j} - \sum_{i \neq 1} \lambda^i \frac{\partial U^i}{\partial \alpha^j} + \mu \cdot \sum_{i=1}^{n} \frac{\partial k^i}{\partial \alpha^j} = 0 \ \forall j$$

$$\frac{\partial \mathcal{L}}{\partial x^j} = \frac{\partial U^1}{\partial x^j} - \sum_{i \neq 1} \lambda^i \frac{\partial U^i}{\partial x^j} + \mu \cdot \sum_{i=1}^{n} \frac{\partial k^i}{\partial x^j} = 0 \ \forall j \tag{B.3}$$

$$\frac{\partial \mathcal{L}}{\partial k^j} = \frac{\partial U^1}{\partial k^j} - \sum_{i \neq 1} \lambda^i \frac{\partial U^i}{\partial k^j} + \mu \cdot \sum_{i=1}^{n} \frac{\partial k^i}{\partial k^j} = 0 \ \forall j$$

Because $\sum_{i=1}^{n} k^i = \bar{K}$, $\sum_{i=1}^{n} \partial k^i / \partial \alpha^1 = 0$ and $\sum_{i=1}^{n} \partial k^i / \partial k^1 = 0$. Thus, the first order conditions can be rewritten.

$$\frac{\partial \mathcal{L}}{\partial \alpha^1} = \frac{\partial U^1}{\partial \alpha^1} - \sum_{i \neq 1} \lambda^i \frac{\partial U^i}{\partial \alpha^1} = 0$$

$$\frac{\partial \mathcal{L}}{\partial k^1} = \frac{\partial U^1}{\partial k^1} - \sum_{i \neq 1} \lambda^i \frac{\partial U^i}{\partial k^1} = 0 \tag{B.4}$$

Rearranging and dividing these equations, the following is seen.

$$\frac{\partial U^1 / \partial \alpha^1}{\partial U^1 / \partial k^1} = \frac{\sum_{i \neq 1} \partial U^i / \partial \alpha^1}{\sum_{i \neq 1} \partial U^i / \partial k^1}$$

$$\Rightarrow \frac{\partial U^1}{\partial \alpha^1} \sum_{i \neq 1} \frac{\partial U^i}{\partial k^1} = \frac{\partial U^1}{\partial k^1} \sum_{i \neq 1} \frac{\partial U^i}{\partial \alpha^1} \tag{B.5}$$

Given that

$$\frac{\partial U^i}{\partial \alpha^j} = \frac{\partial U^i}{\partial x^i} \frac{\partial x^i}{\partial \alpha^j} + \frac{\partial U^i}{\partial e^i} \frac{\partial e^i}{\partial \alpha^j}, \tag{B.6}$$

30

the characterization of the first-best resource distribution and policy choices can be derived from (B.5).

$$-\frac{\partial x^1}{\partial \alpha^1} = -\frac{\partial U^1/\partial k^1}{\partial U^1/\partial x^1} \cdot \frac{\sum_{i \neq 1} \partial U^i/\partial \alpha^1}{\sum_{i \neq 1} \partial U^i/\partial k^1} + \frac{\partial U^1/\partial e^1}{\partial U^1/\partial x^1} \cdot \frac{\partial e^1}{\partial \alpha^1} \qquad \text{(B.7)}$$

Chapter 3

The Industrial Geography Impacts of the Clean Air Act

The Clean Air Act and its amendments are designed to improve local air quality by targeting polluting sources. In localities with poor air quality, polluting industries are required to make additional investments in pollution abatement. Industry-level studies have shown that these requirements affect the output and location of polluting industries. To understand the overall impacts of the Clean Air Act on local economies, analysis not limited to polluting industries is necessary; inter-industry linkages will also result in regulatory impacts in nonpolluting industries.

This chapter focuses on the impacts of the Clean Air Act on regional industrial geography. By considering impacts aggregated across polluting and nonpolluting industries, the overall local and regional impacts of the Clean Air Act can be understood. Recognizing that regional economies are highly interdependent, this analysis considers the regulatory impact both in regulated counties and the surrounding areas to capture the regional effects of the Clean Air Act.

The Clean Air Act regulates a number of pollutants, and this study focuses on ground-level ozone regulations. While ozone is beneficial in the upper atmosphere, ground-level ozone presents health risks and is harmful to vegetation. Ground-level ozone is formed by a chemical reaction between nitrous oxides (NO_x) and volatile organic compounds (VOC) that is caused by sunlight. Thus, ozone regulations focus on emissions of NO_x and VOC. Roughly half of these emissions are generated by electric power plants and other industrial facilities; the other half of emissions are from motor vehicles. It is regulations imposed on these sources of pollution in areas with too much ground-level ozone that alter the regional industrial geography.

The remainder of this chapter is organized as follows. After a brief overview of the Clean Air Act, the existing literature on the impacts of ozone regulation under the Clean Air Act and extensions to this literature are discussed. Then, two analyses follow; the first considers impacts on county wide economic indicators, and the second focuses on manufacturing sector impacts in both cities and counties. These analyses contribute to the understanding of how the regional industrial landscape by ozone regulations under the

Clean Air Act. The chapter concludes with a comparison of these two analyses and a discussion of policy implications.

The Clean Air Act

The Clean Air Act regulates several pollutants, which are known as criteria pollutants. National ambient air quality standards (NAAQS) determine the permissible levels for each criteria pollutant. If a locality fails to meet these standards over a three-year period, it is subject to being declared a nonattainment area. This determination is not automatic, but is an administrative decision within the EPA. Once an area is declared to be in nonattainment, the state is required to develop a state implementation plan, or SIP, detailing what actions will be taken to meet the NAAQS.

While states are given flexibility in developing SIPs, there are specific requirements a state implementation plan must meet before it is approved by the EPA. Technology-based pollution abatement standards are enforced in nonattainment areas that require existing polluting facilities to use Reasonably Available Control Technology, which typically involves retrofitting. New polluting facilities are required to use the technology necessary to attain the Lowest Achievable Emission Rate, regardless of cost. These requirements are more costly than those for new firms in attainment areas, which are typically required to use the Best Available Control Technology. These requirements are negotiated on a case by case basis, and cost is taken into consideration. Thus, polluting industries located in nonattainment areas face higher pollution abatement costs than do similar facilities in attainment areas.

Nonattainment areas that satisfy the NAAQS may be reclassified as being in attainment. When this occurs, the regulatory requirements in the SIP for that particular locality no longer apply. Instead, a plan for maintaining attainment status is required. Regulations in this plan need not be as stringent as in the SIP because their purpose is to maintain, not improve, the present air quality.

Current Literature and Extensions

The current literature details many of the industrial impacts of air quality regulations. A number of studies have found that Clean Air Act regulations had a

real impact on the location of polluting industries. Henderson (1996), Becker and Henderson (2000), and List and McHone (2000) find that polluting firms consider local air quality regulations when making location decisions. Henderson (1996) and Becker and Henderson (2000) observe that ozone nonattainment status reduces firm births in a county, and List and McHone (2000) find that ozone attainment status affects location decisions for relocating plants.

Looking beyond firm locations, Becker and Henderson (2000) also find that nonattainment regulations affect investment and growth patterns in polluting facilities. Greenstone (2002) finds significant reductions in employment, capital stock, and output in pollution-intensive industries for nonattainment counties. Pollution abatement expenditures underlie all of these impacts on polluting industries. Nonattainment regulations typically result in hundreds of thousands of dollars in abatement costs for polluting industries (Becker, 2005).

While the current literature describes many of the industrial impacts of ozone nonattainment under the Clean Air Act, there are still several questions that deserve more attention. First, it is likely that nonattainment regulations under the Clean Air Act will not only impact industries in nonattainment areas but also industries located in the surrounding areas. Regional economic linkages and industry agglomeration may cause the industrial impacts of nonattainment regulations to extend beyond the borders of nonattainment areas, producing similar impacts in surrounding areas. Alternatively, regional economic linkages may encourage the relocation of polluting activity from nonattainment areas to neighboring jurisdictions that are in attainment. For example, List et al (2003) observe in their dataset of firm locations in New York that a majority of firm relocations were to adjacent counties. As mentioned by Greenstone (2002), if this relocation does occur, studies that only estimate the industrial impact in nonattainment areas will overstate the regional and national impacts of nonattainment status.

Second, little is known concerning the persistence of nonattainment impacts. It is important to understand how these impacts change with time as an area continues to be in nonattainment and whether these impacts persist even after attainment status has been gained. Concerning the first issue, regulatory impacts likely change with time in nonattainment areas; it is likely that industrial responses to nonattainment regulations will

increase as an area continues to be subject to nonattainment regulations and firms can no longer delay investment or relocation decisions. The extent of these changes is an important aspect to understanding the industrial impacts of the Clean Air Act. Turning to the second issue, it is important to understand the persistence of nonattainment status impacts after attainment status has been gained. Once an area has achieved the national ambient air quality standards for ground-level ozone and the area is reclassified as being in attainment, the nonattainment regulations are replaced with new regulations developed by the state aimed at maintaining attainment status. The new regulations need not cause the same degree of changes in polluting industries as was caused by the nonattainment regulations because they are focused on maintaining, not improving, the current air quality. The removal of nonattainment regulations will likely impact polluting industries, although the impacts of nonattainment regulations may also persist to some extent because of the nature of both the former nonattainment regulations and the regulations replacing them.

Finally, the current literature focuses on impacts on polluting industries but largely misses the impacts of nonattainment status under the Clean Air Act on aggregate economic indicators. While it is important to understand the responses of industries directly affected by nonattainment regulations, analyzing aggregate economic indicators will shed light on the overall local and regional impacts of nonattainment status. Estimates of impacts on polluting industries will overstate the net local and regional impacts of nonattainment status to the degree that reductions in polluting activity are offset by increases in other industries as labor and capital are reallocated across industries. Analyzing net economic indicators provides an understanding of how nonattainment status affect local economies.

Aggregate County Economic Impacts

I use data from the Bureau of Labor Statistics to estimate the aggregate economic impacts of ozone attainment status on Ψ, the total number of establishments, total employment, or total wages in each county. These variables serve as indicators of general economic activity across industry sectors and include almost all jobs in the U.S.; this data is summarized in Table 3.1.

Table 3.1: Descriptive Statistics for Dependent Variables (BLS Data, All Industries)

	Untransformed Dependent Variable	Years Included in Data	Observations	Median	Mean	SD
County Governments	Number of Establishments	1978-2003	58567	613	2,226	7,623
	Employment	1978-2003	58671	8,583	59,294	265,314
	Wages	1978-2003	58567	$196,000	$1,170,000	$4,910,000

Monetary values are in $1,000s of (2000) dollars
Number of Establishment and Employment data are actual values, not 1,000s

This analysis uses the following model to assess the impacts of attainment status:

$$\ln(\Psi_{ct}) = \alpha + \beta_{1p}(\Phi_{ctp}) + \beta_{2p}(\Phi_{ctp} \cdot Y_{ctp}) + \beta_{3p}(\Phi_{ctp} \cdot Y_{ctp}^2)$$
$$+ \gamma_{1p}(\Theta_{ctp}) + \gamma_{2p}(\Theta_{ctp} \cdot Y_{ctp}) + \gamma_{3p}(\Theta_{ctp} \cdot Y_{ctp}^2)$$
$$+ \eta_{1p}(\phi_{ctp}) + \eta_{2p}(\phi_{ctp} \cdot Y_{ctp}) + \eta_{3p}(\phi_{ctp} \cdot Y_{ctp}^2)$$
$$+ \chi_{1p}(\theta_{ctp}) + \chi_{2p}(\theta_{ctp} \cdot Y_{ctp}) + \chi_{3p}(\theta_{ctp} \cdot Y_{ctp}^2)$$
$$+ \lambda(X_{ct}) + \varepsilon_{ct}$$

The variables Φ, Θ, ϕ, and θ comprise a mutually exclusive set of dummy variables denoting whether a particular county is in nonattainment, has gained attainment status, is contiguous to a nonattainment county, or is contiguous to a county that has gained attainment, respectively. The assignment criteria for these categories will be discussed later. Y indicates the number of years a particular county, c, has been continuously classified in one of these categories for a particular pollutant p in year t. X contains a vector of control variables.

The establishment, employment, and wage data in this analysis contains annual county-level observations covering 1978 through 2003; 1978 was the first year counties or parts of counties were identified as being in nonattainment under the Clean Air Act. In 2003 some counties created Early Action Compacts to address ozone pollution and avoid nonattainment status. Because these counties were implementing ozone-related air quality regulations but were not in nonattainment, I exclude observations from these 99 counties in 2003 from the analysis. The total county wage data was deflated using the BLS personal consumption expenditures price index; presumably this index measures what cost of living wage adjustments are responding to.

36

To analyze the persistence of regulatory impacts on nonattainment counties and the surrounding areas, all counties in the U.S. are partitioned into five groups: those containing nonattainment areas, those containing areas that have gained attainment, those contiguous to nonattainment counties, those contiguous to counties that have gained attainment, and all remaining counties. Figure 3.1 maps counties according to their assignment to these categories in 2003. Nonattainment designations often follow county boundaries, and the EPA data used in this analysis is reported according to counties. In this analysis a county is considered to be in nonattainment if all or part of the county is listed in nonattainment.

In the above model, Φ, Θ, ϕ, and θ are dummy variables indicating the attainment status of each given county, c. Each particular county in each year, t, will only be in one of these categories or in the reference group of all remaining counties. Nonattainment counties are identified by Φ, and counties that have gained attainment are identified by Θ. If a county does not qualify for either of these groups, it then may be classified as being contiguous to a nonattainment county, ϕ. Contiguous counties are determined by a Census Bureau dataset (U.S. Dept. of Commerce, 1991) that identifies counties as contiguous if they are physically adjacent, connected by a major road or bridge, or have significant commuting ties. Because the primary regulatory impact is expected to arise from nonattainment status and not from gaining attainment status, a county may be classified as being contiguous to a county that has previously gained attainment, θ, only if it was not classified in one of the previous groups. Table 3.2 summarizes the sample size by attainment status category.

The county classifications are repeated for each criteria pollutant, p. Greenstone (2002) highlights the importance of this inclusion; including coefficients only for ground-level ozone implicitly restricts the regulatory impacts of nonattainment for other criteria pollutants to zero. However, SIPs addressing other criteria pollutants are expected to have significant industrial impacts. For example, Gallop and Roberts (1983) find that sulfur dioxide air quality regulations reduce productivity growth for power plants. Also, many counties are in nonattainment for more than one criteria pollutant; ignoring the impacts of regulations for other criteria pollutants incorrectly attributes those impacts to the ground-level ozone regulations for such counties.

Figure 3.1: Ground-Level Ozone Attainment Status, 2003

Ground Level Ozone Nonattainment

- County Contains Nonattainment Areas
- Contiguous to Nonattainment County
- County Contains Areas that have Gained Attainment
- Contiguous to County that has Gained Attainment
- All Other Counties
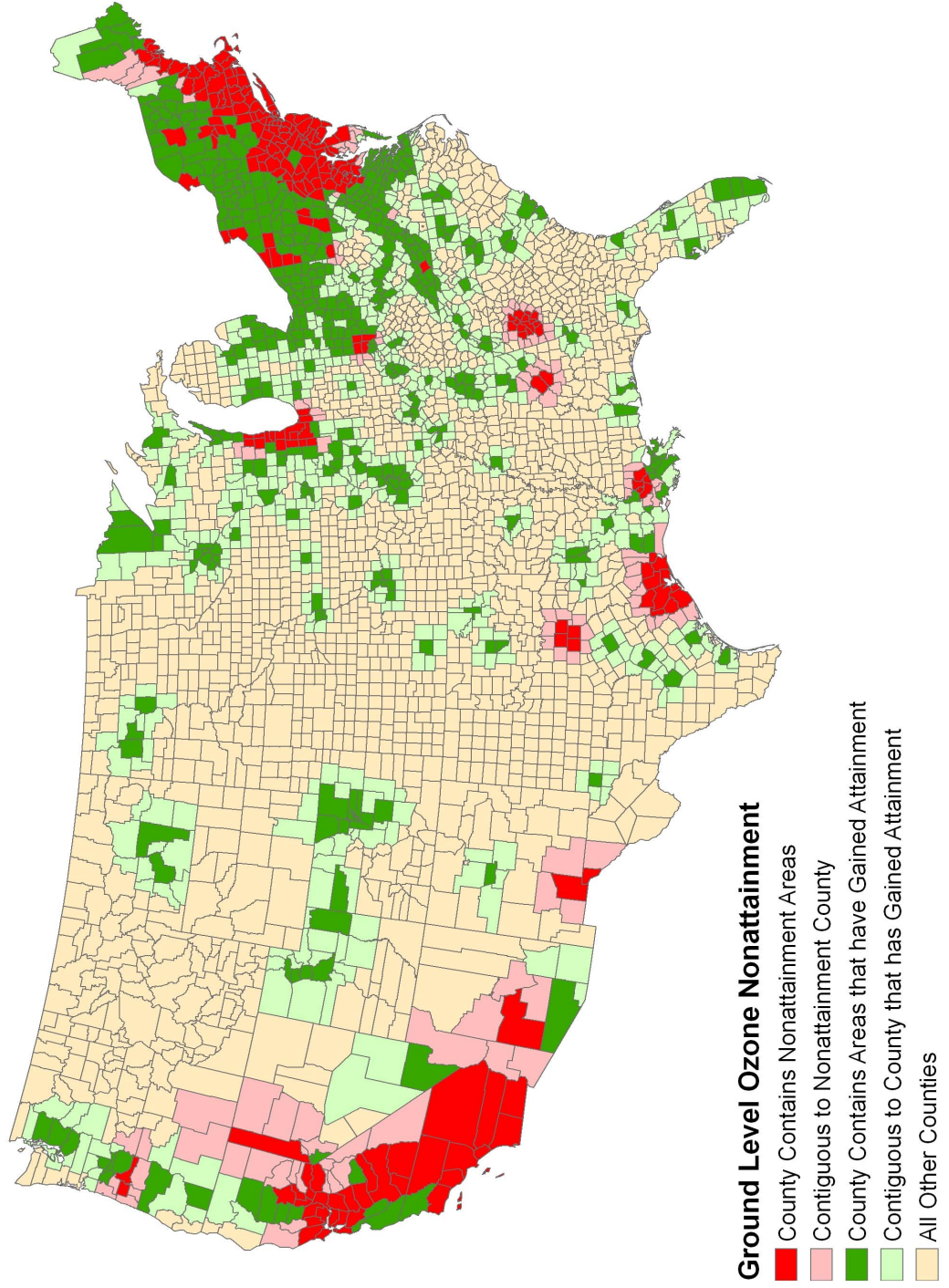
Table 3.2: Sample Size by Attainment Status (BLS Data, All Industries)

| | | Total Observations | | Unique Counties | |
		Frequency	% of Total	Frequency	% of Total
	Total	58,567		3,050	
	Nonattainment	7,833	13%	601	20%
	Gained Attainment	6,233	11%	458	15%
County Governments	Contiguous to Nonattainment	6,993	12%	790	26%
	Contiguous to Gained Attainment	7,651	13%	663	22%
	All Other Observations	29,857	51%	538	18%

The dummy variables Φ, Θ, ϕ, and θ are interacted with Y and Y^2, allowing the regulatory impact to vary with time[1]. For counties that are in nonattainment or have gained attainment, Y indicates the number of consecutive years the county has had that particular attainment status for criteria pollutant p at time t. For counties labeled as being contiguous to nonattainment counties or to counties that have gained attainment, Y indicates the greatest number of years a neighboring county has been in nonattainment or has maintained attainment after gaining this status.

The vector X_{ct} contains fixed effects for state and year. State fixed effects are included because SIP regulations are developed by states. The log of both county population and per capita income for each jurisdiction are included; income data is taken from the 1980, 1990, and 2000 decennial censuses. To control for the industrial and residential mix within a county, X_{ct} includes the variable "mix", which is the ratio of population to employment in the county. Also, to control for urbanization, the log of the jurisdiction's population density is included as a control.

Columns (1) through (3) of Table 3.3 list the regression results for each dependent variable. Within each column, the joint significance for sets of variables is given. I report the joint significance of each set of policy variables because the regulatory effect is estimated using each policy variable and both interaction variables jointly; each variable taken on its own has little value for understanding the overall impact of nonattainment status. For example, relative to counties that have always been in attainment and that are

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[1] Modifying the model to only include Y and not Y^2 does not significantly alter estimated regulatory impacts.

Table 3.3: Regression Results for Counties: Impacts on All Sectors (1978-2003)

	(1) ln (num estab)				(2) ln (employment)				(3) ln (wages)			
		Significance				Significance				Significance		
Independent Variable	Coefficient (Std. Err.)	Joint Test	Y=10	Y=1	Coefficient (Std. Err.)	Joint Test	Y=10	Y=1	Coefficient (Std. Err.)	Joint Test	Y=10	Y=1
Nonattainment (β_1)	-0.1059 *** (0.0088)				-0.1119 *** (0.0146)				-0.0692 *** (0.0141)			
Nonattainment * Y (β_2)	-0.0011 (0.0016)	***			-0.0058 ** (0.0026)	***		***	-0.0070 *** (0.0025)	***		***
Nonattainment * Y^2 (β_3)	0.0002 *** (0.0001)				-0.0002 ** (0.0001)				0.0003 *** (0.0001)			
Gained Attainment (γ_1)	-0.0624 *** (0.0083)				-0.0859 *** (0.0136)				-0.0028 (0.0132)			
Gained Attainment * Y (γ_2)	0.0020 (0.0016)	***			0.0012 (0.0027)	***			0.0020 (0.0026)			
Gained Attainment * Y^2 (γ_3)	-0.0001 (0.0001)				-0.0001 (0.0001)				0.0000 (0.0001)			
Contiguous to Nonattainment (η_1)	-0.0932 *** (0.0077)				-0.0777 *** (0.0127)				-0.0726 *** (0.0123)			
Contiguous to Nonattainment * Y (η_2)	-0.0052 *** (0.0016)	***		***	-0.0033 (0.0026)	***		*	-0.0055 ** (0.0025)	***		***
Contiguous to Nonattainment * Y^2 (η_3)	0.0002 *** (0.0001)				0.0000 (0.0001)				0.0001 (0.0001)			
Contiguous to Gained Attainment (χ_1)	-0.0623 *** (0.0069)				-0.0524 *** (0.0115)				-0.0451 *** (0.0111)			
Contiguous to Gained Attainment * Y (χ_2)	-0.0038 ** (0.0015)	***		***	-0.0062 ** (0.0025)	***		**	-0.0019 (0.0024)	***		
Contiguous to Gained Attainment * Y^2 (χ_3)	0.0001 * (0.0001)				0.0003 ** (0.0001)				0.0001 (0.0001)			
ln (Population)	0.9979 *** (0.0020)				1.2834 *** (0.0033)				1.1631 *** (0.0032)			
ln (Per Capita Income)	0.755715 *** (0.006199)				0.724728 *** (0.010211)				0.916983 *** (0.009874)			
Mix (population/employment)	-0.0021 *** (0.0001)				-0.0116 *** (0.0001)				-0.0031 *** (0.0001)			
ln (Population Density)	-0.0775 *** (0.0019)				-0.0393 *** (0.0032)				-0.0145 *** (0.0031)			
Joint test: State Fixed Effects	***				***				***			
n	58,567				58,671				58,567			
R^2	0.9632				0.9626				0.957			

1 Hour Ozone NAAQS

*** Significant at the 1% level   ** Significant at the 5% level   * Significant at the 10% level

only contiguous to counties that have always been in attainment, after 10 years of nonattainment status total employment in column (2) is expected to change by $\left[\beta_1+\left(\beta_2\cdot 10\right)+\left(\beta_3\cdot 10^2\right)\right]$ % , or -7.39%. The results of a significance test for $\left[\beta_1+\left(\beta_2\cdot 10\right)+\left(\beta_3\cdot 10^2\right)\right]-\left[\beta_1+\left(\beta_2\right)+\left(\beta_3\right)\right]=0$, or $\left(9\cdot\beta_2+99\cdot\beta_3\right)=0$, are reported in the column labeled Y=10 – Y=1. This test indicates whether there is a statistically significant difference between the expected change in employment between the first and tenth years of nonattainment. Statistical significance here indicates that the impact of nonattainment status does vary with time over a ten-year period as a county continues to have a particular attainment status.

To understand the impact of nonattainment status, it is helpful to graph $\beta_1+\left(\beta_2\cdot Y\right)+\left(\beta_3\cdot Y^2\right)$ against *Y*. Figures 3.2 through 3.5 graph this expected impact of nonattainment status over a ten-year period. These figures only graph the expected impact when this impact is statistically significant. Of the 7,833 observations of nonattainment counties, 3,781 observations are for counties that have been in nonattainment for at least 10 years. Also, 2,680 of the 6,233 observations of counties that have gained attainment are of counties that had maintained attainment status for at least ten years. Therefore, analyzing the impact of nonattainment status over a ten-year period is within the data.

These graphs should be interpreted sequentially; counties are in nonattainment before they have the opportunity to gain attainment status. To understand the impact of gaining attainment status, the expected impacts shown in Figure 3.3 should be compared against those in Figure 3.2. If the expected impacts of nonattainment status and of gaining attainment status are the same, then the regulatory effects of nonattainment completely persist after attainment status has been gained.

Figure 3.2 indicates that nonattainment status has a negative impact on the number of establishments, employment, and total wages in a county. Employment and total wages also decrease over time in a county as it continues to be in nonattainment. After ten years of nonattainment status, a 19% reduction in total county employment and an 11% reduction in total wages is expected.

Figure 3.2: Economic Impacts for All Sectors for Counties in Nonattainment
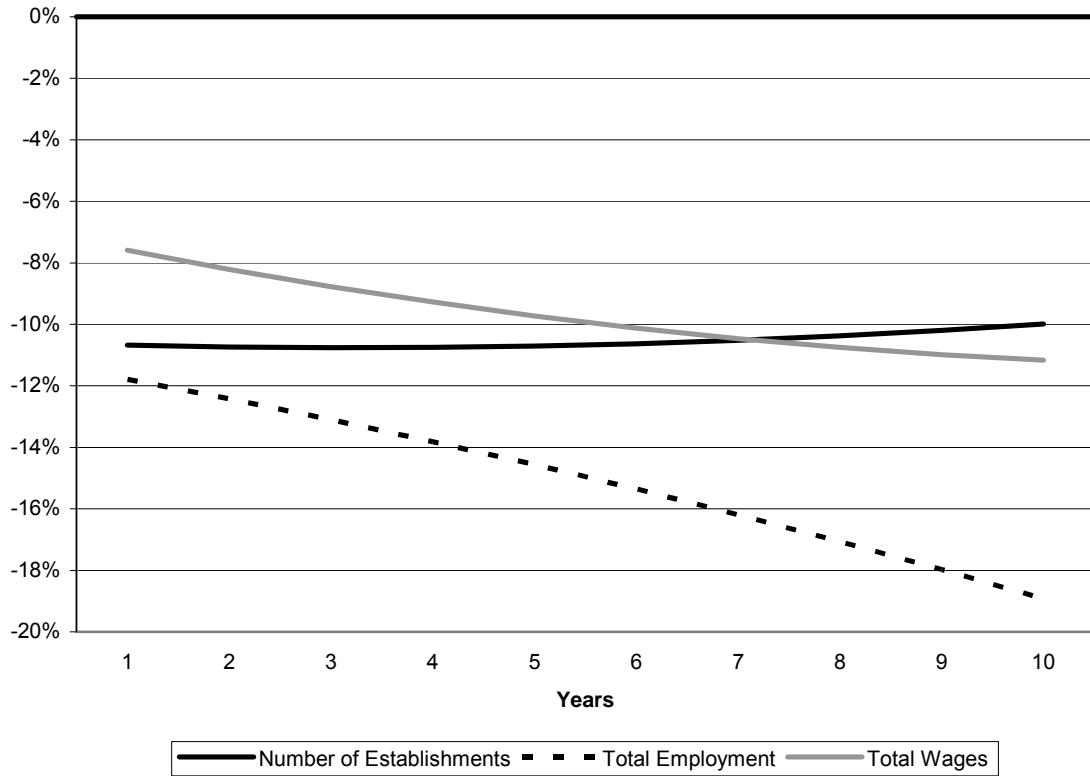
Once attainment status has been gained, the number of establishments and total employment in a county increase relative to their expected values under nonattainment. This is seen in Figure 3.3. However, they are still expected to be respectively about 6% and 8% lower than counties that have never been in nonattainment and are only contiguous to counties that have always been in attainment. This indicates that gaining attainment only partially reverses the impacts of nonattainment status. This is likely a function of the nature of the nonattainment regulations and the regulations that are implemented to maintain attainment status. It is important for those pursuing local economic development to understand this partial persistence of economic impacts after attainment status has been gained. Gaining attainment status will enable greater local economic development, but it should not be expected to return the local economy to where it would have been had the county never been in nonattainment.

Figure 3.3: Economic Impacts for All Sectors for Counties That Have Gained Attainment
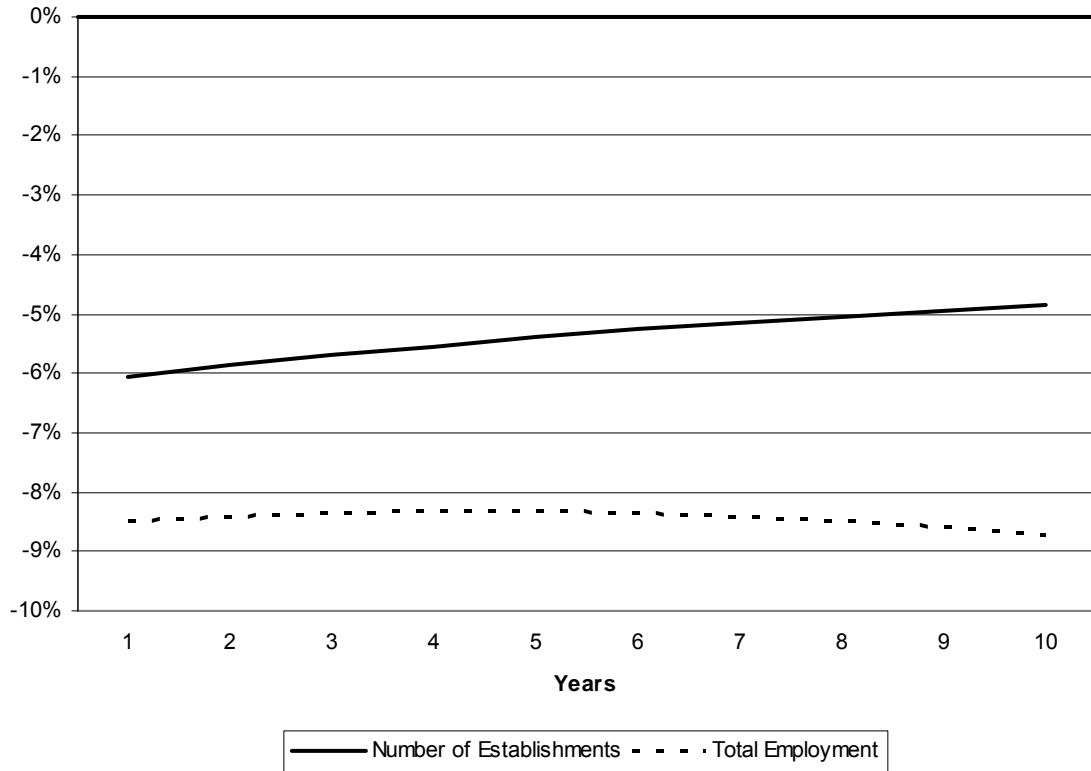
Counties contiguous to nonattainment counties also experience negative economic impacts from the nonattainment regulations in neighboring counties, as shown in Figure 3.4. It is important to note that the magnitude of the impact in contiguous counties is similar to that in nonattainment counties. This suggests that nonattainment status has economic impacts beyond the borders of nonattainment areas because of regional economic linkages.

Figure 3.5 indicates that similar to counties that gain attainment, those contiguous to counties that gain attainment experience a partial mitigation of economic impacts. For example, compared with about an 11% decrease in employment and total wages after ten years of nonattainment in a neighboring county, employment and total wages are expected to be respectively 6% and 5% lower when the neighboring county gains attainment. The persistence of the economic impacts of ground-level ozone regulations geographically extends beyond nonattainment areas into the surrounding counties.

This analysis follows the trend in the literature by considering counties to be in nonattainment if all or part of the county contains nonattainment areas. This assignment

Figure 3.4: Economic Impacts for All Sectors for Counties Contiguous to Counties that are in Nonattainment
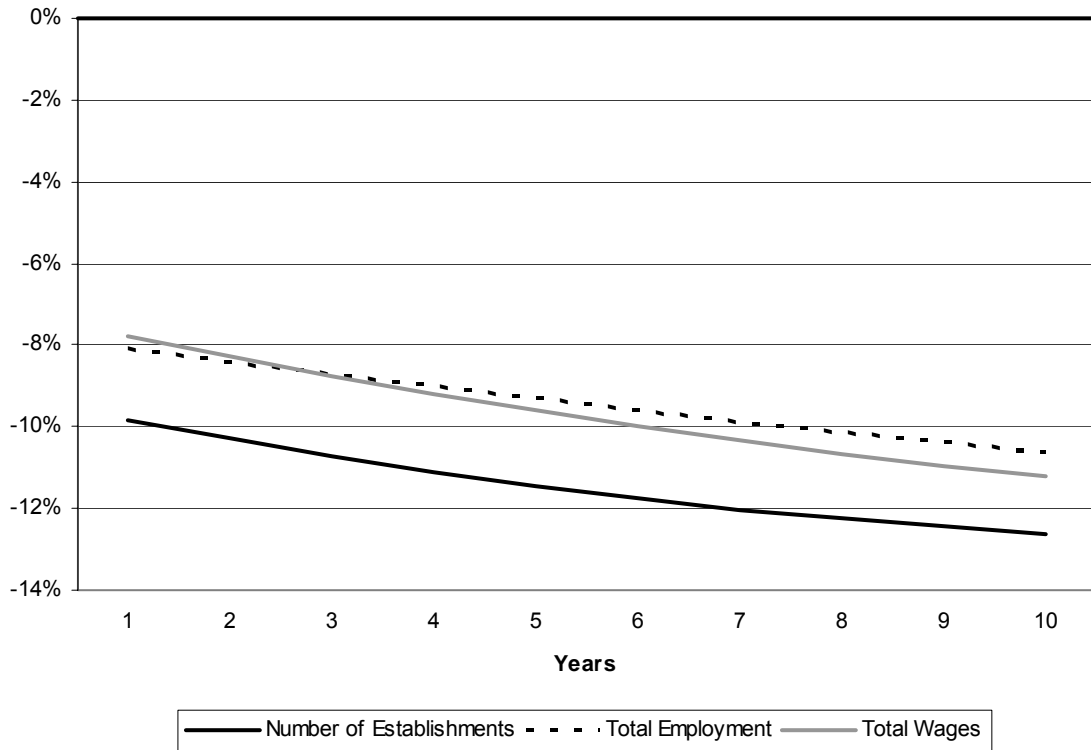
rule over assigns economic activity to nonattainment areas; some of the facilities in counties that only partially contain nonattainment areas are outside the nonattainment boundaries and are not subject to SIP regulations. The above findings that counties contiguous to nonattainment areas experience economic impacts very similar to the impacts in nonattainment areas suggest that this over assignment is not a problem. Instead, the danger lies in under assignment; because nonattainment regulations impact the surrounding region, the region surrounding nonattainment areas should be included in the analysis of regulatory impacts. Treating surrounding areas as being unaffected by nonattainment regulations and including those in the reference group against which regulatory impacts are compared will cause the regulatory impacts in nonattainment areas to be understated unless all of the decreases in contiguous counties are offset by increases in other counties. Also, ignoring the regulatory impacts in jurisdictions surrounding nonattainment areas will understate the regional and national regulatory impacts of nonattainment status.

Figure 3.5: Economic Impacts for All Sectors for Counties Contiguous to Counties That
Have Gained Attainment
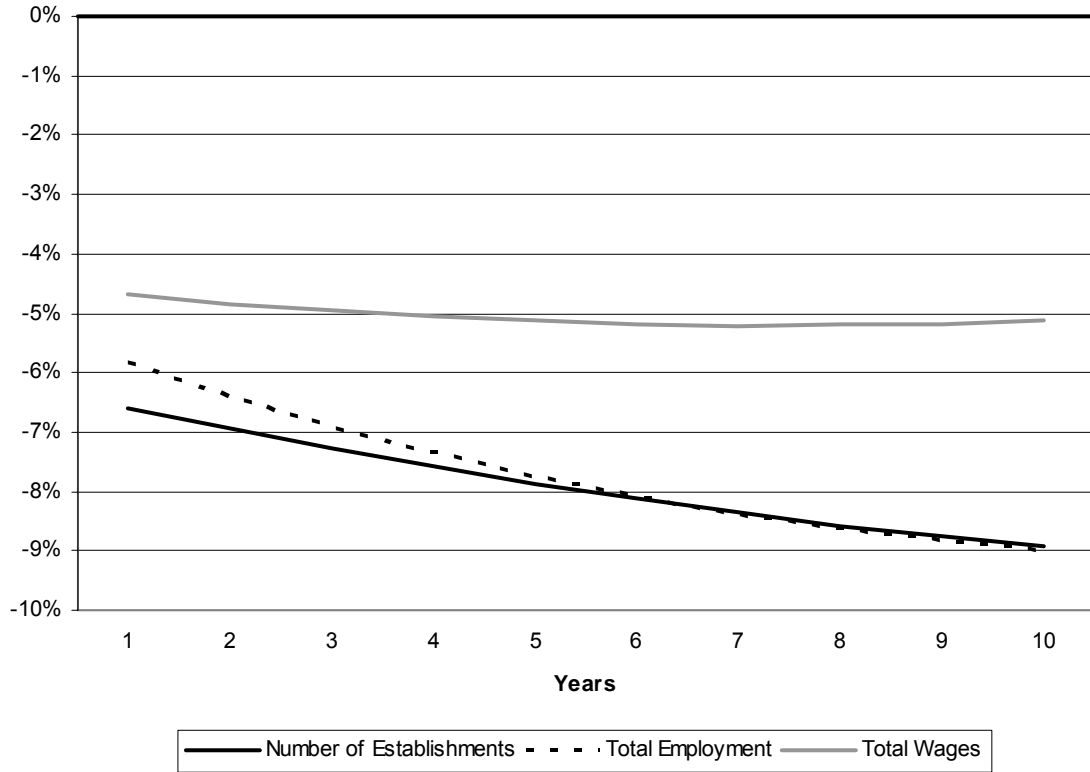
Manufacturing Industry Impacts: Cities and Counties

The preceding analysis describes the aggregate economic impacts of
nonattainment status on counties. Counties are often the unit of analysis in nonattainment
regulatory studies, but they are not the only type of local jurisdiction worth studying.
Cities are often involved in local economic development activities; analyzing the
economic impacts of attainment status on cities is an important part of understanding the
impacts of nonattainment status.

As previously discussed, the current literature largely focuses on polluting
industries. Such analysis captures industry-level impacts by analyzing the responses of
firms directly affected by nonattainment regulations, but it is less suited for
understanding geographically oriented impacts. Instead analysis of impacts aggregated
across industries will better capture local impacts as skilled workers and facilities may
transition from polluting to nonpolluting industries. Such shifts would mitigate the local
impacts of SIP regulations. Furthermore, changes in the industrial geography of polluting

industries can be expected to impact related nonpolluting industries in the region. Regional impacts measured net of changes in both polluting and nonpolluting industries better describe the economic effects for jurisdiction oriented analysis.

Many polluting industries are in the manufacturing sector, and many inter-industry linkages involving polluting industries will be within the manufacturing sector. To analyze the impacts of attainment status on the manufacturing sector, I use data from the 1987 and 1992 Economic Censuses. This data permits analysis of changes in total shipments in addition to changes in employment and wages. After 1992 the Economic Census switched from the SIC to the NAICS industry classification system, making post-1992 data incomparable with data from before the switch. Economic Census data is reported by both city and county, making city-level analysis possible.

Table 3.4 describes this data. The BLS producer price index for the manufacturing sector was used to deflate wage and total shipment data[2]. To avoid disclosure of data for specific firms, some observations in the Economic Census are censored; the censored observations are not included in the analysis. Table 3.5 summarizes the sample size by attainment status. The same model as was used in the previous section is used here to analyze the Economic Census data. Tables 3.6 and 3.7 report the results of these fixed effects regressions.

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[2] Deflating wage data using the BLS personal consumption expenditures price index that was used to deflate total county wages in the previous section instead of the producer price index does not alter the estimated regulatory impacts on total manufacturing wages or production wages.

Table 3.4: Descriptive Statistics for Dependent Variables (Economic Census Data, Manufacturing Sector Only)

Untransformed Dependent Variable	Years Included in Data	Observations	Median	Mean	SD
County Governments					
Value of Shipments	1987, 1992	4927	$183,746	$885,266	$3,170,000
Employment	1987, 1992	4789	1,800	6,801	25,026
Pay	1987, 1992	4922	$30,239	$168,396	$699,679
Wages	1987, 1992	4909	$20,869	$87,635	$312,125
Municipal Governments					
Value of Shipments	1987, 1992	5019	$198,216	$566,585	$1,580,000
Employment	1987, 1992	5019	1,900	4,525	12,919
Pay	1987, 1992	5019	$40,630	$116,570	$349,015
Wages	1987, 1992	5018	$23,130	$57,573	$147,838

Monetary values are in $1,000s of (1984) dollars
Employment data are actual values, not 1,000s

Table 3.5: Sample Size by Attainment Status (Economic Census Data, Manufacturing Sector Only)

	Total Observations Manufacturing Only (1987 & 1992)		Unique Observations Manufacturing Only (1987 & 1992)	
	Frequency	% of Total	Frequency	% of Total
County Governments				
Total	4,927		2,650	
Nonattainment	600	12%	352	13%
Gained Attainment	546	11%	314	12%
Contiguous to Nonattainment	600	12%	402	15%
Contiguous to Gained Attainment	696	14%	423	16%
All Other Observations	2,485	50%	1,159	44%
Municipal Governments				
Total	5,019		2,917	
Nonattainment	2,408	48%	1,423	49%
Gained Attainment	703	14%	447	15%
Contiguous to Nonattainment	452	9%	321	11%
Contiguous to Gained Attainment	404	8%	269	9%
All Other Observations	1,052	21%	457	16%

Table 3.6: Regression Results for Counties: Manufacturing Sector Impacts (1987 & 1992)

Independent Variable	(1) ln (Manufacturing Shipments) Coefficient (Std. Err.)	(1) Joint Test Sig.	(2) ln (M employment) Coefficient (Std. Err.)	(2) Joint Test Sig.	(3) ln (M wages) Coefficient (Std. Err.)	(3) Joint Test Sig.	(4) ln (M production wages) Coefficient (Std. Err.)	(4) Joint Test Sig.
Nonattainment (β_1)	0.0839 (0.1864)		-0.1425 (0.1255)		0.0039 (0.1635)		-0.0371 (0.1689)	
Nonattainment * Y (β_2)	-0.0410 (0.0482)	*	0.0370 (0.0324)		-0.0324 (0.0422)	**	-0.0269 (0.0437)	***
Nonattainment * Y² (β_3)	0.0014 (0.0027)		-0.0021 (0.0018)		0.0011 (0.0024)		0.0006 (0.0024)	
Gained Attainment (γ_1)	-0.1613 (0.2017)		-0.1148 (0.1356)		-0.2185 (0.1769)		-0.2272 (0.1828)	
Gained Attainment * Y (γ_2)	0.0866 * (0.0499)	*	0.0591 * (0.0336)		0.0840 * (0.0437)		0.0823 * (0.0452)	
Gained Attainment * Y² (γ_3)	-0.0052 * (0.0030)		-0.0037 * (0.0020)		-0.0050 * (0.0026)		-0.0048 * (0.0027)	
Contiguous to Nonattainment (η_1)	0.1943 (0.1538)		-0.0548 (0.1041)	*	0.0443 (0.1349)		0.0818 (0.1394)	
Contiguous to Nonattainment * Y (η_2)	-0.0254 (0.0408)		0.0340 (0.0278)		0.0065 (0.0358)		0.0010 (0.0370)	
Contiguous to Nonattainment * Y² (η_3)	0.0011 (0.0023)		-0.0016 (0.0016)		-0.0005 (0.0020)		-0.0003 (0.0021)	
Contiguous to Gained Attainment (χ_1)	-0.1622 (0.1450)		0.0141 (0.0995)		-0.1041 (0.1279)		-0.0835 (0.1322)	
Contiguous to Gained Attainment * Y (χ_2)	0.0985 ** (0.0406)	**	0.0120 (0.0280)		0.0685 * (0.0358)	*	0.0675 * (0.0370)	*
Contiguous to Gained Attainment * Y² (χ_3)	-0.0069 *** (0.0026)		-0.0011 (0.0018)		-0.0048 ** (0.0023)		-0.0050 ** (0.0024)	
ln (Population)	1.1178 *** (0.0340)		0.8761 *** (0.0241)		1.0570 *** (0.0298)		1.0310 *** (0.0309)	
ln (Per Capita Income)	0.092951 (0.104000)		-0.126121 * (0.073114)		0.281798 *** (0.091265)		-0.052742 (0.094467)	
Mix (population/employment)	-0.0575 *** (0.0034)		-0.0714 *** (0.0033)		-0.0515 *** (0.0030)		-0.0520 *** (0.0031)	
ln (Population Density)	0.2762 *** (0.0327)		0.1867 *** (0.0231)		0.2842 *** (0.0287)		0.2705 *** (0.0298)	
Joint test: State Fixed Effects	***		***		***		***	
n	4,927		4,673		4,922		4,909	
R²	0.7381		0.7669		0.7744		0.7369	

1 Hour Ozone NAAQS

*** Significant at the 1% level   ** Significant at the 5% level   * Significant at the 10% level

Table 3.7: Regression Results for Cities: Manufacturing Sector Impacts (1987 & 1992)

1 Hour Ozone NAAQS

Independent Variable	(1) ln (Manufacturing Shipments) Coefficient (Std. Err.)	(1) Sig.	(1) Joint Test (Y=10, Y=1)	(2) ln (M employment) Coefficient (Std. Err.)	(2) Sig.	(2) Joint Test (Y=10, Y=1)	(3) ln (M wages) Coefficient (Std. Err.)	(3) Sig.	(3) Joint Test (Y=10, Y=1)	(4) ln (M production wages) Coefficient (Std. Err.)	(4) Sig.	(4) Joint Test (Y=10, Y=1)
Nonattainment (β_1)	0.1458 (0.1395)			-0.0659 (0.1102)			0.0435 (0.1220)			0.0675 (0.1261)		
Nonattainment * Y (β_2)	-0.0057 (0.0351)			0.0202 (0.0277)			0.0039 (0.0306)			0.0018 (0.0317)		
Nonattainment * Y^2 (β_3)	0.0001 (0.0019)			-0.0011 (0.0015)			-0.0001 (0.0017)			-0.0003 (0.0017)		
Gained Attainment (γ_1)	0.1372 (0.1479)			-0.0157 (0.1168)			0.0250 (0.1292)			-0.0074 (0.1336)		
Gained Attainment * Y (γ_2)	-0.0089 (0.0389)			-0.0104 (0.0307)			-0.0002 (0.0340)			0.0010 (0.0351)		
Gained Attainment * Y^2 (γ_3)	0.0004 (0.0025)			0.0010 (0.0020)			0.0003 (0.0022)			0.0003 (0.0023)		
Contiguous to Nonattainment (η_1)	0.0356 (0.1658)			-0.0601 (0.1310)			-0.0442 (0.1449)			-0.0129 (0.1497)		
Contiguous to Nonattainment * Y (η_2)	0.0264 (0.0435)		**	0.0363 (0.0344)		*	0.0441 (0.0380)		**	0.0368 (0.0393)		**
Contiguous to Nonattainment * Y^2 (η_3)	-0.0011 (0.0025)			-0.0016 (0.0019)			-0.0021 (0.0022)			-0.0017 (0.0022)		
Contiguous to Gained Attainment (χ_1)	0.0217 (0.1529)			0.0761 (0.1208)			0.0788 (0.1337)			0.0500 (0.1382)		
Contiguous to Gained Attainment * Y (χ_2)	0.0467 (0.0453)			0.0037 (0.0358)			0.0185 (0.0396)			0.0299 (0.0409)		
Contiguous to Gained Attainment * Y^2 (χ_3)	-0.0042 (0.0031)			-0.0009 (0.0024)			-0.0021 (0.0027)			-0.0028 (0.0028)		
ln (Population)	0.8008 *** (0.0141)			0.7073 *** (0.0112)			0.7616 *** (0.0124)			0.7407 *** (0.0128)		
ln (Per Capita Income)	-0.340016 *** (0.055620)			-0.081747 * (0.043906)			0.180427 *** (0.048570)			-0.448338 *** (0.050253)		
Mix (population/employment)	-0.1418 *** (0.0122)			-0.1180 *** (0.0097)			-0.1384 *** (0.0107)			-0.1339 *** (0.0110)		
ln (Population Density)	-0.2994 *** (0.0235)			-0.2174 *** (0.0185)			-0.2337 *** (0.0205)			-0.2634 *** (0.0212)		
Joint test: State Fixed Effects	***			***			***			***		
n	5,019			5,019			5,019			5,018		
R^2	0.4577			0.5018			0.5196			0.4464		

*** Significant at the 1% level   ** Significant at the 5% level   * Significant at the 10% level

Similar to the impact on all economic sectors in nonattainment counties, Figure 3.6 shows that ground-level ozone nonattainment status has a negative impact on manufacturing sector output and wages. As would be expected, the wage reductions in the manufacturing sector are greater than the wage reductions in all sectors combined in Figure 3.2. Gaining attainment status appears to have a positive impact on shipments from manufacturing industries but not on wages or employment, as seen in Figure 3.7. This suggests that the responses of manufacturing firms to the removal of nonattainment regulations are concentrated in production more than in labor. This result should be taken with a grain of salt, however; the coefficients for total shipments are jointly only marginally statistically significant.

Figure 3.6: Manufacturing Sector Impacts for Counties in Nonattainment
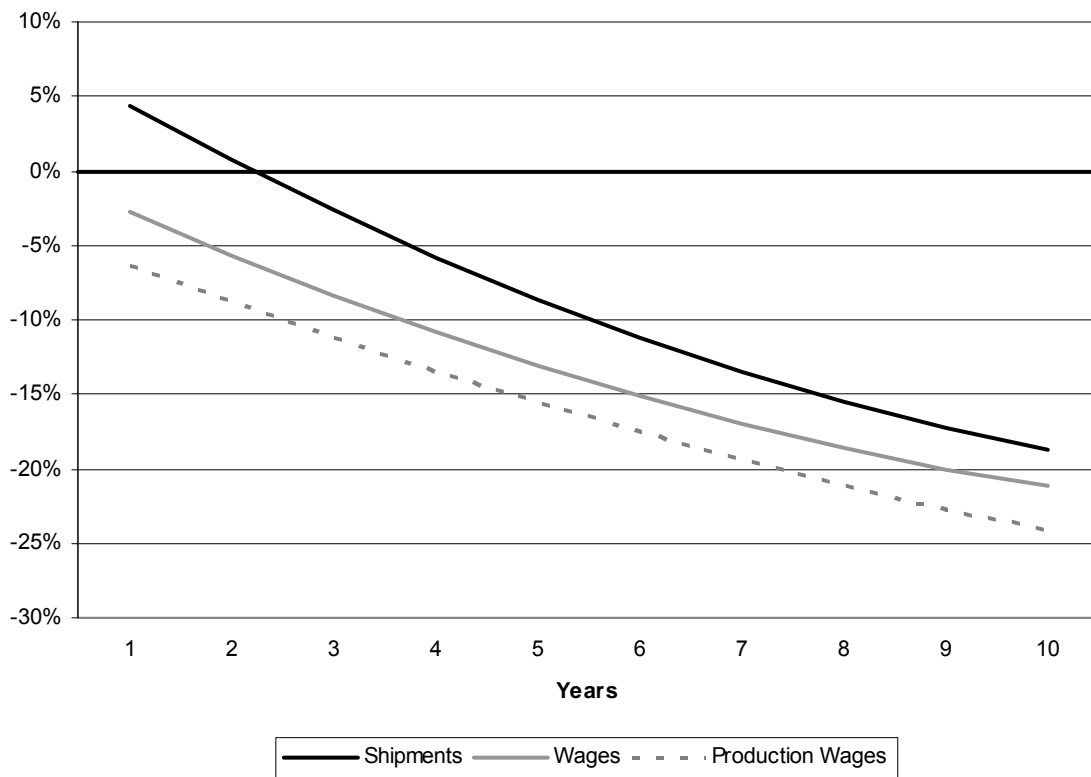
Figure 3.7: Manufacturing Sector Impacts for Counties That Have Gained Attainment
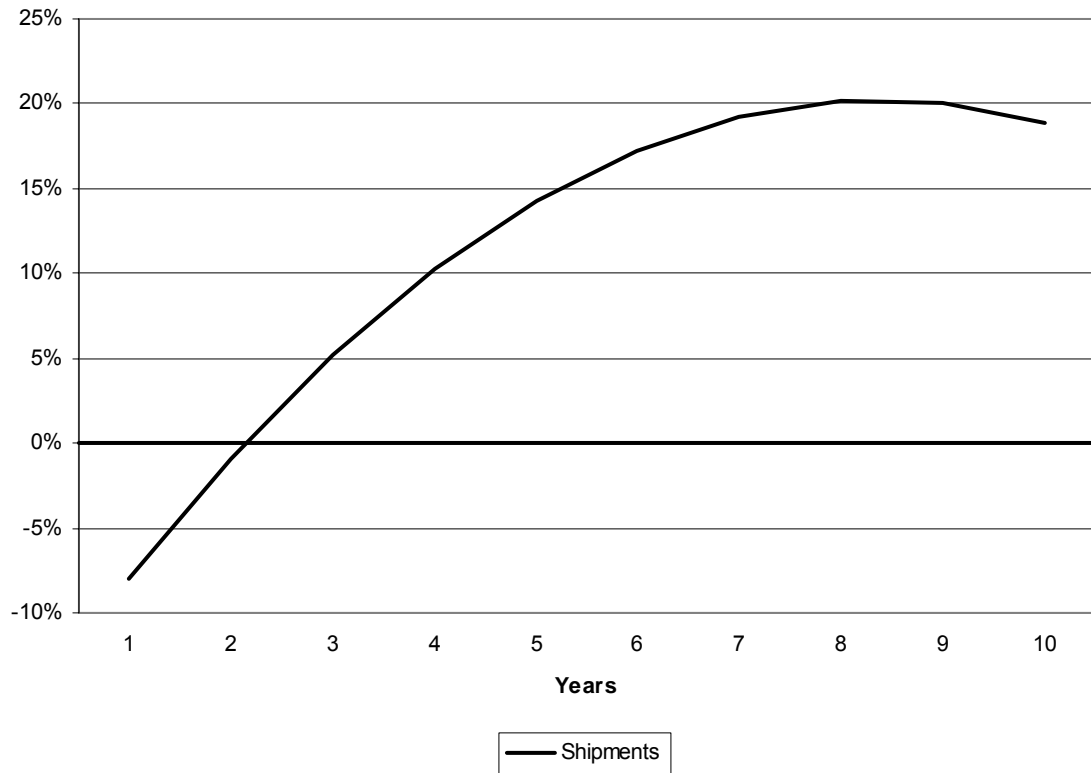
Figure 3.8 indicates that manufacturing sector employment increases in counties contiguous to nonattainment counties. As with total shipments in counties that have gained attainment status, these results are only marginally statistically significant. Total wages and total employment should experience similar changes, but wages in counties contiguous to nonattainment counties are not expected to be affected. Thus, further analysis with additional data is needed to understand the manufacturing sector impacts in counties contiguous to nonattainment counties.

Figure 3.8: Manufacturing Sector Impacts for Counties Contiguous to Nonattainment Counties
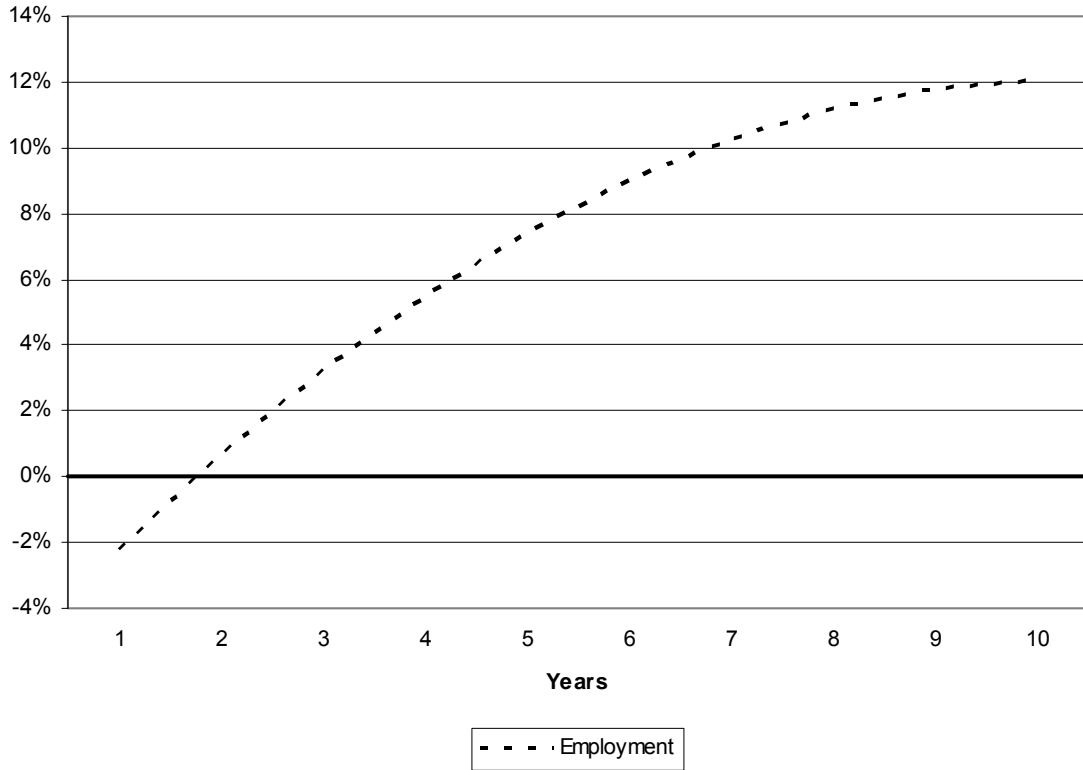
Manufacturing sector shipments and wages benefit from gained attainment status in a neighboring county, as seen in Figure 3.9. As with impacts on all economic sectors, similar impacts are seen in counties that gain attainment and in the surrounding counties. This provides further evidence that regional economic linkages cause the impacts of nonattainment status to extend beyond the borders of nonattainment areas into the surrounding region.

Figure 3.9: Manufacturing Sector Impacts for Counties Contiguous to Counties That Have Gained Attainment
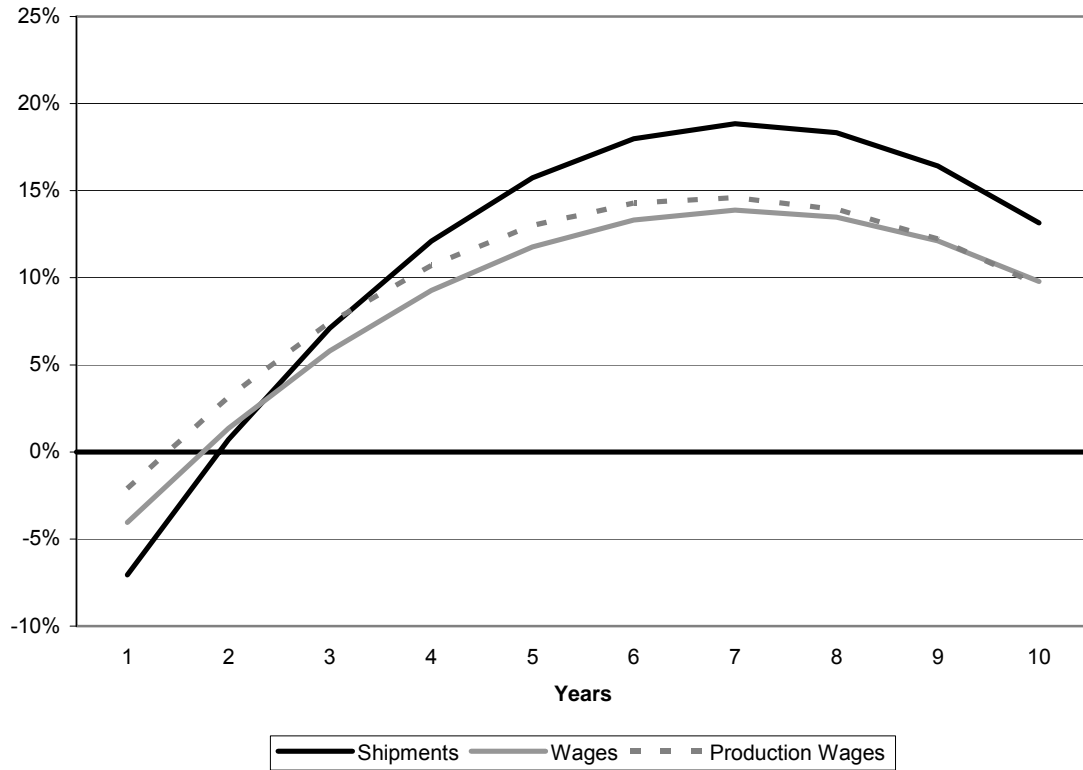
When analyzing the regulatory impact on the manufacturing sector using cities as the geographic unit of analysis, a statistically significant regulatory impact is only observed for cities contiguous to nonattainment counties. As seen in Figure 3.10, in these cities manufacturing output, employment, and wages are expected to increase with the removal of nonattainment status in neighboring areas. It is interesting to note that unlike for counties, these are the only statistically significant impacts for the manufacturing sector in cities. This suggests that the manufacturing sector impacts are concentrated in unincorporated areas. Industry agglomeration or infrastructure and public service advantages in cities may be mitigating the negative impacts of nonattainment regulations. However, this could also be a result of insufficient data. These estimates are based on two years of data; city level analysis using more data may produce more descriptive estimates.

Figure 3.10: Manufacturing Sector Impacts for Cities Contiguous to Nonattainment
Counties
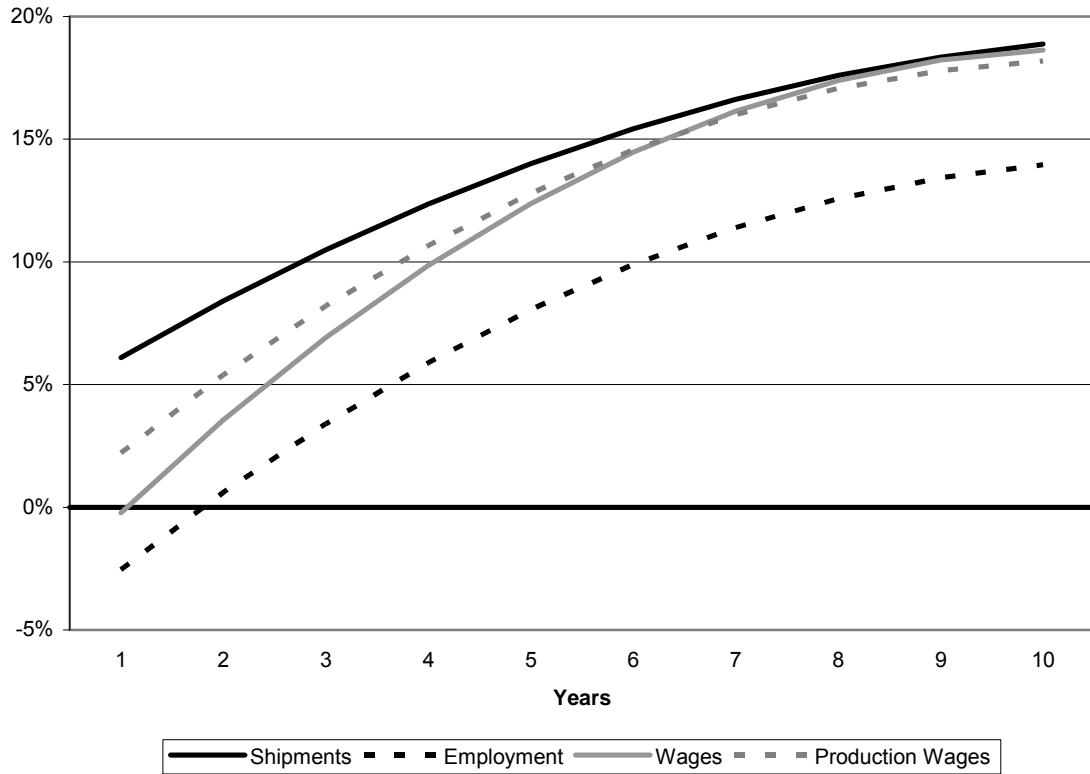
Discussion and Policy Implications

Very similar regulatory impacts are observed in both nonattainment areas and in
surrounding areas. While nonattainment regulations are not applied beyond the borders of
nonattainment areas, regional industry linkages extend the regulatory impacts to
surrounding areas. It is important to understand that attainment status affects the regional
industrial landscape. Regional impacts beyond the borders of nonattainment areas should
be included when analyzing attainment status effects; ignoring these effects will result in
underestimating the total regulatory impacts.

Regional industrial impacts likely also produce regional air quality impacts.
Ground-level ozone regulations are effective in improving local air quality in regulated
areas (Henderson 1996); manufacturing sector activity is seen to increase in cities
surrounding nonattainment areas. It is likely that air quality will decline in these
surrounding areas. Increased ground-level ozone in surrounding areas is expected
because of the manufacturing sector impacts of nonattainment status in neighboring areas.

The nonattainment regulation literature typically considers a county to be in nonattainment if all or part of the county is actually included in a nonattainment area. This apparent over assignment of industrial activity to regulated areas is not problematic, however, because the industrial regulatory impacts of nonattainment status extend beyond the nonattainment area. Instead, a problem of under assignment occurs. When calculating the national impacts of nonattainment regulations, it is important to include the impacts that occur beyond the boundaries of nonattainment areas.

Analysis of aggregate economic indicators provides an understanding of the local and regional impacts of attainment status. These impacts are net of changes in the mix of local industries as an area continues in nonattainment. It is significant that even after a decade of changes in the local industrial composition, net regulatory impacts are not reduced. Total employment, total and manufacturing sector wages, the total number of establishments, and manufacturing shipments are all reduced by nonattainment status net of local adjustments in industry composition.

Partial persistence of economic impacts is also observed after attainment status has been gained. Gaining attainment status reverses a portion of the nonattainment status impacts, but continued economic effects are observed in areas that have gained attainment status. This is likely caused by both the nature of the SIP regulations in nonattainment areas and the regulations implemented in areas that have gained attainment status to maintain that status. These effects provide another piece of the regulatory impact picture.

These observations lead to several policy suggestions. In light of the fact that nonattainment status does not merely shift the local industrial composition away from polluting industries but lowers local net economic indicators, it is important to evaluate the characteristics of SIP regulations. It may be possible to improve air quality at a reduced local economic cost. SIP regulations are required to include technology based standards, which are less efficient than market based regulations. Krupnick and McConnell (2000) discuss efficiency gains under alternate SIP regulations for NO_x, one of the precursors of ground-level ozone. Implementing more efficient SIP requirements could mitigate their local economic impacts while still achieving improved air quality.

While only limited flexibility currently exists for SIP regulations in nonattainment areas, greater regulatory flexibility is granted for Early Action Compacts. In 2003 the EPA offered the Early Action Compact, or EAC, as an alternative to communities that would otherwise likely fail to meet the new 8-hour ozone NAAQS. A successful EAC will achieve the required air quality improvements sooner than would be required under nonattainment regulations. Provided that air quality milestones are met, nonattainment status designation is deferred. Communities participating in Early Action Compacts have the opportunity to design more efficient air quality regulations, thus mitigating their economic impacts.

Finally, local economic development efforts should be guided by the understanding that nonattainment status historically reduces local economic indicators net of any changes in industrial composition. Employment, wages, and production decrease with time as an area continues in nonattainment, indicating that any shifts in local industrial composition are too small to keep up with the impacts on polluting industries and on firms with close ties to polluting industries. Greater effort to change the local industrial base could reduce the net local economic costs of nonattainment.

Local economic development in jurisdictions surrounding nonattainment areas should also address the impacts of nonattainment status. While nonattainment regulations are not applied to surrounding areas that are in attainment, the regulatory impacts extend to these areas. Also, gaining attainment status does not remove the need for development efforts to attract industries unaffected by ozone regulations. Because economic impacts persist after attainment status has been gained, shifts in the local industrial composition would be useful in mitigating these persisting economic impacts.

Chapter 4
The Intergovernmental Fiscal Impacts of the Clean Air Act

Regulatory policy in the U.S. is a mixture of federal, state, and local activity. This is the case for air quality regulation, which is governed at the federal level by the Clean Air Act. Localities failing to meet national air quality standards are declared to be in nonattainment and become subject to additional environmental regulations, which are implemented by the states. These regulations target polluting industries in specific localities in an effort to improve local air quality. Firm responses to these additional regulations will not only alter local patterns of industrial activity, but will also affect the fiscal realities of local governments.

This chapter focuses on the fiscal impact of ground-level ozone regulation. Ground-level ozone, a component of smog, presents respiratory health risks and is also harmful to vegetation. It is formed by a chemical reaction between nitrogen oxides (NO_x) and volatile organic compounds (VOC) that is caused by sunlight; therefore, ground-level ozone regulations focus on emissions of NO_x and VOC. Roughly half of these emissions are from motor vehicles; most of the remaining emissions are from industrial and electric generation facilities. The focus of this analysis is to examine the impacts of ozone regulation on the revenues of local governments – cities and counties – in the metropolitan areas where these regulations are applied. In addition, recognizing that regional economies are highly interdependent, this analysis investigates the impacts of ozone regulations not only on the revenues of jurisdictions directly affected by these regulations, but also on neighboring localities.

The concept of vertical fiscal externalities, now familiar in the literature of fiscal federalism (i.e. Keen and Kotsogiannis 2002), is at work in the fiscal impacts of federal air quality regulations. Vertical fiscal externalities are generally seen when one level of government uses the same tax base as another level of government. For example, in the Keen and Kotsogiannis model, local governments set taxes that result in reduced consumption of the taxed good. This in turn reduces the tax revenue of the national government. However, the reduction in national tax revenue is not taken into consideration by local governments when setting tax rates. This chapter considers an

analogous situation. Under the Clean Air Act, the federal government imposes regulations that affect the tax bases of local governments. These federally-originated regulations will therefore impact local tax revenues. The impact of federal regulatory policies on subnational government revenues is a matter of considerable importance for those governments. These impacts should also interest federal policymakers and, ideally, would be taken into account in the formulation of federal regulatory policies. At present, however, almost nothing is known about the effects of ground-level ozone regulations on the revenues of local governments. This chapter serves as a positive analysis of these effects.

A number of studies have found that ozone regulation under the Clean Air Act does impact polluting industries (i.e. Henderson 1996, Becker and Henderson 2000, Greenstone 2002, List et al 2003, List and McHone 2000). In general, the literature finds that ground-level ozone nonattainment status reduces output from and the number of firms in polluting industries. However, this literature pays little attention to the impacts on localities immediately adjacent to regulated areas; the study of the impacts of air quality regulations on jurisdictions neighboring regulated areas is a contribution of this chapter aimed at understanding the regional regulatory impacts. Responses by polluting industries both in and surrounding regulated areas will impact the tax bases of local governments.

Ground-level ozone regulations do result in improvements in local air quality (i.e. Henderson 1996). Clean air is an amenity, and ceteris paribus, localities with cleaner air are expected to be more desirable places to live. Increases in amenities via air quality regulations will be capitalized in property values, and this capitalization in turn impacts property tax revenues. Thus, while taxed industrial activity decreases in nonattainment areas putting downward pressure on tax revenues, the amenity of cleaner air can create upward pressure on revenues. The net impact on local tax revenues is a composite of these differing tax base influences.

One would expect, a priori, that various types of governmental units are affected differently by the Clean Air Act. For example, cities and counties in the same nonattainment area have different tax bases that may be impacted differently by the additional regulations in nonattainment areas. The regulatory impact on polluting

industries will have a greater impact on local governments with tax bases more reliant on polluting industries.

The remainder of this chapter is organized as follows. I begin with a discussion of the Clean Air Act and its implementation, followed with a discussion of the existing literature on industrial impacts of the Clean Air Act and several extensions to this literature. I then develop an empirical model to test the intergovernmental fiscal effects of the Clean Air Act and describe the data used in this analysis. I find that nonattainment status depresses tax revenues in urban centers but results in higher revenues in outlying areas. These fiscal impacts persist after attainment status has been gained, and these revenue changes are reflected in similar changes in current expenditures; ground-level nonattainment status has lasting impacts on local public service provision. I conclude by discussing implications for important public policy questions and directions for future research.

Air Quality Policy and Implementation

The Clean Air Act Amendments have created national ambient air quality standards (NAAQS) which apply to specific pollutants, known as criteria pollutants. These standards are applied at the local level, and localities failing to meet the standards over a three year period are declared to be nonattainment areas. Based on air quality measurements, attainment status is determined independently for each pollutant. A list of nonattainment counties is published each year in the Federal Register.

Once an area is declared to be in nonattainment, the state is required to submit a state implementation plan (SIP) outlining what actions will be taken to achieve the ambient air quality standards. Localities are declared as nonattainment areas for specific pollutants; corresponding state implementation plans address the polluting sources that contribute the pollutants exceeding the air quality standard.

State implementation plans create additional regulations for industries that are located within nonattainment areas. The EPA gives states some discretion in determining what will be done to improve air quality, so the specific regulatory impacts of a SIP will have some variation across states. This variation notwithstanding, industries will be affected when an area is declared to be in nonattainment.

Existing facilities in nonattainment areas are required to use Reasonably Available Control Technology, which typically involves retrofitting. New facilities in nonattainment areas face the stricter requirement of the Lowest Achievable Emission Rate, regardless of cost. To prevent large air quality deterioration in attainment areas, many new facilities in most attainment areas are also subject to air quality regulation; such facilities are required to use the Best Available Control Technology. These specific technology requirements are negotiated on a case by case basis, and cost is taken into consideration. Thus, firms located in nonattainment areas face stricter regulations than do firms in attainment areas.

While the EPA sets the air quality standards, state and local governments are responsible for monitoring and enforcement. Federal penalties add weight to state and local enforcement efforts. Federal regulators also have an indirect role in monitoring and enforcement. The EPA must approve SIPs, and it has the authority to impose additional regulations if a SIP fails to bring an area into compliance with the NAAQS. Nadeau (1997) finds that plant-level monitoring does lead to effective enforcement of air quality regulations; implementation of air quality regulations does have real impacts on polluting firms.

Existing Literature and Extensions

A number of studies examine the industrial impacts of environmental regulations. One branch of this literature evaluates the location decisions of firms. Henderson (1996) and List and McHone (2000) find that air quality regulations affect firm location decisions. Firms make location decisions when opening a new facility or relocating an existing plant. Henderson (1996) finds that nonattainment status under the Clean Air Act reduces firm births in a county, and List et al (2003) find that air quality regulations affect location decisions for relocating plants.

A few studies have considered impacts other than firm location decisions. Greenstone (2002) finds that nonattainment status reduces employment, capital stock, and output in pollution-intensive industries, and Gallop and Roberts (1983) find that air quality regulations reduce productivity growth for power plants. While environmental regulations appear to have a number of significant industrial impacts, there is little

evidence that environmental regulations have reduced the international competitiveness of U.S. firms. For a survey of this literature, see Jaffe et al (1995).

While the existing literature focuses on industrial impacts of nonattainment status under the Clean Air Act, there are several important questions that this literature does not address. In particular, little attention has been paid to the effects of *gaining* attainment status, the impacts in localities *contiguous* to nonattainment areas, or the *fiscal impacts* of attainment status on local governments.

Extensions for the Existing Literature

Once an area gains attainment status, the additional environmental regulations that had been imposed are no longer required by the Clean Air Act. However, the effect of these regulations may persist after they have been removed. The purpose of the temporary additional regulations created by the SIP is to bring the area into sustained compliance with the ambient air quality standards. Thus, the impact of a successful SIP on local industrial activity may extend beyond the life of the SIP, either because of the nature of the temporary regulations, or because the SIP regulations are replaced with other state or local regulations to maintain compliance. However, there is no necessary theoretical reason to expect the regulatory effects to fully persist after attainment status has been gained. Even when jurisdictions maintain additional regulations to avoid future nonattainment status, such regulations are not subject to the same specific EPA requirements that govern SIPs. For example, SIPs must include technology-based standards; those standards could be replaced with more flexible regulations once attainment status has been gained, mitigating some of the SIP impacts on polluting firms. Also, once attainment status has been gained, regulations are focused on maintaining rather than improving air quality. Maintenance of current pollution levels is expected to be less costly than the reduction of pollution levels.

Empirical research on the Clean Air Act has focused on regulatory effects in nonattainment counties. While I extend this understanding by examining the affects of gaining attainment status, I also consider the regulatory effects on localities that are contiguous to nonattainment areas. The regulatory impact on polluting industries may or may not be the same as in nonattainment areas. Local economic linkages and industry agglomeration may produce similar impacts in regions surrounding nonattainment areas,

or polluting industries may relocate from nonattainment jurisdictions to surrounding areas that are still in attainment to escape the nonattainment regulations. For example, List et al (2003) observe in their dataset of firm locations in New York that a majority of firm relocations were to adjacent counties. Also, the air quality improvements in nonattainment areas will spill over to adjacent areas; these adjacent areas are expected to experience some air quality improvements unless polluting activity relocates into these areas. Air quality improvements would be capitalized in property values and reflected in property tax revenues. Thus, localities near to nonattainment areas may experience revenue changes that are either similar to or opposite from changes observed in the neighboring nonattainment areas. There is no a priori expectation for the fiscal impacts of nonattainment status for local governments in the surrounding attainment areas.

Empirical Model and Data

This analysis partitions all counties in the U.S. into five groups: those containing nonattainment areas, those containing areas that have gained attainment, those contiguous to nonattainment counties, those contiguous to counties that have gained attainment, and all remaining counties. To illustrate, Figure 4.1 gives a snapshot of these areas in 2002. This analysis includes data covering 1978 through 2002; 1978 was the first year specific counties were identified as being out of attainment for the criteria pollutants.

To assess the affects of attainment status on local government revenues and expenditures I use the following model:

$$
\begin{aligned}
\ln\!\left(\Psi_{jt}\right) = {} & \alpha + \beta_{1p}\!\left(\Phi_{jtp}\right) + \beta_{2p}\!\left(\Phi_{jtp}\cdot Y_{jtp}\right) + \beta_{3p}\!\left(\Phi_{jtp}\cdot Y_{jtp}^{2}\right) \\
& + \gamma_{1p}\!\left(\Theta_{jtp}\right) + \gamma_{2p}\!\left(\Theta_{jtp}\cdot Y_{jtp}\right) + \gamma_{3p}\!\left(\Theta_{jtp}\cdot Y_{jtp}^{2}\right) \\
& + \eta_{1p}\!\left(\phi_{jtp}\right) + \eta_{2p}\!\left(\phi_{jtp}\cdot Y_{jtp}\right) + \eta_{3p}\!\left(\phi_{jtp}\cdot Y_{jtp}^{2}\right) \\
& + \chi_{1p}\!\left(\theta_{jtp}\right) + \chi_{2p}\!\left(\theta_{jtp}\cdot Y_{jtp}\right) + \chi_{3p}\!\left(\theta_{jtp}\cdot Y_{jtp}^{2}\right) \\
& + \lambda\!\left(X_{jt}\right) + \varepsilon_{jt}
\end{aligned}
$$

In this model, Ψ_{jt} is the fiscal variable of interest for local government j at time t: total revenue, own source revenue, total current expenditures, and property tax revenue. The variables Φ, Θ, ϕ, and θ comprise a mutually exclusive set of dummy variables

Figure 4.1: Ground-Level Ozone Attainment Status, 2002

Ground Level Ozone Attainment Status

- County Contains Nonattainment Areas
- Contiguous to Nonattainment County
- County Contains Areas that have Gained Attainment
- Contiguous to County that has Gained Attainment
- All Other Counties
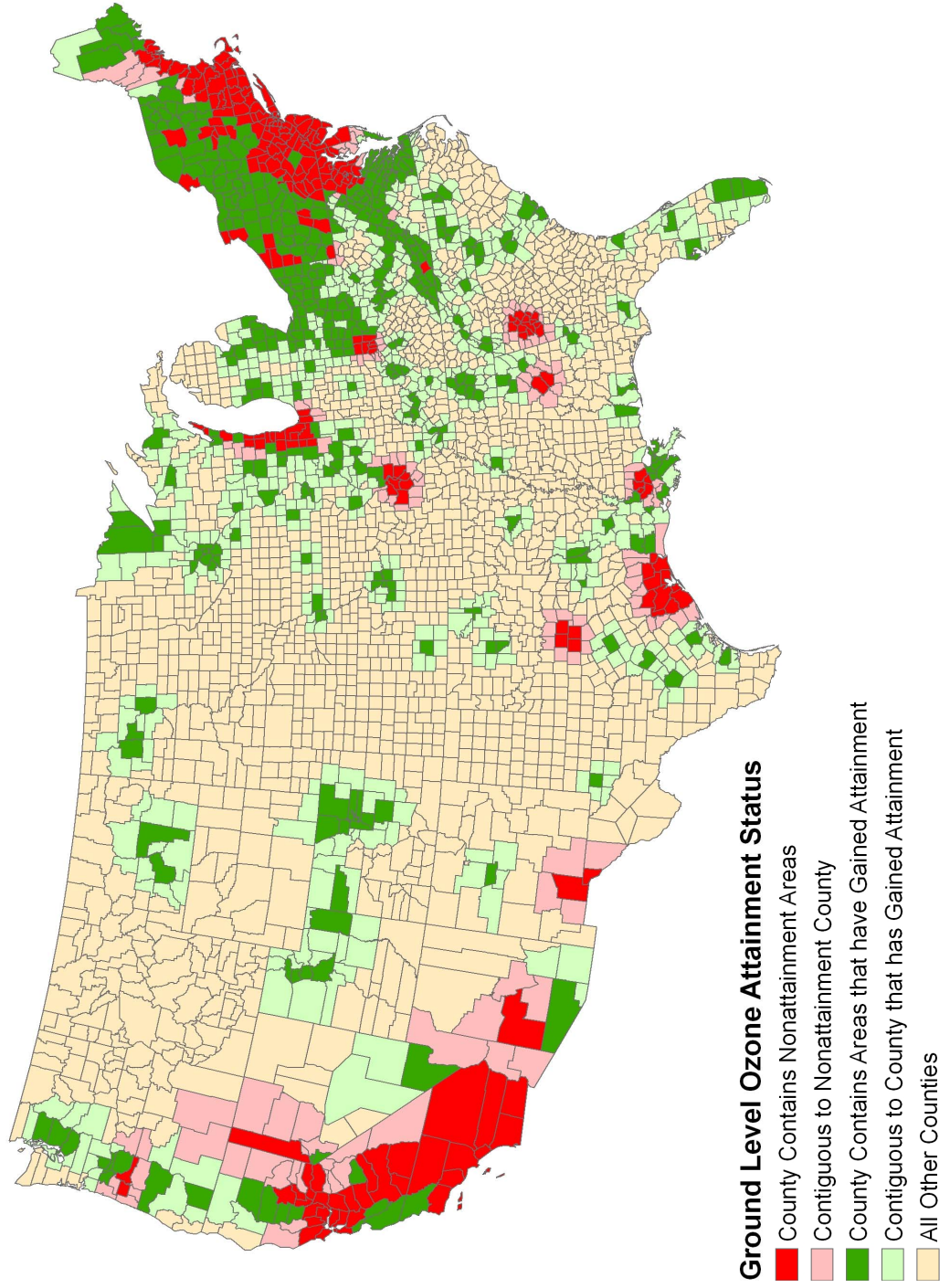
denoting whether a particular county or the county containing a particular city is in nonattainment, has gained attainment status, is contiguous to a nonattainment county, or is contiguous to a county that has gained attainment, respectively. The assignment of counties to these categories will be discussed later. *Y* indicates the number of years a particular county, *c*, has been continuously classified in one of these categories for a particular pollutant *p* in year *t*. *X* contains a vector of control variables.

The local government fiscal data used in this analysis is available from the Census Bureau's Census of Governments for 1982, 1987, 1992, 1997, and 2002. Total current expenditures, which excludes capital expenditures, is used instead of total expenditures because capital expenditures are often lumpy over time; current expenditures more closely reflect current public service delivery. The revenue variables were deflated using the Bureau of Economic Analysis price index for GDP, and government expenditures were deflated using the Bureau of Economic Analysis price index for state and local government consumption expenditures. Table 4.1 summarizes this data by government type.

Table 4.1: Descriptive Statistics for Fiscal Data

	Untransformed Dependent Variable	*Observations*	*Median*	*Mean*	*SD*
County Governments	Total Revenue	14,929	11,403	59,025	298,419
	Total Own Source Revenue	14,929	7,265	37,174	159,977
	Total Current Expenditures	14,927	10,628	55,319	283,802
	Property Tax Revenue	14,907	3,062	14,724	65,442
Municipal Governments	Total Revenue	92,177	616	13,858	370,662
	Total Own Source Revenue	91,749	454	10,626	249,046
	Total Current Expenditures	91,868	527	12,347	348,803
	Property Tax Revenue	84,251	96	2,545	61,809

The local governments affected by these regulations include not only county governments, but also the other local governments found within a county, including municipal governments. Counties are the relevant *geographic* units of analysis in that they are the units to which regulations are often applied, but they are not the sole or nor necessarily the most interesting political units of analysis when assessing fiscal impacts. Therefore, this analysis considers the fiscal impacts on cities in addition the impacts on county governments.

In this analysis, local governments are assigned the attainment status of the county they are located within. The fiscal effects for governments in nonattainment counties and in counties that were in nonattainment but have since gained attainment status are estimated. Specifically, Φ_{jtp} is a dummy variable equaling 1 if the county containing local government j had nonattainment status in year t for pollutant p, and Θ_{jtp} is a dummy variable equaling 1 if the county containing local government j had gained attainment status prior to year t for pollutant p. The reference group for governments that are in nonattainment counties and that are in counties that have gained attainment status is local governments located in counties that have never been in nonattainment and have never been contiguous to a nonattainment county; SIP regulations have not affected the counties in the reference group.

Departing from the existing literature, Φ and Θ are interacted with Y_{jtp} and Y_{jtp}^2, where Y_{jtp} is the number of years of continuous attainment or nonattainment for the county containing local government j in year t for pollutant p^1. One would not expect the fiscal effects of air quality regulations to be instantaneous or constant over time. After a SIP has been developed and implemented, air quality regulations are expected to have greater local impacts over time as existing facilities make new investments and are required to comply with tighter regulations. Also, facility relocation in response to SIP regulations is not immediate; these decisions are made over time as a county continues to be in nonattainment. This is why it is important to permit the fiscal impacts of attainment status to change over time in the model. This model specification allows a constant or parabolic relationship between the number of years a county has had a given attainment status and the impact of the status on the fiscal variable of interest.

Nonattainment status for each county in the U.S. was obtained from the EPA. Many nonattainment designations follow county boundaries, and the EPA reports nonattainment status according to counties. In the dataset used in this analysis a county is considered to be in nonattainment if all or part of the county is listed in nonattainment. Table 4.2 lists the number of governments used in this analysis by attainment status.

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[1] Modifying the model to only include Y and not Y^2 does not significantly alter estimated regulatory fiscal impacts.

Table 4.2: Sample Size by Attainment Status (1982, 1987, 1992, 1997, and 2002 Data)

		Total Observations	
		Frequency	*% of Total*
	Total	14,929	
County Governments	Nonattainment	1,500	10%
	Gained Attainment	1,574	11%
	Contiguous to Nonattainment	1,496	10%
	Contiguous to Gained Attainment	2,253	15%
	All Other Observations	8,106	54%
	Total	93,540	
Municipal Governments	Nonattainment	19,338	21%
	Gained Attainment	12,441	13%
	Contiguous to Nonattainment	8,489	9%
	Contiguous to Gained Attainment	13,532	14%
	All Other Observations	39,740	42%

In the model, ϕ_{jtp} indicates whether the county containing local government j was contiguous to a nonattainment county in year t for pollutant p, and θ_{jtp} indicates whether the county containing local government j was contiguous to a county that had gained attainment status prior to year t for pollutant p. This analysis uses a dataset from the Census Bureau (U.S. Dept. of Commerce, 1991) that defines contiguous counties to be those that are physically adjacent, connected by a major road or bridge, or have significant commuting ties. If a local government is in a county that is contiguous to a nonattainment county, it is considered to be contiguous to the nonattainment county.

Like Φ and Θ, ϕ and θ are also interacted with Y_{jtp} and Y_{jtp}^2. In this analysis if a local government is contiguous to more than one nonattainment county, the number of years of continuous nonattainment status is recorded for the contiguous county that has been in nonattainment for the greatest number of years. Likewise, for local governments contiguous to multiple counties that have gained attainment status, the number of continuous years of attainment status is recorded for the contiguous county that has been in attainment for the longest time.

A local government may be considered contiguous to a nonattainment county or to a county that has gained attainment status, but not both in this analysis. The primary regulatory effect in a region occurs because of nonattainment status; gaining attainment status is expected to have a smaller, secondary impact on local industry. Because

nonattainment status is expected to produce the primary regulatory effect in a region, if a local government is contiguous to a nonattainment county and to a county that has gained attainment status, it is recorded as simply being contiguous to a nonattainment county. Also, counties that are in nonattainment or that have gained attainment are not also recorded as being contiguous to areas in nonattainment or that have gained attainment. This partitions all counties into five distinct categories: those that contain nonattainment areas, those that have gained attainment, those that are contiguous to a nonattainment county, those that are contiguous to a county that has gained attainment, and all remaining counties. Therefore, the reference group for local governments contiguous to nonattainment counties and contiguous to counties that have gained attainment status is all local governments in counties that have never been in nonattainment and that are only contiguous to counties that have never been in nonattainment.

Greenstone (2002) explains that including coefficients for each criteria pollutant in the model is valuable. When considering the effect of attainment status for a particular pollutant, the effect of attainment status for the other criteria pollutants is not restricted to zero when the model includes all criteria pollutants. This is important because many nonattainment counties are out of attainment for multiple pollutants. β_p, γ_p, η_p, and χ_p are all vectors containing coefficients for each criteria pollutant regulated between 1978 and 2002: 1 hour ozone, carbon monoxide, lead, particulate matter smaller than 10 microns, nitrous oxide, sulfur dioxide, and total suspended particulates.

In the model, X_{jt} is a vector of control variables. These include state fixed effects because SIPs are developed at the state level. Fixed effects for nonattainment status (Φ, Θ, ϕ, and θ) by year are included for each criteria pollutant to account for national industry-wide characteristics in polluting industries that change over time. Year fixed effects are also included.

The revenue estimation literature highlights the importance of controlling for population and income (i.e. Groves and Kahn 1952, Legler and Shapiro 1968, and Buchanan and Weber 1982). X_{jt} includes the log of population and per capita income estimates for counties and cities. City population data is taken from the Census of Governments, and annual county population estimates are from the Census Bureau

Population Division. Per capita income for each city and county is also included and is taken from the 1980, 1990, and 2000 decennial censuses. Because income data summarized by cities and counties is only available based on the decennial census, the Census of Governments data is matched with the temporally closest income data.

To control for the industrial and residential mix within a county, X_{jt} includes the variable "mix", which is the ratio of population to employment in the county. County employment data is from the Bureau of Labor Statistics. Also, to control for fiscal characteristics, the log of the jurisdiction's population density is included as a control; higher population densities are expected to reduce service delivery costs.

Results

Tables 4.3 and 4.4 list selected coefficient estimates for cities and counties. Because these types of governments have different tax bases and functions, it was important to estimate the model separately for each type of government. Using this approach instead of using a dummy variable for each government type allows all of the coefficients to vary between government types; this variation captures how the Clean Air Act affects each type of local government differently.

Columns (1) through (4) in each table give the regression results for each dependent variable. Within each column, the joint significance for sets of variables is given. I report the joint significance of each set of policy variables because the fiscal effect is estimated using each policy variable and both interaction variables jointly; each variable taken on its own has little value for understanding the overall intergovernmental fiscal impact of the Clean Air Act. For example, relative to counties that have always been in attainment and that are contiguous to counties that have always been in attainment, total revenues for counties that have been in nonattainment for three years are expected to change by $\beta_1 + (\beta_2 \cdot 3) + (\beta_3 \cdot 3^2)$%, or -9.53%; this is seen from column (1) of Table 4.4. The results of a significance test for $\left[\beta_1 + (\beta_2 \cdot 10) + (\beta_3 \cdot 10^2)\right]$ − $\left[\beta_1 + (\beta_2) + (\beta_3)\right] = 0$, or $(9 \cdot \beta_2 + 99 \cdot \beta_3) = 0$, are also reported in the column labeled Y=10 – Y=1. This test indicates whether the expected fiscal effects after 10 years are statistically significantly different than the expected fiscal effects in the first year.

Table 4.3: Regression Results for Cities

1 Hour Ozone NAAQS

Independent Variable	(1) ln (Total Revenue) Coefficient (Std. Err.)	Joint Test	Y=10	Y=1	(2) ln (Own Source Revenue) Coefficient (Std. Err.)	Joint Test	Y=10	Y=1	(3) ln (Current Expenditures) Coefficient (Std. Err.)	Joint Test	Y=10	Y=1	(4) ln (Property Tax) Coefficient (Std. Err.)	Joint Test	Y=10	Y=1
Nonattainment (β_1)	-0.1433 *** (0.0390)				-0.1613 *** (0.0444)				-0.1753 *** (0.0405)				0.0303 (0.0393)			
Nonattainment * Y (β_2)	-0.0041 (0.0050)	***			-0.0073 (0.0057)	***			-0.0081 (0.0052)	***			0.0030 (0.0050)	***		
Nonattainment * Y^2 (β_3)	0.0001 (0.0002)				0.0002 (0.0002)				0.0003 * (0.0002)				0.0000 (0.0002)			
Gained Attainment (γ_1)	-0.1999 *** (0.0216)				-0.2170 *** (0.0246)				-0.1983 *** (0.0224)				-0.0597 *** (0.0218)			
Gained Attainment * Y (γ_2)	-0.0021 (0.0042)	***			-0.0041 (0.0048)	***			-0.0065 (0.0043)	***		*	-0.0037 (0.0042)	***		
Gained Attainment * Y^2 (γ_3)	0.0001 (0.0002)				0.0002 (0.0002)				0.0002 (0.0002)				0.0001 (0.0002)			
Contiguous to Nonattainment (η_1)	0.0262 (0.0604)				0.0402 (0.0688)				0.0536 (0.0629)				0.1965 *** (0.0631)			
Contiguous to Nonattainment * Y (η_2)	-0.0019 (0.0071)				-0.0043 (0.0081)				0.0026 (0.0074)				0.0009 (0.0074)	**		
Contiguous to Nonattainment * Y^2 (η_3)	0.0000 (0.0003)				0.0001 (0.0003)				-0.0002 (0.0003)				-0.0003 (0.0003)			
Contiguous to Gained Attainment (χ_1)	-0.0597 *** (0.0202)				-0.0680 *** (0.0230)				-0.0538 ** (0.0209)				-0.0712 *** (0.0208)			
Contiguous to Gained Attainment * Y (χ_2)	-0.0017 (0.0040)	***			-0.0048 (0.0046)	***			-0.0055 (0.0042)	***			0.0009 (0.0042)	***		
Contiguous to Gained Attainment * Y^2 (χ_3)	0.0001 (0.0002)				0.0001 (0.0002)				0.0002 (0.0002)				0.0000 (0.0002)			
ln (Population)	1.2567 *** (0.0021)				1.3057 *** (0.0024)				1.2661 *** (0.0022)				1.1951 *** (0.0022)			
ln (Per Capita Income)	0.320041 *** (0.008763)				0.472433 *** (0.010012)				0.298285 *** (0.009109)				0.812225 *** (0.009142)			
Mix (population/employment)	-0.0005 (0.0005)				-0.0006 (0.0005)				-0.0004 (0.0005)				0.0002 (0.0005)			
ln (Population Density)	-0.0396 *** (0.0033)				-0.0216 *** (0.0038)				-0.0240 *** (0.0035)				-0.0632 *** (0.0036)			
Joint test: State Fixed Effects	***				***				***				***			
Joint test: Ozone Attainment Status by Year													***			
n	92,177				91,749				91,868				84,251			
R^2	0.8695				0.8561				0.8645				0.8292			

*** Significant at the 1% level   ** Significant at the 5% level   * Significant at the 10% level

70

Table 4.4: Regression Results for Counties

Independent Variable	(1) ln(Total Revenue) Coefficient (Std. Err.)	(1) Joint Test	(1) Y=10	(1) Y=1	(2) ln(Own Source Revenue) Coefficient (Std. Err.)	(2) Joint Test	(2) Y=10	(2) Y=1	(3) ln(Current Expenditures) Coefficient (Std. Err.)	(3) Joint Test	(3) Y=10	(3) Y=1	(4) ln(Property Tax) Coefficient (Std. Err.)	(4) Joint Test	(4) Y=10	(4) Y=1
Nonattainment (β_1)	-0.1722 ** (0.0769)				-0.1720 * (0.0926)				-0.1344 * (0.0779)				0.0396 (0.0752)			
Nonattainment * Y (β_2)	0.0276 *** (0.0100)	***	***		0.0250 ** (0.0120)	***	***		0.0180 * (0.0101)	***	***		0.0195 ** (0.0098)	***	***	
Nonattainment * Y^2 (β_3)	-0.0001 (0.0004)				-0.0001 (0.0005)				0.0003 (0.0004)				-0.0002 (0.0004)			
Gained Attainment (γ_1)	0.1419 *** (0.0394)				0.1884 *** (0.0474)				0.1416 *** (0.0399)				0.1253 *** (0.0385)			
Gained Attainment * Y (γ_2)	-0.0056 (0.0073)	***			-0.0047 (0.0088)	***			-0.0072 (0.0074)	***			0.0038 (0.0072)	***		
Gained Attainment * Y^2 (γ_3)	0.0001 (0.0003)				0.0001 (0.0004)				0.0002 (0.0003)				-0.0001 (0.0003)			
Contiguous to Nonattainment (η_1)	-0.0119 (0.0806)				-0.0219 (0.0971)				-0.0385 (0.0817)				0.1132 (0.0788)			
Contiguous to Nonattainment * Y (η_2)	-0.0007 (0.0097)	***			0.0031 (0.0117)	***			0.0021 (0.0099)	***			-0.0033 (0.0095)	***		
Contiguous to Nonattainment * Y^2 (η_3)	0.0003 (0.0004)				0.0002 (0.0005)				0.0003 (0.0004)				0.0002 (0.0004)			
Contiguous to Gained Attainment (χ_1)	-0.0605 ** (0.0301)				-0.0505 (0.0362)				-0.0436 (0.0305)				-0.0925 *** (0.0295)			
Contiguous to Gained Attainment * Y (χ_2)	0.0089 (0.0061)				0.0068 (0.0073)				0.0061 (0.0061)				0.0159 *** (0.0059)	**		***
Contiguous to Gained Attainment * Y^2 (χ_3)	-0.0003 (0.0003)				-0.0003 (0.0003)				-0.0002 (0.0003)				-0.0006 ** (0.0002)			
ln (Population)	0.8994 *** (0.0089)				0.9065 *** (0.0107)				0.8916 *** (0.0090)				0.8576 *** (0.0087)			
ln (Per Capita Income)	0.747634 *** (0.027223)				1.167191 *** (0.032787)				0.655309 *** (0.027577)				1.138569 *** (0.026642)			
Mix (population/employment)	-0.0006 *** (0.0002)				-0.0009 *** (0.0003)				-0.0007 *** (0.0002)				0.0002 (0.0002)			
ln (Population Density)	-0.1524 *** (0.0088)				-0.1374 *** (0.0105)				-0.1382 *** (0.0089)				-0.1368 *** (0.0086)			
Joint test: State Fixed Effects	***				***				***				***			
Joint test: Ozone Attainment Status by Year					*											
n	14,929				14,929				14,927				14,907			
R^2	0.7139				0.7161				0.7088				0.7069			

1 Hour Ozone NAAQS

*** Significant at the 1% level   ** Significant at the 5% level   * Significant at the 10% level

Significance indicates that the fiscal effect of that particular attainment status does change over a ten-year period.

To understand how the fiscal effects change with time, it is useful to graph the expected fiscal impact across time. For example, to graph the impact of nonattainment status on total revenue, plot of $\beta_1 + (\beta_2 \cdot Y) + (\beta_3 \cdot Y^2)$ against Y. To understand how the impact changes with time, the difference in the expected revenue changes between the first and tenth years can be calculated: $[\beta_1 + (\beta_2 \cdot Y) + (\beta_3 \cdot Y^2)] - [\beta_1 + (\beta_2) + (\beta_3)]$.

Figures 4.2 through 4.9 graph the expected impact on revenues or expenditures, such as $\beta_1 + (\beta_2 \cdot Y) + (\beta_3 \cdot Y^2)$, when the regulatory impact on expected revenues or expenditures is statistically significant; these graphs show the regulatory impact for each attainment status on each of the fiscal dependent variables. Each graph covers a ten-year period. Of the 468 counties that have contained nonattainment areas between 1978 and 2002, 322 have been in nonattainment for a period of ten or more years. Also, 290 of the 388 counties that have gained attainment status have subsequently maintained attainment for ten or more years. Thus, estimating the regulatory impact over a ten-year period is within the data.

These graphs should be interpreted in sequence; local governments are in nonattainment before gaining attainment, so when extrapolated to a particular government, graphs for nonattainment areas temporally precede graphs for areas that have gained attainment status. This is important when considering the persistence of nonattainment impacts. For example, an absence of change between the graphs for nonattainment areas and for areas that have gained attainment would mean that the fiscal changes shown in the nonattainment graph persist after attainment status has been gained.

Before discussing specific findings, some key geographic differences between the types of governments included this analysis should be highlighted. Counties typically do not follow urban boundaries; urban, suburban, and rural areas can all be found in one county. While regulations can benefit the entire local area via air quality improvements, the costs of regulations targeted at polluting industries are concentrated in more industrialized areas. Analysis at the county level will aggregate the regulatory fiscal impact across all areas in a county, both urban and rural. Cities, however, are

incorporated in population centers. Because outlying areas surrounding cities are often not incorporated, analysis at the city level will capture the regulatory fiscal impacts in more urban areas. The qualitative fiscal impacts in rural areas can then be understood by "subtracting" the impacts in cities from the impacts in counties. Because cities and counties rely on different mixes of taxes, this comparison is most meaningful for a specific type of tax, such as the property tax. Nonattainment status is expected to impact the tax bases for various taxes differently; thus, it will affect the total revenues of each type of local government differently. For example, counties rely more heavily on property taxes than do cities; in the data used in this analysis, on average property taxes comprise 31% of total county revenues and 19% of total city revenues.

As indicated in Figure 4.2, nonattainment status results in reduced total and own source revenues for city governments located in counties containing nonattainment areas. After 10 years of nonattainment, total revenues have fallen by 18%. SIP regulations on

Figure 4.2: Fiscal Effects for Cities in Nonattainment Counties

73
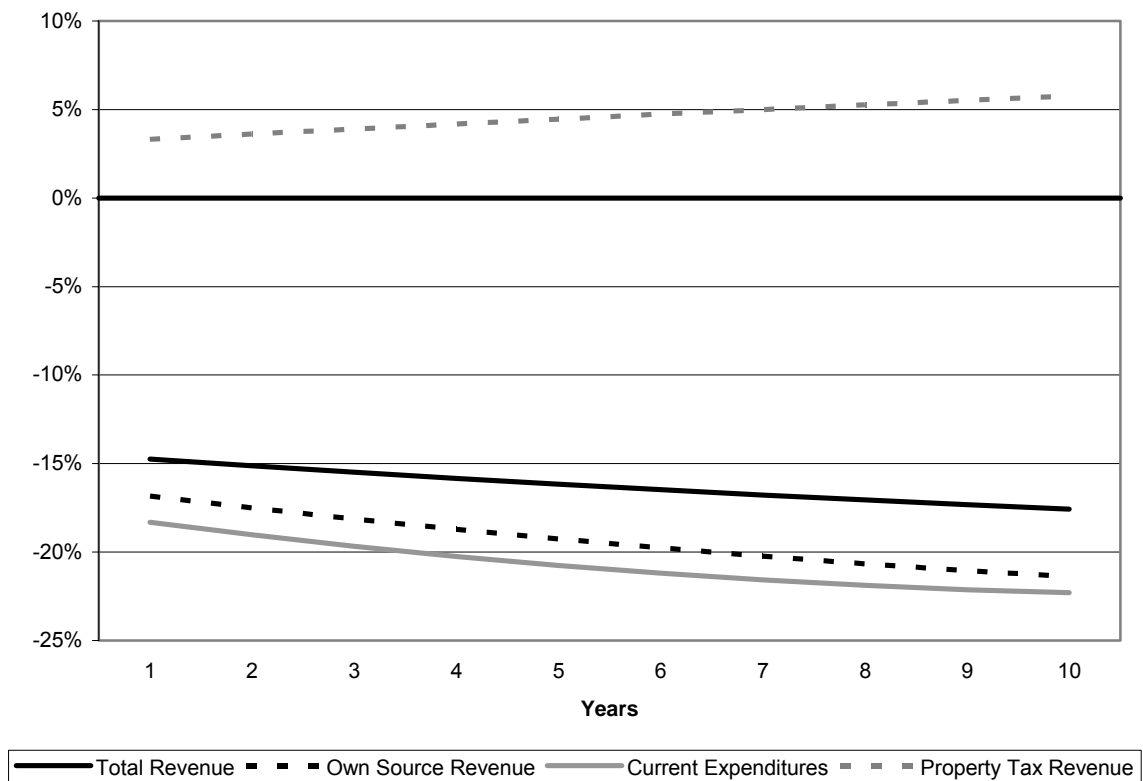
polluting activity appear to reduce the positive impact of this polluting activity on tax revenues.

For cities, the fiscal effects of nonattainment status persist after attainment status has been gained. This is seen in Figure 4.3. Instead of returning to their pre-nonattainment levels, revenues and expenditures continue to be lower. This indicates that gaining attainment status in urban or suburban areas is associated with continued downward fiscal impacts.

In contrast to cities, Figure 4.4 shows that tax revenue increases for counties while in nonattainment. This suggests that while tax revenue collection is reduced in urbanized areas, more money is collected in outlying areas; counties in nonattainment then gain more tax revenue from outlying areas than they lose in tax revenues from incorporated areas. On net, unincorporated outlying areas appear to benefit from nonattainment status as evidenced by this apparent increase in tax revenue collection.

Figure 4.3: Fiscal Effects for Cities in Counties That Have Gained Attainment
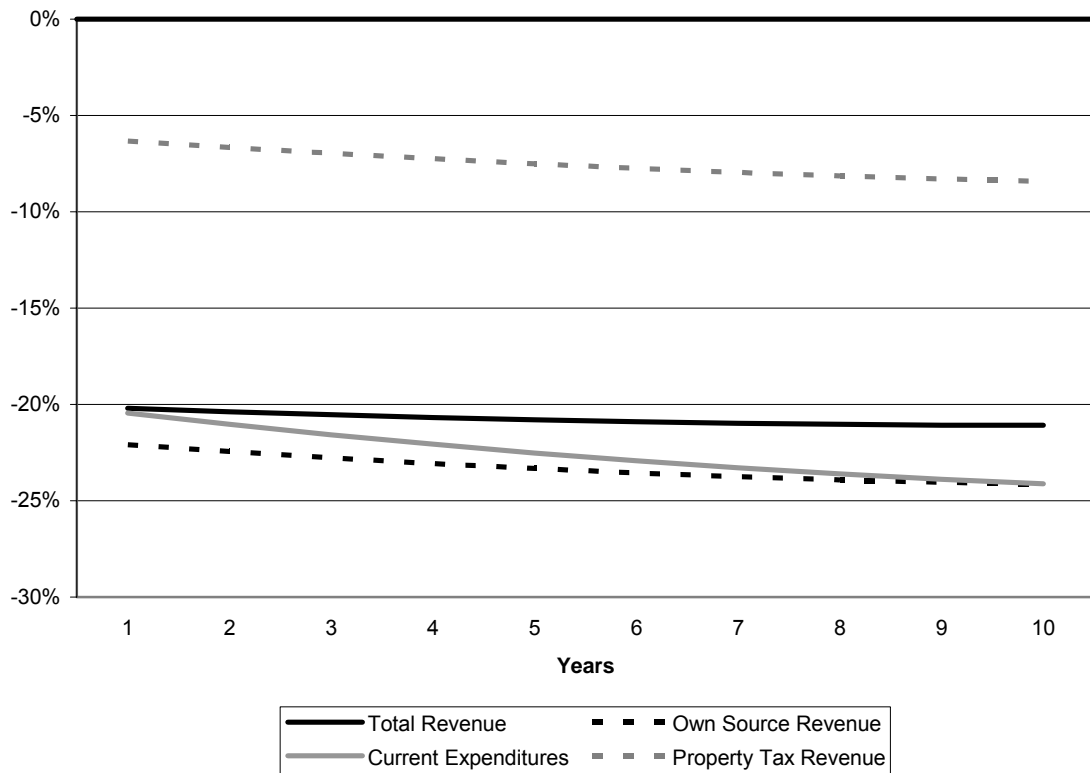
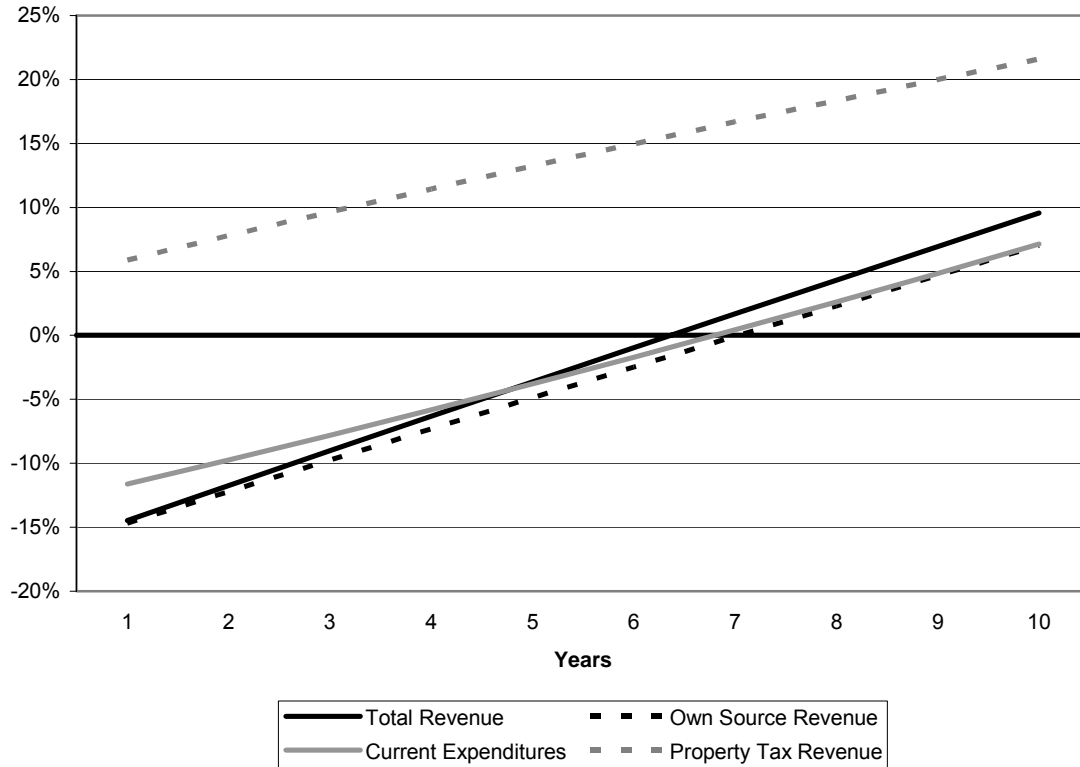Figure 4.4: Fiscal Effects for Counties in Nonattainment

Figure 4.4 shows a statistically significant and large increase in total revenues across time; during ten years of nonattainment, total county revenues are expected to increase 24%. At the beginning of this period, total revenues were 15% lower than revenues in the reference group; the increase in revenues during the nonattainment period more than makes up for this. Areas surrounding urban population centers appear to significantly benefit fiscally from nonattainment status. These increases could reflect economic development as polluting industries relocate to outlying areas that have cleaner air. The property tax revenue increases could also reflect the capitalization of air quality improvements into land values. Outlying areas are typically residential and agricultural where clean air is an amenity; air quality improvements make these areas more desirable.

Figure 4.5 illustrates that after rising during nonattainment, revenues and expenditures remain at higher levels once attainment status has been gained; the increases observed during nonattainment persist after attainment status has been gained. A decade after attainment status has been gained total revenues and current expenditures are still experiencing positive impacts from the local air quality regulations. It is interesting to

75

Figure 4.5: Fiscal Effects for Counties That Have Gained Attainment
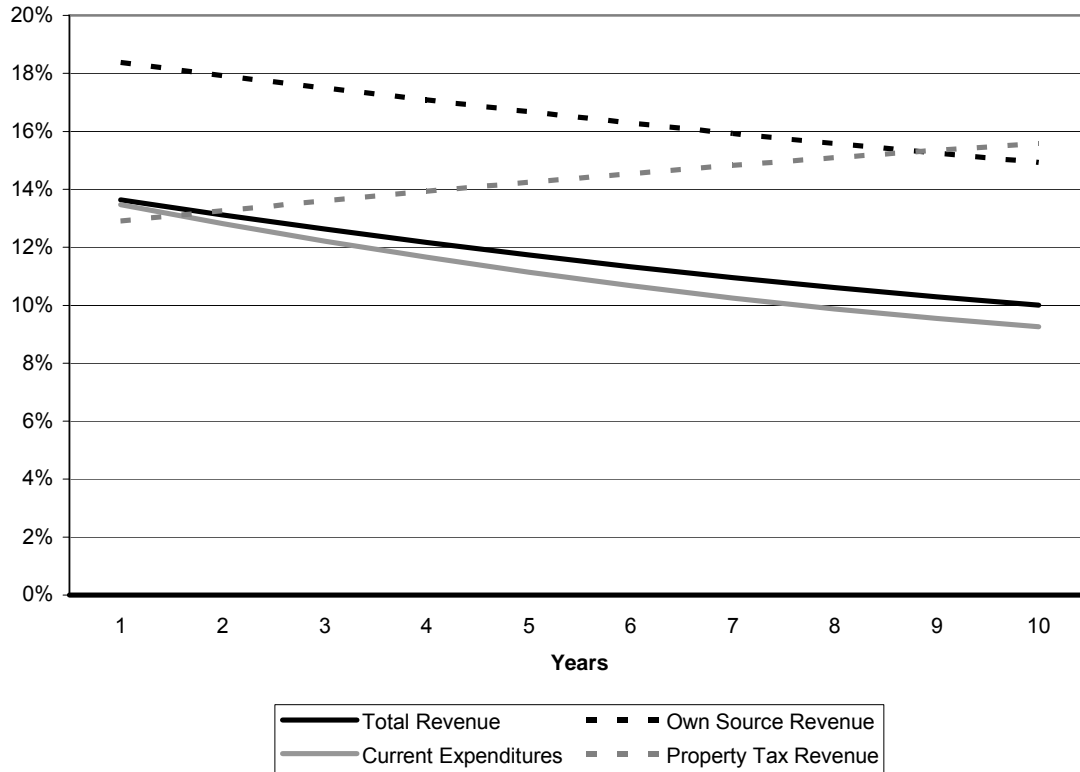
note that the expected fiscal changes over the first decade of attainment status are smaller in magnitude than the changes experienced during the nonattainment period. For example, while total revenues are expected to increase 24% over ten years of nonattainment, they are not expected to experience statistically significant changes during the ten years following the gaining of attainment status. This indicates that regulations employed to maintain attainment status have a smaller fiscal impact at the county level than do the regulations required by the EPA to bring an area into compliance with the ground-level ozone NAAQS. This is likely because regulations in attainment areas are less stringent than those in nonattainment areas; once attainment status has been gained, the current air quality only needs to be maintained instead of improved.

Turning attention to jurisdictions contiguous to nonattainment areas, I find statistically significant impacts on city and county government finances. Figures 4.6 and 4.7 show a large increase in property tax revenues for jurisdictions near nonattainment areas. This increase indicates that outlying areas are more desirable; this could occur as

Figure 4.6: Fiscal Effects for Cities Contiguous to Nonattainment Counties
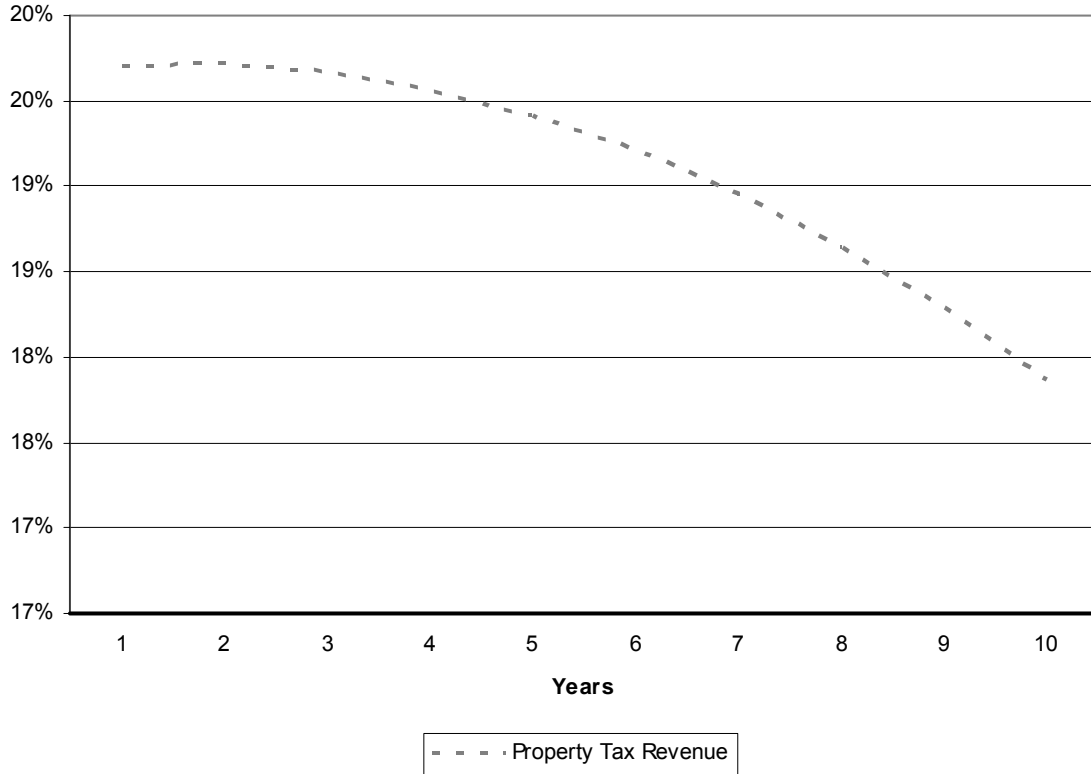
polluting industries relocate to nearby areas that do not face nonattainment regulations or as individuals prefer to live in surrounding areas with cleaner air.

The fiscal impacts for counties contiguous to nonattainment areas as shown in Figure 4.7 are qualitatively similar to those in Figure 4.4 for nonattainment counties. However, it is interesting to note that the impacts on total revenues, own source revenues, and current expenditures are much smaller in magnitude in Figure 4.7. As discussed above, the increases observed in Figure 4.4 for nonattainment counties are driven by revenues collected in unincorporated areas. The smaller effects in Figure 4.7 for counties contiguous to nonattainment areas suggest that the fiscal impacts of nonattainment regulations diminish with distance from the urban core.

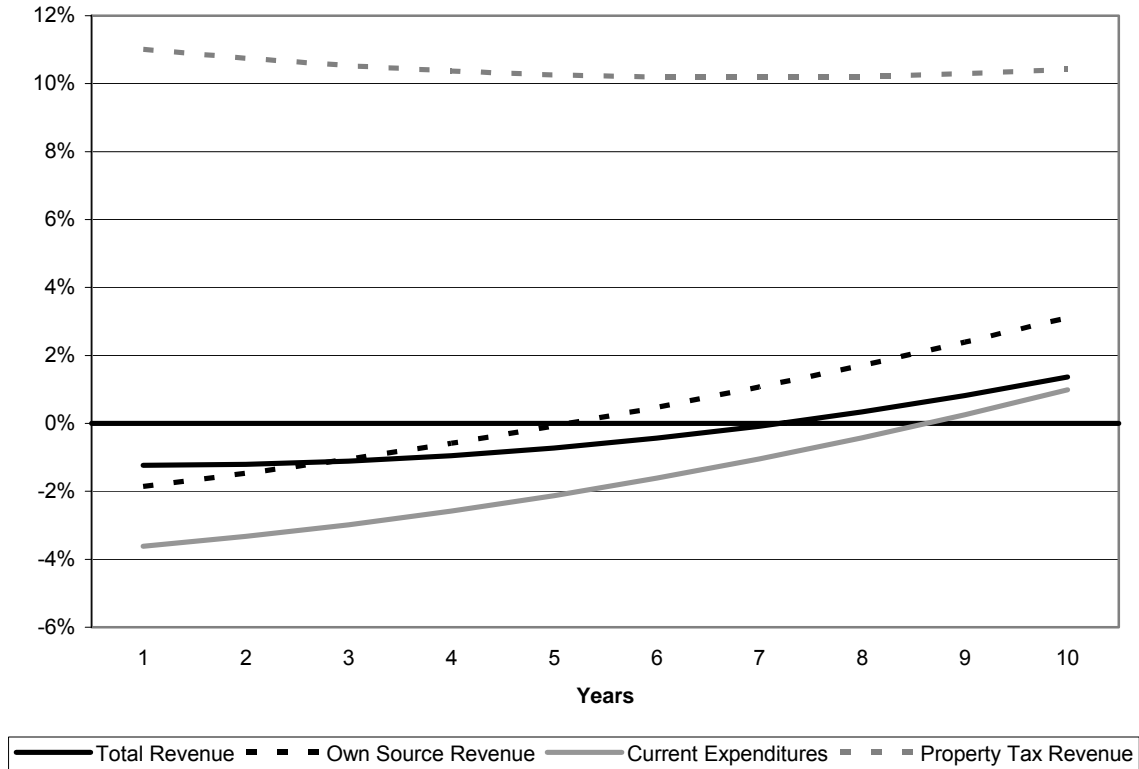Figure 4.7: Fiscal Effects for Counties Contiguous to Nonattainment Counties

Figure 4.8 also tells a similar story, but for cities contiguous to counties that have gained attainment. The negative impacts for total revenue, own source revenue, and current expenditures are much smaller in magnitude when compared to Figure 4.3 showing the fiscal effects for cities located in counties that have gained attainment. The fiscal effects of gaining attainment status appear to diminish with distance from regulated areas. Also, outlying cities do not fare as well as unincorporated areas. Figure 4.5 shows positive impacts for counties that have gained attainment status; again, qualitatively subtracting the negative effects for cities in Figure 4.3 indicates that the positive impacts for counties are driven by impacts in unincorporated areas. Outlying cities likely see negative, albeit small, fiscal impacts from the removal of nonattainment status in nearby counties because they no longer have as large of a regulatory environment advantage over the formerly regulated central cities.

Figure 4.8: Fiscal Effects for Cities Contiguous to Counties that have Gained Attainment
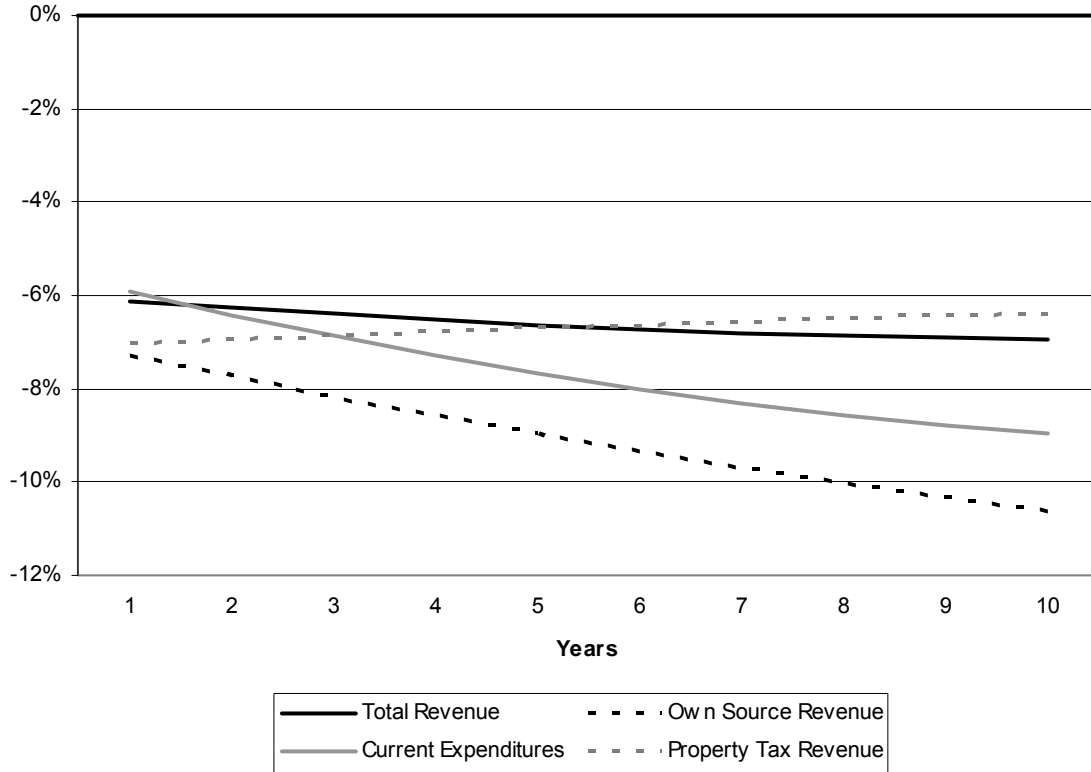
The loss of regulatory advantage also affects county property tax revenues. These revenues fall when a neighboring county gains attainment, as seen in Figure 4.9. This reduction is largely temporary, however. Compared with county property tax revenues after ten years of nonattainment in a contiguous county, these revenues are expected to be 18% lower when the contiguous county gains attainment; after ten years of attainment in the neighboring county, property tax revenues are only 9% lower than during nonattainment in the contiguous county. This indicates that while the removal of nonattainment status appears to hurt economic development in surrounding counties, this particular negative impact is temporary.

Finally, this analysis indicates that local governments do not use debt financing or changes in expenditures on capital projects to smooth expenditure changes associated with revenue shifts resulting from ground-level ozone regulations. Instead, total revenues and current expenditures tend to rise and fall together. This is not surprising, as this relationship between revenues and expenditures is observed for general revenue shocks by Buettner and Wildasin (2006). Consistent with expenditure responses to other revenue

Figure 4.9: Fiscal Effects for Counties Contiguous to Counties That Have Gained Attainment
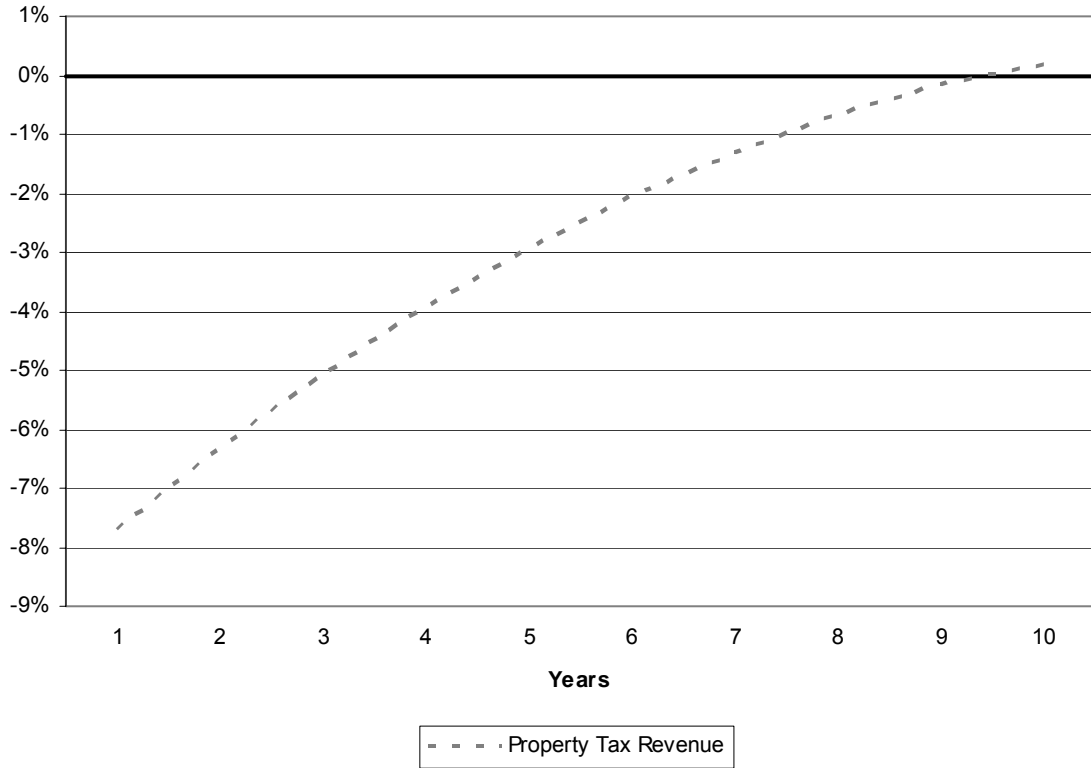
shocks, revenue changes associated with ground-level ozone regulations result in similar changes in current expenditures. Thus, nonattainment status has a real impact on public service delivery. Whether or not local governments anticipate the revenue changes associated with nonattainment status, they do not maintain current public service expenditure levels when in nonattainment for ground-level ozone.

Discussion and Policy Implications

The fiscal impacts of ground-level ozone attainment status vary according to geography. Nonattainment status results in revenue decreases in population centers where compliance costs are concentrated. This is evident in the analysis of city revenues. Revenues in outlying areas increase in the presence of nonattainment status, and these increases diminish with distance from the urban core. There are two likely causes behind these observations. Nonattainment regulations are applied throughout the nonattainment area, but compliance costs are not expected to be concentrated in outlying areas because polluting activity is most concentrated in urbanized areas. While outlying areas

experience lower compliance costs, the regulatory benefits of cleaner air make outlying areas more desirable; the amenity of cleaner air would be capitalized in property values. Also, taxed industrial activity could migrate from urban centers with concentrated pollution to outlying areas. These increases in industrial activity in outlying areas would also lead to higher commercial or industrial property values.

Even after attainment status has been gained, the fiscal effects of the nonattainment regulations persist in regulated areas. The lower revenues for cities and the higher revenues for counties after several years of nonattainment status persist after attainment status has been gained. Gaining attainment status does affect revenues in contiguous jurisdictions; the surrounding areas no longer have the same regulatory advantage. This results in small revenue decreases for contiguous cities and temporary property tax revenue decreases for contiguous counties.

Finally, local governments address the revenue changes resulting from nonattainment status by altering current public service expenditure levels. Thus, the fiscal impacts of nonattainment status not only affect bureaucrats, but they also have tangible impacts on residents via changes in local public service delivery.

Understanding these fiscal impacts could encourage local officials in population centers to pursue Early Action Compacts, an alternative to nonattainment status offered by the EPA beginning in 2003. These Early Action Compacts permit localities that will likely face nonattainment status to implement their own regulations to improve air quality instead of following the SIP requirements. Under an Early Action Compact, local officials have greater flexible in designing pollution regulations; this flexibility could be used to mitigate negative tax revenue impacts in urban centers. Future research could compare the fiscal effects of Early Action Compacts to the effects of nonattainment status. This would shed light on whether the fiscal effects of nonattainment status are unique to the EPA requirements for SIPs.

Because nonattainment regulations are implemented at the state level, public officials in central cities that are in nonattainment may argue for special grants from the state government to compensate for revenue losses. Should state governments create grant programs for central cities in nonattainment areas because revenue reductions result in reduced spending on public services? Should outlying jurisdictions that surround

nonattainment areas be required to share a portion of their tax revenues? In light of the persistence of the fiscal effects of nonattainment status, how long should any revenue sharing or grant policies last? Or because city tax revenues in nonattainment areas appear to be the result of unhealthy levels of polluting activity, are such transfers unfounded because they ignore the health benefits of cleaner air? The results of this analysis provide an empirical framework for future research into these issues.

If cities in nonattainment areas do not receive additional funds from the state or from other jurisdictions, they still have other options at their disposal to mitigate the negative revenue effects of nonattainment status. Cities can use tax incentives aimed at encouraging industries to invest in pollution abatement technology instead of relocating. Tax incentives would be effective for mitigating local tax revenue losses if a relatively small incentive would prevent a firm from relocating. Also, while cities in nonattainment areas are at a regulatory disadvantage compared with outlying areas, they have the potential of other advantages, such as infrastructure. Similar to tax incentives, local investments in public infrastructure could encourage firms to invest in pollution abatement instead of relocating production activities. Finally, instead of seeking direct intergovernmental transfers from the state, cities in nonattainment areas could attempt to persuade the state to offer tax incentives or to fund infrastructure investments aimed at mitigating local tax revenue losses.

Chapter 5

Conclusion

Dissertation Summary

The analysis in this dissertation tells a story of inter-jurisdictional environmental policy impacts. National environmental policy that causes capital migration is a tool for inter-jurisdictional competition, providing a political motivation for a national environmental policy. Also, the Clean Air Act is empirically shown to alter regional industrial geographies and the fiscal situations of local governments.

Some environmental policies, such as ground-level ozone regulations under the Clean Air Act, are centralized regulations addressing primarily local issues. Inter-jurisdictional competition offers one explanation for why national policies regulating local issues exist. A national environmental policy will affect national returns to capital, causing capital migration and altering local wage rates throughout the economy. These changes may benefit capital importing jurisdictions while harming capital exporting jurisdictions. These effects provide a motivation to influence national environmental policy. Thus, a national environmental policy may be used as a tool for inter-jurisdictional competition. This model extends the current literature by providing a political motivation for supporting a national environmental policy that appears to have strictly local policy targets.

The outcomes of national environmental policy are empirically examined via the Clean Air Act. The net local economic impacts of ozone nonattainment status are best understood using aggregate economic indicators. Nonattainment status is seen to reduce net economic activity both in nonattainment counties and in the surrounding counties. Furthermore, the reductions in surrounding counties are similar in magnitude to those in nonattainment counties. The net economic impacts of the Clean Air Act extend beyond nonattainment area boundaries, indicating the significance of regional economic linkages. Manufacturing sector activity declines in nonattainment counties and increases in cities contiguous to nonattainment areas. This suggests that manufacturing activity does migrate from nonattainment counties into surrounding population centers.

Ozone nonattainment status also impacts the fiscal realities of local governments. Revenues are initially reduced in nonattainment counties, and nonattainment cities experience sustained revenue reductions. Greater sustained revenue declines in cities than counties indicate that revenue collection increases in unincorporated nonattainment areas. Also, revenues show a small increase over time in surrounding counties. Thus, while nonattainment status reduces revenues collected in regulated population centers, surrounding areas experience fiscal benefits over time. These benefits appear to reduce with distance from regulated population centers.

These findings extend the existing empirical literature by analyzing the regional impacts of ozone regulations under the Clean Air Act. By focusing on both nonattainment areas and contiguous counties, the inter-jurisdictional regulatory impacts can be understood. The existence of significant findings in jurisdictions surrounding nonattainment areas indicates the importance of not excluding such areas from environmental regulatory impact studies even when the environmental regulation appears to be strictly local in its implementation.

Analysis of the aggregate economic effects is a departure from the existing literature, which primarily focuses on polluting industries. By analyzing regulatory impacts on aggregate economic indicators, I am able to assess the overall local and regional economic impacts of nonattainment regulations. This analysis captures production changes as firms may shift operations toward production in nonpolluting industries, as well as capturing reductions in nonpolluting industries that have significant ties to regulated polluting industries. While analysis of polluting industries highlights the direct regulatory impacts on targeted industries, this analysis of aggregate economic indicators reveals the overall regulatory impacts on local economies.

This dissertation reveals inter-jurisdictional impacts not only through its regional approach, but also by analyzing the intergovernmental fiscal effects of ozone attainment status. Federal air quality regulations are found to indirectly impact the revenues and expenditures of local governments as local tax bases are altered. Also, these effects are not only observed in nonattainment areas. Federal ozone regulations applied to individual jurisdictions appear to have positive fiscal impacts in surrounding jurisdictions.

This research also extends the current literature by taking a more dynamic approach to analyzing policy impacts. Policy impacts change as firm investment and relocation decisions are affected over time in nonattainment areas. Furthermore, the removal of nonattainment regulations should not be expected to immediately and completely reverse nonattainment policy impacts. Understanding the ways in which impacts persist after attainment status has been gained paints a more complete picture of ozone regulatory effects.

The empirical analysis in Chapters 3 and 4 shows that economic and fiscal impacts experienced during nonattainment largely persist after attainment status has been gained. Specifically, the overall economic declines experienced during nonattainment partially persist after attainment status has been gained. Also, compared with the expected total revenues after a decade of nonattainment, revenues are relatively unchanged when cities and counties gain attainment.

In summary, this research extends the existing literature in several directions. The regional approach, dynamic emphasis, and inter-jurisdictional focus provide a broader understanding of ozone nonattainment regulatory impacts. This research also provides a political motivation for the formation of national environmental regulations. The remainder of this discussion focuses on the implications of these findings.

Reflecting on Regional Impacts

Ozone nonattainment regulations are seen to have economic impacts not only in nonattainment areas but also in surrounding areas. Both manufacturing sector and total economic activity is reduced in nonattainment areas. Total economic activity is also reduced in counties contiguous to nonattainment areas, although the reductions are smaller than they are in nonattainment areas. This suggests that regional economic linkages cause nonattainment regulations to have regional impacts that extend beyond the borders of nonattainment areas. The current literature focuses on nonattainment counties when assessing the impacts of nonattainment regulations. The exclusion of surrounding areas results in underestimates of regional and national impacts.

Nonattainment regulations impact both the regional economy and the fiscal realities of local governments. Much can be learned by comparing these regulatory

effects. Cities and counties in nonattainment areas experience initial declines in total revenue. These initial reductions are likely the result of reduced economic activity in nonattainment areas. Total revenues for nonattainment cities remain depressed as the city continues in nonattainment status, while revenues recover in nonattainment counties. This could be explained by differing industrial impacts in cities and unincorporated areas. While net county economic activity decreases in nonattainment areas, this could be driven by decreases in cities. Economic activity migrating into the surrounding unincorporated areas would explain why city revenues remain depressed while county revenues recover. Economic recovery may be more difficult in cities where regulatory costs are likely concentrated.

Manufacturing activity increases in cities that are contiguous to nonattainment areas. This observation supports the hypothesis that polluting activity relocates to surrounding areas, driving the positive fiscal impacts in the region surrounding regulated urban areas. However, declines in total economic activity are seen in counties contiguous to nonattainment areas. This suggests that manufacturing activity is more closely tied to local revenues than is other economic activity. Thus, while total economic activity declines in regions containing nonattainment areas, the fiscal effects of nonattainment regulations diminish with distance from the regulated population centers.

Policy Implications and Future Research

This analysis has several implications for public policy. First, national environmental regulatory outcomes would likely be more efficient if horizontal competition did not occur. If policy impacts were limited to regulated jurisdictions, inter-jurisdictional competition would not be a factor in the formation of national air quality regulations. Because regional economic linkages cause Clean Air Act regulatory impacts to spill over into neighboring jurisdictions, perhaps the best way to limit regulatory impacts outside nonattainment boundaries is to limit the economic impacts within nonattainment areas. Regulations governing state implementation plan, or SIP, approval require technology-based approaches to mitigating local pollution. Replacing these requirements with market-based approaches is expected to reduce the industrial impacts of nonattainment regulations (Krupnick and McConnell, 2000).

A policy experiment currently exists that could be used to empirically test the impacts of different ozone regulations. In 2003 the EPA offered localities that would likely face nonattainment for the new 8-hour ozone standard the opportunity to form an Early Action Compact, or EAC. Each EAC is charged with complying with the new 8-hour air quality standard sooner than would be required by nonattainment regulations; as long as the EAC meets intermediate air quality goals, nonattainment status is deferred. An EAC is not subject to the same regulatory requirements that govern a SIP. As data become available in the coming years, it would be enlightening to analyze how replacing SIP regulations has altered the regional regulatory impacts.

To the extent that horizontal competition is not removed from air quality regulations, jurisdictions could use focused local economic development efforts to improve their ability to compete. Given that aggregate economic activity declines in and around nonattainment areas, local economic development efforts could focus on replacing the locally declining polluting industries with other industries that are less affected by nonattainment regulations. Such economic development would be helpful not only in nonattainment areas, but also in the surrounding jurisdictions. Furthermore, because economic impacts partially persist after attainment status has been gained, local commitment to this type of economic development would be beneficial even after the gaining of attainment status.

Finally, because federal regulations governing the implementation of state policies result in local revenue decreases for nonattainment cities, these cities may argue for intergovernmental grants to offset declining revenues. Even though revenue declines in these cities are permanent, persisting after attainment status has been gained, permanent annual grants from the state or federal government would likely be difficult to secure. Instead of compensating for reduced revenue, temporary intergovernmental grants could be used to spur local economic development. Improvements to local infrastructure or some public services could make a locality more attractive to business, helping mitigate nonattainment regulatory impacts.

Future research should focus on reducing the horizontal competition related to environmental policies. Theoretical research could compare national policy outcomes resulting from the horizontal competition described in Chapter 2 with the outcomes of

different policy instruments. Also, the empirical impacts of altering air quality policy tools can be assessed by studying EAC impacts as data becomes available.

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"Geographic Information System Applications in the Public Sector," Book Chapter in G. David Garson (ed.), <u>Modern Public Information Technology: Issues and Challenges</u>, (Idea Group Publishers, forthcoming). Coauthored with T.R. Carr.

Professional Experience

   Research Assistant, University of Kentucky (2002-2007)
   Project Analyst, Online survey research project (2004-2005)
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   Consultant, Grant County, Indiana Economic Growth Council (April 2002)
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