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By Ronald Shadbegian and Ann Wolverton[1]

Abstract

Economists have long been interested in explaining the spatial distribution of economic activity, focusing on what factors motivate profit-maximizing firms when they choose to open a new plant or expand an existing facility. We begin our paper with a general discussion of the theory of plant location, including the role of taxes and agglomeration economies. However, our paper focuses on the theory, evidence, and implications of the role of environmental regulations in plant location decisions. On its face, environmental regulation would not necessarily be expected to alter location decisions, since we would expect Federal regulation to affect all locations in the United States essentially equally. It turns out, however, that this is not always the case as some geographic areas are subject to greater stringency. Another source of variation is differences across states in the way they implement and enforce compliance with Federal regulation. In light of these spatial differences in the costs of complying with environmental regulations, we discuss three main questions in this survey: Do environmental regulations affect the location decisions of polluting plants? Do states compete for polluting plants through differences in environmental regulation? And, do firms locate polluting plants disproportionately near poor and minority neighborhoods?

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Subject Matter Classifications: Distributional Effects, Economic Impacts
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Introduction

Economists have long been interested in explaining the spatial distribution of economic activity. On a microeconomic level, we study what factors motivate profit-maximizing firms when they choose to open a new plant or expand an existing facility. Differences across geographic locations in factors such as wages and the quality of labor, land values, proximity to transportation corridors, and taxes have been posited as potentially important in such decisions. The purpose of this paper is to review the theory, evidence, and consequences of differences in the costs of complying with environmental regulations with regard to plant location decisions in the United States.

Papers evaluating the importance of environmental regulation in U.S. plant location decisions only began to appear in the 1980s. In part this was due to a paucity of micro-level data. However, it is also related to the history of environmental regulation in the United States. Before the passage of the Clean Air and Clean Water Acts in the mid 1970s, complying with environmental regulations did not contribute significantly to a firm's production costs. With the creation of the U.S. Environmental Protection Agency (EPA) in 1970 to carry out the objectives of, among others, the Clean Air and Clean Water Acts, the Federal government took a leading role in setting environmental policy and, in turn, requiring that firms meet specific regulatory requirements. On its face, Federal regulation would not necessarily be expected to alter location decisions. We would expect Federal regulation to affect all locations in the United States essentially equally – in other words, no matter where a plant is located, it is expected to comply with the same set of regulations. It turns out, however, that this is not always the case. Some geographic areas are subject to more stringent Federal regulations than others, in part because of physical characteristics of the location (e.g. regular thermal inversions) and higher concentrations of economic activity. It is also the case that Federal, state, and local governments have different, yet overlapping responsibilities, to protect citizens from harmful emissions. The main responsibility for implementing and enforcing compliance with Federal regulation lies with the states. State-level differences in regulation or in monitoring and enforcement can cause the costs of compliance to differ substantially by geographic location, potentially making some locations more or less appealing as a place to do business, particularly for plants in heavily polluting sectors of the economy.

In light of these spatial differences in the costs of complying with environmental regulations, we discuss three main questions in this survey: First, do environmental regulations affect the location decisions of polluting plants? Second, do states compete for polluting plants through differences in environmental regulation? Finally, do firms locate polluting plants disproportionately near poor and/or minority neighborhoods?

Early evidence indicated that environmental regulations did not play a very prominent role in firms' decisions of where to locate new plants. However, more recent studies have found evidence that differences in environmental regulation across states and counties matter for plant location. Furthermore, the effects of environmental regulations appear to differ across domestic and foreign firms. The finding that stringency of environmental regulations matters for plant location in the more recent literature is due to several factors. First, as better micro-level data has become available, studies have tended to rely less on cross-sectional data and more on panel data. Second, with richer data sets researchers have also come to rely on more sophisticated empirical techniques to address econometric issues such as endogeneity due to unobserved heterogeneity, omitted variable bias, and reverse causality. Third, environmental regulations have increased in stringency over time, making them potentially a more important factor in firm decision-making now than they were in the 1970s or 1980s.

Another strand of the literature has explored whether states compete for new businesses through differences in environmental regulation. This question is an extension of a similar line of inquiry in the tax literature. It seems intuitive that states will look for ways to attract new businesses that provide jobs for its residents and a source of revenue to supply public goods and services to its communities. However, if states are competing for new plants at the expense of environmental quality this may be a cause of concern – it is not obvious in this case that the state or local government is acting in the best interest of its residents. However, even with advances in data sets and empirical techniques, there is little evidence that U.S. states compete to attract polluting plants by lowering environmental standards. However, there is some evidence of a modest pollution haven effect at the country level due to relatively stringent environmental regulations in the United States that cause a shift in production to other countries.

Finally, economists have evaluated the question of whether firms locate plants disproportionately in poor and minority neighborhoods. In this case, after controlling for differences in costs across locations, a finding that firms do in fact locate new plants in poor and minority communities would run counter to the expected economic motivation: they would be trading profits for prejudice. Early studies asserted this to be the case. However, later evidence – again relying on richer data sets and more sophisticated empirical approaches – has found that the evidence is in fact much more mixed.

We organize the rest of the paper around these three questions, discussing the empirical evidence, analytic construct, and econometric techniques utilized in some detail. However, we begin with a general discussion of the theory of plant location, including the role of taxes and agglomeration economies, because the rest of the literature builds on this foundation.

1. The Theory of Plant Location

Existing location theory, including papers by Weber (1909), Marshall (1920), and Moses (1958), outline criteria for identifying a set of feasible location sites: the availability of natural resources, a reliable source of labor, proximity to potential markets, and other technical conditions. Once a firm has decided to open a new plant, the choice of a particular site from this feasible set is based on the principle of profit maximization.[2]

The basic analytic framework used by much of the literature is set out by Bartik (1985). He uses a Cobb-Douglas production function to derive a log-linear profit function where profits are a function of the market prices and quantities of inputs.   It is generally assumed that the revenue opportunities across locations are similar but that there is variation in costs that help determine where a firm decides to locate its plant. Wasylenko (1980) points out that the manufacturing and wholesale trade sectors tend to be more cost-oriented and therefore potentially more sensitive to differences across locations, while the retail and service industries tend to exhibit differences in revenues across locations. However, the bulk of the literature and this paper concentrate on the manufacturing sector since it is the primary focus of environmental regulation.

The firm location literature highlights two broad categories of costs that vary with location: transportation and production costs. Transportation costs include freight rates, distance to input markets, and distance to output markets. If transportation costs are an important component of a firm's costs, then a firm will want to locate where the

[2] This is consistent with the results of Schmenner's (1982) interviews with corporate CEOs who stated that first firms decide if they need to open a new plant and then they decide where to open it. The plant location literature does not typically model the first stage – the reason why a new plant is being opened (or an existing plant is being closed) – instead taking the new plants as given and attempting to predict where they locate.

appropriate transportation infrastructure exists – places with good roads, port access, and/or the existence of rail lines. The firm will also locate its plant in between its input and output markets in such a way as to minimize costs incurred from transporting inputs to the plant and from transporting the final good to market. Production costs include the factor prices and the quality of relatively immobile inputs such as land, labor, and proximity to raw materials.

While the early literature varies in terms of which of these factors are included in its empirical models, the results are fairly consistent across studies. For instance, wage rates have been found to be negatively related to plant location, as expected, but usually insignificant (Carlton 1983, Bartik 1985, Gray 1997, and Becker and Henderson 2000). Union presence has been found to be a significant deterrent of plant location (Bartik 1985, Gray 1997). Access to skilled labor and the concentration of manufacturing employment were positively related to the location of new plants (Carlton 1983, Becker and Henderson 2000), while energy costs had a large, negative effect (Carlton 1983). Access to highways has been found to be positively related to the likelihood of plant location (Bartik 1985, Lambert et al. 2006). Unemployment, which some have hypothesized is a signal of a readily available labor pool, and education levels, a proxy for the quality of the labor force, were positively related to plant location (Gray 1997, Lambert et al. 2006). Other papers have confirmed similar results for new foreign plant location decisions in the United States (Friedman et al 1992; Friedman et al 1996). Friedman, Gerlowski, and Silberman (1992) find that proximity to markets is particularly important in the location decisions of foreign manufacturing branch plants in the United States.

The literature also hypothesizes that costs related to taxes, complying with environmental regulations, and public utility fees matter in location decisions. We discuss the role of environmental regulations in plant location decisions in greater detail below. The evidence on the effect of differences in taxes across states or local municipalities on plant location decisions is mixed. Wasylenko (1980) notes that we should not expect firms to relocate (this could also mean locating new plants) due to differences in tax rates when the market is already in equilibrium. This is because, by virtue of being in equilibrium, the net return to capital is equal at the margin across locations. Otherwise, adjustments would continue to occur until equilibrium is restored. However, Wasylenko acknowledges that infra-marginal firms will move when the present value of the increase in profits due to lower taxes is greater than the cost of relocation.[3] Thus, all else equal, we would expect infra-marginal firms to locate plants in jurisdictions with lower taxes on capital. Early work, which mainly focused on intra-metropolitan location decisions, found little evidence that differences in taxes matter (see Newman and Sullivan 1988). However, Wasylenko (1980) found that if locations that could not be chosen due to zoning laws are omitted from the set of feasible locations, then in some industries taxes can affect intra-metropolitan location decisions (in his case, differences in taxes mattered for manufacturing and wholesale trade but not for construction, retail trade, finance or services). Likewise, Bartik (1985) found that taxes were significantly related to plant location decisions, though their influence was described as modest. Carlton (1983), Gray (1997), and Lambert et al. (2006) found that taxes were not significantly related to plant location for all plants, though Gray found that they matter for plants in highly polluting industries. Likewise, Friedman et al (1996) found that taxes do not matter for new foreign plants location decisions in the United States. On the other hand, Coughlin et al (1991) found that taxes matter, but they pool new plants with mergers and acquisitions in their study.

Finally, it is important to consider any offsetting location benefits from agglomeration economies such as a shared infrastructure, information, or labor pool. Agglomeration economies have been shown to play a consistently important role in plant location decisions. Fujita et al. (2001) notes that - aside from variation in natural resources, population density, and other fixed attributes - one would expect economic activity to be spread relatively uniformly across space. However, we do not observe this to be the case. Instead we observe the self-reinforcing concentration of economic activity as firms are attracted to larger markets and workers are drawn to areas with greater opportunities for employment.

Marshall (1920) noted three reasons why economic activity tends to be spatially concentrated, also referred to as agglomeration economies or external (to the plant) economies of scale: knowledge spillovers; better matching between firm needs and worker skill sets when plants are located near larger labor markets; and backward and forward linkages in large markets. However, as Fujita et al. (2001) point out, there is a certain circular logic to these reasons: spatial concentration begets more concentration. The result is that relatively small differences in the economic size of two locations can result in relatively large differences over time that continue to persist. This explanation relies fundamentally on the assumption of increasing returns. Without such an

[3] Infra-marginal firms have access to some specialized resource, which allows them to make positive profits even in the long-run.

assumption, a firm would locate plants near each market it supplies. Instead, we observe that the firm makes plant location decisions based on a combination of economies of scale, transportation costs, and factor mobility.[4]

Empirical studies demonstrate that potential spillovers are greater among similar plants (i.e. in the same industry) than they are for dissimilar plants (i.e. in different industries). For instance, Henderson (2003) finds that local information spillovers matter for the two types of industries he examined, high-tech and machinery. In particular, Henderson found that single plant firms benefit more from being located near other plants in the same industry than plants owned by corporations, while there is little evidence of an external benefit from locating near plants outside a plant's own industry. Similarly, Rosenthal and Strange (2003b) find that, for the six industries they studied, own-industry effects are more important than other-industry effects at the margin.

2. How do Environmental Regulations Affect Location Decisions for Polluting Plants?

Beginning in the 1980s, researchers began to evaluate whether, in addition to the production and transportation costs typically considered important, differences in the costs of complying with environmental regulations affected where a firm located a new plant. Differences in regulatory compliance costs are driven by both differences in stringency and enforcement by location. This is due, in part, to varying levels of enforcement across the states. However, even at the Federal level, environmental regulation can vary substantially by location. For example, since the 1977 Clean Air Act Amendments the U.S. EPA has been required to determine annually whether counties are in attainment with National Ambient Air Quality Standards (NAAQS) for six criteria air pollutants: particulate matter (PM), sulfur dioxide (SO_2), nitrous oxides (NO_x), ozone (O_3), carbon monoxide (CO), and lead (Pb). If a county is found out-of-attainment, its plants face more stringent regulatory requirements. In this section, we discuss the basic analytic framework for considering differences in environmental regulation as a potential factor in the plant location decision; econometric techniques that have been used to estimate the impacts of environmental regulation on plant location; how compliance costs have been measured in the literature; and finally, the empirical evidence.

[4] See the review by Rosenthal and Strange (2003a) for a detailed discussion of evidence in support of the various explanations for why agglomeration economies exist.

Analytic Framework and Empirical Techniques

Levinson (1996a), building on the work of Bartik (1988) and others, provides an instructive analytic framework for evaluating plant location decisions in the context of varying environmental regulatory costs. A firm is assumed to have an unobserved profit function for each possible location that is a function of location-specific variables such as factor prices, fixed factors (land, labor) and the stringency of environmental regulation. Levinson models firm *i* as considering the location of a new plant according to an unobserved profit function for each feasible neighborhood *j* :

$$\pi^*_{\mathrm{ij}} = g\left[\mathrm{f_i}\left(p_{\mathrm{j}}, x_j, r_j\right), s_{ij}\right]$$

where p_j is neighborhood-specific input prices, x_j is neighborhood-specific fixed inputs, r_j is the costs of complying with environmental regulation, and s_{ij} is other firm or plant-specific factors that may vary by neighborhood.

Remembering that profits are nothing more than total revenues less total costs, an increase in the cost of location – be it from an increase in input prices or the stringency of environmental regulation - implies a decrease in profits. An increase in the availability of inputs implies an increase in profits. Without price rigidities or other market failures in the input market, an increase in the availability of inputs will also result in a decrease in their price. Thus, input availability can be eliminated as a separate variable in the latent profit function, yielding:

$$\pi^*_{\mathrm{ij}} = g\left[\mathrm{f_i}\left(p_{\mathrm{j}}, r_j\right), s_{ij}\right]$$

Since the profit function in each location is not observable, many papers (for example, Bartik 1988; McConnell and Schwab 1990; Finney 1994; Friedman et al. 1992; Levinson 1996a, Wolverton 2009a, 2009b) rely on a variation of binary or multiple choice models where the dependent variable is given a value of one if the neighborhood contains a plant and a value of zero otherwise. In a binary choice approach, the actual location is compared to either the average characteristics of all other sites not chosen or to one other possible location alternative. Discrete, multiple choice models such as a conditional logit model allow for a comparison of the actual location choice to more than one alternative on the basis of choice and plant-specific attributes.

More recently, other empirical approaches have been explored to avoid challenges inherent in the conditional logit approach, including Poisson regression and difference-in-differences approaches. These challenges include possible correlation across alternative locations, feasible location alternatives that outnumber observed plant locations, and endogeneity due to inadequately controlling for unobserved factors related to plant location. We discuss each briefly below as well as the alternate empirical approaches suggested to mitigate these complications.

One key challenge of the conditional logit approach is that it requires the assumption of independence of irrelevant alternatives (IIA), which does not allow for correlation across subsets of choices. If one believes that profits are correlated across locations—for instance, states or counties in a particular region have correlated disturbance terms due to regional market trends then the IIA assumption is inappropriate. Bartik (1985) notes that one way to relax the IIA assumption is to include regional dummy variables in the conditional logit estimation. At the state level it appears that correlation between states in a region may be a concern (Bartik 1985, Levinson 1996a). McConnell and Schwab (1990) include dummies to allow for correlation between counties in four broad regions and find that the coefficients are not significant. Later studies (see Gray 1997; Becker and Henderson 2000; List, McHone, and Millimet 2003; Millimet and List 2004; and Condliffe and Morgan 2009) that rely on panel data often include fixed effects to isolate the effects of changes over time from inherent differences in location.

Another possible alternative to relax IIA is a nested logit (McFadden 1978; Guimaraes et al. 1998). In a nested logit approach, firms are modeled as first selecting a city or region, and then selecting a particular location within that city or region as determined by profit maximization. In this way, IIA is maintained across locations within a particular city or region, but this assumption is relaxed across cities or regions. That said, the nested logit approach has rarely been used in practice to evaluate plant location decisions (see Hansen 1997 for one example).

Guimaraes et al. (2003) point out that these approaches to relaxing IIA - regional dummies or nesting - are only valid if the researcher assumes IIA still holds between subsets of choices. However, it seems likely that the more disaggregated the set of locations from which a plant chooses, the more likely that they will be correlated. Guimaraes et al. (2003) demonstrate the equivalence between a Poisson and conditional logit approach but argue that a Poisson approach with fixed effects is a better way to address the IIA problem than the inclusion of regional dummy variables.

Another key challenge when using a conditional logit is how to defensibly restrict the set of alternatives so that estimation is possible. Typically, the number of possible locations from which firms can choose (the dependent variable) is far larger than the number of firms making these choices (the number of observations). Some studies address this issue by defining the location choices at an aggregate enough level that all alternatives can be included. For instance, Levinson (1996a) allows each firm to choose to locate in one of the 48 continental states. However, as Guiramaes et al. (2003) point out, many factors deemed important to the plant location decision such as labor market conditions and agglomeration economies may vary at a more disaggregated level and would therefore be missed at the state level. Finney (1994) analyzes a firm's decision to locate a plant in one of ten Houston school districts, which is more likely to capture some of this variation.

McFadden (1978) suggests one technique for reducing the number of alternatives within the conditional logit framework: Define the reduced choice set for the firm as the selected location and a given number of randomly selected alternatives from the full choice set. He shows that this technique yields consistent estimates. McConnell and Schwab (1990), Friedman, Gerlowski, and Silberman (1992), and Wolverton (2009a, 2009b), among others, use this technique. Both the Poisson and difference-in-differences approaches effectively skirt this issue by asking the question in a somewhat different way. For instance, a Poisson regression examines the relationship between the number of facilities sited in a particular location during a particular time period and various location-specific attributes. Guimaraes et al. (2003) argue that the Poisson approach is likely to be more efficient since less information is omitted from the regression analysis. Becker and Henderson (2000), List et al. (2003), and Wolverton (2009a, 2009b) all explore this alternative to the conditional logit, though Henderson (2000) and List et al. (2003) use a fixed effects Poisson model with panel data.

Another concern is that the regression adequately accounts for important differences across feasible alternatives that could affect location choice. Differencing out some of the variation through either a fixed effects or difference-in-differences panel-based approach reduces the potential for omitted variable bias by reducing the number of explanatory factors that need to be included in the regression (Gray 1997; Becker and Henderson 2000; List, McHone, and Millimet 2003; and Condliffe and Morgan 2009). A fixed effects model differences out all cross-sectional variation across observations and instead focuses on explaining within-observation variation over time. For this reason, fixed effects models usually do not focus on explaining an individual plant's location decision, but rather the number of plant births and/or deaths in a particular location.

A difference-in-differences regression also removes any observation-specific effects but it goes one step further and differences out average effects over time as well. It does this using a comparative static approach. It looks at the number of new plants over time as a function of an exogenous change that varies by region. In this context, the exogenous change is often an environmental regulation that implies a change in compliance costs in some locations. The researcher then examines how the distribution of economic activity changes in response to this exogenous shock to re-establish a new equilibrium. A major advantage of this approach is that any observation or site-specific characteristics that can be shown, or sensibly argued, to be constant across the time period of interest can be omitted. This substantially reduces the number of variables included in the empirical model without introducing omitted variable bias. A major disadvantage is that the regression focuses only on explaining a potentially small proportion of the total variation, the intersection between within-observation variation and deviations from the average effect over time. As long as the exogenous shock is strong, its effects can still be readily identified and measured. However, if it is difficult to identify when the shock occurs, and which plants are affected by it, then other problems could be introduced into the regression such as measurement error. Both Greenstone (2002) and Millimet and List (2004) use a difference-in-differences approach.

Given the spatial nature of the location decision and strong evidence of agglomeration economies, it is somewhat surprising that spatial econometric techniques have rarely been applied in this context.[5] The characteristics of a particular location may look more similar to those of nearby locations but less similar to those further away geographically. Treating each location as identical without accounting for the fact that some are closer alternatives than others may bias the results. For instance, the existence of near neighbors with highly skilled labor pools could make it more probable that a plant locates in a particular location. As Anselin (1988) explains, spatial dependence can occur in the error terms when spatially correlated explanatory variables are omitted from the model or when the dependent variable is itself spatially correlated, which could be the case if the dependent variable is influenced by location-specific external pressures (for example, a county that does not strictly enforce its environmental standards could have a set of plants with poor environmental

[5] Lambert et al (2006) use a spatial Poisson model to examine spatial distribution of new manufacturing plant announcements in Indiana, but do not include environmental regulation as a variable. They find that spatial weighting amplifies their original results. Gray and Shadbegian (2007) use spatial econometric techniques to examine factors affecting the environmental performance, as measured by air pollutant emissions and regulatory compliance, of 521 plants located within 50 miles of three U.S. cities.

performance). Spatial econometric techniques allow the researcher to explicitly account for the possibility of spatial dependence, though they are subject to the same potential disadvantages as fixed effect or difference-in-differences approaches because the remove some variation from the regression.[6]

Measuring the Stringency of Environmental Regulations

Measuring the level of environmental stringency in any meaningful way is quite difficult, whether at the national, state or local level. One of the main difficulties is that there is tremendous variation among industries (and between plants within industries) in the degree to which they must comply with various Federal, state, and local regulations. Furthermore, any particular polluting plant usually must comply with a myriad of air, water, and/or solid waste regulations. The difficulty in measuring the stringency of environmental regulation has led researchers to use many different proxy measures.

Levinson (1996a) notes that in the academic literature quantified measures of regulation fall into three classes: qualitative indices, quantitative measures of enforcement, and quantitative measures of compliance costs. We have also included a fourth category, compliance with National Ambient Air Quality Standards (NAAQS). We list the main measures used in the academic literature in each of these categories in Table 1. We describe and then briefly discuss the advantages and disadvantages of each of these categories below.

There are several qualitative indices that have been used in the literature as measures of environmental stringency. Levinson (1996a) includes three such measures: the Conservation Fund (CF) index; FREE index (Fund for Renewable Energy and the Environment 1987); and Green Index (Hall and Kerr 1991). However, several other researchers have also used the League of Conservation Voters (LCV) index, List and d'Arge index and conservation membership as measures of environmental stringency.

In general, each of these qualitative indices attempts to aggregate a multitude of state environmental characteristics (e.g. state hazardous waste laws, expenditures to monitor and enforce pollution abatement, etc.) to provide an overall stringency measure of a state's environmental laws. For example, Hall and Kerr's "Green Index" is intended to measure the stringency of state environmental regulations based on a set of more than

[6] Anselin (1988, 1991) suggests one way to weight alternatives by a measure of its "distance" from its neighbors to explicitly account for spatial correlation, but there are many other ways of accounting for spatial dependence that are discussed in the literature (for instance, see Folmer and Oud 2008).

70 specific indicators, such as the presence of state laws for recycling and superfund sites.[7] Likewise, the LCV index is a scorecard for each member of Congress (House and Senate) that tabulates by state the votes on environmental issues back to the early 1970s. The types of qualitative indices described here have the advantage of breadth – that is they try to capture more than the stringency of a single regulation, which is appropriate since nearly all polluting plants will need to comply with many regulations. However, it is sometimes difficult to interpret the meaning of a regression coefficient for these qualitative indices. These types of indices may also be too general to measure with precision a state's regulatory stringency. For example, Levinson (1996a) finds that three qualitative measures – the CF, FREE and Green indices – all have a negative impact on plant location, but only the FREE index has a significant effect.[8]

Researchers such as Gray and Shadbegian (2010), List and Co (2000), and Bartik (1988) have used various measures of state-level spending on pollution abatement and conservation of natural resources to measure the stringency of environmental regulation. These expenditures are predominantly for enforcement (see our discussion of environmental federalism), research and development, technical assistance, and environmental quality planning and are normalized by variables such as manufacturing employment or state population. Levinson (1996a) and Gray and Shadbegian (2010) use two additional measures of state enforcement activity: state environmental monitoring employment and enforcement activity, respectively. Levinson proxies a state's ability to monitor polluting plants with the number of employees in state environmental agencies, normalized by the number of manufacturing plants. Gray and Shadbegian measure enforcement activity as the total number of air inspections at manufacturing plants normalized by the number of manufacturing plants. These measures have the same advantages and disadvantages as the above mentioned qualitative indices – that is they are general enough to capture more than the stringency of a single regulation but empirical results based on them are somewhat difficult to interpret.

Another common measure of regulatory stringency, which is used by Bartik (1988), Levinson (1996a), List and Co (2000), and Gray and Shadbegian (2010), is the direct costs of complying with regulations. While each of these studies measure compliance costs in

[7] Some researchers like Levinson (1996a) have excluded some of these 70 + measures when employing Hall and Kerr's Green Index.

[8] We interpret Levinson's results as evidence that his qualitative index measures lack the necessary precision to capture state-level regulatory stringency (as opposed to there being no affect of regulatory stringency on plant location), since more recent studies, using measures of regulatory stringency with time variation, generally find statistically significant negative impacts of regulatory stringency on plant location (see below).

a slightly different way, they all rely on data from the U.S. Census Bureau's Pollution Abatement Costs and Expenditures (PACE) survey. The PACE survey reports the dollar amount spent on pollution abatement operating costs by manufacturing establishments. Researchers have typically aggregated across industries to provide a measure of how much money manufacturing establishments must spend to comply with environmental regulations in each state.[9] Each of the above studies normalizes aggregate compliance costs by some measure of the size of the manufacturing sector (e.g. total value of manufacturing shipments, the number of production workers etc). The PACE survey might seem to provide the perfect measure of regulatory stringency as it indicates the total cost of complying with all environmental regulations, but as Levinson (1996a) points out states that attract polluting industries will generally have higher abatement costs regardless of the stringency of the state's environmental standards. Several researchers including Levinson (1996a), and Gray and Shadbegian (2010) have attempted to eliminate this problem by adjusting state-level pollution abatement operating for a state's industrial mix.[10,11]

All the stringency measures we have described so far are measured at the state-level. However, a state's environmental regulations can also vary significantly within the state, which would bias the impact of the state-level measures towards zero (referred to as attenuation bias). In spite of this limitation, a case can be made that these state-level measures of environmental stringency still contain a relatively high "signal-to-noise" ratio. In other words, it can be argued that it is always easier to open a plant in states with less stringent environmental regulations than in states with more stringent regulations. Thus, the variation in these state-level measures of stringency would contain mostly "signal" and measurement error would only be a small fraction of the variation.

[9] The PACE survey is conducted at the level of an individual manufacturing establishment: it tells us how much individual manufacturing plants actually spend to bring themselves into compliance with environmental regulations and thus could be used to construct sub-state measures of environmental stringency. However, this requires access to the confidential microdata at the Census Bureau's Center for Economic Studies or one of the U.S. Census Bureau's Research Data Centers located in various areas around the United States. The most disaggregated level of geography publicly available is at the state level.

[10] The PACE survey has also been criticized for potentially under estimating the costs of complying with environmental regulations (see Gray and Shadbegian (1995, 2002, 2003); Shadbegian and Gray (2005); Becker and Henderson (2000)). Even if true, as long as the effect is monotonic it will not change the relative state rankings.

[11] In a more recent paper, Levinson (2001) uses aggregate PACE data from 1977-1994 to construct an index of state environmental compliance costs that also accounts for a state's industrial mix across time.

Currently the literature uses only one measure of the stringency of environmental regulation, compliance with the NAAQS, which captures within-state variation in the stringency of environmental regulation.[12] Manufacturing plants located in non-attainment counties are likely to face substantially stricter regulation (e.g. new plants opening in nonattainment counties are subject to the lowest achievable emission rate without consideration of cost, with further limitations on new plant openings and modifications of existing plants with stricter enforcement). Thus, environmental regulations may be more stringent in some parts (non-attainment areas) of a state than other parts (attainment areas). There are three main criticisms of using the designation of non-attainment status as a measure of environmental stringency. The first is that it only applies to air regulations and, in particular, air regulations of criteria pollutants. The second is that it is potentially endogenous. As List et al (2003) note, since "… the location of new polluting plants in areas currently in attainment leads to higher pollution levels, and subsequently more stringent regulation if the attainment status threshold is bypassed, the assumption that attainment status is strictly exogenous is not trivial."[13] The third, and somewhat less important criticism, is that the effects of attainment status should depend on whether the plant emits the pollutant for which the county is out of attainment, since counties can be in non-attainment for one criteria pollutant and not for others. However, most manufacturing plants emit more than one criteria pollutant, so if the county is out of attainment with respect to one criteria pollutant plants in that county are likely to face more stringent regulations regardless.

[12] A recent study by Becker (forthcoming), using establishment-level PACE data, estimates a county-level index of environmental compliance costs similar to Levinson's (1996a) state-level index and finds that it can explain roughly 10-20 times more of the variation in compliance costs than state-level variation alone. Thus, Becker's results show that it may be important to consider variation in regulatory stringency below the state level. The county-level index will be made available by the author in the future.

[13] Note the endogeneity of plant location and attainment status should depend on which industries the new plants are in and the size of the new plants relative to the size of the region (e.g. some counties are much larger than other counties and therefore could potentially absorb more emissions without causing it to becoming out of attainment).

Table 1: **Measures of the Stringency of Environmental Regulations**[14]

Stringency Measure	Source	Studies
Indices:		
Conservation Foundation Index	Duerksen (1983)	Levinson (1996a)
FREE Index	Fund for Renewable Energy and the Environment (1987)	Levinson (1996a)
Green Index	Hall and Kerr (1991)	Levinson (1996a); Gray (1997); Gray and Shadbegian (2010)
List and d'Arge Environmental Protection Index	List and d'Arge (1996)	List and Co (2000)
LCV Index	League of Conservation Voters	Gray (1997); Gray and Shadbegian (2010)
Conservation Membership	Hall and Kerr (1991)	Gray (1997); Gray and Shadbegian (2010)
Enforcement:		
Regulatory Expenditures	Council of State Governments	Bartik (1988); Gray (1997); List and Co (2000); Shadbegian and Gray (2010)
Regulatory Employment	National Governors Association	Levinson (1996a)
Inspections	EPA	Gray (1997); Gray and Shadbegian (2010)
Compliance Costs:		
Total Abatement Operating Costs	Pollution Abatement Costs and Expenditures Survey (1973-1994, 1999, 2005)	Bartik (1988); Levinson (1996a,2001); Gray (1997); List and Co (2000) ; Gray and Shadbegian (2010)
Industry Specific Abatement Operating Costs		Levinson (1996a)
NAAQS Attainment Status:		
PM	EPA	Bartik (1988)[15]; Kahn (1997); Greenstone (2002)
SO_2	EPA	Bartik (1988); Greenstone (2002), Wolverton (2009a, 2009b)
NO_x	EPA	Greenstone (2002)
Ozone	EPA	McConnell and Schwab (1990); Becker and Henderson (2000); Greenstone (2002); Greenstone (2002) List, McHone, and Millimet (2003); Millimet and List (2004); Condliffe and Morgan (2009).

[14] This table only includes regulatory stringency measures that are used by studies referenced in this paper.

[15] Bartik, unlike the other studies in this table that incorporate NAAQS attainment status, does not use a dummy variable indicating an area is in or out of attainment because his study precedes EPA's assignment of such county designations. However, Bartik uses energy prices, the level of the state PM standard, and the required percentage reduction in PM.

Empirical Evidence

One question of interest to policy-makers and academics is, what impact, if any, does environmental regulation have on the location of economic activity? As previously noted, environmental regulation is only one of a large set of factors (including quality of labor and costs of other inputs) that potentially impact a firm's profits at a particular location. Thus, the role that environmental regulations play in the decision to open a new plant or relocate an existing one to a particular location depends on how compliance costs compare to the costs (including relocation costs for existing plants) and benefits of all other factors at the current and alternative locations (Jeppsen and Folmer 2001). Jeppesen and Folmer (2001) note that the impact of environmental regulation on the location of economic activity (within a country or internationally) is far from conclusive. Based on a thorough literature review they argue that there are a number of potential reasons for the contradictory results observed in the literature including the type of data set used (e.g. panel versus cross-sectional), the sectors analyzed (e.g. dirtier versus cleaner), the measure of environmental stringency (e.g. private pollution abatement costs versus attainment status), econometric methodology (e.g. conditional logit versus Poisson fixed effects), and unit of analysis (e.g. countries, states, counties). Below we review the literature to shed some light on this debate.

Early Cross-Sectional Studies

The relative importance of environmental compliance costs to plant location decisions has many similarities to the literature on taxes. Early studies by researchers such as Carlton (1983), Bartik (1988), McConnell and Schwab (1990) and Levinson (1996a) find little evidence that environmental regulatory differences factor significantly into firms' decisions of where to locate new plants. These studies all use cross-sectional data and a conditional logit estimator, but they differ in their sample of plants, time period studied, and measures of environmental regulatory stringency. In spite of the differences between these studies all find similar non-results. Below we describe these early studies and then attempt to explain their non-result with regard to environmental regulation by examining more recent studies that control for unobserved location heterogeneity (a form of endogeneity), something early studies were unable to do because of the cross-sectional nature of their data.

Bartik (1988) was one of the first researchers to use micro-data to examine the impact of state-level environmental regulations on plant location decisions. The decision to focus on the location of new plants, as opposed to existing plants, is important. Bartik argues that the location decision for a new plant should be more sensitive to the stringency of environmental regulations than for existing plants because new plants face stricter regulations while existing plants have limited mobility due to existing capital investment. Thus focusing on new plants should increase the likelihood of detecting even small effects that variation in the stringency of environmental regulations has on plant location. Since there is no direct measure of state environmental regulatory stringency, Bartik uses six measures of regulatory stringency – two measures of state water pollution regulations and four measures of state air pollution regulations that are based on regulatory expenditures and abatement costs (see Table 1).

Bartik applies a conditional logit model to a cross-section (1972-1978) of Fortune 500 firms and does not find any systematic negative impact of state environmental regulation on the location of new branch plants. In fact, in some cases he finds a positive, though insignificant, impact. Bartik's results may not be too surprising given his earlier work. Bartik (1986) showed that, to a first-order linear approximation, the effect of any particular input on profits is proportional to that particular input's factor share. Assuming firms locate plants to maximize profit and given that the cost of complying with environmental regulation is a small fraction of total cost, we should expect environmental regulations to only have second order effects on plant location. On the other hand, Bartik's lack of evidence that environmental regulation affects plant locations could be due to his period of study (i.e. relatively lax environmental regulations during most of 1972-1978) or the use of cross-sectional data (which does not allow him to control for unobserved state characteristics).

Two other early studies by McConnell and Schwab (1990) and Levinson (1996a) use a similar empirical approach to Bartik – both of these studies also apply a conditional logit model to cross-sectional micro-data. However, they use different data sets, employ different measures of environmental regulation, and do so during time periods in which environmental regulation became more stringent. Levinson's study is more similar to Bartik than is McConnell and Schwab as he examines the impact of state-level environmental stringency on the siting decisions of a broad set of new manufacturing plants between 1982 and 1987, while McConnell and Schwab focus on the automotive industry. Noting how difficult it is to measure the stringency of environmental regulation, Levinson employs six different measures including three qualitative indices (see Table 1 above). Levinson does not find much systematic evidence that state-environmental stringency has a negative effect on the location choices of most manufacturing plants. But his results do suggest that branch plants of large manufacturing firms are more sensitive to differences in state-level environmental stringency than manufacturing plants in general. However, these effects tend to be small and not statistically significant. Moreover, Levinson does not find any evidence that the relative degree of aversion to regulation increases in pollution intensive industries.

McConnell and Schwab (1990) focus on plant openings in the automotive industry, which allows them to use a more precise measure of the stringency of environmental regulation. They use county-level attainment status with the ozone NAAQS, since volatile organic compounds (VOCs) emissions are a major problem for the automotive industry and are one of the major sources of ambient ozone. Despite this more precise measure of environmental regulation, McConnell and Schwab also did not find any evidence that the stringency of environmental regulation had a negative impact on plant location. In fact, they found it had an insignificant positive effect on plant location. However, they find evidence suggesting that, at the margin, firms were discouraged from opening plants in ozone non-attainment areas with the highest ambient concentration of ozone.

Recent, Panel Data Studies

Later studies tell a different story. Gray (1997), Becker and Henderson (2000), List, McHone, and Millimet (2003), Millimet and List (2004), and Condliffe and Morgan (2009) use panel data to examine the impact of environmental regulation on plant location. By relying on panel data these studies can control for unobserved location heterogeneity (a form of endogeneity), which the previous studies could not do since they were limited to cross-sectional data.[16] All of these studies, except Gray (1997), use the same measure of environmental regulation – ozone attainment status – and four of them, Gray (1997), Becker and Henderson (2000), List, McHone, and Millimet (2003), and Condliffe and Morgan (2009) - use Poisson count models. Millimet and List (2004) use a propensity score matching difference-in-differences estimator. Jeppensen et al (2002) point to several reasons why these later studies find that environmental regulatory costs significantly influence plant location. Based on a meta-analysis of 11 studies, they find that studies based on panel data tend to find greater evidence of the importance of environmental regulation on plant location. They also find that studies that rely on county measures of environmental regulatory costs such as attainment status show a larger influence than those at a more aggregate level (e.g. the state). We discuss several of these studies in greater detail below.[17]

[16] Gray (1997) also uses a linear regression model and a conditional logit model. Also Gray does not control for unobserved location heterogeneity in his Poisson regressions.

[17] Greenstone (2002) does not examine impact of environmental regulations on plant location decisions, instead focusing on their impact on the economic activity of polluting plants. In particular, Greenstone examines the effect of county nonattainment status for PM, SO_2, O_3, and CO on employment, capital stock, and output. Greenstone, like Becker and Henderson (2000), merges county attainment status with establishment level data from Census of Manufacturers (1972-1987). However, Greenstone includes all manufacturing plants in his sample. Using a difference-in-differences model, which includes plant, industry-by-period, and county-by-period fixed effects, Greenstone finds that nonattainment counties (relative to attainment ones) lost roughly 590,000 jobs, $37 billion in capital stock, and $75 billion (1987 dollars) of output in pollution-intensive industries.

Gray (1997) uses confidential establishment level data from the Census of Manufacturers for 1963-1987 to test whether state-level environmental regulation had an impact on the location of new manufacturing plants. Gray finds that, after controlling for the typical factors expected to affect plant location, states with stricter regulations, more political support for environmental regulation, and greater abatement costs tend to have lower birth rates of new plants over his sample period. Further, Gray finds that with increasingly strict Federal regulation during the 1980s the impact of the stringency of state regulations on plant location diminished over time.

Becker and Henderson (2000), like Gray (1997), use confidential establishment level data from the Census of Manufacturers (1967-1992) to examine the impact of environmental regulation on a firm's plant location decision. Unlike Gray who considers all of manufacturing, Becker and Henderson concentrate on four major polluting industries (industrial organic chemicals, metal containers, plastics, and wood furniture) and use ozone attainment status as their measure of environmental regulation. They find that counties in non-attainment attract 26-45 percent fewer plants. In other words, the stringency of environmental regulation changes the pattern of new plant openings by inducing a reallocation of the stock of plants towards attainment counties. They also find that the effect of regulation on new plant openings increases with the extent of non-attainment with ozone air quality standards. Finally, Becker and Henderson find that the net present value of a representative new plant (in one of their four heavily polluting industries) that locates in a nonattainment county could decline by 13–22 percent.

In a similar study to Becker and Henderson (2000), Millimet and List (2004) examine the effect that the stringency of environmental regulation has on the location of new plants and the exit of existing plants in pollution-intensive industries across counties in New York from 1980 to 1990. A novel feature of this study is that they allow the impact of environmental stringency to vary spatially, by using a difference-in-differences, semi-non-parametric propensity score matching estimator. Allowing environmental stringency to vary spatially helps to avoid masking effects when pooling across diverse counties. Millimet and List find that the impact of stricter environmental standards varies widely across counties and that much of the variation can be accounted for with observable county-level attributes. In particular, they find that ozone non-attainment counties with higher manufacturing employment, higher average manufacturing wages, higher unemployment rates, and smaller populations lose fewer plant openings due to county attainment status, which indicates that these factors help to offset some of the costs of stricter environmental standards. Furthermore, non-attainment counties with higher manufacturing employment, higher per capita income, smaller population, and lower property taxes experience fewer exits due to their attainment status.[18]

Condliffe and Morgan (2009) also study the impact of environmental regulation on plant location, but they use a unique panel data set on a census of establishment births and deaths across all counties in the continental United States developed by the U.S. Census Bureau's Department of Statistics of U. S. Business. The data set contains the number of annual births and deaths in each county from 1996-1998 by three digit industrial classification. Condliffe and Morgan exploit the industry classification to disaggregate births and deaths into low-, medium-, and high-polluting manufacturing industries, which allows them to examine whether the effect of environmental regulation varies across the pollution intensity of establishments as previously done by Levinson (1996a), Gray (1997), Greenstone (2002), and Millimet and List (2004). The main finding of their study is that ozone nonattainment status has a statistically negative effect on plant births, and that most of this effect is concentrated in pollution-intensive manufacturing plants.

List, McHone, and Millimet (2003) examine the impact of ozone nonattainment, not on the location of new plants, but on the relocation of existing plants in New York state in industries that are major emitters of NOx and VOCs (important pre-cursors to ozone). In particular, they use an annual county level panel data set for all 62 New York counties from 1980-1990 and find evidence that when a county moves from attainment to nonattainment (and vice-versa), all else equal, it experiences over a 50 percent decrease (increase) in the flow of newly relocating plants. In other words, counties with more stringent environmental regulations attract significantly fewer relocaters than counties with less stringent environmental regulations. As pointed out by Henderson (1996), the attainment status of a county may not be strictly exogenous. As a robustness test, List et al estimate a two-stage semi-nonparametric propensity score matching model, which has been shown to provide a more precise estimate of potentially endogenous treatment effects than standard parametric models, and find similar results to their Poisson model.[19]

Gray and Shadbegian (2010) examine the impact of state environmental regulatory stringency not on plant location, but on a firm's allocation of production across states. They note that it is unclear whether differences in environmental regulation will affect a firm's allocation of

[18] In a similar study, with the same data set, List et al (2003), find that ozone nonattainment has a statistically significant negative effect on the location decisions of pollution-intensive plants.

[19] Henderson (1996) finds that over time pollution-intensive industries tend to move to areas which are consistently in attainment, seemingly to avoid greater regulatory scrutiny. Kahn (1997) finds that manufacturing plants are less likely to close in PM nonattainment areas, but that growth in employment, conditional on a plant not closing, is significantly lower in PM non-attainment areas.

production across states more than plant openings and closings. It could be easier to shift production among existing plants than opening or closing plants, making such shifts relatively *more* sensitive to differences in regulatory stringency. However, many air quality regulations impose stricter standards on new plants and exempt older plants, making production shifts among existing plants more costly. In their sample of pulp and paper mills, shifts in production between existing plants accounts for approximately two-thirds of the overall changes in firms' production shares over time, whereas plant openings and closings together account for only one-third. Gray and Shadbegian estimate a conditional logit model of the firms' production shares in each state on confidential plant-level Census of Manufacturers data for the pulp and paper industry during 1967-2002. They find, using various measures of regulatory stringency (see Table 1) that, all else equal, firms produce less output in states with more stringent regulations, but that firms with high compliance rates are less sensitive to regulatory stringency than firms with low compliance rates. This result implies that firms that find it less costly to comply with environmental regulation do not avoid producing in states with more stringent regulations as much as firms with higher compliance costs.

Foreign Plant Location Decisions

Recently a parallel literature has examined the relative importance of environmental regulations to the plant location decisions of foreign multinational corporations. Studies in this area include List and Co (2000), Keller and Levinson (2002), and List, McHone and Millimet (2004). List and Co (2000) examine the impact U.S. state environmental regulations have on foreign multinational corporations' new plant location decisions between 1986 and 1993. Using four different measures of regulatory stringency – two measures of state spending on regulation and enforcement, private pollution abatement costs, and the List and d'Arge index – they find consistent evidence that foreign multinational corporations avoid siting new plants in states with more stringent pollution regulations.

Measuring the stringency of environmental regulation as aggregate state pollution abatement costs from the PACE survey adjusted for each state's industrial composition, Keller and Levinson (2002) also find that states with higher compliance costs between 1977 and 1994 attracted relatively fewer new, polluting foreign plants. Other studies, using international data sets, have also tested for the impact of environmental regulation on foreign direct investment, but Keller and Levinson believe that by examining differences in foreign direct investment across U.S. states, they increase the likelihood of accurately measuring the effect of differences in regulatory stringency. Henderson and Millimet (2007) test the robustness of Keller and Levinson's (2002) results to nonparametric specifications and find that there is substantial heterogeneity in the effect of abatement costs on foreign plant location across states and that, while higher compliance costs are, on average, negatively related to foreign plant location, the effect is smaller than suggested by Keller and Levinson and not robust to all specifications.

List, McHone and Millimet (2004) examine the location decisions of both domestic and foreign firms in one empirical model. Simultaneously examining the location decision of domestic and foreign firms allows List et al to compare the relative sensitivity of domestic and foreign plant location decisions to variation in environmental stringency. Jeppensen et al (2002) suggest, based on their meta-analysis, that foreign firms are likely to be more sensitive than domestic firms to differences in environmental regulations when making plant location decisions. List et al examine whether this is the case using the same data set, empirical models, and measure of regulatory stringency (ozone nonattainment) as List et al. (2003). Similar to List et al (2003) they find that ozone nonattainment has a significantly negative effect on the births of domestic-owned plants, but they find it has little or no impact on the births of foreign-owned plants. This is an important result because, as has been well-documented (see Howenstine and Zeile 1994, Figlio and Blonigen 2000), foreign plants also normally create more jobs and raise local wages by more than domestic plants.[20]

This section has demonstrated that, while early evidence indicated that environmental regulations did not play a very prominent role in firms' plant location decisions, later studies found that differences in environmental regulation matter for plant location. Improvements in data, empirical technique, and the increasing stringency of environmental regulations over time are the main drivers behind the evolution of the plant location literature. Our review also indicates a few areas where additional research is needed. For instance, a few studies find that domestic and foreign plants vary in their sensitivity to environmental regulations in siting decisions, but shed little light on why this might be the case. Likewise, the literature could benefit from the incorporation of spatial effects into plant location studies.

3. Do Governments Compete on the Basis of Environmental Regulation to Attract Polluting Plants?

[20] Friedman, Gerlowski, and Silberman (1992) examine the location decision of foreign-owned plants between 1977 and 1988. While the impact of environmental regulation is not the focus of this paper, Friedman et al do include one regulatory stringency variable – pollution abatement capital expenditures normalized by the manufacturing portion of gross state product. They find that environmental regulations do not have a significant impact on the location of foreign-owned plants. However, they note that because they aggregate all industries together, this could mask the impact environmental regulations may have on the location decisions of plants in high polluting industries.

Aside from the question of the importance of environmental regulation to U.S. plant location decisions, two related areas also have received much discussion in the literature. The first focuses on whether governments compete for plants by establishing relatively less stringent regulations. This question is usually raised at the sub-national level and often is referred to as jurisdictional competition between states. The second area of research focuses more on differences across countries and attempts to evaluate whether firms relocate production from the United States to other countries with relatively lax environmental regulations as a result of relatively stringent U.S. requirements, thus creating "pollution havens."

Domestic Inter-jurisdictional Competition

Prior to the passage of the Clean Air and Clean Water Acts and the creation of the U.S. Environmental Protection Agency (EPA) in the 1970s, environmental policy was primarily the purview of state and local governments. However, since that time, the Federal government has taken the lead in setting environmental policy, though it is still not the only player. The EPA is mainly responsible for promulgating regulations, while the states' are responsible for implementing and enforcing compliance with regulations. In some circumstances, states also are allowed to establish regulations at a level more stringent than those set at the Federal level. The Federal role is justified by the cross-border nature of many environmental externalities, which Oates (1972) shows can result in the suboptimal provision of environmental quality.

The basic theory of fiscal federalism developed by Musgrave (1959) and Oates (1972) describes the normative framework for the allocation of public functions and responsibilities to different levels of government and the most suitable fiscal instruments for raising revenues to meet these responsibilities.[21] The central tenet of fiscal federalism is that the Federal government should be responsible for achieving macroeconomic stability, redistributing income to the poor, and providing for national defense (Oates 1999). The role of state and local governments should be limited to supplying public goods and services with no inter-jurisdictional externalities, since they have better information on and can better match the preferences of their constituents, thereby providing them with higher utility relative to the more uniform level that would likely occur if provided by the Federal government.[22]

[21] Oates (1999) points out that the term "fiscal federalism" seems to imply a narrow focus on budgetary matters. However, economists view nearly all public sector functions (e.g. budgetary, regulatory etc.) as more or less federal in the sense that various levels of government play important roles in the action and have at least some decision-making power. Thus "fiscal federalism" encompasses a wide range of public sector issues beyond taxes, including how environmental regulation is promulgated and enforced.

[22] In the European Union, the term fiscal federalism is referred to as subsidiarity. For more information on subsidiarity, see papers by Sinn (1994,1998), and Inman and Rubinfeld (1998).

Oates and Schwab (1988) and Wellisch (2000) illustrate that it is possible for state and local governments to provide an efficient level of public goods – even with inter-jurisdictional competition. However these results depend on very strong assumptions: local governments are price-takers in national markets; they have access to a full set of regulatory instruments to tax residents for the public services they receive and firms for their use of public inputs; they welfare maximize and do not strategically interact with neighboring governments; and they do not have cross-border externalities.

The potential for suboptimal provision of public goods and services at the state and local level was first discussed in the context of taxes. For instance, Zodrow and Mieszkowski (1986) and Wildasin (1989) show that financing local public goods and services with a local property tax on mobile capital causes both a spatial misallocation of capital and a local fiscal externality. More specifically, taxes on mobile capital cause the local government to incur an additional cost to provide a public good or service, namely the loss of tax base (capital) to other competing jurisdictions. Therefore, local governments only increase the property tax rate to the point where the marginal cost of the public good or service, including the negative fiscal externality of a smaller capital stock, equals the marginal benefits. This in turn leads to an under-provision (Pareto inefficient allocation) of local public goods and services, since the local government losing the capital does not take into consideration the positive externality it confers on the communities receiving the capital (Wildasin 1989). Under this framework, state and local governments are prone to competitive impulses that could result in a "race to the bottom" in an effort to attract industry.

As with taxes, due to inter-jurisdictional economic competition, state and local officials in their zeal to attract new business capital and create new jobs may provide too little environmental quality (Oates 2001). In one sense, the argument seems puzzling. Assuming state and local governments officials want to promote the well-being of their residents, they should be concerned with creating new jobs as well as maintaining environmental quality. Thus, if the marginal benefits from raising environmental quality are greater than the marginal costs, we would expect the improvement to receive public support and be carried out. This should be the case when environmental quality is truly local in nature – it is paid for and received entirely by local constituents. However, the inter-jurisdictional nature of many environmental externalities – for instance, many types of air pollution - often makes this impossible.

In this case, more stringent environmental regulations increase firms' operating costs but local constituents only capture a portion of the benefits (which also accrue to its neighbors). Oates and Schwab (1988) theoretically demonstrate that in a model with inter-jurisdictional economic competition local communities choose excessively lax environmental standards to attract capital (i.e. increase the tax base) while attempting to free-ride on neighboring jurisdictions. However, if all local and state governments act in similar fashion, this will result in suboptimal levels of environmental quality at the state or local level (also see Wilson 1996).

There are only few empirical studies that examine the evidence for an environmental "race to the bottom" in the United States.[23] Most that have studied the issue - List and Gerking (2000), Millimet (2003), Millimet and List (2003), and Konisky (2007) - generally find little or no evidence of jurisdictional competition between states.[24] List and Gerking (2000) test whether President Reagan's policy of returning responsibility for environmental regulation to the states resulted in a "race to the bottom." They find that SO_2 and NO_x emissions per capita at the state level either continued to decrease or at least did not significantly increase through the 1980s into the 1990s. Millimet (2003), and Millimet and List (2003) similarly find that Reagan's environmental federalism policy did not lead to a deterioration in state-level environmental quality. Furthermore, Konisky (2007) finds that states use environmental policy to compete for economic investment but not in an asymmetric way that would suggest a "race to the bottom." However, Frederiksson et al. (2004) point out that the potential exists for strategic interaction across multiple policy dimensions. Studies that focus only on whether states compete for plants by lowering the stringency of environmental regulation may miss inter-jurisdictional competition that occurs through a combination of incentives – for instance, the promise of expanded infrastructure and some relaxation of regulatory stringency.

International Pollution Havens

Grossman and Krueger (1993) outline three principal ways in which liberalization of trade affects the environment: by increasing the scale of economic activity, by changing the technology utilized in production, and by altering the composition of economic activity. The pollution haven hypothesis pertains to this third effect. In particular, the pollution haven

[23] Traub and Sigman (2007) find that states with the strongest environmental preferences are also those with the most stringent state regulations for water quality and hazardous waste, two areas where the states are granted the ability to establish standards that are more stringent than they are at Federal level. That said, Sigman (2005) found that plants located near jurisdictional borders face less regulatory oversight than other plants in the state since some of the externalities resulting from the pollution are borne by residents in a neighboring jurisdiction. Helland and Whitford (2003) and Gray and Shadbegian (2004) found that plants near state borders emit more pollution.

[24] Fredickkson and Millimet (2002) find that states react to the environmental policies of neighboring states, but that if anything states are induced to set more stringent levels of environmental regulations as a result of improvements in neighboring states with already relatively stringent regulations. On the other hand, environmental improvements made by a state with relatively lax regulations is found to have no impact on the environmental policy in neighboring states.

hypothesis posits that as countries open to trade, environmental regulatory differences cause pollution-intensive firms in countries with relatively stringent environmental regulations like the United States to shift production to countries with relatively lax regulations in order to minimize compliance costs.

Early empirical investigations of the pollution haven hypothesis, however, yielded little evidence that plants were relocating production overseas to escape U.S. environmental regulations. The most commonly offered explanation for the absence of a discernible pollution haven effect has been that, relative to other costs, compliance costs in the United States are still too small to have a significant impact on firm production decisions (for surveys of these early studies, see Dean (1992), Jaffe et al. (1995) and Levinson (1996b)). For instance, Grossman and Krueger (1993), using pollution abatement expenditures as a measure of regulatory stringency, find that the composition effect created by further U.S.-Mexico trade under NAFTA is more likely to be affected by differences in factor endowments than by differences in pollution abatement costs.

Two endogeneity issues have complicated empirical tests of the pollution havens hypothesis: unobserved heterogeneity and reverse causality. Unobserved heterogeneity in this context is defined as industry or country characteristics that are likely to be correlated with both the propensity to impose strict environmental regulations and the propensity to export goods. For instance, Levinson (2008) provides an example of a country with an unobserved comparative advantage in a polluting good (e.g., a large endowment of high sulfur coal). In this case, the country may be more likely to both export the polluting good and to strictly regulate its use. Not accounting for these unobserved characteristics may lead to inconsistent estimates that cannot be meaningfully interpreted, and could potentially mask a pollution haven effect.

Cross-sectional studies cannot control for these unobserved variables, which may be one reason why early studies tend to reject the pollution haven hypothesis: The coefficient for the environmental regulatory stringency variable is usually statistically and economically insignificant. Some of these studies even find a counter-intuitive positive sign on the environmental variable (for example, Grossman and Krueger, 1993 and Mani et al. 1996) – that is, they find that economic activity is attracted to jurisdictions with stricter environmental regulations. The simplest way to account for this unobserved heterogeneity is to use panel data and incorporate country/state/industry fixed effects into the model. These fixed effects capture unobservable heterogeneity or inherent characteristics that vary cross-sectionally but are constant over time.

The second issue complicating these analyses is that it is difficult to disentangle the causal relationship between pollution regulations and trade. In other words, not only does trade liberalization shift U.S. production to countries with less stringent environmental regulations, but other countries also may adjust environmental regulations in response to the influence of trade with the United States. This could come in the form of a positive influence on environmental policy: if greater economic activity resulting from trade leads to higher income, and higher income leads to greater demand for environmental quality, then environmental regulations may become more stringent. Likewise, if international attention due to a trade agreement exerts pressure on a country with laxer standards to improve environmental performance, then environmental quality may improve. Trade may influence environmental quality negatively as well: to attract more firms to relocate from the United States, countries decrease environmental regulatory stringency. The typical solution to account for bias introduced by the endogeneity of trade and environmental regulatory policy is to employ an instrumental variable approach, as described in Ederington and Minier (1999), Xing and Kolstad (2002), and Levinson and Taylor (2008).

Corrections for these two sources of endogeneity - unobserved heterogeneity and reverse causality - alter the results reported in the earlier literature. Recent studies find some evidence of a moderate pollution haven effect. This effect has been noted both at the U.S. state or county level using plant location data (Henderson 1996; Becker and Henderson 2000; List and Kunce 2000 and Keller and Levinson 2002) and at the national industry level using net imports and capital flows data (Levinson and Taylor 2008, Brunnermeier and Levinson 2004, and Xing and Kolstad 2002). For example, Levinson and Taylor (2008) find that U.S. industries that experienced the largest increases in pollution abatement costs during the 1970s and 1980s also experienced the largest relative increase in net imports, thereby lending some empirical support for a trade-induced composition effect. Likewise, Ederington and Minier (1999) find that industries in the United States with relatively high levels of trade - and higher net imports – tend to face more stringent environmental regulation.

Xing and Kolstad (2002) examine the effect of unobserved regulatory stringency on capital movement from the U.S. to 22 host countries in manufacturing. The authors find that this instrument is significant and negatively related to capital flows for the two heavily polluting industries (chemicals and primary metals) but is insignificant for the less polluting industries. Finally, Brunnermeier and Levinson (2004) investigate the pollution haven hypothesis in the context of the proposed Free Trade Agreement of the Americas (FTAA) while controlling for both types of endogeneity. While they find evidence for a significant and positive relationship between net US imports and pollution abatements costs, they find no evidence for an “indirect” pollution haven effect: that liberalization of trade through the reduction of barriers has caused dirtier industries to alter their net imports.

Cole, Elliott, and Shimamoto (2005) offer an intuitive explanation for why these studies find little evidence of a pollution haven effect as a result of relatively stringent environmental regulations in the United States. They observe that pollution intensive industries are also relatively capital intensive. They find that the relative lack of physical and human capital in developing countries more than counters any attraction due to differences in regulatory stringency. Cole and Elliott (2005) study U.S. outbound foreign direct investment to Brazil and Mexico, two countries with relatively high capital endowments but lower environmental stringency compared to the United States. They find that availability of capital is a key determinant of foreign direct investment. However, pollution abatement costs in the United States are also significant.

In this section, we discussed two related empirical questions: First, do states compete for plants by establishing relatively less stringent regulations? Second, do firms relocate production from the United States to other countries with relatively lax environmental regulations as a result of relatively stringent U.S. requirements? In general, there is little widespread evidence that states compete for plants on the basis of environmental regulation. On the other hand, recent studies suggest that plants relocate to other countries due to regulatory costs, though this effect is moderate. The results from Frederikkson et al. (2004), that it is important to examine the interaction between environmental and other government policies used to compete for plants, suggests a useful area for continued future research.

4. Do Plants Choose to Locate Disproportionately in Poor and Minority Neighborhoods?

Another active area of research has centered on the hypothesis that firms locate dirtier activities disproportionately in poor and minority neighborhoods. Papers in this area started out looking at the most obvious candidates (hazardous waste facilities, TSDFs), and then later moved to asked the same question for a broader set of polluting plants.

The early literature was responsive to media and activist attention on landfill siting decisions. While these papers used small data sets and fairly simple statistics, they are important because they are the first to point out a potential relationship between the location of economic activity and poor and minority populations. Bullard (1983) examined several landfill and incinerator sites in the Houston area and found that the vast majority of these sites are located in African-American neighborhoods. GAO (1983) examined four hazardous waste landfill sites, pointing out that these sites are surrounded by predominantly poor and minority communities. The United Church of Christ (1987) broadened its examination to study the relationship between U.S. commercial treatment, storage, and disposal facilities for hazardous waste (TSDFs) and the socioeconomic characteristics of surrounding communities and found evidence of a disproportionate location pattern.[25] These studies, and many that followed, have argued that the correlation between waste facility location and poor and minority communities points to a disturbing trend of siting discrimination. However, these papers are not able to differentiate between correlation and causation. A correlation between plant or waste sites and contemporaneous neighborhood characteristics tells us nothing about how the neighborhood has evolved over time. We cannot tell whether a firm decided to locate a plant in an already existing poor or minority neighborhood, or the poor and minority neighborhood grew up around the plant after its siting.

Since that time, the literature has evolved in three ways. First, subsequent research has attempted to develop a theoretical construct to help guide empirical work in this area. Early research often did not control for possible alternative explanations for plant or waste siting decisions aside from socioeconomic characteristics. Second, more sophisticated empirical techniques have been used to better tease out the relationship between site or plant location and the demographic characteristics of the surrounding area. This has been achieved in two ways: one set of papers matches plant location to socioeconomic characteristics at the time of siting to test if the relationships that have been identified contemporaneously still hold, while another set of papers examines the ways in which neighborhoods have evolved over time after the siting of a plant or hazardous waste facility. As the literature has tried to meet these theoretical and empirical challenges, it has found a more mixed record with regard to the relationship between siting and demographics. Third, given this mix of findings, the literature has discussed how the way the neighborhood is defined affects the empirical outcome, though few studies have systematically explored how robust results are to a particular definition.

Establishing a Theoretical Construct

Hamilton (1995) posited three hypotheses for why the placement of polluting plants or waste sites could be correlated with poor and minority populations. The first hypothesis stems from Coase (1960): a plant is established where residents' valuation of environmental quality is lowest, and therefore the potential compensation by the firm to neighborhood residents, is lowest. Since local willingness to pay for environmental quality is positively correlated with

[25] Goldman and Fitton (1994) reexamine and update data from the United Church of Christ study and conclude that “the disproportionate impacts first identified and documented in the 1987 report…have grown more severe.”

income, firms tend to locate plants in poorer neighborhoods to minimize the costs of compensation.

The second hypothesis is grounded in Olson's work. Olson (1965) pointed out that there is a risk of free-riding when groups collectively organize for the provision of public goods. Environmental quality is one such public good. From the perspective of the firm, it is less costly to locate polluting sites or plants where the likelihood that a community will engage in collective action against the site and its expected pollution is relatively low.[26] In this case, a firm owes less to the community in the form of compensation not because the neighborhood values the externality any less than other communities, but because the transaction costs of collective action are higher. A less-politically-powerful community may have limited ability to participate in political or legal processes through which opposition is voiced and compensation is gained. One would expect poorer neighborhoods to have less ability to organize collectively. How the ability to take collective action correlates with race or ethnicity is less clear. Recent work by Videras (2007) finds a negative correlation between heterogeneity of populations with regard to race and ethnicity and the public provision of environmental goods. However, he also finds that support for environmental referenda differs across groups as they become more homogenous. At least for the time and place he studied (i.e., California in the year 2000), white and Hispanic populations tend to give greater support to environmental referenda as their share grows, while the opposite is true for African-American and Asian populations. Hamilton (1995) and others that followed have tended to use voter participation - sometimes as predicted by socioeconomic factors - as a proxy for collective action.

Hamilton's final hypothesis is that a firm - or rather the manager or owner - discriminates against a particular demographic group by locating a polluting plant or waste site in that community. This seems to run counter to what is implied by Becker (1971). He pointed out that employers that wish to discriminate are willing to incur an additional cost to avoid hiring a particular type of worker (e.g. minorities) of equivalent productivity even if they are willing to work at a lower wage. In competitive industries, we would expect less discrimination, since incurring these additional costs puts the firm at a disadvantage relative to others by "trading off profits for prejudice" (Hamilton 1995). In the context of a polluting plant, some have argued that firms wishing to push environmental disamenities onto minority populations can do so more easily in neighborhoods with a substantial minority population.

[26] A more politically active community may even block the establishment of a polluting plant, causing the plant to lose both money and time.

These hypotheses have shaped many papers that came after Hamilton (1995), though many still do not tie themselves to the plant location literature. Wolverton (2009a) links the two literatures by extending Levinson's framework for analyzing the effects of environmental regulation on plant location to include Hamilton's three hypotheses. A firm *i* that is considering the location of a new plant has an unobserved profit function for each feasible neighborhood *j* :

$$\pi^*_{\mathrm{ij}} = g\left[\mathrm{f_i}\left(p_j, r_j, d_j, e_j, a_j\right), s_{\mathrm{ij}}\right]$$

where p_j is neighborhood-specific input prices, r_j is costs of complying with environmental regulation, d_j is foregone profits due to discrimination, and s_{ij} is other firm or plant-specific factors that may vary by neighborhood. Compensation is a function of two components: the value placed on environmental amenities in the neighborhood e_j, and the propensity of the neighborhood to engage in collective action a_j.

It is still the case that within this framework the firm will choose to locate a plant in the neighborhood that yields the highest potential profit (or at least the one that best minimizes costs). However, in addition to the factors previously considered in the plant location literature, the costs of discrimination and compensation are explicitly considered. The higher the cost of discrimination and the level of compensation required, the less likely a firm will locate a plant or site in that location due to its negative effect on profits.

Empirical Evidence

Early studies by the UCC (1987) and GAO (1983) sparked wide interest in studying the question of whether firms locate polluting sites or plants disproportionately in poor or minority neighborhoods. Subsequent studies applied a variety of empirical techniques, examined a range of siting decisions, and tested the robustness of results while controlling for alternative explanations. As a result, this literature tells a much more mixed story than the first studies would indicate. We discuss three branches of this literature: studies that match site location to contemporaneous neighborhood characteristics; studies that examine neighborhood characteristics at the time of siting; and studies that examine siting decisions in the context of changing socio-economic dynamics.

Studies that match site location to contemporaneous socioeconomic characteristics find mixed results.[27] For instance, Zimmerman (1993) finds that a greater percent of minorities live near

[27] A wide variety of analytical techniques are used in these studies, ranging from an examination of simple correlation coefficients and differences in means across samples to binary logit regressions.

inactive hazardous waste sites that appear on the National Priority List (NPL), but that the population living in poverty does not differ significantly from the national average.[28] Boer et al. (1997) find a significant and positive relationship between the location of hazardous waste treatment, storage, and disposal facilities (TSDFs) and race in Los Angeles, California. They find a U-shaped relationship with regard to income. The poorest avoid disproportionate impacts as do the richest, but working class populations have a larger number of sites. One possible explanation for why poverty acts as a deterrent to plant location—which is opposite of the sign predicted by many environmental justice advocates—is that poverty-stricken areas are less likely to have highly skilled workers for the plant to hire (recall from above that plants are attracted to areas with highly skilled labor pools). While Baden, Noonan, and Turaga (2007) find that race and ethnicity are correlated with the presence of a NPL site at the national level, they find that this relationship is sensitive to changes in both geographic scale and scope (i.e., how the neighborhood is defined). Anderton et al. (1994) and Davidson and Anderton (2000) find only limited evidence of disproportionate numbers of TSDF or RCRA sites located in minority or poor neighborhoods. Sadd et al. (1999) find little evidence of a correlation between the location of TRI plants and race in Los Angeles at the census tract level, but find evidence of a positive and significant relationship for tracts within one mile radius of the plant. Income is significant for both sets of regressions.

These studies and others similar to them have a number of limitations when viewed from the perspective of what informs plant location decisions. First, they often include only a limited set of controls aside from socio-economic characteristics. For instance, Anderton et al (1994) includes only two additional controls aside from those associated with race, ethnicity, or poverty: percent employed in particular industries and mean housing value. Davidson and Anderton (2000) add education variables to the list of controls. Boer et al (1997) also include population density in addition to education, employment, and housing value controls. Second, because these studies match contemporaneous socioeconomic data to facility location, it is only possible to say that sites are disproportionately located in neighborhoods in which the current population is poor or minority. Such relationships are undoubtedly important in determining whether certain populations face disproportionate health impacts. However, they do not shed light on whether the relationship between race, income, and site location existed at the time of siting or developed over time. To determine whether a firm considered differences in race or income across neighborhoods in its location decision, the characteristics of the neighborhood at the time of siting are the most relevant.

[28] Zimmerman(1993) also found that NPL sites in minority neighborhoods had made less progress in putting a cleanup plan in place, though this appears to be a function of changes in the program over time. See also Anderton et al (1997), Hamilton and Viscusi (1999) and Sigman (2001).

There are a handful of studies that examine the relationship between neighborhood characteristics and facility location decisions at the time of siting. Most of these studies control for few cost-relevant location variables, instead concentrating on socioeconomic factors. These studies find a mixed record with regard to the importance of socio-economic variables to plant location decisions. They vary in empirical technique as well as scale and scope. They also differ in the type of facility studied. Many studies continue to focus on heavily polluting sites such as landfills or hazardous waste TSDFs. These types of facilities are expected to bring large quantities of pollution and risk to a neighborhood and few jobs. Later research expands these empirical studies to manufacturing facilities that report to the Toxic Releases Inventory. While these facilities pollute, they are also likely to bring many more jobs. Thinking back to Hamilton's hypotheses for why one might expect to see a relationship between plant location and poor or minority populations, this may imply that communities with fewer employment opportunities will use its collective abilities to attract rather than spurn such facilities. A key gap in the literature is the lack of systematic exploration of how robust results are to these differences, though a few studies do explore the effects of scale or scope (see Baden et al 2007).

Been (1994) reexamines site location data used by the GAO (1983) and Bullard (1983) studies,[29] matched to socioeconomic characteristics at the time of siting. Even without additional explanatory variables, Been obtains much more mixed evidence of environmental inequity at the time of siting than the original studies. The GAO data still demonstrate a case for disproportionate siting in minority communities, while the Bullard data indicate that at least part of the relationship developed after siting. Been and Gupta (1997), using a larger data set, also obtain mixed evidence for the hypothesis that race played a role at the time of siting for active commercial hazardous waste TSDFs in the United States. While waste disposal sites are correlated with certain 1990 socioeconomic characteristics such as race and income, neither percent poor nor percent African-American are significant factors at the time of siting. However, the percent Hispanic remains significant at the time of siting.[30] Hamilton (1995) focuses his study on the capacity expansion decisions of hazardous waste treatment, disposal, storage and recycling facilities, though his data only indicate whether facilities plan to accept more waste, not how much waste they may accept. Hamilton finds that race is not a significant determinant of site expansion. On the other hand, income is positively related to site expansion, a counter-intuitive result that Hamilton suggests may have resulted from multicollinearity. Voter turnout, a proxy for collective action, is negatively related to site

[29] Bullard (1983) examined several landfill and incinerator sites in the Houston area and found that the vast majority of these sites are located in African-American neighborhoods.

[30] One serious problem with the study is the limited sample size of the original data sets. GAO only has a sample size of four, while Bullard (after Been's adjustments) has a sample size of ten. As Been points out, however, her research does effectively illustrate gaps in the literature.

expansion. Pastor, Sadd, and Hipp (2001) examine the location of TSDF sites in Los Angeles County and find greater evidence of disproportionate siting in established Latino and African American communities than minority move-in after the TSDF establishment.

Baden and Coursey (2002) examine the location of Superfund sites in Chicago and find that sites were disproportionately located in poor neighborhoods in the 1960s but not in the 1990s. However, they find little evidence for disproportionate exposure of African Americans either currently or at the time of siting. Jenkins, Maguire, and Morgan (2004) study compensation to communities in exchange for hosting municipal solid landfills. Controlling for tipping fees paid from the landfill to the community, they find that socioeconomic characteristics such as income and race do not matter at the city level but do appear to matter at the county level. Finally, Wolverton (2009a) examines the siting decisions of TRI plants in the 1980s and 1990s in the state of Texas and finds that input-related cost factors are consistently more important than determinants related to the socio-economic characteristics of the surrounding neighborhood. Race and ethnicity are not related to plant location decisions, while poverty appears to act as a deterrent. Wolverton (2009b) finds that these results are largely insensitive to scale: they hold at both the state and city-level.

Unlike the plant location literature that examines the role environmental regulation may play, most studies of plant or waste site location in the environmental justice literature tend to rely on binary response models (e.g., Pastor, et al. 2001, Davidson and Anderton 2000, Been and Gupta 1999, Boer et al. 1997, and Anderton et al. 1994). Wolverton (2009a, 2009b) is somewhat unusual in its application of a conditional logit model to represent the choice of a particular location from a set of many neighborhoods. A firm is allowed to select a location for its plant from the actual location chosen and 49 randomly selected alternatives drawn from the full choice set. Likewise, many of these studies fail to consider determinants of plant location identified in the broader literature.[31] A few environmental justice studies include variables to proxy for land and labor costs but rarely include other variables associated with firm location. Kriesel et al. (1996), while focusing on the incidence of emissions rather than plant location, is one exception. Along with land and labor costs, they include proximity to an interstate highway and find that the inclusion of these factors renders race and poverty insignificant. Wolverton (2009a, 2009b) also includes measures of the costs of land and labor, the quality of labor, the degree of urbanization, average plant size, and distance to rail-based transportation. The existence of a pre-existing polluting plant is also included to proxy for zoning restrictions or as an indication of agglomeration economies and has significant explanatory power.

[31] See Carlton (1983), Bartik (1985), Lee and Wayslenko (1987), McConnell and Schwab (1990), Finney (1994), and Levinson (1996a).

Finally, several studies examine site location at the time of establishment in the context of changing socioeconomic dynamics. These studies also often focus on a particular city or region and are therefore difficult to generalize to other locations. Lambert and Boerner (1995) do not find large initial differences in the percent of poor and minority residents between neighborhoods with and without waste sites. However, housing values grew less rapidly in neighborhoods with waste sites, and minority populations moved into these neighborhoods at a faster rate. Hersh (1995) conducts a historical analysis of the change in racial and industrial dynamics for firms reporting to the Toxic Release Inventory (TRI). He finds that, in general, industries and blue-collar neighborhoods located near each other for job-related reasons. Also, he notes that both white and rich residents took flight to cleaner parts of the city after firms located in a particular neighborhood, and that there was an eventual movement of minorities into more polluted areas. Krieg (1995) finds that race is associated with the number of waste sites in areas with a long history of industrial activity and that class is more closely associated with the number of waste sites in areas with more recent industrial activity. Cameron and Crawford (2003) examine changes in the demographic profiles of neighborhoods near Superfund sites. They find little evidence that minorities have moved to the nuisance due to heterogeneity across sites and over time. However, they do find some evidence that single-parent households respond to lower housing prices by moving closer to Superfund sites.

Defining the Neighborhood

In addition to differences in empirical technique, control variables, and the type of facility examined, Mohai and Bryant (1992) and Anderton et al (1994) point out that how a researcher defines the neighborhood can have a large impact on the results of the study. Broad neighborhood definitions may hide important underlying trends in plant behavior, while narrow definitions may exclude areas that should be included in the neighborhood. There is widespread disagreement in the literature on the appropriate level of aggregation (see Baden et al 2007 for a summary of the scale used in different location studies). However, few papers explore how differences in the way the neighborhood is defined affects the results.[32] It is also worth noting that spatial autocorrelation, discussed earlier in relation to the more general plant location literature, usually is not adequately addressed in this context. Cameron and Crawford

[32] Shadbegian and Gray (2009) , using data from 2000-2002, examined whether or not environmental regulatory activity (inspections and enforcement actions) directed at U.S. manufacturing plants in Los Angeles, Boston, Columbus, and Houston varied systematically by the socioeconomic characteristics of the neighborhoods. As part of this study they explored how different sized neighborhoods (e.g. closest Census block group and all Census block groups within 1, 5, and 10 miles of a manufacturing plant) affected their results. Their results were mixed – some of their socioeconomic variables had stronger effects when measured in smaller neighborhoods, while others were stronger when measured in larger neighborhoods.

(2003) is one of the few papers that explicitly accounts for heterogeneity in distance between neighbors.

From an environmental perspective, the most relevant way to define the neighborhood is based on the potential exposure of the surrounding community to pollution from the plant or site. It is nearly impossible to acquire the data to precisely map such exposure, however, and so many have settled for alternative definitions of the affected community. Early work related to environmental justice used fairly broad neighborhood proxies in the form of counties or zip codes (GAO 1983, UCC 1987). Later studies have defined the relevant neighborhoods (the actual choice and the alternatives) based on concentric circles or at the census tract level.

The use of concentric circles is meant to approximate the range of distances at which a resident is concerned about the location of a hazardous waste or other polluting facility. Glickman and Hersh (1995) prefer concentric circles to a census-based neighborhood definition for several reasons. First, a census-based definition ignores how households or different socioeconomic groups are distributed within the neighborhood; this is especially problematic when assuming broad neighborhood definitions. Second, a census-based definition such as tracts or blocks often reflects topographical features such as rivers, highways, and railroads that may exclude a portion of those who, although separated by some physical feature, receive a large portion of the negative externalities from the site or plant. One reason for not using the concentric circle technique is the arbitrary choice of a radius: the circles drawn are unlikely to reflect community-defined borders between neighborhoods. Been and Gupta (1997) instead chose the census tract as their unit of analysis because it allows for a fine degree of analysis, tends to be consistently defined over time, is generally a comparable unit of analysis, and is usually defined by the community itself to reflect its own view of the neighborhood.

While others have raised the importance of exploring the way in which the neighborhood definition affects results, Baden, Noonan and Turaga (2007) is one of the few papers to systematically explore the effects of both spatial scope (e.g., studying all plant locations within a state, city, or county) and scale (e.g. how possible locations are defined). They do so by examining the correlation between the location of National Priority List Superfund sites and the race and income of the neighborhood using a logit regression with state fixed effects. They find that the results are sensitive to both scope and scale, emphasizing the need for researchers to explore this aspect more thoroughly.

In this section, we discussed the evidence related to whether firms locate plants disproportionately in poor and minority neighborhoods and find that it is decidedly mixed. Key areas for future research include examining how robust results are to the way in which researchers define the relevant neighborhood and low income status (e.g. percentage of families living below the poverty line or some other income measure); examining the robustness of results across type of polluting plant; and using panel data and spatial econometric techniques in this context.

Conclusion and Suggestions for Further Research

This paper provides an overview of the literature on the role of environmental regulations in plant location decisions. In particular, it explores the theory, evidence, and implications related to three empirical questions. Do environmental regulations affect the location decisions of polluting plants? Do states compete for polluting plants through differences in environmental regulation? And, do firms locate polluting plants disproportionately near poor and minority neighborhoods?

Understanding whether or not environmental regulation affects the location decisions of polluting plants is important for policymakers. The literature prior to 1997, relying on cross-sectional data and suffering from not being able to control for important factors such as unobserved location heterogeneity, found little evidence that environmental regulations played an important role in a firms' decisions of where to locate new plants. However, more recently, as researchers developed richer micro-level data sets and as more sophisticated econometric techniques became easier to implement, many studies began to find that more stringent environmental regulation deters new plant openings and may even cause firms to relocate its plants to areas with more lax environmental regulations. This effect seems relatively more important for foreign firms locating plants in the United States. The fact that environmental regulations have become increasingly more stringent over time also makes them potentially more important in firm decision-making than in the 1970s or 1980s, a point the current literature does not address well.

In the early 1980s, during the time of President Reagan's 'New Federalism,' which included relinquishing the responsibility for many environmental regulations to the states, there was a concern among some environmental advocacy groups of a so-called environmental "race to the bottom." Specifically, there was a worry that state and local governments would compete with each other by relaxing environmental standards to attract new businesses, thereby resulting in lower environmental quality. However, unlike the plant location literature, the competition literature consistently finds very little evidence of inter-jurisdictional competition via environmental standards in the United States.

Finally, the literature addresses the question of whether firms locate plants disproportionately in poor and minority neighborhoods. The findings in this area have many parallels with the environmental regulation-plant location literature. Early studies relied on cross-sectional data, which did not allow them to control for the neighborhood characteristics at the time the plant was sited, and relatively unsophisticated empirical techniques. These studies found some evidence that firms disproportionately located polluting plants in poor and minority neighborhoods. But once researchers began using richer data sets to examine many important location-specific factors including neighborhood characteristics at the time of plant siting, the literature found much more mixed evidence that firms disproportionately located polluting plants in poor and minority neighborhoods.

While the econometric approaches used to evaluate these three research questions have become increasingly nuanced and sophisticated, little has been done to make use of techniques that account for the possibility of spatial autocorrelation. Given that these questions examine differences across geographic space, it would be surprising to discover that potential locations for a polluting plant were in fact independent of each other: instead, we expect the characteristics of a particular location may look similar to those of nearby locations. Treating each location as an independent alternative without accounting for this possibility may bias the estimation results. In fact, not accounting for spatial autocorrelation can lead to another form of omitted variable bias. We hope that future research will explore how accounting for spatial similarities or differences across locations affects these findings.

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