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The author of this dissertation is:

Peter Stuart Bluestone
Fiscal Research Center
Georgia State University
PO Box 3992
Atlanta, GA 30302-3992

The director of this dissertation is:

Dr. Laura O. Taylor
Agricultural and Resource Economics
North Carolina State University
Campus Box 8109
Raleigh, NC 27695-8109

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GOVERNMENT FRAGMENTATION AND THE ATTAINMENT OF REGIONAL
ENVIRONMENTAL QUALITY

by

Peter Stuart Bluestone

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree
of
Doctor of Philosophy
in the
Andrew Young School of Policy Studies
of
Georgia State University

GEORGIA STATE UNIVERSITY
2007

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Peter Stuart Bluestone
2007

ACCEPTANCE

This dissertation was prepared under the direction of the candidate's Dissertation Committee. It has been approved and accepted by all members of that committee, and it has been accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics in the Andrew Young School of Policy Studies of Georgia State University.

Dissertation Chair:	Dr. Laura O. Taylor
Committee:	Dr. David L. Sjoquist
	Dr. Paul J. Ferraro
	Dr. Jonathan C. Rork
	Dr. Jason F. Shogren

Electronic Version Approved:

James Alm, Dean
Andrew Young School of Policy Studies
Georgia State University
December 2007

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ABSTRACT

GOVERNMENT FRAGMENTATION AND THE ATTAINMENT OF REGIONAL ENVIRONMENTAL QUALITY

by

Peter Stuart Bluestone
December 2007

Committee Chair: Dr. Laura O. Taylor

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This dissertation investigates whether higher levels of “governmental fragmentation” in metropolitan statistical areas (MSA) leads to worse environmental outcomes. Fragmentation refers to the number of local governments in a given region or MSA as defined by the census. This research contributes to two bodies of literature, that of environmental federalism and that of urban growth and local government form. In the area of environmental federalism this dissertation extends the collective action model to include local governments. An empirical framework is developed that includes cross-sectional and panel data. In the urban growth and local government form literature, this dissertation comprehensively tests many existing measures of local government fragmentation within an environmental policy framework. It also modifies and extends some of the fragmentation variables. The results suggest that local government fragmentation does hinder MSAs from attaining the ozone standard.

This dissertation extends the literature by examining the effect that local government fragmentation has on regional environmental quality. Six local government structure variables, jurisdiction count, special district dominance, central city dominance,

county primacy, central city growth, and metropolitan power diffusion index are comprehensively tested to determine which might affect regional environmental quality. In addition, this research extends the use of the computationally complex measure of metropolitan power diffusion index to include additional local government expenditures as well as additional years of panel data.

Two empirical estimation strategies were implemented, a cross-sectional approach and a panel data approach. The cross-sectional approach estimates the effects that long-term changes in local government structure have on attaining the ozone standard by measuring differences across MSAs. The panel data model's primary purpose was that of a robustness check on the cross-sectional results.

Three of the six tested fragmentation variables were found to have statistically significant effects on MSA attainment of the ozone standard in the cross-sectional model. Higher levels of metropolitan power diffusion index and jurisdiction count were found to hinder attainment of the ozone standard, while greater values of central city growth aided in reaching the attainment standard. Generally, the panel data results' supported the results from the cross-sectional models. In addition, the panel model resolved some important estimation issues. Metropolitan power diffusion index was found to be correlated with unobservables in the random effects model, indicating that the cross-sectional results for metropolitan power diffusion index may be biased as well. This was not an issue for the variable jurisdiction count. Metropolitan power diffusion index and jurisdiction count are highly correlated with each other and this relationship was used to estimate a reasonable range for the effect metropolitan power diffusion index might have on the attainment of the ozone standard.

CHAPTER 1

INTRODUCTION

The Clean Air Act has been in existence for over thirty years. However, many Metropolitan Statistical Areas (MSAs) continue to fail to meet the environmental quality standards prescribed by these laws. The inability of state and local governments to tackle the regional nature of environmental problems has been a source of frustration for policy makers. As such, regional-level government has been cited as a cure for poor environmental quality, fixing the mismatch between state and local government form and the spatial nature of the environmental problems (Rusk 1999, Cieslewicz 2001). Local government form includes not only the types of local governments such as general or special purpose governments, but also the number of governments. Empirically, it remains an open question whether local government form affects environmental quality (K. Foster 2001).

This research investigates whether higher levels of “governmental fragmentation” in MSAs leads to worse environmental outcomes. Fragmentation refers to the number of local governments in a given region or MSA as defined by the census. This is a timely and important topic as Environmental Regionalism is enjoying a resurgence. The Harvard Environmental Regionalist Project was formed in 1998 to study the possibility of improving environmental quality through the regional implementation of standards and guidelines (See also C. Foster 2002, K. Foster 2001, Foster and Meyer 2002). While the federal government sets environmental standards for air quality and the states determine how those goals are to be met, individual local jurisdictional policy can still have direct and indirect effects on outcomes. Through control of land use, budgets and municipal

programs individual jurisdictions can help or hinder regional environmental goals.¹ For example, jurisdictional large-lot zoning policies and mandatory preservation of open space are thought to encourage sprawl and increase vehicle miles traveled (VMT) thus, hindering attainment of air quality standards in the MSA (Fischel 1999). Yet a jurisdiction could state a legitimate public purpose for enacting such policies, and even claim environmentally friendly reasons such as maintaining green space for animal habitat.

Other hurdles might exist for jurisdictions wishing to enact regulations that improve environmental quality. For instance, competition among jurisdictions for scarce capital could provide incentives for keeping costs of locating in that jurisdiction low (i.e., to lower taxes). This type of “tax competition” reduces jurisdictional incentives to set costly environmental regulation, hindering their ability to affect transboundary environmental amenities (see Hoyt 1993 and Shogren and Kuncce 2002).

The environmental federalism literature addresses the theoretical link between government structure and environmental quality. The heart of the debate is whether centralized environmental laws and standards are best or would member states enact environmental legislation that best served the interests of their constituents and thus the country as a whole? Theoretical arguments have been made for both schools of thought. Cumberland (1979) was one of the earliest to suggest that states, in competition for industry, would relax environmental standards engaging in a “race to the bottom” (See also Oates 1972 and Break 1967). Oates and Schwab (1988) took a contrary position and

¹ For example the new Regional State Implementation Plan (SIP) in Georgia for reducing ground-level ozone, anticipates greater reductions in pollution in the future due to efficient land use planning in accordance with the increased availability of mass transit. When asked about such planning, many municipalities refused to commit their support either politically or fiscally to the plan. (SELC 2001)

developed a model suggesting that when states set taxes on mobile capital as well as environmental standards, they would set efficient levels of taxes and environmental quality. However, little empirical work has been done to support either position.

While the environmental federalism debate can be extended to the local government level, there are two aspects of the models used in this literature that are not appropriate for the question I wish to explore. First, the environmental federalism literature focuses on jurisdictions as environmental *standard-setting* entities (i.e., state governments as the jurisdiction setting the environmental standards for air and water quality). In this context environmental goals are endogenous for the decision-making agents. However, the issue I wish to explore is how the number of local jurisdictions within the borders of the MSA affect its ability to meet *exogenously* set air and water quality standards. Another usual assumption in the environmental federalism literature is that decisions made by one jurisdiction do not affect the environmental quality of another jurisdiction. In particular, it is assumed that pollution does not spillover across borders. The tax competition literature does not generally incorporate spillovers into its analysis either. But in the context of an MSA consisting of many jurisdictions in close geographic proximity, it is clear that decisions made by one jurisdiction will have an effect on its neighbor. Thus, the effects of border spillovers will be important to incorporate into a model of the effects of local government fragmentation on environmental quality.

The collective action model is better suited for modeling why environmental quality may be under-provided in a MSA composed of many jurisdictions when spillovers are present. Collective action models seek to explain why individual rationality does not guarantee an outcome that is rational for the group (Olson 1965). In some cases,

such as the provision of public goods, individual rationality predicts an outcome that is clearly at odds with the Pareto efficient outcome for the group.² This notion is embodied in the Samuelson social welfare function (Samuelson 1954). Samuelson showed that the Pareto optimal level of public good provision requires the vertical summation of marginal benefits be set equal to marginal cost.

This contrasts with when private markets provide public goods. In this case the problem associated with the provision of public goods is one of excludability or free riding. Individuals cannot be kept from enjoying the benefit of a public good, say environmental quality, once provided even if they did not contribute to its provision. Without some type of coordinating authority or social planner, incentives exist for individuals to hide their preference for the public good and thus give too little towards its provision (Hanley, Shogren, and White 1997).

The collective action model is best suited to explain the behavior of individual jurisdictions in an MSA faced with exogenously set environmental quality standards. The MSA is required by federal and state law to meet certain environmental standards. The federal and state governments also prohibit certain activities that directly lead to environmental degradation. If the MSA fails to meet these standards it can be sanctioned or prohibited from participation in certain lucrative federal programs. Thus, it would seem to be in the best interest of all jurisdictions in an MSA to do what it takes to meet these standards.

² Public goods are defined as goods that are nonrival in consumption and nonexcludable. An example is air quality. In general an individual enjoying the benefits of clean air does not preclude another individual from enjoying those benefits, thus it is nonrival. Nor can an individual be kept from enjoying the benefits of clean air once it is provided, thus it is nonexcludable (Hanley, Shogren, and White 1997).

However, many activities under local jurisdictional control which affect environmental quality are not directly regulated by federal or state statutes. Land use planning, zoning and the local budgetary process can have an effect on environmental quality and are regulated at the local jurisdiction level. Thus the problem of attaining exogenously set environmental standards can be framed as one of voluntary contributions to the provision of a public good by the jurisdictions within the MSA. Jurisdictions could choose to contribute a larger amount to providing environmental quality (the public good) through zoning and planning or funding public transportation. However such measures are costly to the jurisdiction. Furthermore, if other jurisdictions contribute to the provision of environmental quality and the standard is achieved, the noncontributing jurisdictions cannot be excluded from enjoying the benefits of better MSA wide environmental quality as well as the accompanying federal government benefits. Thus the incentives of jurisdictions are parallel to those described in the collective action literature where decision makers are individuals rather than government units.

The manner in which environmental standards are set and implemented has implications on the ability of jurisdictions within the MSA to influence attaining such standards. The Clean Air Act standards for air quality are determined at the federal level. The 1970 amendments to the Clean Air Act set up the national standards for six criteria pollutants: Ozone, Carbon Monoxide, Nitrogen Dioxide, Sulfur Dioxide, Particulate Matter and Lead.

States were instructed to designate air control regions in order to monitor these standards. Each region is called an air shed. Progress has been made in cleaning the nation's air, however many urban areas still cannot meet air quality standards for ozone

and carbon monoxide. This is due to the high correlation between these pollutants and vehicle miles traveled (VMT). While automobiles pollute less than they did in 1970, VMT has increased by 400 percent since that time. At present in the United States motor vehicles emit up to half of the smog-forming Volatile Organic Compounds (VOC) and Nitrogen Oxides (NOX); emit more than 50 percent of the hazardous air pollutants; and emit up to 90 percent of the carbon monoxide found in urban air. (EPA Plain facts, 1998) Federal and state statutes impose limits on point source pollution such as power plants and factories and require technology standards for automobile emissions and fuel mileage. However local jurisdictions can directly and indirectly affect transportation policy, thus VMT, through zoning, land use planning, public transit development and budget control for programs that could affect environmental quality.

Congress and the EPA were aware of the potential effect “indirect causes of pollution” could have on air quality and tried to regulate these in the 1974 Clean Air Act Amendments.³ However such measures were attacked by state and local governments as infringing on traditional areas of autonomy. The federal government backed down in subsequent amendments and rulemaking decisions. It wasn’t until the 1990 amendments to the Clear Air Act that Congress attempted to again control indirect sources of air pollution.

Thus, for MSAs that do not meet air quality standards, it is necessary that they control VMT, a current leading cause of poor urban air quality. Currently it is local

³ In addition to direct transportation controls, such as restricting on-street parking, curtailing heavy-duty commercial vehicle use, and instituting mandatory parking fees, preferential bus/car pool lanes, computer car pool matching, bike paths, mass transit projects, and even gasoline rationing, the EPA also required implementation plans to include permit requirements for indirect sources of pollution, such as shopping centers, sports facilities, major roads, and airports, which attracted heavy automobile traffic (see Garret and Wachs 1996).

jurisdictions that control land use planning, zoning and access to public transportation all of which affect VMT.

This research investigates, theoretically and empirically, the relationship between the number of jurisdictions in an MSA, and the MSA's environmental quality. In particular, I will focus on air quality within the MSA. In Chapter 2 the theoretical model will be developed. Why local jurisdictions might fail to institute costly policies that would improve environmental quality in their jurisdiction and the MSA as a whole will be analyzed in this chapter. Various theoretical frameworks that have explored similar issues in the past will also be discussed. Chapter 3 will develop the fragmentation measures used in the analysis. Chapter 4 discusses the data and develops the empirical model to be tested. Chapter 5 presents the results and discusses their policy implications.

CHAPTER 2

THEORY

There are several frameworks available to analyze inter-jurisdictional relations and their effects on environmental quality: the tax competition model, fiscal/environmental federalism and collective action models. While each approach has unique features, they share a common intellectual thread. Olson, in his 1965 book, *The Logic of Collective Action*, theorized that as the number of contributors to a public good increased the level of contribution as well as the level of provision would decrease. This would also lead to a greater gap between the efficient level of provision and actual level of provision. This has become known as the “Olson collective action paradox.” To combat the declines in efficiency and provision of public goods, associated with this paradox, Olson suggested that there should be a separate level of government which insures that those who receive the benefits of a collective good, within a geographical boundary, pay for that good. This idea has been incorporated into discussions of fiscal and environmental federalism.

In the following sub-sections, an overview of the environmental federalism and tax competition models and discuss the shortcomings of these frameworks for this research is presented. The collective action model will then be discussed. We next illustrate why it is the appropriate model to be applied here.

Environmental Federalism

Environmental federalism refers to the notion that environmental standards should be set at an appropriate level of government (generally thought to be the federal level) in order to avoid free riding and negative pollution spillovers by smaller jurisdictions. Improper implementation of environmental federalism has been theorized to lead to “a race to the bottom.” The idea is that if states or local jurisdictions were left to set their own levels for pollution control, inter-jurisdictional competition for scarce capital would lead jurisdictions to set inefficiently low levels of environmental quality.

Environmental federalism grew out of the earlier fiscal federalism and public choice doctrines. One of the earliest public choice theories put forward by Tiebout (1956), states that multiple jurisdictions benefit residents by allowing them to “vote with their feet.” People will move to areas that provide the bundle of public services they desire for the price they are willing to pay. This is referred to as Tiebout sorting. This sorting mechanism theoretically ensures that each jurisdiction will provide optimal levels of public services for its residents. Additional support for the benefits of multiple jurisdictions came from Brennan and Buchanan (1980) who proposed the state as leviathan doctrine. This doctrine contends that government attempts to maximize revenue and that inter-jurisdictional competition acts to constrain such behavior and leads to a Pareto improved outcome for the provision of taxes and public services.

The opposing view, as espoused by Cumberland (1979, 1981), Oates (1972), and Break (1967), is that inter-jurisdictional competition to attract business will result in inefficiently low tax rates. Thus public services will be under provided, including environmental quality. Cumberland (1979) suggested that such competing jurisdictions

would engage in a “race to the bottom” to attract industry by relaxing environmental standards.⁴

Oates and Schwab (1988) provide the seminal theoretical model describing environmental federalism. They attempted to bridge the gap between the two competing ideas in the literature; competition between jurisdictions leading to an efficient provision of public goods and competition between jurisdictions leading to an inefficiently low provision of public goods. The model examines how jurisdictions set two variables, one a tax or subsidy on mobile capital and the second a jurisdictional standard for environmental quality. The model assumes the following:

1. There are a large number of jurisdictions.
2. Individuals live and work in the same jurisdiction.
3. Pollution generated in one jurisdiction does not spill over into other jurisdictions.
4. Labor is immobile.
5. The labor market is perfectly competitive.
6. The median voter decision rule is used by jurisdictions to decide on the level of environmental quality and the tax rate.

Under this set of six assumptions, Oates and Schwab find that jurisdictions will set optimal levels of environmental standards such that the marginal willingness to pay for higher environmental quality equals marginal social costs of higher environmental quality, if no taxes on mobile capital are put in place. However with the introduction of distortionary taxes on mobile capital or heterogeneous jurisdictions, sub-optimal levels of environmental quality are set.

The Oates and Schwab analysis deals with the “competitive” case, when there exists a larger number of jurisdictions without market power that are able to set

⁴ Glazer (1999) develops a framework in which jurisdictions won’t race to the bottom if benefits from attracting industry are small. Shogren and Kuncie (2002) generalizes the Glazer result. He argues that the Glazer assumptions overly constrains the analysis. If the benefits of industry were small than why would jurisdictions compete? He shows that the occurrence of a race to the bottom depends on the number of jurisdictions competing for limited industry.

environmental quality standards as well as a tax on mobile capital. They also examine the result on environmental standard setting if heterogeneous jurisdictions are introduced. However they do not examine the effects on environmental standards based on the number of jurisdictions present in the economy.

The work of Hoyt (1993) continues the basic analytical framework of Oates and Schwab but examines how the number of jurisdictions affects the provision levels of a public good. While Hoyt works in the area of tax competition, the provision of public services in his model could be equated to setting of environmental standards as modeled in Oates and Schwab. Either a higher environmental standard or a higher level of public good provision will result in higher costs to the home jurisdiction. Because Hoyt incorporates how the number of jurisdictions in the economy affects public good provision, his model is reviewed in more detail below.

Tax Competition Literature

The result that inter-jurisdictional competition leads to a “race to the bottom” is supported by Hoyt’s (1993) tax competition model. This model indicates that an increase in the number of jurisdictions playing a Nash game in the tax rate would lead to inefficiently low levels of public goods and taxes as the number of jurisdictions grow. Shogren (2001) has used a similar framework to establish that such a result will hold if jurisdictions are left to set environmental quality standards while competing for scarce capital.

Hoyt, building on work by Wildasin (1988), developed a model that indicates in a given metro area, welfare improves and tax rates increase with fewer jurisdictions.

Hoyt's model assumes the following:

1. A single private good is produced in each jurisdiction using capital and labor.
2. Capital is completely mobile.
3. Land and labor are fixed in each jurisdiction.
4. Jurisdictions have a single resident.
5. Production of a private good is a function of capital, $F(K_j)$, where K_j is the amount of capital in the jurisdiction.
6. Jurisdictions all have the same production process, $F(K)$, where $F' > 0 > F''$.
7. All jurisdictions are identical.
8. One unit of the private good can produce one unit of the public service.
9. The public service in each jurisdiction is financed with a tax on capital, τ_j .

Given the previous assumptions, the government budget constraint, g_j , for jurisdiction j is:

$$\tau_j K_j = g_j. \quad (1.1)$$

Assume the supply of capital in the economy is fixed:

$$\sum K_j = \bar{K}, \quad (1.2)$$

where \bar{K} equals the supply of capital to the whole economy. Because capital is mobile the after tax rate of return on capital, ρ , must be equal across all jurisdictions:

$$F'(K_j) - \tau_j = \rho, \quad j=1, \dots, J, \quad (1.3)$$

where $F'(K_j)$ is the marginal product of capital. The allocation of capital is determined by equations (1.2) and (1.3) and the rate of return, ρ on capital. Hoyt then differentiates (1.2) with respect to the tax rate in jurisdiction one. This gives:

$$K'_1 + \sum_{j=1}^J K'_j \frac{d\rho}{d\tau_1} = 0, \quad (1.4)$$

where K'_j is the derivative of the demand for capital in jurisdiction j with respect to its price. Hoyt considers only the case when all jurisdictions are identical. Thus all jurisdictions set the same tax rate. In equation (1.4) $K'_i = K'_j$ for all i and j thus equation (1.4) simplifies to:

$$\frac{d\rho}{d\tau_1} = -m, \quad (1.5)$$

where m represents the market share of capital of jurisdiction j and equals $1/J$ when jurisdictions are identical. Using equation (1.5) it can be shown how a tax increase affects the movement of capital throughout the metropolis:

$$\frac{dK_1}{d\tau_1} = (1-m)K'_1, \quad (1.6)$$

$$\frac{dK_2}{d\tau_1} = -mK'_2. \quad (1.7)$$

Capital flows out of jurisdiction 1 due to the tax increase and into all other jurisdictions. Capital is equally allocated between all other jurisdictions not raising taxes, so as to satisfy the condition that ρ remain equal across jurisdictions. Equations (1.6) and (1.7) show that the amount of capital moving out of the jurisdiction raising its taxes is directly proportional to the total number of jurisdictions.

Each resident has the utility function $U(x_i, g_i)$ with the following properties:

$$\frac{\partial U}{\partial x_i} > 0; \quad \frac{\partial U}{\partial g_i} > 0; \quad \frac{\partial^2 U}{\partial x_i^2} < 0; \quad \frac{\partial^2 U}{\partial g_i^2} < 0.$$

The amount of private good x_i that a resident in jurisdiction i will be able to consume is determined by the local rents plus capital income he receives:

$$x_i = F(K_i) - (\rho + \tau_i)K_i + \theta_i \bar{\rho} \bar{K}, \quad (1.8)$$

where θ_i is the share of capital for jurisdiction i . Hoyt assumes all residents receive the same endowment of capital thus $\theta_i = m$ for all jurisdictions, where $m = 1/J$

To solve for the optimal tax policy and public service level in a jurisdiction Hoyt first determines the response of consumption of the private and public service to a tax change. Given $\theta = m$ and $F'(K_1) = \rho + \tau_1$ and differentiating (1.6) and (1.7) for $i=1$ with respect to τ_1 gives:

$$\frac{dx_1}{d\tau_1} = -K_1, \quad (1.9)$$

Differentiating the government's budget constraint (1.1) with respect to τ_1 gives:

$$\frac{dg_1}{d\tau_1} = K_1 \left[1 + \frac{(1-m)\tau\varepsilon}{(\rho + \tau)} \right], \quad (1.10)$$

where $\varepsilon = K' / K \cdot (\rho + \tau)$ is the elasticity of demand for capital in jurisdiction i. The subscripts for equation (1.10) and the expression for ε are suppressed because (1.10) is derived assuming that all jurisdictions tax rates are equal. Hoyt assumes that other jurisdictions do not adjust their tax rate in response to jurisdiction one's change in the tax rate. Rather the other jurisdictions adjust their level of public service, given their higher levels of capital and therefore revenue.

Jurisdiction one chooses a tax rate and public service level to maximize the utility of its resident. The jurisdiction assumes that other jurisdictions won't change their tax rates due to its policy choice. Thus the maximization problem for jurisdiction one is:

$$\underset{\tau_1}{\text{Max}} U(x_1(\tau_1), g_1(\tau_1)), \quad (1.11)$$

Hoyt shows that x_1 is a function of τ_1 and equal to equation (1.9). The public service level as a function of the tax rate as defined by equation (1.10). The Nash equilibrium tax rate τ^* is such that it solves (1.11) when the tax rate in the remaining jurisdictions τ_2 equals τ^* . This first order condition for maximization of (1.11) is:

$$\frac{\partial U}{\partial x_1} \cdot \frac{dx_1}{d\tau_1} + \frac{\partial U}{\partial g_1} \cdot \frac{dg_1}{d\tau_1} = 0. \quad (1.12)$$

Substituting for $dx_1/d\tau_1$ and $dg_1/d\tau_1$ and using equations (1.9) and (1.10) equation (1.12)

becomes:

$$MRS_1 = 1 - \frac{(1-m)\tau\varepsilon}{[\rho + \tau(1 + (1-m)\varepsilon)]}. \quad (1.13)$$

Where $MRS_1 = (\partial U / \partial g_1) / (\partial U / \partial x_1)$ is the marginal rate of substitution between the public service and the private good. Tau (τ) is defined by equation (1.13) to be the Nash equilibrium tax rate when all jurisdictions have identical production, endowments, and objectives. The marginal rate of substitution between the public service and the private good is greater than one, because the term being subtracted from one in equation (1.13) is negative. This makes the MRS_1 greater than the marginal rate of transformation which is stated earlier in the article to be one. This implies the public good is inefficiently provided. This low level of public good provision is due to the loss of capital the jurisdiction suffers when it raises its tax rate and loses tax revenue.

The models put forth by Oates and Schwab, and Hoyt do not allow for spillovers between jurisdictions. This assumption may be appropriate when considering states as a “jurisdiction,” but is not appropriate for modeling spatially smaller jurisdiction behavior, such as townships within an MSA. Furthermore, these models attempt to describe how standards are set, not how an exogenously imposed standard is to be met by a group of jurisdictions.

In the case of MSAs and municipalities environmental standards for air and water quality are already set. Federal and state permit programs are in place to determine the levels of point source pollution for air criteria pollutants. The federal government sets standards for factory point source emissions, auto fuel efficiency and tailpipe emissions and the states implement an inspection and maintenance program for cars.

However local governments are in charge of many factors that can directly or indirectly affect environmental quality. In almost all jurisdictions land use planning is strictly a local decision making process.⁵ The decision to allow or create public transportation in the jurisdiction is also made by the local authority. Other programs such as encouraging car-pooling, establishing parking fees and increased pedestrian access are all under local control (Southworth 2001). While none of the above policies individually may have a large impact on environment quality, when used in concert the effect can be substantial. For example, a recent empirical model by Bento et. al. (2003) indicated that if Atlanta had the transportation infrastructure, road system and land use density of Boston, VMT would decline by 25 percent.

Thus, local jurisdictions could do more to improve air quality. However many actions would be undertaken “voluntarily” (i.e., decided upon by jurisdictions but not compelled by the state or federal governments). Thus, the most appropriate model for this scenario is the collective action framework that takes into account both the voluntary nature of contributions to a pure public good and the spillovers involved in public good provision.

⁵ Exceptions exist in Portland, Oregon, Minneapolis Saint Paul, Minnesota and Atlanta, Georgia where regional commissions have authority over some land use decisions. State Governments that are involved in land use planning include Tennessee, Maryland, Florida and New Jersey (see McKinney 2002).

Collective Action Model

The last class of models we explore are those describing collective action. The collective action model seeks to explain how groups arrive at the provision levels of goods and services for their members. The underlying concern is that, individual rationality will not always insure actions and outcomes that are rational for the group (Olson 1965). This result is often the case when dealing with the provision of public goods. This idea can be extended to include a group of municipal governments that form an MSA trying to maximize the welfare of its residents. If residents in a jurisdiction are assumed identical then a benevolent social planner in the municipal government would only need to maximize the utility of a representative agent to maximize the utility of the jurisdiction. However if social planners do not coordinate and only seek to maximize the utility of their own jurisdiction then the result will not be Pareto optimal as Olson predicted.

Olson (1965) predicted that as the number of contributors to a public good (N) increased the provision level of the public good would decrease. Furthermore as N increased the gap between the provision level of the public good and the Pareto optimal level would increase. Olson developed a limited formal mathematical model for provision of a public good in a collective action setting. He goes on to show that in such a setting, the Nash provision level of the public good is less than the Pareto optimal level.

The model has several shortcomings: It does not specify the form of the utility function of the group members, nor does it account for the provision technology of the public good. Olson assumes a value function for individuals that indicates the benefit

received from the provision of the public good. While Olson shows that in a group, the Nash provision level of the public good will be less than the Pareto optimal, it cannot be determined from the model how increasing group size will affect the outcomes. Olson conjectures that the larger the group the greater the gap will be between the Nash provision level and the Pareto optimal provision level. Olson also states that absolute provision levels will decrease as group size increases. (Olson 1965, 44)

However others have shown the opposite. Chamberlin (1974) and McGuire (1974) proved that total provision of a public good could increase with increasing group size. The public and private goods are assumed to be normal and supplied with summation technology.⁶ Group members are assumed identical and the equilibrium is symmetric, meaning all members contribute an equal amount.

Chamberlin (1974, 712) and McGuire (1974, 112) show that while individual contributions decline as group size increases, these declines are offset by contributions from the new members. Thus, average contributions fall while total provision increases. Their result is demonstrated by summing individual reaction or expenditure functions of the group membership and generating an expression for total contributions. This expression contains an aggregate term that quantifies the spillovers/spillins from the additional new group members. Spillins are similar to positive externalities. They are benefits that accrue to individuals through the additional provision level of the public good. It is these spillovers/spillins that generate income effects that increase absolute provision levels.

⁶ Summation technology ensures that all group members contributions to the public good are equally valuable and costly.

However Mueller (1989) showed that for Cobb Douglas utility functions that Olson's notion that increased N would lead to larger departures from an efficiency standard was true. Mueller assumes that the public good will be provided by summation technology and that contributions are voluntary. There are only two goods, a public good and a private good. He also assumes that individuals will not take into account the level of provision of others when choosing the amount to provide (i.e., assume other contributions are fixed).

Mueller shows the fairly standard result that individuals in a group will choose to provide a level of public good only up to the point where the individual's marginal rate of substitution equals the price ratio of the two goods. He calls this level of provision the Nash/Cournot level.⁷ He shows that this is not the Pareto optimal level. Rather if the individuals coordinated and maximized their utility subject to the aggregate budget constraint they would set provision levels of public goods so that the sum of marginal benefits equal the ratio of the prices of the public and private good. This is similar to the familiar Samuelson (1954) result that states that for the Pareto optimal level of public goods the sum of marginal benefits should equal the marginal cost.

Mueller also adds some additional conditions to the model. He assumes Cobb Douglas utility functions and that all individuals have identical income. He is then able to derive that as the number of individuals increase, the gap grows between the Nash/Cournot provision and the Pareto optimal. Cornes and Sandler, (1986, ch. 5) extend this conclusion to include quasi-linear and Leontif utility functions. It is interesting to

⁷ Mueller claims that this is frequently referred to as the Nash or Cournot provision level as it is very similar to the behavioral assumption Cournot made concerning the supply of a homogeneous private good in an oligopolistic market (Mueller 1989, 18).

note that because of the many possible forms of collective action models, the inverse relationship between group size and Pareto efficiency cannot be established generally (Sandler 1992).

Collective Action Model For an MSA with Multiple Jurisdictions

In this section we adapt the Mueller framework to describe jurisdictional choice over voluntary decisions to increase levels of environmental quality by taking costly actions. Summation technology for public good provision is assumed by Mueller. An alternative to summation technology is weakest-link technology.

In the weakest-link formulation of public good provision, the level of public good is determined by the minimum contributor. The classic example of weakest-link technology in public good provision is a dam. If each agent builds a section of the dam, it will only be as strong as the weakest section. Efforts to keep a disease or pest from spreading are other examples of weakest-link public good provision technology (Sandler and Vicary 2002). A potential example of weakest-link technology in ozone formation might be a point source that emits large amounts of precursor pollutants.

However, most of the precursor pollutants that contribute to ozone formation come from many lower emitting nonpoint and mobile sources. Thus, to increase the level of public good, clean air, it is the emissions from these smaller nonpoint and mobile sources that must be curtailed, rather than a few large point source emitters. Summation technology provides a more accurate description of ozone pollution because it requires that all inputs be added together and the sum is the level of public good provision.

Ozone pollution and its precursor emissions also mix relatively homogenously through the air shed. Due to inter-jurisdictional spillovers of ozone as well as precursor pollutants, it is highly unlikely that one jurisdiction acting alone could solve an MSA's ozone problem. Nor is it likely that a single jurisdiction is solely responsible for creating an MSA's ozone pollution problem. Therefore, the assumption of summation technology and the formation of ozone also fit more closely into the collective action framework. Thus, summation technology is the more appropriate assumption for ozone formation than weakest-link.

Suppose an MSA is composed of a number of different jurisdictions, j , where $j = 1 \dots J$. Each jurisdiction has a social planner who decides how much that jurisdiction will contribute to an MSA wide public good, G . Assume summation technology is used to supply the public good in the MSA thus:

$$G = G_1 + G_2 + G_3 + \dots + G_J. \quad (1.14)$$

Let residents of jurisdiction j be identical and have the utility function $U_{ij}(X_{ij}, G)$, where X_{ij} is the quantity of private good resident i of jurisdiction j consumes.⁸ The budget constraint for resident i of jurisdiction j is $Y_{ij} = P_x X_{ij} + P_g G_j / R_j$, where Y_{ij} is her income and P_x , and P_g are the prices of the private and public goods, respectively. R_j is the number of residents in jurisdiction j . Since all residents of jurisdiction j are identical, we drop the subscript i for ease of notation. Without any coordination method between jurisdictions in the MSA, each social planner will set the level of public good contribution treating what is given by all other jurisdictions in the MSA as fixed. By

⁸ Residents are assumed immobile.

fixed it is meant that other jurisdictions will not change the amount contributed based on what jurisdiction j contributes. The social planner of each jurisdiction will seek to maximize the utility of the representative resident of jurisdiction j using a jurisdiction wide budget constraint, $R_j Y_j = R_j P_x X_j + P_g G_j$. The social planner from jurisdiction j will then maximize the objective function for that jurisdiction:

$$O_j = R_j U_j(X_j, G) + \lambda_j (Y_j - P_x X_j - P_g G_j / R_j) . \quad (1.15)$$

Maximizing (1.15) with respect to G_j and X_j yields:

$$\frac{\partial U_j}{\partial G} R_j - \lambda_j P_g / R_j = 0 , \quad (1.16)$$

$$\frac{\partial U_j}{\partial X_j} R_j - \lambda_j P_x = 0 , \quad (1.17)$$

from which we obtain:

$$\frac{\partial U_j / \partial G}{\partial U_j / \partial X_j} = \frac{P_g}{R_j P_x} , \quad (1.18)$$

as the condition for utility maximization. The left hand side of equation (1.18) represents the marginal rate of substitution between the public good and the private good. It tells us how many units of the private good a representative individual in jurisdiction j would be willing to give up to get an additional unit of the public good. The right hand side of equation (1.18) represents the relative price of the public good per unit of the private

good per person in jurisdiction j . In this case the social planner treats the MSA wide public good as a private good, equating the marginal rate of substitution to the price ratio of the two goods. Per the convention in Mueller (1998), we will call this the Nash/Cournot level.

To determine the Pareto optimal solution the following welfare function is maximized. Here ϕ_j is a positive weight on all individual utility functions and γ_j represents the positive weight on utility at the jurisdictional level:

$$\begin{aligned}\phi &> 0, \\ \gamma_j &= \phi R_j, \\ W &= \gamma_1 U_1 + \gamma_2 U_2 + \dots + \gamma_J U_J .\end{aligned}\tag{1.19}$$

Thus (1.19) must be maximized subject to the aggregate budget constraint of all jurisdictions in the MSA:

$$\sum_{j=1}^J R_j Y_j = P_x \sum_{j=1}^J R_j X_j + P_g G,\tag{1.20}$$

we obtain the first-order conditions:

$$\sum_{j=1}^J \gamma_j \frac{\partial U_j}{\partial G} - \lambda P_g = 0,\tag{1.21}$$

and

$$\gamma_j \frac{\partial U_j}{\partial X_j} - \lambda P_x R_j = 0 \quad j=1 \text{ to } J, \quad (1.22)$$

where λ is the Lagrangian multiplier on the budget constraint. Using the J equations in (1.22) to eliminate the γ_j in (1.21), we obtain:

$$\sum_j \frac{\lambda P_x R_j}{\partial U_j / \partial X_j} \cdot \frac{\partial U_j}{\partial G} = \lambda P_g, \quad (1.23)$$

which after rearranging yields:

$$\sum_j R_j \frac{\partial U_j / \partial G}{\partial U_j / \partial X_j} = \frac{P_g}{P_x}. \quad (1.24)$$

This is similar to the Samuelson social welfare function optimization involving public goods. Here the summation of all jurisdictions marginal rates of substitution (MRS) must be set equal to the price ratio of the two goods in the economy. As residents within a jurisdiction are identical the MRS is multiplied by the number of residents R_j to make it a jurisdictional measure.

If G and X are normal goods then the quantity of public good provided under the Nash/Cournot solution will be less than under the Pareto solution. See (1.25) below.

$$R_j \frac{\partial U_j / \partial G}{\partial U_j / \partial X_j} = \frac{P_g}{P_x} - \sum_{l \neq j} R_l \frac{\partial U_l / \partial G}{\partial U_l / \partial X_l}, \quad \text{where the term } \sum_{l \neq j} R_l \frac{\partial U_l / \partial G}{\partial U_l / \partial X_l} > 0, \quad (1.25)$$

The right hand side of (1.25) equals the marginal rate of substitution for jurisdiction j under Pareto optimality. It is clear from equation (1.25) that this is smaller than the Nash/Cournot solution for the MRS in equation (1.18). This implies that under the Pareto formulation the residents of jurisdiction j consume more G and thus it is less valuable than under the Nash/Cournot formulation. Thus under Pareto optimality the level of G provided in jurisdictions j is greater than under the Nash/Cournot conditions.

To show that as increasing the number of jurisdictions widens the gap between the Pareto optimum and the Nash provision, it is helpful to use the assumption of Cobb-Douglas utility functions. Where $U_i = X_i^\alpha G^\beta$, $0 < \alpha < 1$, and $0 < \beta < 1$. Under this assumption (1.18) becomes:

$$\frac{R_j \beta X_j^\alpha G^{\beta-1}}{\alpha X_j^{\alpha-1} G^\beta} = \frac{P_g}{P_x}, \quad (1.26)$$

rearranging (1.26) yields:

$$G = \frac{P_x \beta}{P_g \alpha} X_j R_j. \quad (1.27)$$

Substituting the right hand side of equation (1.14) for G and inserting the jurisdictional budget constraint for $X_j R_j$ yields:

$$\sum_j G_j = \frac{P_x}{P_g} \frac{\beta}{\alpha} \left(\frac{R_j Y_j}{P_x} - \frac{P_g}{P_x} G_j \right), \quad (1.28)$$

rearranging we obtain:

$$G_j = -\frac{\alpha}{\alpha + \beta} \sum_{l \neq j} G_l + \frac{\beta}{\alpha + \beta} \frac{R_j Y_j}{P_g}. \quad (1.29)$$

Equation (1.29) implies the social planner in jurisdiction j will reduce G_j as other jurisdictions increase their provision level of G . This is so because in equation (1.29) $\partial G_j / \partial G_l < 0$.

To illustrate how increasing the number of jurisdictions in the MSA affects the equilibrium level of G additional structure must be added to the model. All jurisdictions are assumed to have the same number of residents, R . All residents of the MSA are identical and have the same income, Y . When this is the case the level of G_j set by all jurisdictions in the MSA will be equal. Therefore (1.29) can be used to find the contribution in equilibrium of a single jurisdiction:

$$G_j = -\frac{\alpha}{\alpha + \beta} (J-1)G_j + \frac{\beta}{\alpha + \beta} \frac{RY}{P_g}, \quad (1.30)$$

from which we obtain:

$$G_j = \frac{\beta}{\alpha J + \beta} \frac{RY}{P_g}. \quad (1.31)$$

The amount of the public good provided by all jurisdictions, acting independently, then becomes:

$$G = JG_j = \frac{J\beta}{\alpha J + \beta} \frac{RY}{P_g} . \quad (1.32)$$

These quantities can be compared to the Pareto-optimal quantities. When all individuals are identical with the same income, all residents of jurisdiction j will contribute the same amount to G_j , and have the same X , left over, so that (1.24) becomes:

$$\frac{RJ\beta X^\alpha G^{\beta-1}}{\alpha X^{\alpha-1} G^\beta} = \frac{P_g}{P_x} . \quad (1.33)$$

Using the budget constraint to eliminate the X and rearranging yields for the Pareto-optimal contribution of a single jurisdiction:

$$G_j = \frac{\beta}{\alpha + \beta} \frac{RY}{P_g} , \quad (1.34)$$

and

$$G = JG_j = \frac{J\beta}{\alpha + \beta} \frac{RY}{P_g} . \quad (1.35)$$

Calling the Pareto-optimal quantity of public good defined by (1.35), G^{po} , and the quantity under the Cournot/Nash equilibrium determined by equation (1.32), G^{cn} . Their ratio is then

$$\frac{G^{cn}}{G^{po}} = \frac{\frac{J\beta}{\alpha J + \beta} \frac{RY}{P_g}}{\frac{J\beta}{\alpha + \beta} \frac{RY}{P_g}} = \frac{\alpha + \beta}{\alpha J + \beta} . \quad (1.36)$$

Thus, if the number of jurisdictions in an MSA is greater than 1, the provision of the public good will be less than the Pareto optimum. This gap grows as J increases.

Model Summary

To capture the relevant issues for the problem of how MSA government fragmentation affects environmental quality, a model must account for, spillovers between jurisdictions and be able to describe how the private maximization solution compares to the Pareto optimal solution as the number of jurisdictions in an MSA increases. The three models discussed in this chapter, environmental federalism (Oates and Schwab), tax competition (Hoyt) and collective action (Mueller) models are all able to demonstrate a Pareto in-efficient outcome arises when multiple jurisdictions set uncoordinated tax rates or contributions to a public good, such as environmental quality. However both the Oates and Schwab model and the Hoyt model do not incorporate the effects of either spillovers or increasing jurisdictions.

The Oates and Schwab model shows that jurisdictions will set sub-optimal levels of environmental standards when distortionary taxes on mobile capital or heterogeneous jurisdictions are introduced. However the effect of increasing the number of jurisdictions on the level of provision relative to the Pareto standard is not shown. In addition public good spillover is assumed away.

Hoyt's (1993) tax competition model shows that an increase in the number of jurisdictions playing a Nash game in the tax rate would lead to inefficiently low levels of public goods and taxes as the number of jurisdictions grow. However public good spillovers are not explicitly modeled.

In the Mueller model spillovers are taken into account and the model can also show how changing the number of individuals in the group can affect the provision choices of individuals. The Mueller model framework can be extended to jurisdictions providing public goods within an MSA.

The model shows that jurisdictions within an MSA acting independently will choose to provide a level of public good only up to the point where the individual residents' marginal rate of substitution equals the price ratio of the two goods. The model shows the fairly standard result that this is not the Pareto optimal level. Rather if the individual jurisdictions coordinated and maximized their utility subject to the aggregate MSA budget constraint they would set provision levels of public goods so that the sum of marginal benefits equal the ratio of the prices of the public and private good. Mueller showed by adding some additional conditions to the model such as: Cobb Douglas utility functions and that all individual residents have identical income, it is possible to derive that as the number of jurisdictions increases, the gap grows between the uncoordinated provision level and the Pareto optimal. In chapter four the modified Mueller model will be developed into a form that can be tested empirically. In the next chapter we discuss the government fragmentation measures that will be used in this analysis.

CHAPTER 3

GOVERNMENT FRAGMENTATION MEASURES

In order to compare government structure across MSAs, standardized measures of fragmentation must be used. A fragmentation measure should be an index of the level of fractured governmental authority and decision-making at the MSA level. Traditionally, simple measures of fragmentation were used such as the total number of governments in an MSA. However these measures can fail to capture the ways in which special purpose districts or location of the population relative to the central city can affect decision-making. New measures of fragmentation suggested by Foster (1993) try to account for these shortcomings. Additional measures such as the presence of Regional Authorities, Central City Elasticity and the Metropolitan Power Diffusion Index will also be examined. In the following section we will describe how fragmentation has been measured in the literature.

Early Measures of Fragmentation

Early literature uses simple measures of fragmentation that focused on either absolute or relative levels of fragmentation. One absolute measure of fragmentation is the number of governments within a given area (Zeigler and Brunn 1980). Governments include counties, municipalities, townships, special districts and school districts. This is the simplest method and embodies the idea that the more governments in a region, the more fragmented the decision making in the region. This method follows the logic of Olson's collective action model. The more decision makers, the less likely they are

to come to an agreement that optimizes the welfare of the group (Olson 1965). This measure is a good starting point, however it is limited in its ability to deal with the subtler distinctions in local government fragmentation, as we will discuss later.

Relative fragmentation is another aggregate measure; this measures the number of governments for some increment of the population (Dye and Hawkins 1971, Razin and Rosentraub 2000, Carruthers and Ulfarsson 2002). Relative fragmentation takes into account the population of an MSA when determining fragmentation levels. It stands to reason that more populous MSAs should have more governments. Thus an MSA with one government and a population of 100,000 is equally as fragmented as an MSA with 10 governments and 1,000,000 people. Smaller midwestern MSAs tend to confound the effectiveness of this measure. In midwestern MSAs many small township governments are still counted by the census even though the town has essentially vanished.⁹

Local Government Characteristics

Foster (1993) criticizes these traditional measures and suggests ways to broaden them. The size, scope and type of local governing bodies within an MSA could mitigate the degree of fragmentation. These are not considered by traditional aggregate measures of fragmentation. Foster focused on three particular factors that could serve to offset the effect of an additional government on MSA fragmentation. The first is inclusiveness of local governments, second is local government scale, and third is the primacy of county government. She developed six fragmentation variables to try to capture the three different aspects of fragmentation: Central City Dominance, Suburban Un-incorporation,

⁹ There are more than 1000 towns with a population of less than 100 in the country. Some towns have zero population. Almost all of these are located in the midwest.

Suburban Municipal Fragmentation, School District Decentralization, Special District Dominance and Special District Overlap. In the following sections we will describe the variables relevant to this analysis and their relationship to each of the three aspects of fragmentation Foster developed.

Inclusiveness

Inclusiveness of local governments tries to separate how various local forms of government, general purpose or special district, can affect fragmentation. There are two competing ideas about how the presence of special districts might affect fragmentation. They could either act as consolidating agents reducing fragmentation or they just add another layer of governance, increasing fragmentation.

First, it is possible that special districts might decrease fragmentation. While municipal governments have mutually exclusive boundaries, special districts can overlap individual municipalities and serve to integrate government function. The case of several small municipalities within an MSA might benefit from a special district that integrates the water and sewer systems. While the special district represents an additional government unit in the MSA, it is actually acting to coordinate the area rather than increase its fragmentation (Foster 1993). The second competing idea is that special districts are merely another layer of local governance and increase the level of fragmentation in the MSA (Foster 1993, Nelson and Foster 1999).

Foster (1993) suggests several ways to measure inclusiveness. The first is the number of special districts divided by the number of general purpose governments,

towns, cities and county governments. This is referred to as special district dominance (SDD):

$$SDD = \frac{SD}{GOV_s}, \quad (2.1)$$

where SD is defined as the number of special districts and GOVs is the number of general purpose governments. Based on equation (2.1), lower values of SDD imply a less fragmented MSA.

The second measure of inclusiveness is the number of “overlapping” special districts divided by the number of nonschool district governments. Overlapping is defined as a special district that serves more than one municipality, township or county government. Thus for this measure nonoverlapping special districts are counted in the denominator. The equation for overlapping special district dominance (OSDD) is:

$$OSDD = \frac{OSD}{GPG}, \quad (2.2)$$

where OSD is the number of “overlapping” special districts and GPG is the number of nonschool district governments, including nonoverlapping special districts. Equation (2.2) indicates that higher values of OSDD represent a less fragmented area. Foster found that OSDD was highly correlated with SDD and so did not include it in her analysis. This makes sense as 97 percent of all special districts only have one function (Miller 2001).

Overlapping special district dominance is also difficult to calculate for all MSAs. For the 1997 census of governments, data for OSD is incomplete.¹⁰ Due to its correlation with SDD and the shortcomings in data availability for all MSAs, we will not be including OSDD in my fragmentation variable set.

Scale

Local government scale is of particular interest due to the potential effect of central city dominance. Foster states that an area with a dominant central city in which most of the population lives, will have a mitigating effect on fragmentation, because the majority of the people in the MSA are served by one general-purpose government. Foster suggests measuring central city dominance by dividing the number of people living in cities with a population greater than 50,000 by the total metropolitan population. Other measures similar to Foster's are proportion of population in cities with at least 100,000 residents and proportion of population in the largest city (Razin and Rosentraub 2000). Foster's measure is defined by equation (2.3):

$$CCD = \frac{POP50}{MSAPOP}, \quad (2.3)$$

where POP50 is the total number of people living in cities with a population greater than 50,000 and MSAPOP is the total metropolitan population. A larger number for the central city dominance measure would indicate a less fragmented MSA.

¹⁰ For every state and county some have service area designated as overlapping while other special districts report no designation. Thus it is not possible to select out only complete MSAs because almost all have special districts that don't report service area. This data constraint was confirmed via email from the census.

Values for CCD can range from zero to one. A value of zero means no central city has a population of over 50,000. While a value of one means all people in the MSA live in the central city. Many smaller MSAs have no city with over 50,000 people. Most of these MSAs have populations of less than 100,000. At the top of the CCD list is Anchorage and Honolulu with values of one. Both these cities have only one city and it covers the entire geographic area of the MSA, However neither of these MSAs is included in the sample.

Primacy

The primacy of county government is important in dealing with areas of an MSA that are unincorporated. If a significant portion of the population lives in unincorporated areas, general-purpose county governments may act as consolidating agents for decision-making. County primacy is empirically somewhat the opposite of Central City Dominance. However both measures attempt to quantify the affect of a dominant form of local government on the MSA. County primacy may be more of a factor for MSAs with lower populations or for those MSAs out west which consist of only several large counties. Foster measures county government primacy as, the population in unincorporated area divided by noncentral city population:

$$CP = \frac{POPUN}{POP_{NCC}}, \quad (2.4)$$

where CP is county primacy, POPUN is population in the unincorporated area and POPNCC is the noncentral city population. The larger the number for CP the less fragmented the MSA.

Nelson and Foster (1999) use percent of population of the MSA living in unincorporated areas, which on its face seems similar to the primacy of county government measure. For this measure Nelson and Foster assert that higher percentages of the population living in unincorporated areas signify a higher level of fragmentation. This assertion is based on the increased number of special districts in unincorporated parts of counties. The more people that live in unincorporated areas, the more people who are served by these districts. Thus this measure is actually more of a special district dominance indicator than a measure of county primacy.

The key local government characteristic measures as defined by Foster (1993) fall into three categories: the inclusiveness of local governments, local government scale, and the primacy of county government. For my analysis three variables were deemed relevant for measuring these characteristics. Under the inclusiveness category is Special District Dominance. The more special districts in the MSA the less inclusive and the higher the level of fragmentation. To capture local government scale, we use the variable Central City Dominance. The more dominant the central city in terms of population the less fragmented the MSA. The primacy of county governments is measured by the variable called County Primacy. If a large portion of the population lives in unincorporated areas, a dominant county will indicate a lower level of fragmentation in the MSA. In the following sections we will discuss three additional fragmentation measures that are found

in the literature, regional authorities, central city elasticity and metropolitan power diffusion index.

Regional Authorities

The presence of regional authorities can also be used to determine the degree of fragmentation of an MSA. These types of governments can serve to integrate an entire MSA. However the form and powers of the regional body will greatly determine its effectiveness. In general there are several different types of regional governments, general purpose, city-county consolidation, special purpose regional districts, and regional multipurpose districts.

City-county consolidations merge central cities with mostly unincorporated county populations. In the single-county two-tiered federations of government a countywide entity establishes the framework for decision-making that is implemented by subordinate local governments (such as Metropolitan Dade County, Florida [Miami]). Regional single-purpose districts are based on the economies of scale associated with large-scale infrastructure provision such as water and wastewater systems, which typically deliver their services over large areas and to large numbers of customers. Regional multipurpose governments include such examples as Minneapolis/St. Paul, MN Portland, OR and Seattle, WA.

The problem with using regional authorities as indicators of fragmentation is that not many authorities are officially governments. As of 2001 only nine were in existence that were considered governmental entities by the United States Census of Governments (Foster 2001). The Census recognizes five basic types of local governments: county

governments, municipal governments, township governments, special districts and school districts. A government entity is defined for Census Bureau reporting as follows:

A government is an organized entity, which, in addition to having governmental character, has sufficient discretion in the management of its own affairs to distinguish it as separate from the administrative structure of any other governmental unit.

Thus, to be regarded as a government for Census Bureau purposes, an entity must possess all three of these critical attributes: existence as an organized entity, governmental character, and substantial autonomy. Substantial autonomy is often translated into an ability to raise revenue. There are over 450 regional councils in the country that are not counted as local governments because they fail to meet at least one of the above three attributes. Often they lack substantial autonomy and merely serve in an advisory capacity. Because of these issues, we will control for the presence of a regional government in an MSA in my analysis but we will not include them in the more formal fragmentation measures.

Central City Elasticity

A central city that is able to accommodate growth through annexation of additional urban area should help to limit the amount of fragmentation of an MSA. If the central city has historically been limited in its ability to annex or expand its boundaries, the new urban areas that surround it will form their own governments and likely add to the fragmentation of the MSA.

Central city elasticity has been defined several different ways in the literature. Nelson and Foster (1999) use the ratio of central-city population in 1980 to 1960 divided by the ratio of land area in 1980 to that in 1960. The authors suggest that an inelastic city will have a low elasticity score that is perhaps negative but usually around 0. San Francisco is given as an example of an inelastic city. Its population has declined and its central city has the same area as it did nearly a century ago (Nelson and Foster 1999).

An example of an elastic city would be one that adds population but does not increase its land area. The authors use Oklahoma City as an example here with over 1500 square miles of incorporated largely undeveloped land, thus it can easily accommodate any added population without increasing its borders. Other similar cities include Kansas City, Missouri, and Denver, Colorado (Nelson and Foster 1999).

Rusk (1995) uses a ranking system to define central city elasticity. He first takes the ratio of population in 1950 to the land area of the central city in 1950. This is score A. He then computes the expansion of the central city area from 1950 to 1990 as a percentage change from the initial area. This is score B. Each city is then ranked by scores A and B and ordered by decile. The final elasticity number is determined by adding each decile ranking for a city with three times score B. For example New York City (NYC) in 1950 had the highest population density so it was in the first decile. It also did not expand its borders from 1950 to 1990 thus it was also in the first decile for elasticity. (Lower rankings mean less elastic.) Thus NYC's overall ranking would be $1 + (1 \times 3) = 4$.

Rusk suggests in his appendix that this rating system is as much art as science. This is reflected by the fact that Rusk groups central cities by population and size of the

MSA they are located in before he orders them. Rusk doesn't use population in his elasticity measure because one of his contentions is that cities that can expand their borders will gain population faster than cities that can't. Thus, two central cities can have the same final elasticity number assigned to them, but in fact be very different based on population and location within a particular MSA. Furthermore due to the grouping by population it is not possible to compare elasticity across cities in different population groups.¹¹ In the empirical model section we will describe how Rusk's measure can be modified so as to be practical to use in my analysis.

Elasticity is an important fragmentation measure as it is a good proxy for cities ability to expand. Annexation laws are myriad and complex and not easily categorized. A central city that has been able to expand its borders over time should have a consolidating effect on the MSA. Another important area to consider for fragmentation is the effect of the number of jurisdictions and the size of their budgets on an MSA's ability to meet environmental quality standards. This will be discussed next.

Metropolitan Power Diffusion Index

In an effort to measure the political effects of fragmentation based on jurisdictional fiscal power, Miller (2002) has developed the Metropolitan Power Diffusion Index (MPDI). The index is similar to the Hershman Herfandahl Index (HHI). To compute the HHI one takes the percentage that a corporation's revenue contributes to total market sales and squares it, these numbers are then summed. Squaring the percentages emphasizes the fact that larger corporations will tend to dominate the

¹¹ Blair, Staley, and Zhang (1996) do find support for using the elasticity measure to predict economic gain. However they only empirically test the central cities located in MSAs with populations over 250,000.

marketplace. Unlike corporations, in the political process small jurisdictions can serve to impede the will of larger jurisdictions in the same geographical area. It is due to this potential to impede that Miller uses the square root of revenue contribution to the whole to accentuate the power of the smaller jurisdictions as seen in equation (2.5).

$$MPDI = \sum_i \sqrt{EXPJD_i / MSAEXP}, \quad (2.5)$$

where $EXPJD_i$ equals the expenditures of individual jurisdictions and $MSAEXP$ is the total expenditure of the MSA. Thus for the MPDI, higher numbers mean greater diffusion of power or fragmentation in the MSA.

Here is an example that Miller developed to illustrate the MPDI. Suppose in Region A there are six governments; in Region B, twelve. Total local government expenditures in both regions are \$1,000,000, of which \$900,000 (or 90 percent) is spent by the largest government in the each region. In Region A, there are five smaller governments that each spends \$20,000 while in Region B there are 11 smaller governments that each spends \$9,091. If one is just counting jurisdictions, Region B would appear to be twice as fragmented as region A. However, with each region possessing an equally dominant jurisdiction, in which 90 percent of the regions expenditures are made, the characterization that region B is twice as fragmented as Region A seems excessive to Miller. Using the MPDI however, indicates that region B is roughly 20 percent more fragmented than Region A. This result is more acceptable to Miller based on the dominance of a single jurisdiction in both regions. Table C1 in appendix C shows the details of how the MPDI is calculated. Table C2 lists the

expenditures included in the MPDI measure used by Miller. It also includes additional expenditures that we include in an alternate measure of MPDI, discussed in chapter 4.

Fragmentation measures have developed substantially from the early aggregate measures used in the older literature that simply counted the number of local governments in a metropolitan area. Recent measures take into account local government characteristics and their relation to that of the greater metropolitan area. These traits are summarized as the inclusiveness of local governments, local government scale, and the primacy of county government (Foster 1993). Regional governments are also taken into consideration when measuring a metropolitan areas' level of fragmentation (Nelson and Foster 1999). The ability of central cities to expand and annex neighboring jurisdictions, often called central city elasticity, is now also taken into account when measuring fragmentation (Rusk 1995, Nelson and Foster 1999). Finally the fiscal power of the local government relative to the region as a whole is considered by the MPDI (Miller 2000).

The development of measure that accurately reflect governmental fragmentation is a key element of any empirical test of fragmentation's effects on urban quality of life, in the next section, we review the performance of the fragmentation measures presented in the previous analysis.

Empirical Results from the Literature

The empirical literature on fragmentation is predominantly concerned with growth and development of a region. In particular, researchers examine whether fragmentation measures can explain observed growth patterns in metropolitan areas. This literature attempts to resolve the question of whether fewer larger centralized local

governments or many smaller decentralized local governments are the most conducive to growth and development. The first two papers discussed below, Razin and Rosentraub (2000) and Carruthers and Ulfarsson (2002), use the more traditional simple measures of fragmentation, while the later papers, Foster (1993), Nelson and Foster (1999), use the more recently developed measures. Once again, the empirical literature is not conclusive as to what form of local government encourages growth.

Razin and Rosentraub (2000) examine the link between urban sprawl and fragmentation in the United States and Canada. They include all MSAs with over 500,000 people in both countries in a cross-sectional analysis. They utilized five measures of fragmentation that include both aggregate measures and broader Foster-type measures. The list includes:

1. Total number of governments per 10,000 residents (including school and special districts);
2. General purpose governments per 10,000 residents;
3. Existence of multipurpose metropolitan level government;
4. Proportion of population in the largest city; and
5. Proportion of population in cities with at least 100,000 residents.

Most of these measures are very similar to measures used in this analysis. The first measure, total number of governments per 10,000 residents, is similar to the relative fragmentation measure. However, this measure includes school districts while the relative fragmentation measure we use does not. The second measure, general purpose governments per 10,000 residents, is also similar to the relative fragmentation measure we use, but does not include special districts. The third measure, existence of multipurpose metropolitan level government, is computed as a dummy variable for my analysis. The fourth measure, proportion of population in the largest city, is also used in my analysis. Lastly, the proportion of the population in cities with at least 100,000

residents is similar to central city dominance, which uses the proportion of population in cities of over 50,000.

Razin and Rosentraub assess the relationship between fragmentation and sprawl in several steps. First they construct fragmentation and sprawl indices. The fragmentation index is based on the variables listed above. The sprawl index is based on various population and housing density measures. They next conduct a simple correlation test between the two indices. Razin and Rosentraub's results reveal that there is a weak but statistically significant association between sprawl and fragmentation. This result remained even when the less fragmented and more compact Canadian metropolitan areas were not included in the analysis.

Next they conduct several different regressions using either the fragmentation index or the sprawl index as the dependent variable. In both regressions they use the control variables, age of housing stock, and country of location for the MSA and percent of population in poverty. The fragmentation index is the dependent variable in the first regression, with the independent sprawl variable being the population per square kilometer. They find that the coefficient for population per square kilometer is positive and statistically significant. Thus they conclude that greater values of residential sprawl are linked to higher levels of government fragmentation.

Next they use the sprawl index as the dependent variable. Here the independent fragmentation variable is general purpose governments per capita. They find the fragmentation variable is not statistically significant. Thus, they conclude that fragmentation may not necessarily predict sprawl.

Carruthers and Ulfarsson (2002) examine how local government structure affect four measures of MSA development; population density, urbanized land area, property values and public expenditures on infrastructure. Their data include MSAs in 14 states covering 283 counties. They utilized time series data from the years 1982, 1987 and 1992. While acknowledging the benefits of the fragmentation measures developed by Foster (1993) the authors choose to use aggregate measures of fragmentation, citing ease of econometrics and consistency with other variables in the model. They use the number of municipalities per capita and number of special districts per capita. They found fragmentation is associated with lower population densities and higher property values. No direct effect on public service expenditures was found. Less fragmented metropolitan areas tended to cover more land. The authors suggest this is due to the extensive annexation needed to bring new development under the control of a central municipality. They claim that their findings support efforts by state and regional planning bodies aimed at increasing cooperation among local governments.

Foster (1993) examines the link between local political structure and metropolitan population growth. In particular Foster attempts to determine empirically whether public choice or regionalist local government policies can best explain population growth in MSAs. Foster examined data for 129 large U.S. metropolitan areas between 1962 and 1982.

Foster tested two linear models using Ordinary Least Squares (OLS). In the first model metropolitan population growth is stipulated to be a function of local government structure variables and environmental factors. The local governmental structure variables are the six previously discussed, Central City Dominance, Suburban Un-incorporation,

Suburban Municipal Fragmentation, School District Decentralization, Special District Dominance and Special District Overlap. The value of the local government structure variable for the first year of the period is used. The environmental factors are: metropolitan age, population density, and location by region. The second model is the same as the first however, lagged values of the changes in the six local government structure variables are added. The second model attempts to measure how changes in local government structure over time affect population growth.

The results from the models were mixed and not easily interpreted. The first model only provided two significant coefficients for government structure. They were suburban unincorporation and school district decentralization. The result for suburban unincorporation supported that public choice perspective.

In the second model, several more variables were significant. The variables from the second model, controlling for change in governing structures over time, tended to support the regionalist perspective. However the results were equivocal, three of the six variables supported the regionalist perspective. They were suburban unincorporation, suburban municipal fragmentation, and special district dominance. The result for the suburban unincorporation in the second model was not consistent to the result in the first model. While one, school district decentralization, supported the public choice position that greater fragmentation induces local government competition and thus encourages population growth. Foster concluded that the six local governmental structure variables used interact in different ways with population growth for MSAs. The result may explain the inability of simple measures of government structure to predict population growth in MSAs in previous work (Foster 1993).

In an effort to build on the work of Foster (1993) and try to further explain the role of government structure and growth, Nelson and Foster (1999) develop a model that includes local and regional government structure variables. This time the goal was to test empirically whether public choice or regionalist theory could explain observed MSA economic growth. They examine the link between local government structure (fragmentation) and per capita personal income growth in MSAs from 1976 to 1996. Their sample was made up of 287 of the largest metropolitan statistical areas in the United States.

In order to compare government structure across MSAs, Nelson and Foster adopt measures very similar to those used by Foster (1993) described above. They compiled two broad measures of government structure based on local governance and regional governance criteria. After controlling for many baseline income and demographic factors, they found some empirical support for the regionalist school of thought that consolidated government promotes growth. They found that central city dominance and suburban city average population had statistically significant effects on MSA income growth, while special district dominance was statistically significant at the ten percent level. However, there were also some insignificant fragmentation measures, such as percent of population in unincorporated areas, school district density and general purpose elected official density. The regional measures were hard to interpret because of some implausibly large coefficients. Also, some of the findings did weakly support the public choice school of thought.

In an attempt to extend the literature, Foster (1993) and Nelson and Foster (1999) had limited successes in showing empirically that these new measures offer improved

explanatory power over the old aggregate measures. Foster only found three of the six to be significant and Nelson and Foster (1999) only used four measures and only two of these were significant at the five percent level. Two other promising measures of fragmentation are explored below.

An alternative measure of fragmentation is the Municipal Government Power Diffusion Index (MPDI) used by Miller (2000) in his analysis of MSA economic growth. Miller collected data on 311 MSAs for two periods 1972 and 1992 and calculated the MPDI for all MSAs for both periods. Miller focused on the trends in MPDI as well as how it related to economic growth over the period. His results were that the 311 MSAs have become more diffuse overtime with the average score going from 3.83 to 4.16. Eighty percent of the 311 MSAs had increased their score. Miller found that these increases in MPDI were uncorrelated with population growth; However the MPDI was correlated with the absolute number of municipal governments. He concluded that this was most likely due to the increased financial role suburban jurisdictions played in providing services. Miller also examined certain areas of Pittsburgh to illustrate, anecdotally, that increasing diffusion may lead to urban decline.

The final measure we adopt in my analysis is a modification of Central City Elasticity, first used in this context by Rusk (1995). Rusk is interested in the way that elasticity affects people's lives through economic development and segregation. His basic premise is that elastic central cities and metropolitan areas thrive by capturing more revenue from wealthier outlying areas. Rusk used census data for 522 central cities located in 320 metropolitan areas from 1950 and 1990. Rusk does many comparisons

using economic growth and housing statistics among pairs of cities. Through these comparisons Rusk finds support for his hypotheses.

Rusk also compares cities based on government fragmentation measures, using the number of suburban jurisdictions and percent of MSA population living in the central city. Using these two measures he makes additional comparisons between cities. He found that fragmented areas, as defined by the number of suburban governments, have a higher segregation index for the selected cities.¹²

Summary

Economists and planners have had limited success trying to explain the role MSA government fragmentation has in regional development. Regional development has been proxied several ways including growth in population and growth in personal income (See Foster 1993, Carruthers and Ulfarrson 2002 and Nelson and Foster 1999). The fragmentation literature tries to attribute the reasons for growth to a decentralized local government structure or a consolidated local government structure. However growth is driven by many factors some of which arguably confound each other when analyzed. Larger regional entities may better serve some government functions such as planning, public transportation, and public utilities (Nelson and Foster 1999). However local governments may in general operate more efficiently due to competition under a more decentralized system. Decentralized local government structure is often associated with the doctrine of public choice. While a more consolidated local government structure is

¹² For a more detailed analysis of fragmentation and racial segregation see Dawkins (2005).

associated with regionalism. Isolating the effect of public choice or regionalism on MSA growth is still an area of ongoing research.

However maintaining appropriate levels of regional environmental quality requires controlling pollution. With air quality, the affected region is the entire air-shed which generally encompasses the MSA boundary. If no single government exists to internalize the externalities generated by each jurisdiction within the affected geographic region, air quality is expected to be less than the optimum. Thus, the level of fragmentation of the MSA should directly affect its ability to comply with air-quality standards. In the next chapter we will develop the empirical model and discuss other important control variables such as MSA demographic characteristics and the price of public good provision.

CHAPTER 4

DATA AND EMPIRICAL IMPLEMENTATION

This chapter develops the data and the empirical model used to test the role of local government structure on the level of urban environmental quality observed in large United States MSAs. The data used comes from the subset of MSAs in the United States with populations over 200,000. Three panels of data were collected for the years, 1992, 1997, and 2002. Two approaches will be used to test the hypothesis that government fragmentation hinders the ability to attain environmental quality standards. The first will be a cross-sectional approach using the 1997 panel. This year is chosen because the richest set of covariates is available.¹³ The second approach will utilize panel data models that include all three years of data. The empirical model will attempt to extend the current governmental fragmentation literature into the environmental arena. In addition, this model will comprehensively test all relevant fragmentation measures used in the literature. we will also test modifications to existing fragmentation measures that we discussed in the earlier fragmentation chapter.

This chapter is laid out as follows. The conceptual framework for the empirical model is developed in the first section. The second section will discuss the data elements needed to implement the empirical model. In the third section, some data trends and patterns will be analyzed. The results of the empirical estimation will be presented in the succeeding chapter.

¹³ These include a fragmentation variable for central city elasticity as well as transit variables.

Context for the Empirical Model

In Chapter 2, we extended a model by Mueller to show that under certain assumptions the amount of public good provided by an individual jurisdiction within the MSA is given by the following equation.

$$G_j = \frac{\beta}{\alpha J + \beta} \frac{RY}{P_g}, \quad (4.1)$$

where G_j is the level of public good provision selected by the social planner in the jurisdiction j . All jurisdictions are assumed to have the same number of residents, R . All residents of the MSA are identical and have the same income, Y . Under these assumptions the level of public good, G_j , set by all jurisdictions in the MSA will be equal. Equation (4.1) illustrates the level of public good provided by a given jurisdiction when all jurisdictions act independently. In Chapter 2 it was shown that an MSA, with only one jurisdiction acting independently, provides the Pareto optimal level of public good. However, as the number of jurisdictions increased, the gap between the optimal level of public good provision and the level provided by jurisdictions acting independently, increased.

The level of public good provision selected by individual jurisdictions within the MSA is difficult to observe. It is usually not possible to separate out county-level provision from city-level provision for most MSAs. Counties, cities and towns are the general purpose government sub-units that makeup an MSA. While environmental quality measurements exist at the county level they often do not at the city level. Thus to

aggregate equation (4.1) to the MSA level requires multiplying the level of public good provided by each jurisdiction. Restating equation (2-32) we see that:

$$G = JG_j = \frac{J\beta}{\alpha J + \beta} \frac{RY}{P_g} = \frac{\beta}{(\alpha J + \beta)} \frac{JRY}{P_g}, \quad (4.2)$$

where the total level of the public good in an MSA, G is a function of total MSA income ($= JRY$), the price of providing the public good, the number of jurisdictions, and taste parameters.

The relationship in (4.2) provides a basis for the empirical hypothesis of interest: do higher levels of governmental fragmentation in MSAs lead to worse environmental outcomes? In other words, our stylized theory gives rise to a general empirical model of the following form:

$$\text{Air quality} = f(\text{Governmental Fragmentation, MSA Total Income, Taste Parameters, Price of Public Good Provision}) \quad (4.3)$$

In equation(4.2), G is the level of public good provided in the MSA. In my application, G refers to MSA air quality, which can be measured in three ways: a binary variable indicating ozone standard attainment, measured ozone levels, or measured emission levels. Governmental fragmentation, J , is my explanatory variable of interest in equation (4.3). While J in equation (4.2) represents a simple count of governments, the concept of government fragmentation is considerably more nuanced, as discussed in chapter three. The empirical model will test all the relevant measures of fragmentation

developed in chapter three, which are listed in Table C3. Additional explanatory variables in (4.3) include the MSA total income and taste parameters for public and private goods. MSA total income will be proxied by MSA level gross metropolitan product (GMP). Taste parameters of individual residents for environmental quality are unobservable and the percent of the MSA that voted for a democratic candidate in elections held between the years 1997-1999 will be used as a proxy variable.¹⁴ In addition several demographic variables are included as well, such as MSA population age distribution, racial composition, and educational attainment.

The last explanatory variable in (4.3), price of the public good (P_g), requires careful consideration. P_g represents the price to a jurisdiction for providing the public good, which we do not observe directly. What we can observe are the policies that jurisdictions can take and the characteristics of the MSA that may make those policies more or less effective. Thus, the price of incrementing the public good is ultimately the opportunity cost associated with a vector of activities designed to improve air quality together with the effectiveness of the policies.

To develop proxy variables for the price of the public good, we must consider how ozone is formed. Ozone formation is driven by a complex relationship between emissions levels, geography, and weather, as discussed earlier. Thus, observable variables that describe emissions levels, geography, and weather can serve as proxy variables for the price of the public good. Jurisdictions can implement policies to reduce emissions (and thus improve air quality). These policies imply certain costs per ton of emissions reduced. But the effectiveness of these policies depends on the existing level of

¹⁴ Improving environmental quality is an issue that is often associated with democrats rather than republicans (O'Conner et. al. 2002).

emissions, urban form, geography, and weather. Thus, the cost of a policy per unit of ozone reduced depends critically on the above listed four factors. As such, we use variables that capture existing emissions, urban form, geography, and weather as our proxy variables for the price of the public good.

Consider the following example, which illustrates how the policy cost per unit of emissions reduced is affected by urban form. A jurisdiction may seek to decrease emissions from automobiles by decreasing VMT through the provision of more public transit for its residents. Public expenditures to encourage transit ridership and thus decrease vehicle miles traveled is more likely to succeed in an area with extensive public transit (Cervero 1994). Thus, areas with more extensive public transit systems may face a lower price per unit of emissions reduced from this type of policy as compared to an MSA with limited public transit system, all else equal.

The variables used to capture urban form are listed in Table C3. Urban form incorporates the spatial features and built environment of the MSA. The urban form variables affect air quality through their impact on automobile emissions and other nonpoint source emissions. Primarily, urban form can affect the nature of automobile trips. Controlling for VMT isolates a large portion of urban form pollution. However, the nature of the vehicle, the length of the trip, and the number of trips also can have an effect on pollution. Many short trips emit more ozone causing pollutants, due to frequent cold starts of a car, than the equivalent amount of mileage in one long trip (Safety Council 2006). More pollutants are also emitted in stop and go traffic, common at rush hours (Safety Council 2006). Thus, controlling for just VMT is not sufficient; a given level of VMT has a different impact on air quality depending on the nature of the

underlying trips and thus additional urban form variables are used to capture these additional elements.

For a given level of VMT, public transit can affect the frequency of trips and the mode of vehicle taken. Thus, the availability of public transit should lower the price of public good provision. Public transit could affect emissions for a given level of VMT in several ways. First, transit availability could help the MSA's low-income residents to substitute transit for driving older vehicles with poor pollution control technology. Also residents might be able to use transit to commute to work, alleviating some of the pollution associated with stop and go rush hour traffic.

There is also a link between VMT, transit usage, and population density. The more dense an MSA the more likely residents are to not own cars (Bento et al. 2003). Denser areas also have higher rates of transit usage (Cervero 1994). Thus, MSAs with higher population densities should have a lower price for emissions reduction. Controlling for vehicle miles traveled and the availability and usage of public transit mitigates much of the effect the style of development in the MSA might have on air quality. However, it is possible that two MSAs with the same population density per square mile but different styles of development can lead to different levels emissions.

Suppose MSA A and B has the same population and the same land area. Suppose MSA A has clustered mixed use residential and commercial development surrounded by green space. MSA B has traditional zoning with single family homes and separated commercial space, without any green space. The development style in MSA B suggests the need for more automobile trips. While it is difficult to measure the zoning practices of all jurisdictions within an MSA, it is possible to measure the percent of single family

housing within the MSA. More single family homes suggest a need for more automobile trips. It is estimated that a large portion of automobile emissions are generated in the first five minutes of operation due to cold starts (Safety Council 2006). Thus, more frequent automobile trips generate more emissions for a given level of VMT.

Whether an MSA is part of a CMSA or not might also affect the price of the public good. CMSAs are urban areas with more than one million people made of distinct component MSAs in close proximity. This close proximity might allow for policy decisions made in one MSA to affect the air quality of a given MSA within the CMSA. If neighboring MSAs make policy decisions that increase air quality, positive spillovers may decrease the price of providing better air quality. If neighboring MSAs make decisions that decrease air quality, negative spillovers may increase the cost of providing better air quality.

Existing types of economic activity within an MSA also impacts policy costs. Observable economic activity that directly results in emissions includes point source emissions from factories and utilities.¹⁵ Changes in the existing levels and mix of point sources can affect the cost of decreasing emissions from these sources. For example, jurisdictions located in an MSA with a few large utilities creating emissions are likely to have different costs of decreasing emissions than those located in MSAs that have primarily diffuse point source emissions such as small industry and manufacturing.

Large polluting industries create several problems for MSAs. First, large industries or utilities are likely to have political clout and use it to defeat costly emissions control initiatives. Second, large amounts of point source emissions increase the cost of

¹⁵ The major source of emissions is area source, primarily motor vehicles. The costs of changing these emissions were discussed as relating to urban form.

implementing an emissions policy. Third, if a significant portion of the jurisdiction economy relies on industry that contributes significantly to emissions, residents may not support emissions reducing initiatives.

General economic activity and growth could also affect the price of public good provision, for those activities that are not covered under point source emissions. Higher levels of employment could increase the price of public good provision, if it leads to greater area source emissions. To control for MSA economic activity, data has been collected on point source emissions, employment, manufacturing employment, presence of dirty industry and utilities. These variables and the data sources are all listed in Table C3.

While urban form, such as existing transit availability, and economic activity, such as point source emissions, affects the ultimate cost per unit of *emissions* reduced, weather and geography affect the ultimate cost per unit of *ozone* reduced. Recall ozone is formed by a complex atmospheric interaction between Nitrogen oxides (NOX), Volatile organic compounds (VOC), and sunlight. As such, the efficacy of emissions reduction activities and thus the price of increasing air quality (decreasing ozone) through any action depend on geography and weather. Summer temperatures, rainfall, and wind speed all are key determinants in ozone formation. For instance, suppose two MSAs, are identical in all respects except their weather and geography. Both jurisdictions take the same actions at the same cost, and reduce their emissions to the same level. For the jurisdiction located in a hot, dry, low altitude MSA, these actions might be less effective in reducing ozone levels than the jurisdiction located in an MSA with greater rainfall and wind. Thus, the effective price of incrementing air quality differs in these two MSAs

because of weather and geography. Weather variables used in my analyses are ozone season average temperature, total rainfall and average wind speed, and are listed in Table C3 along with the source of the data.

Regional geographical features such as mountains and coastlines can also affect ozone formation and thus the price of the public good. Mountains which might trap emissions over an air shed, such as in Los Angeles, will make actions to reduce ozone less effective and thus increase the cost of incrementing air quality. In the cross-section model, the region in which the MSA is located is controlled for. However, each MSA has unique geographical characteristics that are difficult to control for in a cross section, and as such, we will also explore panel models to control for MSA-specific geography.

The above discussion provides a broad overview of the data elements needed to test our hypothesis of interest. In the next section we discuss the data in more detail. In particular we discuss broad trends in key variables over time and relate them to each other.

Data Description

The unit of observation is the Metropolitan Statistical Area (MSA) as defined in 2000. Since metropolitan areas in New England are not always consistent with county borders, New England County Metropolitan Area (NECMA) definitions for these periods were used when appropriate. Only MSAs with populations over 200,000 were included in the sample in an effort to keep comparisons across MSAs as consistent as possible. It seems inappropriate to compare the government structure of Enid, Oklahoma, with a

population of 50,103, to the government structure of Chicago Illinois, with a population over 8 million.

There are 17 Consolidated Metropolitan Statistical areas (CMSAs) in the sample. A CMSA is a group of neighboring MSAs with a total population of over 1 million (See Appendix A for a full definition). These CMSAs contain 53 MSAs. Data are collected at the county level whenever possible and aggregated to the MSA level. Some data are only available by census urbanized area. In that case the value is assigned to all MSAs within the urbanized area. For large MSAs, the urbanized area is often similar to the CMSA definition. Table C4 lists MSAs and CMSAs by region.

Honolulu, Hawaii and Anchorage, Alaska are also dropped, as they are not in the continental United States. Their unique geography and weather patterns make them unsuitable for comparisons with the continental MSAs. The final sample includes the remaining 187 MSAs in the United States. Table C5 presents the summary statistics from the 1997 cross-section. Table C6 presents the correlation coefficients of the three dependent variables and the relevant independent variables. These data are discussed in the following sections in the order in which they are presented in the table.

Air Quality Variables

The empirical model will be tested using two different dependent variables, measured ozone levels and the attainment status of the MSA for a given year. Area total VOC and NOX emissions will also be analyzed. By using two different dependent variables, we attempt to resolve the regulatory inconsistencies and the complexities of ozone formation. Regulatory inconsistencies arise in the following three scenarios. First,

it is possible to attain the ozone standard and yet remain in nonattainment. Second, some MSAs have significantly above average emissions of precursor pollutants yet remain in attainment. Third, other MSAs have below average emissions yet are in violation. The Trends in the Variables section discusses the above MSAs in greater detail as well as the problem of ozone levels and attainment status inconsistencies. The complexity problem arises because ozone formation is a nonlinear process that is dependent on daily weather patterns, emissions, and geography. Thus, the two dependent variables as well as emissions data are used to ascertain the relationship between government fragmentation and environmental quality.

The EPA and the states collect air quality data at the county level, throughout the United States. The counties of interest here are those that lie within MSA boundaries. The reported ozone value, MAXEPA, is calculated by the same method as set out by the EPA's Laxton memo.¹⁶ This method is used by the EPA to determine the design values for the one-hour ozone standard for each county. For each monitoring station in a county, the fourth highest value is selected over a three year period. These values are then aggregated by MSA. The highest monitor value in the MSA is then selected and this is the design value for the MSA. Ozone value summary statistics are reported in Table C5. These variables are most interesting in the context of attainment status, and are discussed in detail in the next section.

Although Ozone formulation and emissions levels of precursor pollutants, VOCs NOX, are not linked in a linear fashion, emissions levels can help to get a clearer picture of an MSA's efforts at achieving the ozone standard. For nonattaining MSAs, a

¹⁶ The Laxton memo was put out by the Director of the Technical Support Division of the EPA, William G. Laxton in June 1990. It specified the methods of calculating new design values after the 1990 Clean Air Act amendments.

preliminary step in reaching attainment is usually to reduce its emissions of precursor pollutants. Also for those MSAs in attainment, maintaining a constant or declining level of emissions is likely to ensure that the MSA stays in attainment. Thus the relationship between fragmentation and these precursor emissions is of interest. The variation in emissions levels over time will be even more important when implementing the panel data model.

The EPA collects data on all criteria pollutants as well as ozone precursor pollutants, VOC and NOX. The data are broken down into point source emissions and area source emissions. Point source emissions were described previously in the section on economic activity. Area source emissions include all nonpoint sources as well as mobile sources. Nonpoint sources can be small factories or businesses that emit criteria pollutants below the threshold for point sources. A common example is a dry cleaner. Area sources are also inventoried by state agencies and reported to the EPA. Mobile sources are considered any vehicle with a gasoline or diesel engine. Cars, trucks, airplanes, trains, and boats are all included in mobile source emissions. The EPA uses a computer model, called MOBILE, to estimate the emissions generated by mobile sources within a given area. Area emissions make up the majority of emissions for almost all MSAs. The emissions data come from the EPA's National Emissions Inventory (EPA 2006). All years are not available, so we used the closest years to the other data. The emissions data are for the years 1990, 1997, and 2001.¹⁷

The EPA designates each county as in attainment or nonattainment for each of the six criteria air pollutants. For the one-hour ozone standard the EPA compares the design

¹⁷ The point source emissions data for these years is all correlated with correlation coefficients for all three years, 1990, 1997, and 2001 of 0.9 or higher.

value to the standard, which is 0.12 ppm. If a county's design value is greater than the standard, the county is deemed to be in nonattainment. To determine whether an MSA is in attainment, we examine all the county designations within the MSA boundary. Per EPA rules, if an MSA has at least one county in nonattainment it is considered in nonattainment for the period (EPA 2006b).

Government Fragmentation Variables

Chapter 3 describes the different ways in which government fragmentation may be measured. The computation of each of these measures is described below.

Two simple measures of fragmentation are absolute and relative fragmentation. The first absolute measure of fragmentation is the number of governments within a given area (Zeigler and Brunn 1980). Governments include counties, municipalities, townships, and special districts. This is the simplest method and embodies the idea that the more governments in a region, the more fragmented the decision making in the region. Thus the more jurisdictions in the MSA, the lower the level of environmental quality expected. Chicago Illinois has the highest jurisdiction count at 1103, while Fayetteville, North Carolina has the fewest jurisdictions with only 10. The mean number of jurisdictions is 121 (see Table C5, "JDCNT").

Relative fragmentation is the second aggregate measure; this measures the number of governments for some increment of the population (Dye and Hawkins 1971, Carruthers and Ulfarsson 2002). Relative fragmentation takes into account the population of an MSA when determining fragmentation levels. Because we have chosen to use only MSAs with a population over 200,000, most of the midwest small town problem is

eliminated. We are using the number of governments per 10,000 residents. Miami, Florida has the lowest relative fragmentation score with one-sixteenth of a government per 10,000 residents. Johnstown, Pennsylvania has the highest score with 8.16 governments per 10,000 residents. The mean is 2.1 (see Table C5, “RELFRAG”). The relationship of relative fragmentation, jurisdiction count, and attainment will be explored further in the next section, Trends in the Variables.

Not all local governments have an equal effect on fragmentation. The size, scope and type of local governing bodies within an MSA can mitigate the degree of fragmentation (Foster 1993). These are not considered by traditional simple measures of fragmentation. The measures that we are including in this analysis are: Special district dominance, Central city dominance, and Suburban unincorporation (County primacy). In the following section we will describe these fragmentation variables.

As discussed in Chapter 3, special districts could either help mitigate fragmentation through coordinating multiple jurisdictions or add to fragmentation by adding an additional layer of government. The presumption here is that special districts add an additional layer of government fragmentation. This is due the fact that most special districts only handle one function. In addition, data does not exist to successfully identify overlapping jurisdictions. Thus, the measure we will be using, special district dominance (SDD), is defined as the number of special districts within an MSA divided by the number of nonschool district governments such as town, cities, and counties, in the MSA. The lower the value of SDD the less fragmented the MSA.

On average, there are approximately two special districts per general purpose unit of government in an MSA (see Table C5, “SDD”). Shreveport-Bossier City Louisiana has

the lowest score for SDD with 0.03 special district per general purpose government.

MSAs in Louisiana and Virginia have six of the lowest ten scores for SDD. Sacramento, California has the highest score for SDD with 13.4 special districts per one general purpose governments. MSAs in California occupy seven of the top-ten highest scores for SDD.

While many single purpose special districts can increase fragmentation, large general purpose governments, such as central cities, could serve to reduce fragmentation. Dominant central cities could be leaders in providing higher levels of environmental quality. They could also coordinate provision efforts by the smaller jurisdictions. The measure of central city dominance we use is calculated by dividing the number of people living in cities with a population greater than 50,000 by the total metropolitan population (Foster 1993). A larger number for the central city dominance measure would indicate a less fragmented MSA and a higher level of environmental quality.

Ten MSAs have a value of zero for CCD. Some MSAs do not have a city with over 50,000 people, while others do not have central city by census definition¹⁸ The MSA with the highest value for CCD is Lincoln, Nebraska with a value of 0.9. New York City has the second highest value. Rather surprisingly seven of the top-ten CCD MSAs are located in the western states of California, Texas and Arizona.

Some MSAs may have a dominant county government rather than a central city government. The primacy of county government is important in dealing with MSAs with large-unincorporated areas. If a significant portion of the population lives in unincorporated areas, general-purpose county governments may act as consolidating

¹⁸ The three MSAs with no formally designated central city are: Monmouth, NJ, Brazoria, TX and Nassau-Suffolk, NY.

agents for decision-making (Foster 1993). The measure for county primacy we are using is the population in the unincorporated area divided by noncentral city population. The larger the number for county primacy the less fragmented the MSA.

There are some inherent difficulties in calculating county primacy due to the way different states treat towns and cities. In some states all the urban area is either covered by a town or a city.¹⁹ Thus the value for unincorporated population is zero and the value of CP is zero.²⁰ This low score for County primacy is appropriate because there is total geographic overlap of general purpose municipal and county governance in these areas. This arrangement would seem to lead to high government fragmentation. Fifty-four MSAs have a score of zero for county primacy.

An MSA can also have an infinite score for county primacy if all its population lives in central cities. For these cases, we inserted a value of 165 to avoid the infinite value. (This is slightly higher than the highest naturally occurring value of 161.) While this is not the traditional idea espoused by Foster (1993), it captures the spirit of the fragmentation measure. All an MSAs citizens are being served by only several large municipal governments. The only MSA in the data set for which this occurred is Reno, Nevada. The MSA with the highest naturally occurring score for CP was Odessa-Midland, Texas with a score of 161.

A central city that is able to accommodate growth through annexation of additional urban area should help to limit the amount of fragmentation of an MSA. If the

¹⁹ Indiana, Maine, Massachusetts, New Hampshire, New Jersey, Pennsylvania, Rhode Island, and Wisconsin have either townships or municipalities covering all urban areas.

²⁰ City and town overlap is controlled for in appropriate states by only counting population of the city or town that was greater if they had the same name. In most cases it was the township. If city population was greater than the MSA population, the MSA was designated as having zero unincorporated area.

central city has historically been limited in its ability to annex or expand its boundaries, the new urban areas that surround it will form their own governments and likely add to the fragmentation of the MSA. To calculate the elasticity measure we will be using the change in land area and population of central cities from 1950 to 2000.²¹

Traditionally elasticity is defined as the percent change in one variable over the percent change in another. Unlike calculating the elasticity of supply or demand, there is no prior theory to ascertain what sign or magnitude the elasticity will be for a city. A city could either expand or contract in land area since 1950, and expand or contract in population since 1950. Any of the four combinations of the above are possible. Due to the nature of cities and growth, the sign of the changes in land area and population become important. A city that is growing in both land area and population will have a positive elasticity as would a city that is both shrinking in population and land area. Yet these two cities would represent opposite patterns of growth.

If the central city controls more land area than it did in 1950, it could have a consolidating effect and reduce fragmentation. This would also be true if the population of the central city grew since 1950. It is also possible that the positive effects of an increase in land area might be mitigated by the negative effects of a decrease in population or vice versa. Thus, it is important that the signs on the numerator and denominator remain the same. Thus, instead of dividing percent change in land area by percent change in population, we will add the two terms together. That way if both are positive it will reinforce the consolidating effect. If both are negative, it will decrease the

²¹ We wish to thank David Rusk for sending his data and thus saving many hours of painstaking research and data entry.

consolidation effect. If the signs are opposite one will mitigate the other. We refer to this measure as central city growth (CCG). Thus the CCG is calculated as follows:

$$CCG = \frac{LA2000 - LA1950}{LA1950} + \frac{POP2000 - POP1950}{POP1950}, \quad (4.4)$$

where LA2000 is the land area of the central city in 2000. LA1950 is the land area of the central city in 1950. POP2000 is the population of the central city in 2000, while POP1950 is the population of the central city in 1950.

Central city growth is an important fragmentation measure as it is a good proxy for a city's ability to expand. Annexation laws are myriad and complex and not easily categorized. A central city that has been able to expand its borders over time or grow in population should have a consolidating affect on the MSA. Thus, a higher score for CCG should have a positive effect on the level of environmental quality.

The MSA that had lowest CCG score is Johnston, Pennsylvania. MSAs with low CCG scores usually had declining populations and constant central city land areas. Five of the top-ten lowest scoring cities for CCG are in Pennsylvania or New York. The MSA with highest CCG score is Lexington-Fayette, Kentucky. Five of the top-ten highest scoring CCG MSAs were in western states of Arizona, Nevada, and California. MSAs with high CCG scores had increasing land area and populations. But for those in the top-ten, increasing land area was the major factor. Two central cities, Lexington, Kentucky and Augusta, Georgia, increased their land area by merging with the surrounding county. Central cities in western states expanded their land area through aggressive use of state annexation laws.

In an effort to measure the political effects of fragmentation based on jurisdictional fiscal power, we will also explore the Metropolitan Power Diffusion Index (MPDI) developed by Miller (2002). Recall from chapter three that MPDI is measured by summing the square root of the share of individual jurisdiction expenditures to total MSA expenditures. The MPDI captures the ability of small jurisdictions to impede the will of larger jurisdictions in the same geographical area. Thus for the MPDI, higher numbers mean greater diffusion of power or fragmentation in the MSA. To calculate MPDI, expenditures were summed by counties, towns, cities, and special districts. School districts were not included as their decisions are not expected to have an effect on environmental quality. We expand on Miller's specification by including almost all expenditures made at the local government level such as educational expenditures made by general purpose governments.²² Such expenditures could add to the clout of a city or county that makes them and could give them additional influence in environmental decision making. A list comparing the expenditures we use and those used by Miller is included in Table C2.

The average value for MPDI in the sample is 5.22. Fayetteville, North Carolina had the lowest value of 1.7 while Boston had the highest value of 17.62. Seven MSAs had scores over ten; Boston, Chicago, St. Louis, Pittsburgh, Philadelphia, Minneapolis-St. Paul and Scranton-Wilkes-Barre. All of these MSAs are in the north or midwest. There were 114 MSAs with MPDI scores below the average of 5.22. Only 21 percent of these were in the north or midwest. A contributing factor to higher MPDI scores in the north and midwest is the existence of townships. Townships only exist in selected north

²² We also calculated the measure used by Miller. Our measure and the Miller MPDI are highly correlated with a correlation coefficient of 0.99.

and midwestern states. Townships add another layer of government that often has concurrent jurisdiction over areas that include municipal and county governments. As was discussed in the section on county primacy, in eight states all the urban area is either covered by a town or a city.

MSA Income, Taste and Demographic Parameters

MSA population, personal income and taste parameters are part of the theoretical model. MSA population and personal income combine in the natural world to contribute to MSA wealth, which we measure as MSA GMP. Taste parameters for the public good and private good are also included in the theoretical model. The taste parameter for the public good is proxied by the percent of the MSA that voted democratic. These measures are discussed next.

The population of each MSA is determined from the counties that make it up from the census of governments for the given year. The least populous MSA in the sample is Waco, Texas with 201,775 people; the largest is Los Angeles, California with 9,727,751. There are 58 MSAs in the sample with over one million people. The distribution of these large MSAs reflects current population growth trends. Only 24 of the largest MSAs are located in the north and midwest while 34 are located in the south and west.

Personal income data were gathered from the Census and is based on the personal income of the corresponding urban area for the MSA. Mcallen-Edinburg-Mission, Texas had the lowest personal income per capita at \$12,056 while New Haven-Meriden, Connecticut had the highest at \$47,190.

There is some minor variation between the mean personal income in the four regions. The north had the highest average MSA per capita personal income of \$27,988 while the south had the lowest at \$23,208. The north also had the greatest variation in MSA per capita personal income, while the midwest had the least.

The theoretical model relies on the income of residents to determine the level of public good provided. However, in the natural world, the total economic productivity of the MSA is a more appropriate measure of wealth. It is the yearly production of the MSA that determines the amount of resources available to employ policies that can improve air quality. The most complete description of MSA productivity would be given by Gross MSA product (GMP). Unfortunately complete data on GMP is not available. In order to calculate GMP, we use a gross state product measure weighted by each MSA's contributions to total state personal income. A similar approach is used by Bauer and Lee (2006) of the Cleveland Fed to estimate gross state product from gross domestic product data. More formally, GMP is measured by:

$$\text{GMP} = \text{GSP} * (\text{MSAPI} / \text{STPI}), \quad (4.5)$$

where GSP is gross state product, MSAPI is total MSA personal income, and STPI is total state personal income. This yields a yearly estimate of GMP for 1992, 1997, 2002. The motivation of the Cleveland Fed was to find a way to estimate GSP due to the long lag in the release of the official GSP. We rely on the official BEA calculations of GSP to estimate MSA GMP. Ocala, Florida had the smallest GMP while New York City had the

largest. The relationship between MSA population, GMP, and attainment of the ozone standard will be explored further in the next section on Trends in the Variables.

The theoretical model includes taste parameters for the preference for the public good and the private good. These parameter values are unobservable and so proxy variables must be used. In the natural world, one assumes that these preferences are linked and move in opposite directions, if one has a high preference for the public good one has a lower preference for the private good. Thus, one variable can be used to quantify both parameters. The variable chosen to proxy for the preference for the public good is the percent of voters in the MSA congressional elections between 1997 and 1999 that voted for a democratic candidate or against a republican candidate. The low value for PERDEM was 4.8 percent in Harrisburg-Lebanon, Pennsylvania while the high value was 100 percent in New Orleans and Lafayette, Louisiana.²³

Surprisingly, PERDEM is not correlated with any of the independent variables. There are some minor trends in the PERDEM variable at the state level. States that Al Gore carried in 2000 had a higher state average PERDEM score than states that George Bush carried in 2000. In the 16 states in the sample that voted for Al Gore in 2000, the state average value for PERDEM was 52 percent. While the 26 states that voted for George Bush in 2000 had a mean PERDEM state value of 46 percent. There is some degree of variation in PERDEM within the 42 state-sample. Twenty-two states have standard deviations higher than ten for PERDEM for the MSAs within the state.

²³ These extreme values are likely the result of two factors. First, the MSA lies primarily in one congressional district. Second, the congressional candidate was a popular incumbent and ran unopposed in that period.

Six of the top-ten most populous MSAs had a value over 52 percent for PERDEM.²⁴ Boston had the highest with 74 percent. The remaining five MSAs with greater than 52 percent for PERDEM were New York City, Los Angeles, Detroit, Chicago, and Philadelphia. Dallas had the lowest score for PERDEM at 33 percent. The remaining three MSAs with below 50 percent were, Houston, Nassau-Suffolk, and Atlanta.

Data was also collected on the age distribution, racial composition, and educational attainment of the MSA populations. It is not known a priori what the effect of the age distribution will have on environmental quality. Three measures of age distribution were collected, the percent of the population less than 25 years old, the percent of the population between 25 and 64, and percent of the population 65 and over. For 1997, the MSA with the highest proportion of its population under 25 was Mcallen-Edinburg-Mission, Texas with 48 percent. The MSA with the lowest proportion of its population under 25 was Sarasota-Bradenton Florida, with only 25 percent. Washington, DC had the greatest proportion of its population between the ages of 25 and 65 with 58 percent. The MSA with the lowest proportion of its population between the ages of 25 and 64 was Mcallen-Edinburg-Mission, Texas with 43 percent. For the category of over 65, Sarasota-Bradenton Florida had the highest proportion of its population with 30 percent, while Austin San Marcos, Texas had the lowest with only 8 percent.

Literature on environmental racism suggests that areas with greater minority populations should have worse environmental quality (see Scorecard 2007). Four racial

²⁴ Commentators suggest that the real trends in the 2000 and 2004 elections are found at the county and district level, not the state level. Urban areas and inner suburbs tended to support the democratic presidential candidate while the outer suburbs and rural areas tended to support George Bush (see Nichols 2005).

categories were used. They are percent of the MSA population that is white, percent black, percent Hispanic, and percent Asian. The MSA with the highest percentage of its population categorized as white was Scranton-Wilkes-Barre, Pennsylvania with 97 percent. The MSA with the lowest percentage white was Mcallen-Edinburg-Mission, Texas with 12 percent. The MSA with highest percentage of its population characterized as black was Jackson, Mississippi with 43 percent. The MSA that had the smallest percentage of its population characterized as black was Mcallen-Edinburg-Mission Texas with 0.3 percent. Charleston, West Virginia, had the lowest percentage of its population characterized as Hispanic, with only 0.4 percent, while Mcallen-Edinburg-Mission, Texas had the highest with 87 percent. San Jose, California, had the highest percentage of its population characterized as Asian with 21 percent, while Baton Rouge, Louisiana and the lowest with an Asian population of only 0.3 percent.

For the category of percent of population graduating from college, it is expected that a higher percentage of college graduates in an MSA should have a positive effect on environmental quality. The intuition here is that if environmental quality is an amenity than people with higher incomes should consume more of it. If college graduates have higher incomes than nongraduates, then places with higher percentages of the population with college degrees should have better air quality all else equal. The MSA with the highest percentage of its population college graduates is Washington, DC with 36 percent. While Little Rock, Arkansas has the lowest percentage with only 16 percent of its population college graduates.²⁵

²⁵ Data on educational attainment levels was only available at the state level for the years 1990, 1998, and 2002. Therefore each MSA in a state is assigned the same level. The years were assigned to the closest corresponding year in the panel model.

Price of Public Good Proxy Variables

The price of the public good is unobservable, thus proxy variables must be used as was discussed earlier. These variables fall into three categories; urban form, economic activity, and weather/geography. In this section the proxy variables for the price of the public good are discussed.

The urban form variables affect air quality through their impact on automobile emissions and other nonpoint source emissions. Urban form can affect the nature of automobile trips. Controlling for VMT isolates a large portion of urban form pollution however it is possible that other aspects of urban form may impact emissions. The public transit variables, land area variable, density and land use variables attempt to control for these additional effects.

The ideal measure to assess the contribution cars make to urban air pollution would be motor vehicles emissions. Motor vehicles emit 48 percent of NOX and VOC (FHWA 2003). While some data exist on motor vehicles emissions at the county level, the data is incomplete. Therefore vehicle miles traveled is used as a substitute for motor vehicles emissions. The daily vehicle miles traveled (DVMT1997) for the urban area of the MSA is in thousands of miles. However for the empirical model, we divide by a million to improve the scaling. Because of the link between automobile emissions and ozone formation, greater levels of DVMT1997 should lead to a higher price for the public good.

The lowest value for DVMT1997 was in Johnston, Pennsylvania with 1.32 million daily vehicle miles traveled. The maximum value is Los Angeles, California with approximately 210 million daily vehicles miles traveled. To put this value in perspective,

the earth lies approximately 93 million miles from the sun. The MSAs of Chicago, Illinois, New York City, Atlanta, Georgia and Detroit, Michigan round out the top-five highest in DVMT1997. DVMT1997 is highly correlated with MSAPOP (see Table C6). This relationship will be examined further in the next section, Trends in the Variables.

Commute time can also influence emission levels for a given level of VMT. Longer commute times suggest that cars are spending more time in rush-hour stop and go traffic. For a given level of VMT, stop and go traffic generates higher emissions levels (Safety Council 2006). Thus, MSAs with longer commute times should face a higher price for the public good. Commute time is the average commute to work in minutes for MSAs in 1999. Lubbock, Texas had the lowest commute time of 17.1 minutes, while New York City had the highest of 38.9 minutes.

For a given level of VMT, public transit can affect the frequency of trips and the mode of vehicle taken. The availability of public transit should lower the price of public good provision as was discussed in an earlier section. We use several variables to measure the effect of public transit on air quality. They include the amount of bus and train routes, as well as the sum of all public transit fares.

There are ten MSAs that do not have any public transit route miles. The average MSA public transit route miles are 928. There are 132 MSAs that have less than the average. The MSA with the most route miles is Los Angeles, California with 8,448. New York City is second with 8,444. Route miles are correlated with the population of the MSA, with a correlation coefficient of 0.83(see Table C6).

An additional transit measure is revenue (SUMFARES). Transit fair revenue serves to measure the utilization of transit in the MSA. If more people use transit, the

price of providing clean air should be lower. Transit ridership rates would be a better measure of utilization, but it is not readily available for all MSAs in the sample.

The ten MSAs without any transit routes also had zero fares collected. Of the MSAs that collected fares, the minimum was Ocala, Florida with \$7,335. The average fare collection was approximately \$37.17 million. One-hundred-sixty-six MSAs collected less than this amount. New York City collected the most fares with approximately \$2.5 billion. Chicago, Illinois, Newark, New Jersey, Nassau-Suffolk, New York and Washington DC round out the top-five MSAs in sum of fares. However, New York City collects dramatically more fares than any other MSA. The total fares collected by the entire remaining top-five MSAs still falls approximately \$627 million short of the New York City total. To normalize these transit measures across MSAs, we divide route miles by sum of fares. Thus, given two similarly situated MSAs; the one with higher transit revenue per route mile should have better environmental quality.²⁶

The leading MSAs in fares per mile are New York City, Philadelphia, Pennsylvania, Nassau-Suffolk, New York, Chicago, Illinois and Washington DC. Fares per mile is not highly correlated with total route miles with a correlation coefficient of 0.44. However, fares per mile is correlated with train routes with a correlation coefficient of 0.77(see Table C6). Only 34 MSAs have some form of rail public transit. It has been observed that commuters prefer trains to buses. Rail can help to ease commuters out of their cars at rush hours (Weyrich 2003). This service varies dramatically from very limited trolley service to MSA wide networks of trains and subways. The smallest rail

²⁶ It is possible that higher revenue is just capturing MSAs with higher transit fares. I am assuming that MSA with higher revenue have higher ridership rates. Fares in the largest MSAs vary by distance, mode of transit, transit plan purchased etc. However the base fares are similar usually ranging from \$1.75-\$2.00.

system is in Johnstown, Pennsylvania which has a 0.2 mile trolley that travels up a steep hill. The largest system is in New York City with 1,706 miles of highly integrated subway and rail service. Chicago, Illinois, Newark, New Jersey, Philadelphia, Pennsylvania, and Nassau-Suffolk, New York round out the top-five MSAs in track miles. Newark and Nassau Suffolk are both part of the New York City CMSA. Track miles and the sum of fares collected are correlated with a correlation coefficient of 0.81(see Table C6). A dummy variable will be used to capture the effects of MSAs with rail service.

Another facet of urban form is population density. Denser MSAs should have a lower price for providing the public good due to the link between transit use and automobile ownership, discussed earlier. Population density is defined as the MSA population divided by its area in square miles. Some adjustments were made in order to consistently compare areas across MSAs. An MSA's area is defined by the contiguous county boundaries that make it up. In most MSAs this corresponds with the population distribution. (See Appendix A for MSA census definition). However in some western MSAs, with very large counties, portions of the county may be totally uninhabited desert. This is the case for the three MSAs with unadjusted areas over 10,000 square miles, Riverside-San Bernardino, California, Phoenix, Arizona, and Las Vegas, Nevada. In order to accurately compare these three MSAs with the rest of the sample, we modified their areas to eliminate portions of the uninhabited desert counties. These western counties are still large but are more in keeping with the inhabited area. St. Louis county Minnesota, which makes up part of the Duluth-Superior MSA, is another large county that has large sections that are uninhabited. We adjusted the area of this county based on

forest and lake coverage as well as its populated area. (See Appendix B for detailed explanation of MSA area changes and calculations.)

The most compact MSA is Jersey City, New Jersey covering only 46 square miles. It is also the most densely populated MSA with 11,974 people per square mile. Trenton is the second smallest covering 226 square miles. Thirty-seven MSAs cover less than 1,000 square miles, 22 of these are in the north and midwest. The MSA with the greatest adjusted land area is Phoenix, Arizona with an area of 11,304 square miles. To put this area in perspective, this is larger than the state of New Hampshire. It has a density of 188 people per square mile. However, Las Vegas is the least dense MSA with only 31 people per square mile.

To control for the effect the style of development in the MSA might have on air quality, we use the percent of single family housing units (PRCNT1FAMILY) in the MSA. A higher percent of single family housing should increase the price of the public good. New York City had the lowest percentage of single family housing units with 40 percent. Peoria-Pekin, Illinois had the highest with 77 percent single family housing.

The presence of regional authorities can also affect urban form and land use decisions. As was discussed in the fragmentation section, there are few regional authorities that are officially recognized as governments by the census. Thus, we are designating the presence of an official regional government in the MSA with a dummy variable. The presence of a regional government would be expected to reduce the price of the public good. The ten cities that have official regional governments are: Miami, Florida, Portland Oregon, Minneapolis-St. Paul, Minnesota, Pittsburgh, Pennsylvania,

Kansas City, Kansas, Denver, Colorado, Louisville, Kentucky, Charlotte, North Carolina, San Antonio, Texas, St. Louis, Missouri.²⁷

The location of an MSA in a CMSA is another urban form factor that may affect MSA emissions. The nature of CMSAs suggests that neighboring MSA activity may affect the ability of a given MSA to reduce its emissions. As was previously discussed, these spillovers could have a positive or negative effect on MSA emissions policy. Thus, the effect on the price of air quality, due to an MSA being in a CMSA, is not known a priori. The location of an MSA in a CMSA is controlled for by a dummy variable (see Table C4).

The economic activity and industrial characteristics of an MSA can also affect the price of public good provision. Industries vary in their levels of pollution. An MSA with a greater amount of large polluting industries will have a higher price for public good provision. Stationary source emissions that come from a large manufacturing facilities or an electric utility are generally considered point source emissions. To qualify as a point source a certain threshold of emissions must be met. The emissions data come from the EPA's National Emissions Inventory (EPA 2006). Not all years are available, so we used the closest years. The emissions data are for the years 1990, 1997, and 2001. If these industries reach the level of point source polluters, all relevant emissions will be captured by the EPA in the National Emissions Inventory.

Two pollutants are the primary constituents of ozone, VOC and NOX (EPA 2006b). Thus an MSA with more large polluting industrial plants will likely have greater point source emissions of VOC and NOX. Point source emissions reported

²⁷ It should be noted that all MSAs have a Metropolitan Planning Organization (MPO) to manage funds from federal programs. However these MPOs are not considered governmental bodies.

(PTSC TTL1997) are a yearly sum of VOC and NOX emitted within the MSA boundary and measured in tons. Eugene-Springfield, Oregon had zero point source emissions. The next lowest MSA was Visalia-Tulare-Porterville, California with 235 tons of point source emissions. Houston, Texas had the greatest amount of point source emissions with 224,877 tons emitted in 1997.

However not all facilities reach the threshold for point source emitters. A significant number of small plants can also emit enough pollution to affect the price of public good provision in an MSA. We have included the number of people employed in manufacturing jobs in an MSA (MFG1997) to account for these small manufacturers. To determine MSA manufacturing sector employment for the years 1992 and 1997, we used the two-digit SIC manufacturing code range 20-39. For 2002, The SIC data were matched with the three digit NAICS data.²⁸ The NAICS sector range was 311-339. There is some duplication between manufacturers that meet the point source criteria and manufacturing employment. However, the correlation coefficient between point source emissions and manufacturing employment is only 0.54. Amarillo, Texas has the fewest manufacturing employees at 2,407. Los Angeles, California has the greatest number of manufacturing employees with 635,005. Manufacturing employment is correlated with MSA population with a correlation coefficient of 0.89 (see Table C6).

Normalized manufacturing employment will also be examined. The percent of manufacturing employment to total employment will be used. For this variable Hartford Connecticut had the minimum with 2 percent of total employment in manufacturing, while Hickory-Morgantown-Lenoir, North Carolina had the maximum with 48 percent.

²⁸ The North American Industry Classification System (NAICS) has replaced the U.S. Standard Industrial Classification (SIC) system.

An additional strategy to control for economic and industrial activity is to include dummy variables for industries and utilities that are known to produce high levels of precursor emissions. The variables of dirty industry and utilities capture the presence of these firms with a dummy variable. Dirty industries were identified by SIC code and include manufactures of; chemicals, nonmetallic mineral products, petroleum & coal products, plastics & rubber products, or primary metals. Utilities were also identified by SIC code and include all fossil fuel power generation facilities. There are 123 MSAs with fossil fuel utilities and 54 that have dirty industry.

General economic activity could also affect the price of public good provision. For those activities that are not covered under point source emissions or manufacturing, we included general employment in the MSA (EMP1997). Higher levels of employment could increase the price of public good provision, if it leads to greater area source emissions. However, higher employment in cleaner service sector jobs might not increase emissions. Thus, a priori, the effect of total employment on the price of providing better air quality is unknown.

The MSA employment variable for 1992 and 1997 was created from the two digit MSA SIC codes. The data was from the BLS web site. For 2002, NAICS data had to be used. The MSA with the lowest number of people employed is Bremerton, Washington with 61,063. The maximum value for employment is Los Angeles, California with 3,855,812. Employment is highly correlated with MSA population with a correlation coefficient of 0.98. MSA employment and manufacturing employment are also highly correlated at 0.93 (see Table C6).

Weather is an important determinant of ozone formation. High summer temperatures are necessary for ozone formation, while rain and wind can help to impede ozone formation. Regional geographic features can also impact environmental quality through their affect on prevailing winds, precipitation cycles, and temperature fluctuations. However, the geography of every MSA is unique and does not to vary over time. Because of these characteristics, the panel data model will be used to try to control for these geographical variations. The following section discusses the weather variables used in the cross-sectional model.

The three weather factors; rain, summer heat, and wind, affect ozone formation in several ways. First, rain tends to wash the ozone out of the air. Second, wind aids in vertical mixing of lower-level polluted air with cleaner upper air, which decreases ozone formation. Third, hot, windless weather seems to inhibit vertical mixing. Less mixing tends to increase ozone formation, this is called stagnation. In order to smooth any unusual weather patterns, three-year averages were taken for rainfall and July temperature for each MSA. The three years corresponds to the time period used to calculate the ozone design value for an MSA.

Different methods of measuring the weather variables were used, depending on how each variable affects the formation of ozone throughout the season. The ozone season for this model is May through September. High temperatures are critical for ozone formation, thus ozone is predominantly a summer phenomenon. In MSAs with cool spring temperatures, ozone is not likely to form in May. However, if those MSAs have hot July temperatures ozone can form. Thus, an average July temperature (JTEMP1997) is more indicative of ozone formation than a seasonal average temperature which is likely

to be considerably lower than the July average. Denver, Colorado had the lowest July average temperature at 61 F° . Tucson, Arizona had the highest with 91 F° .

Rain has a cumulative effect on ozone formulation. Lack of rain in June can allow precursor compounds to accumulate in the air and increase the risk of ozone formation in early July. Because of the cumulative nature of the rain effect, total rain fall is used for the whole season (TTLRAIN1997) as well as total July rainfall (JRAIN1997). MSAs with higher levels of rainfall should have a lower price of public good provision. California MSAs get almost no July rain. Seven MSAs received zero rain in July. The largest reading for a California MSA was San Diego with 0.1 of an inch. Mobile, Alabama received the most July rainfall with 14.6 inches. The MSA that received the least total ozone season rainfall was Bakersfield CA with .4 of an inch. The ten MSAs with the lowest ozone season rainfall were all in California. Miami, Florida had the most ozone season rainfall with 51.3 inches. Seven of the top-ten MSAs in seasonal rainfall were located in Florida.²⁹

Wind speed also plays somewhat of a cumulative role in ozone formation, however only when temperatures are hot enough for ozone to form. Thus, an average wind speed throughout July is more likely to indicate ozone formation than one day of high gusts. Mean July wind speed (JULYMNWIND) over the past 30 years is used here as is available from the National Climate Data Center (NCDC 2006). High summer wind moves precursors from the air shed and thus the area is less susceptible to ozone formation. The minimum average July wind speed of 4.8 miles per hour was measured in

²⁹ The state of Florida receives substantial rain from tropical storms systems and hurricanes; the period of 1995-1997 was no exception. However, Miami did not have a Hurricane hit it directly in the time period.

Huntington-Ashland, West Virginia. The maximum value of 13.6 miles per hour is attained by nine northern California MSAs around the CMSA of San Francisco-Oakland.

The location of an MSA on a large body of water may also effect the formation of ozone. The coastal location allows for some of the precursor emissions to be blown out over the water and thus not be available to form ozone inland. Therefore, the location of an MSA on an ocean or great lake will likely reduce the price of providing clean air. A dummy variable will be used to control for the coastal location of an MSA.

Trends in the Variables

In this section we examine the relationship between the dependent variables and some selected independent variables. Two of the independent variables selected are the demographic variables from the theoretical model, MSA population and personal income. Daily vehicle miles traveled is also selected. Daily vehicle miles traveled is highly correlated with the dependent variable area total emissions, as well as several independent variables. The other independent variables are selected fragmentation variables that illustrate the correlations of some of the fragmentation measures. we will also examine some basic trends and how they correspond to those predicted by the theoretical model developed in Chapter 2.

Independent Variables

Tables C7 and C8 list the MSAs which are clustered around the minimum and maximum values of selected variables. The MSA's attainment status of the ozone standard is also included. The tables show the ten MSAs with the lowest values of the

population and fragmentation variables. We refer to these as the bottom tier. The tables also show the ten MSAs with the highest population and fragmentation variables. we refer to these as the top-tier. The mean values listed in the tables, between the top and bottom tier, are for the full 187 MSA sample. We will use these clustered MSAs at the minimum and maximum values to get a preliminary indicator of how the variables in the sample match with what is predicted by the theoretical model.

Table C7 shows the top and bottom-tier MSAs in population, GMP, and daily vehicle miles traveled. The theoretical model predicts that MSAs with greater populations should have higher levels of environmental quality. Environmental quality in this table is the attainment of the ozone standard. The attainment status of the MSAs at the minimum and maximum values of MSA population does not match what is predicted by the theoretical model. Only two MSAs in the bottom population tier failed to attain the ozone standard, Evansville, Indiana and Brazoria, Texas.³⁰ The top-tier MSAs had much less success meeting the ozone standard. Only one MSA in the top-tier in population met the ozone attainment standard, Detroit, Michigan. This is a problem experienced by many populous MSAs. Only five of the 20 most-populated MSAs were in attainment. The other four were; Minneapolis, Minnesota, Indianapolis, Indiana, Seattle, Washington and Cleveland, Ohio. The mean value of MSA population, 1,013,357, corresponds with the populations of MSAs such as: Grand Rapids-Muskegon, Michigan and Raleigh-Durham, North Carolina. The median value of MSA population, 523,307, corresponds with the populations of MSAs such as: Mobile, Alabama and Wichita, Kansas. The relationship between MSA population, daily vehicle miles traveled is examined next.

³⁰ Brazoria is part of the Houston CMSA, which is in nonattainment.

Vehicle miles traveled and population are highly correlated. This is to be expected as the more people leads to more cars and more car trips. Eight of the bottom 10 MSAs in daily vehicle miles traveled (least DVMT) have populations less than 300,000. Nine of the top-ten MSAs in daily vehicle miles traveled are also in the top-ten in population. The theoretical model predicts that MSAs with high levels of daily vehicle miles traveled should have lower levels of public good provision. The attainment status of the MSAs at the minimum and maximum values of daily vehicle miles traveled follows the theory. Seven of the ten lowest in daily vehicle miles traveled are in attainment of the ozone standard for 1997. While, one of the ten highest MSAs in daily vehicle miles traveled is in attainment of ozone standard in 1997. The mean value of DVMT1997 of approximately 18 million miles, corresponds with the vehicle miles traveled of MSAs such as: Bergen-Passaic, New Jersey and Austin-San Marcos, Texas. The median value of DVMT1997 of approximately eight million miles, corresponds with the vehicle miles traveled of MSAs such as: Jackson, Mississippi and Columbus, Georgia.

In the theory chapter it is predicted that MSAs with higher personal incomes should have higher environmental quality. As was discussed in an earlier section, MSA GMP is a better indicator of MSA wealth. GMP is normalized by MSA population to facilitate comparisons across MSAs. Per capita GMP and MSA per capita personal income are correlated with a correlation coefficient of 0.86 (see Table C6).³¹ The attainment status of the MSAs at the minimum values of MSA GDP per capita does not follow the theory, while the trend of the MSAs at the maximum values is unclear. Seven of the ten lowest MSAs in GMP per capita are in attainment of the 1997 ozone standard.

³¹ This correlation is partially due to the formula used to estimate GMP, which allocates GSP to MSAs as a function of their share of total state personal income.

Six of the ten MSAs with the highest GMP are in nonattainment of the 1997 ozone standard. The mean value of MSA GMP per capita of approximately \$30,000, corresponds with the GMP per capita of MSAs such as: Sacramento, California and Savannah, Georgia. The median value of MSA GMP per capita of approximately \$29,000, corresponds with the GMPs of MSAs such as: Greensboro-Winston Salem, North Carolina and Baltimore, Maryland.

While the daily vehicle miles traveled measure seems to correspond to the theory at the minimum and maximum values of the variable, MSA population and GMP per capita do not. It is likely that MSAs with high GMPs per capita and populations have other confounding factors which contribute to poor environmental quality. It is possible that variables correlated with MSA population such as: daily vehicle miles traveled; and the economic activity variables of employment, manufacturing employment, and point source emissions all overwhelm the positive effects of greater population. These factors will be examined and controlled for in the next chapter.

Table C8 illustrates the top and bottom-tiers of MSAs for selected fragmentation variables. The measures are jurisdiction count, relative fragmentation and metropolitan power diffusion index. These measures were selected as they give a general picture of the composite nature of government fragmentation. Jurisdiction count is a popular measure of fragmentation in the literature. The MSAs in the top and bottom-tiers of jurisdiction count are intuitively appealing. While the MPDI is more complex, it is correlated with jurisdiction count and generates similar results at the maximum and minimum values. Relative fragmentation is not correlated with either jurisdiction count or MPDI and tends to yield less intuitive results.

The theoretical model predicts that MSAs with lower levels of fragmentation should have higher environmental quality. The attainment status of the MSAs at the minimum and maximum values of jurisdiction count and MPDI follow this prediction. Nine of the bottom ten MSAs in jurisdiction count (least fragmented) were in attainment. Only Jersey City, New Jersey was in nonattainment in this group. Of the top-ten MSAs in jurisdiction count (most fragmented) eight were in nonattainment. Only Minneapolis, Minnesota and Kansas City, Missouri were in attainment. The mean value of jurisdiction count, 121, corresponds with the jurisdiction count of MSAs such as York, Pennsylvania and Middlesex-Somerset, New Jersey. The median value of jurisdiction count, 77, corresponds with the jurisdiction count of MSAs such as Tacoma, Washington and West Palm Beach, Florida.

Nine of the ten bottom tier MSAs in MPDI (least fragmented) were in attainment. Only El Paso, Texas was in nonattainment in this group. While, eight of the top-ten MSAs in MPDI (most fragmented) were in nonattainment. Only Minneapolis, Minnesota and Detroit, Michigan were in attainment. All of the five highest ranking MSAs in MPDI and jurisdiction count were in nonattainment (see Table C8). The same MSAs are included in the top-five in both jurisdiction count and MPDI. The mean value of MPDI, 5.2, corresponds with the MPDI of MSAs such as Washington, DC and Tampa-St. Petersburg, Florida. The median value of MPDI, 4.67, corresponds with the MPDI of MSAs such as Wichita, Kansas and Raleigh-Durham, North Carolina.

The attainment status of the MSAs at the minimum and maximum values of relative fragmentation do not closely track the predictions made by the theoretical model. Six out of the bottom-ten MSAs in relative fragmentation (least fragmented) were in

nonattainment. These tend to be populous MSAs located within CMSAs such as New York City and Los Angeles. Three of the top-ten MSAs in relative fragmentation (most fragmented) were in nonattainment (see Table C8). The existence of township governments likely plays a role in relative fragmentation. All of the top-ten MSAs in relative fragmentation are located in states that have townships.³² The mean value of relative fragmentation, 1.54, corresponds with the relative fragmentation of MSAs such as: Tulsa, Oklahoma and Chicago, Illinois. The median value of relative fragmentation, 1.25, corresponds with the relative fragmentation of MSAs such as Birmingham, Alabama and Chattanooga, Tennessee.

In summary, jurisdiction count is an appealing measure of fragmentation because it is easy to quantify and intuitively appealing. MPDI is a more complex measure but is correlated with jurisdiction count. Both variables at their minimum and maximum values track the theory model reasonably well with regard to MSA attainment status. Relative fragmentation is another intuitively appealing measure of government fragmentation. However it does not track the theoretical model as well for MSAs at the minimum and maximum values with regard to attainment status. The relationship of all the fragmentation variables to attainment status will be fully explored in the next chapter.

³² Twenty states have township forms of government they are: Connecticut, Illinois, Indiana, Kansas, Maine, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, South Dakota, Vermont, and Wisconsin.

Air Quality Summary

In this section we highlight some of the differences between the MSAs that are in attainment and those that are not. The relationship between MAXEPA ozone and emissions will be examined in the two groups. The lack of correlation among the three dependent variables will also be examined.

Table C9 lists the summary statistics yielded when the MSAs are split into two groups determined by attainment status of the ozone standard in 1997. Seventy-two MSAs are in nonattainment while 115 are in attainment. Of the MSAs located in CMSAs, seventeen are in attainment, while 36 are in nonattainment. It is possible for MSAs within the same CMSA to have different attainment values. In the Chicago-Gary CMSA, Chicago and Gary are in nonattainment while Southbend is in attainment. Also in the Portland-Vancouver CMSA, Portland and Vancouver are in attainment while Salem is not. The summary statistics of Maximum EPA ozone values (MAXEPA) are compared next.

For those MSAs in attainment, the mean of MAXEPA was 0.1 parts per million (ppm).³³ The maximum value for MAXEPA was 0.14 ppm. This is surprising as the cutoff value for attainment status is 0.12 ppm. In fact 14 MSAs have values above 0.12 ppm in the attainment set. We will refer to these 14 MSAs as attainment-outliers.

For those MSAs in nonattainment, the mean value for the MAXEPA was 0.13 ppm. The maximum for the MAXEPA was 0.22 ppm in Riverside-San Bernadino, California. The minimum value for MAXEPA was 0.09 ppm in Lincoln, Nebraska. Once

³³ Ozone is measured in parts per million. The hourly ambient air quality standard is 0.12 parts per million. This represents a concentration of 0.12 molecules of ozone for every one-million molecules of air mixture. Ozone values are shown as one-hour averages.

again, this minimum value is surprising in that the cutoff value for being in nonattainment is 0.12 ppm. In fact 21 MSAs in nonattainment had values below the threshold value of 0.12 ppm. We will refer to these 21 MSAs as nonattainment-outliers.

Several potential explanations for the above inconsistencies exist. They involve how the EPA designates MSAs and counties as reaching attainment of the ozone standard. While data on ozone and emissions are collected every year, the EPA does not review an MSA's designation as attaining or nonattaining every year. Historically the EPA has universally revisited the designations of attainment of ozone standards for counties and MSAs only after significant changes to the clean air act.³⁴ This corresponds to three different years: 1978, after the NAAQS were changed in 1977; 1991, after the 1990 clean air act amendments; and in 2004, after litigation was finally settled regarding the 1997 changes. Another reason the EPA would revisit the attainment status of an MSA is if a petition or lawsuit was filed challenging the EPA's designation. For the time period we are examining, this suggests that some MSAs might have fallen in or out of attainment but had not yet been reclassified.

To try to understand the potential magnitude of this effect, we examined the county level data in the year before and after 1997 to see if there were changes to MSA status that had been in process in 1997, but not yet reflected in official attainment status. Looking at the yearly county level data only four MSAs changed status from 1996 to 1997.³⁵ Ten changed status from 1997-1998.³⁶ All fourteen MSAs went from

³⁴ Personal correspondence with M. Chang, Senior Research Scientist, Center for Urban and Regional Ecology, Georgia Institute of Technology.

³⁵ These four were: Evansville-Henderson, Indiana-Kentucky, Salt Lake City-Ogden, Utah, Richmond-Petersburg, Virginia and Norfolk-Virginia Beach-Newport News, Virginia.

³⁶ These ten were: Salinas, Californian, Santa Cruz-Watsonville, California Lake Charles, Louisiana, Bangor, Maine, Portland-Vancouver, Oregon, Reading, California, Nashville, Tennessee, Seattle-Bellevue-Everett, Washington, Tacoma, Washington, and Sheboygan, Wisconsin.

nonattainment to attainment. Only two of the 21 nonattainment outliers correspond to the above 14 MSAs that changed status to attainment, Evansville-Henderson, located in Indiana and Kentucky and Norfolk-Virginia Beach-Newport News, Virginia. The five MSAs in the San Francisco CMSA changed status in 1995 to attainment only to relapse by 1999.³⁷ Only San Jose and Oakland correspond to the list of the 14 attainment outliers.

However, it is also possible for an MSA to violate the ozone standard in a given year but not fall into nonattainment because the EPA did not revisit its designation and no lawsuit was filed. In Georgia, this happened in the Macon MSA. From 1997 through 2003, Macon was in violation of the three year average ozone attainment value. Similarly it is possible for an MSA to petition for attainment status, only to relapse back into violation before the status is changed. In an attempt to gather additional information on why some nonattainment areas had low ozone readings while some attainment areas had high readings, we next examine the data on ozone precursor emission at the MSA level.

In Table C10, MSAs are again separated by attainment versus nonattainment. The table illustrates the nonlinear nature of the emissions /attainment relationship. It is possible for an MSA to have very low emissions and be in nonattainment and it is also possible for an MSA to have very high emissions and be in attainment.

Table C10 compares the ten highest and lowest emitting MSAs based on attainment status. The top section of the table compares the ten lowest emitting MSAs in attainment versus those in nonattainment. The bottom section of the table compares the ten highest emitting MSAs in attainment versus those in nonattainment. Emissions are the

³⁷ The five San Francisco area MSAs were: Santa Rosa, Oakland, San Francisco, San Jose, and Vallejo-Fairfield-Napa.

total amount of VOC and NOX measured in tons. Emissions are also broken out into area and point source totals. The mean values are only for the ten listed MSAs.

For the ten MSAs with the lowest emissions, there is a small difference in the means between those in attainment and those that are not. For the ten attaining MSAs, the mean value for total emissions is 28,131 tons. For those ten in nonattainment, the mean total emissions were 34,840 tons. The mean emissions for the least emitting nonattaining MSAs were 24 percent greater than the mean for those in attainment. Surprisingly the MSAs in attainment had a slightly higher point source mean emissions value; 3,276 tons versus only 2,811 tons for the nonattaining MSAs.

For the ten highest emitting MSAs, there were far greater differences in emissions for those in attainment versus those in nonattainment. Detroit emitted the largest amount of any MSA in attainment with 678,763 tons. Chicago topped the list for MSAs in nonattainment at 906,628 tons. The mean values were also very different. The mean value for total emissions for the highest emitting MSAs in nonattainment was 68 percent greater than for those in attainment.

Table C12 measures the ratio of area emissions and point source emissions to total emissions. The average ratio for area and point source emissions is also calculated. While the absolute values of emissions differed considerably for the highest emitters, the average ratio of area source emissions to total emissions was similar in both the lowest emitters and the highest emitters. For the top-ten emitters, the average ratio of area emissions to total emissions was 74 percent for those MSAs in attainment and 78 percent of total emissions for those MSAs in nonattainment. For the ten lowest emitting MSAs, the ratio of area emissions to total emissions for attainment MSAs was 89 percent; for

those MSAs in nonattainment the ratio was 92 percent. The next section looks at the relationship of emissions and fragmentation in the two outlier groups.

Lack of Correlation in Air Quality Indicators

Earlier the lack of correlation among the air quality indicators in the 187 MSA sample was discussed. This is surprising given that MAXEPA ozone is used to determine attainment status. Furthermore while emissions and ozone formation may not have a linear relationship, a greater positive correlation is expected than is found. In this section we further examine the MSAs described as attainment-outliers and nonattainment-outliers earlier.

Previously, it was noted that some MSAs attainment status seemed to be contrary to what the values for MAXEPA ozone would indicate. Table C12 separates these 35 MSA outliers by attainment status and then lists the MAXEPA ozone values, total emissions, and three fragmentation variables. This table further illustrates the lack of correlation between ozone, emissions, and attainment.

Twenty-one MSAs in the sample of 187 have MAXEPA ozone values appeared to have met the standard for attainment in 1997 with values below 0.12 ppm, yet were deemed in nonattainment for 1997. Of the 21, four are in the bottom tier for emissions in Table C8 (these are the lowest emitters). The mean value for total emissions for this group was 115,791 tons.

Fourteen MSAs in the sample have ozone values greater than the cutoff value of 0.12 ppm, but were considered to be in attainment for 1997. Four of these are in the top-

tier for emissions from Table C10 (these are the highest emitters). For the 14 attainment-outliers, the average emissions were 206,272 tons.

Turning to the three fragmentation variables, the 21 nonattaining-outliers have on average; 156 jurisdictions and 2.44 governments per 10,000 people. The 14 attainment-outliers have on average; 140 jurisdictions and 1.19 governments per 10,000 people. The average MPDI value for the nonattaining MSAs is higher than that of the attaining MSAs as well.

When the 35 outliers are removed from the sample, the correlation coefficients for the air quality indicators rise. Table 4.14 compares the correlation coefficients with and without the outliers. The correlation between attainment and MAXEPA rises to a fairly high level of -0.77. The other two variables still are not in the range in which they would be called highly correlated. This is in keeping with the nonlinear relationship between emissions levels and ozone formation.

Table C12 demonstrates some of the shortcomings of the cross-sectional approach. The 21 MSAs that are nonattainment-outliers have lower mean ozone and emissions than those 14 MSAs that are attainment-outliers. However, the means of the three fragmentation variables are all higher for the 21 nonattainment MSAs. There is likely to be some unobserved heterogeneity that is present in the data that contribute to these unusual results.

There is possible unobserved heterogeneity at several levels. Twelve of the 21 nonattainment-outliers are in three states, Pennsylvania, New York, and Colorado. Unique geographic or political features might allow some of the outliers to maintain their unusual status of attainment or nonattainment. It is possible that state level institutions

could be playing a role. There is also an overlap of states in both the attainment-outliers and the nonattainment-outliers. California and Michigan have MSAs in both groups. This suggests that the unobserved heterogeneity may also occur at the local level, again suggesting the need for a panel estimation approach.

Trends in Key Variables Over Time

This section analyzes some basic trends across years. The years we examine are 1992, 1997 and 2002. Trends in attainment will be examined. In addition, the data panels will be divided into groups of MSAs based on their attainment status over the three periods. The relative means of these groups will be compared with what the theoretical model predicts.

Table C13 shows the trends over the three periods for the means. The general trend seems to be toward cleaner air. More MSAs are in attainment and mean emission values have declined. In 1992, Seventy-five MSAs were in attainment. By 1997, forty more MSAs reached attainment, bringing the total MSAs in attainment to 115. Only six more MSAs reached attainment by 2002, for a total of 121. The mean values of area total emissions declined by 24 percent from 1992 to 2002. However, the mean values of MAXEPA ozone stayed relatively constant over the three panels. This suggests that nonattainment MSAs, with the worst ozone levels, were improving air quality, but MSAs in attainment were experiencing rising ozone levels. There were no overall trends in the other variables. The next section examines MSA trends based on their attainment status over the three periods.

There are three basic attainment groups in the panel data set. The first is the 75 MSAs that have always been in attainment, we will refer to these MSAs as the AIA group. The second is the 61 MSAs that have never been in attainment, we will refer to these MSAs as the NIA group. The third is the 51 MSAs whose attainment status has changed; we will refer to these MSAs as the CIA group.

Almost all MSAs in the CIA group went from nonattainment to attainment. There are only six anomalous MSAs. Five are in the CMSA of San Francisco-Oakland. These all went from nonattainment in 1992, to attainment in 1997, back to nonattainment in 2002. Springfield, Massachusetts is the other anomalous MSA. It went from attainment in 1992, to nonattainment in 1997, back to attainment in 2002. Next we examine selected means of the three groups.

Table C14 lists the means of the three MSA groups. For MAXEPA ozone, the NIA group has a mean value of 0.13 ppm and the AIA group has a mean of 0.1 ppm. The value for the CIA group is 0.11. The NIA and AIA group means are intuitively appealing as the NIA mean exceeds the ozone threshold value of 0.12 ppm but the AIA mean does not. For area total emissions, the NIA group has the highest mean value, followed by the CIA group. The AIA group has the lowest value.

The NIA group has both the highest mean population and highest GMP of the three groups. The AIA group has the lowest means for both MSA population and MSA GMP. The NIA group population mean is over three times greater than the AIA population mean. The CIA group means for MSA population and GMP fall in between the NIA and AIA group.

The NIA group is generally more fragmented than the other two groups. The NIA means for MPDI and SD are approximately 50 percent larger than the means of the AIA group. While the JDCNT mean is approximately 140 percent larger than the AIA group mean. For CCD and RELFRAG the means are similar. The mean values of the fragmentation variables for the CIA group tend to fall in between the NIA and AIA group means.

Summary

In this chapter, an empirical framework which guided data collection was presented. Variable development was discussed and data trends were presented. Overall, there is considerable heterogeneity among MSAs in attainment and out of attainment. While we have attempted to capture relevant features of our theoretical model, there may continue to be important unobserved factors across MSAs. As such, in the next chapter we will develop two estimation approaches; one based only on the 1997 cross section data and one based on the 1992 to 2002 panel data. Estimation results are also presented in the next chapter.

CHAPTER 5

EMPIRICAL ESTIMATION

This chapter will present the empirical model as well as estimation results. The first section discusses the cross-sectional model. Several estimation issues, including the estimation technique and specification tests are addressed. Results from the cross-sectional approach are also presented. The second section discusses the panel model. Estimation technique and specification tests are addressed. Results from the panel approach are presented and used as a robustness check for the cross-sectional results. The third section discusses the implications of both the cross-sectional and panel model empirical results and concludes.

Cross-sectional Model

The theoretical model predicts that as the number of jurisdictions increases the level of public good provision decreases. In this stylized model the change is immediate. However, in the natural world the effect local government structure has on air quality is determined by the ability of local governments to control emissions, in particular area source emissions. Policies that affect emissions take time to develop and implement. In addition, the residents that live in the MSA will take time to adjust to new conditions. The influence on air quality that an additional unit of government fragmentation has on MSA air quality is likely to be gradual. Therefore, changes in air quality in the short-term will likely be modest in a particular MSA due to incremental changes in government structure when compared to differences in governmental structure across MSAs.

For instance in Atlanta, the new city of Sandy Springs was created in 2006, several other areas are also likely to incorporate within the Atlanta MSA in the near future. In the short term these additional jurisdictions are likely to have a minimal effect on MSA air quality. However over time, as these new jurisdictions' land use and transit policies are put in place residents throughout the MSA will adjust their behavior. It is these long-term changes that are expected to influence area emissions and have larger affects on air quality. Over time Atlanta will resemble MSAs with higher degrees of fragmentation. For these reasons, a cross-section model which exploits inter-MSA variation is first explored. Specifically, the long-term effect of differing levels of government fragmentation across MSAs is explored through the following cross-sectional model:

$$AQ_i = \alpha_i + \beta_F F_i + \sum_n \beta_p \text{PREFDEM}_{ip} + \sum_j \beta_j \text{UF}_{ij} + \sum_n \beta_n \text{GEO}_{in} + \sum_q \beta_q \text{ECON}_i + e_i, \quad (5.1)$$

where AQ_i is a variable representing the air quality of the i^{th} MSA. MSA government fragmentation is represented by F_i . PREFDEMi is a vector of relevant demographic and preference variables, UF_i is a vector of urban form measures, GEO_i is a vector of relevant geographical variables, and ECON_i is a vector of economic activity measures in the MSA. The error term is represented by e_i . Table C16 lists the variables explored in each category and their definitions. For a detailed description of the variables and the source of the data, see chapter four.

If AQ_i is a binary variable, then equation (5.1) is estimated via logistic or probit regression. If instead AQ_i is a continuous variable, OLS can be used if the following four

classical assumptions are met: 1) the expected value of the error term is zero, 2) errors have uniform variance and are uncorrelated, 3) observations on independent variables can be considered fixed in repeated samples, 4) there is no exact linear relationships between independent variables.

In the model presented in equation (5.1), there may be concern that some of the urban form variables and economic activity variables could be endogenous. Consider the following model were the variables of urban form and economic activity are listed and highlighted in bold type:

$$AQ_i = \alpha_i + \beta_F F_i + \sum_n \beta_p \text{PREFDEM}_{ip} + \beta_1 \text{PRCNT1FAMILY} + \beta_2 \text{DVMT} + \beta_3 \text{COMTIME} \\ + \beta_4 \text{FARESPERMI} + \beta_5 \text{CMSA} + \beta_6 \text{REGGOV} + \beta_7 \text{DENSITY} + \beta_{11} \text{MFGAVGT} + \\ \beta_8 \text{PTSCTTL} + \beta_9 \text{PTSCTTLSQ} + \beta_{10} \text{EMP} + \sum_n \beta_n \text{GEO}_{in} + e_i, \quad (5.2)$$

and definitions for these variables are in Table C3. In the above equation the endogeneity could be from two sources simultaneity bias or unobserved heterogeneity. Simultaneity bias occurs when one or more of the independent variables are jointly determined with the dependent variable. Such a problem might exist if jurisdictions made decisions regarding the amount of public transit to provide contemporaneously with their decision on the amount of air quality to provide. Another possibility of simultaneity bias is if firms made location decisions based on air quality in the MSA. If simultaneity bias exists then estimates from OLS or probit models would be biased and inconsistent.

Unobserved heterogeneity bias occurs if one of the independent variables is correlated with characteristics of the MSA that are unobservable. For instance, if the level of public transit provided in an MSA is correlated with a characteristic of the MSA that is

not controlled for in the model, such as local political will, or the ability of local governments to secure federal transit financing.

The results of both unobserved heterogeneity and simultaneity bias is that one or more of the independent variables is correlated with the error term in equation (5.1). This leads to bias in the estimation. Simultaneity bias and unobserved heterogeneity bias can generally be controlled for in a similar manner using IV variables and two stage least squares estimation. The next section discusses the possible sources of endogeneity followed by a more formal treatment of estimation with endogenous regressors.

Potentially Endogenous Regressors

There are seven urban form variables: PRCTN1FAMILY, DVMT, COMTIME, FARESPERMI, CMSA, REGGOV, and DENSITY. Of these variables, two are potentially endogenous: FARESPERMI and DVMT. The decision of an MSA or jurisdiction to provide public transit to its residents is likely based on a variety of factors. Some of these factors are observable such as road congestion. Others may be unobservable, such as resident's willingness to ride public transit, local political will, or the ability of local governments to secure federal transit financing. In addition, current transit levels are likely to reflect decisions made in prior years. This is particularly true when considering large capital expenditures for such things as trains and train stations. If an MSA experienced poor air quality in the past, it might allocate more money to transit for the future. Thus, the transit variables are possibly endogenous.

Another urban form variable that might be endogenous is DVMT. MSAs may make decisions that can affect DVMT simultaneously with decisions on air quality.

MSAs that are not in compliance with the ozone standard may choose policies that limit DVMT such as high occupancy vehicle lanes or policies to encourage car pooling. Thus, DVMT is possibly endogenous.

In the category of “economic activity”, there are five variables considered in my models: EMPGROWTH, MFGAVGT, PTSCTTL, DIRTYIND, and UTILITY. For these variables, it is possible that MFGAVGT and PTSCTTL are endogenous if firms base their location decisions in part on the air quality of the MSA. Henderson (1996) found that firms which produce high levels of VOCs were more likely to locate in counties that had experienced at least three years of attainment of the ozone standard. However, most firms that produced high levels of VOCs were located in nonattainment counties. Also, counties that had never been in attainment, counties that had always been in attainment, as well as counties that switched from nonattainment to attainment, all experienced growth in polluting industries from 1978-1987 (Henderson 1996). Counties that had been in attainment for the entire period experienced the fastest growth rate for new polluting firms. However the nonattainment counties started with close to 90 percent of all the major polluting industries. Therefore, it is unlikely that the overall distribution of industry changed dramatically. Thus, the variables of MFGAVGT and PTSCTTL will be treated as exogenous in the cross-sectional model. The validity of this assumption will be tested in the panel data specification.

In summary, based on economic intuition, only two variables out of 14 used in the urban form and economic activity, fares per mile (FARESPERMI) and daily vehicle miles traveled (DVMT), are considered endogenous. All variables in the geography category are considered exogenous. The variables capturing preferences and demographic

composition of an MSA are also considered exogenous. Given the long process involved in changing jurisdiction structure within an MSA, the fragmentation variables are initially considered to be exogenous. However, we test this latter assumption.

Estimation with Endogenous Variables

The problem of endogenous variables due to omitted variables, unobserved heterogeneity, or simultaneity can generally be dealt with in three ways. First, a suitable proxy variable for an omitted variable can be used. Second, a suitable instrumental variable may be found for the omitted variable or independent variable that is correlated with the unobservable. Third, one can assume that the endogenous variable as well as the omitted variable that it is correlated with does not change over time and use the panel data approach of fixed effects (Wooldridge 2000). We will be discussing all three approaches in this chapter. The first and second options will be discussed next. The third option will be discussed in the section on the panel data model.

The cross-sectional model developed in chapter four, and repeated here: Air quality = f (Governmental Fragmentation, MSA Total Income, Taste Parameters, Price of Public Good Provision), contains the unobservable variable for the price of the public good. If this variable is omitted, both OLS and the logit model will yield biased and inconsistent estimates. Thus proxy variables are used to minimize this problem. To see this, consider our base empirical model equation (4.3):

$$\begin{aligned} \text{Air quality} = & f(\text{Governmental Fragmentation, MSA Total Income,} \\ & \text{Taste Parameters, Price of Public Good Provision}), \end{aligned} \quad (5.3)$$

equation (5.3) can be restated in general form as follows for ease of exposition:

$$y_1 = \alpha_i + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3^* + e_i, \quad (5.4)$$

where y_1 is a variable representing the air quality of an MSA. Assume x_1 and x_2 are observable variables while x_3^* is not observed. If a proxy variable x_3 is available such that:

$$x_3^* = \delta_0 + \delta_3 x_3 + v_3, \quad (5.5)$$

then equation (5.5) can then be substituted into equation (5.4) for x_3^* . The following assumptions must be made in order for the proxy variables to be suitable. The coefficient values for x_1 and x_2 must be nonzero and that the error term v_3 must be uncorrelated with, x_1 , x_2 , as well as x_3 . In addition the proxy variables must also be uncorrelated with the error term in the structural equation (5.4). This last condition can be restated by equation (5.6),

$$E(x_3^* | x_1, x_2, x_3) = E(x_3^* | x_3) = \delta_0 + \delta_3 x_3. \quad (5.6)$$

The assumptions present in equation (5.6) are rather strong and they need not be completely true for the proxy variable to still be useful (Wooldridge 2000). However, if the basic assumption that the proxy variables are uncorrelated with the error term in the structural equation is violated the results of an OLS or logit or probit regression will

again be biased and inconsistent. Controlling for this correlation using instrumental variable estimation is discussed next.

The instrumental variables estimation method is used to control for the correlation of independent variables with the error term. A suitable instrumental variable for the correlated independent variable must be related to the correlated independent variable as well as be exogenous and uncorrelated with the error term. Generally this relationship is expressed using the structural equation below:

$$y_1 = \alpha_0 + \beta_1 y_2 + \beta_2 z_2 + u, \quad (5.7)$$

where z_2 is assumed exogenous. In our application y_1 would be a measure of air quality and y_2 would be DVMT or FAREPERMI. If y_2 is correlated with u , the OLS and logit and probit coefficients estimates will be biased and inconsistent. In order to control for this endogeneity, a suitable instrumental variable (IV) can be used in place of y_2 and then equation (C21) is estimated using two stage least squares.

A suitable IV must be correlated with y_2 as well as be exogenous and uncorrelated with u . The above conditions for an appropriate IV for the transit variables are expressed using equation (5.8),

$$y_2 = \pi_0 + \pi_1 z_1 + \pi_2 z_2 + v_2. \quad (5.8)$$

where by definition $E(v_2) = 0$ and the $\text{Cov}(z_1, v_2) = 0$ and $\text{Cov}(z_2, v_2) = 0$. The relevant identification condition is that π_2 does not equal zero. This will be tested for by using

standard OLS and a t test. One cannot test for whether the IV is uncorrelated with error term; this must just be assumed (Wooldridge 2000, p 473). Before writing the IV model for our application we first discuss potential outside instruments.

Recall our two potentially endogenous regressors are transit fares per route mile as well as daily vehicle miles traveled. The MSA population in 1900 might be a suitable instrument for 1997 levels of transit. The instrument for the transit variable must be correlated with 1997 transit levels but not be correlated with the unobservable factors discussed above that might lead an MSA to choose to provide transit. Population in 1900 is chosen because it precedes the mass-production of the automobile and the accompanying expansion and improvement of roads. The proliferation of automobiles and roads is a leading cause of MSA area ozone component emissions. Population in 1900 does not have a direct effect on current ozone levels or attainment status and is not correlated with past attainment, air quality, or emissions. Population in 1900 is positively correlated with 1997 MSA transit variables however, for the variables of FAREPERMI, SUMFARES, and TRACKMI, it has the correlation coefficients of 0.80, 0.83, and 0.74 respectively. It is slightly less correlated with TRANRTE with a correlation coefficient of 0.51. we estimated a standard OLS regression to test the validity of this instrument on FAREPERMI. The R-squared is 0.63 and the coefficient has the expected sign and is statistically significant at the 5 percent level. Thus, MSAPOP1900 may be a reasonable instrument for the transit variable of FAREPERMI.

Vehicle miles traveled is another potentially endogenous variable. An instrument must be correlated with DVMT yet be uncorrelated with air quality. Instruments for DVMT could be the number of drivers licenses issued in an MSA and the gas tax in the

state.³⁸ Gas tax is set at the state level and thus is not likely to be influenced by MSA air quality concerns. The more drivers licenses the higher the expected value of DVMT all else equal. For the gas tax, the higher the gas tax the lower the level of DVMT all else equal. we ran a standard OLS regression to test the validity of these instruments. The R squared is 0.92 and both coefficients have the expected signs and are statistically significant at the 5 percent level. Thus, driver's licenses and state gas tax seem to be reasonable instruments for VMT.

With suitable instruments in place, the IV model is estimated by two stage least squares. Equation (5.1) is the structural equation and equations (5.9) and (5.10) below are the IV equations,

$$\text{DVMT} = \pi_0 + \pi_1 \text{driverslic} + \pi_2 \text{gastax} + \beta \mathbf{X} + \nu_2 \quad (5.9)$$

$$\text{FAREPERMI} = \theta_0 + \theta_1 \text{MSAppop1900} + \beta \mathbf{X} + \omega_2. \quad (5.10)$$

The next section presents results of estimates for equation (5.1) using OLS and using the IV estimation just discussed.

Cross-section Results

The following section discusses the results of the cross-sectional analysis. Four different estimation strategies are presented. The first two specifications are probit and IV probit models with the binary dependent variable being the attainment of the ozone standard. The second two specifications examine the continuous dependent variable

³⁸ The number of driver's licenses issued is only available by state. To estimate the number of driver's licenses per MSA, the statewide total was allocated by MSA population.

ozone level using OLS and IV two-stage least squares.

Several model specification tests were run to check for the appropriate functional form, the presence of heteroskedasticity and multicollinearity. The Ramsey RESET test was used to test different functional forms. The Ramsey RESET test is a general model specification test. It tests whether nonlinear combinations of the predicted values help explain the dependent variable. Specifically for the model,

$$y = \alpha_0 + \sum \beta_i x_i + e, \quad (5.11)$$

the residuals are calculated and inserted back into the original model as the terms as \hat{y}^2 and \hat{y}^3 ,

$$y = \alpha_0 + \sum \beta_i x_i + \delta_1 \hat{y}^2 + \delta_2 \hat{y}^3 + e, \quad (5.12)$$

the null hypothesis is that (5.11) is correctly specified and therefore in equation (5.12) $\delta_1 = \delta_2 = 0$. The intuition behind the test is that, if nonlinear combinations of the explanatory variables have any power in explaining the dependent variable, then the model is misspecified (Wooldridge 2000, p281).

The choice of functional form was informed by the physical process of ozone formation. Recall from the discussion of air quality variables that ozone formation is a nonlinear process due to the complex interaction of emissions, sunlight, and other weather and geographical features of the MSA. Several different nonlinear functional

forms were tested.³⁹ Log-linear, semi-log, and quadratic specifications were all tested with the Ramsey RESET test. The RESET tests indicated that a form of the quadratic specification in which only the variable PTSC TTL is squared is preferred.

A link test was also conducted on the linear model. The link test creates two additional variables and includes them in the regression. The first variable is just the predicted values of the dependent variable, \hat{y} . The second is \hat{y}^2 . The coefficient for the \hat{y} should be significant while the coefficient for \hat{y}^2 should not be significant if the model is specified correctly (StataCorp., 2007). A statistically significant coefficient on the square term of the link test indicated that the linear specification was not ideal. The link test result further supports the RESET test findings, indicating that a nonlinear specification is to be preferred.

The models were also tested for heteroskedasticity. Both the Breusch-Pagan and White test found evidence of heteroskedasticity. To correct for this, White's robust standard errors are used when available (Wooldridge 2000). In the IV probit model specification, robust standard errors are not available. However, when computing the IV OLS standard errors with and without White's corrections, the difference in the standard errors was minimal. In general, the robust standard errors were larger, leading to less precise estimates of the coefficients. Thus, care should be taken when one evaluates the statistical significance of the coefficients in the IV probit specification.

Multicollinearity was tested for using the variance inflation factor test. The variance inflation factor test (VIF) measures the impact of multicollinearity among the independent variables in a regression model on the precision of the estimation. It

³⁹ All testing was done using the OLS specification. Testing becomes quite onerous with the probit model. In addition, to facilitate comparisons across the OLS and probit specifications, models should have a common functional form.

expresses the degree to which multicollinearity among the predictors degrades the precision of an estimate. Typically a VIF value greater than ten indicates a high degree of multicollinearity.

Values over 10 for the variance inflation factor test were generated for GMP and DVMT suggesting high levels of multicollinearity. Three potential strategies exist for dealing with the issue of multicollinearity. The best is to gather more observations. However, this is not possible as we are using all suitable United States MSAs in my cross-section. Another option is to do nothing and realize that hypothesis tests are conservative. A third option is to drop one or more of the offending variables. GMP is in the theoretical model, therefore it is not appropriate for it to be dropped. DVMT is also crucial to the urban form variables and again would not be appropriate to drop. Therefore, some multicollinearity remains and estimates will have to be interpreted accordingly.

Of paramount interest in this analysis is modeling the ozone attainment status of an MSA. Therefore, the probit results will be the focus of the discussion. The OLS results will be used to illustrate potential inconsistencies in the probit results. The empirical estimates for the air quality models are presented in Tables C17 through C23. The discussion of the parameter estimates is divided into four groups of variables which potentially affect the ozone's standard attainment status of an MSA. To aid in the interpretation of the results, the marginal effects of each explanatory variable on the "average" MSA will be discussed. The fragmentation measures are discussed first followed by urban form, economic activity, and the preference variables.

Probit Fragmentation Measures

Table C17 shows the results for the six fragmentation measures using the probit specification. This variable is equal to one if the MSA is in attainment of the ozone standard and zero otherwise. Six different models are explored and reported in Table C17. In each model, the only change is the fragmentation measure included in the model. The expected sign for each fragmentation variable is given at the top of each column in Table C17. Each fragmentation variable is modeled separately, as it is usually not possible satisfy the *ceteris paribus* conditions when more than one fragmentation measure is included. In addition, the interpretation of the results becomes difficult when more than one measure of fragmentation is used. Relative fragmentation cannot be used in a model because it was not possible to satisfy the *ceteris paribus* condition with any type of population measure.⁴⁰

The empirical results suggest that none of the three local government form variables, central city dominance (CCD), special district dominance (SDD), or county primacy (CP), have a statistically significant impact on the ozone attainment status of the MSA. These results are in general agreement with Foster (1993) and Nelson and Foster (1999) in their studies on the impacts of fragmentation on MSA economic growth.

The empirical results suggest that MSAs with higher values of MPDI and jurisdiction count (JDCNT) are less likely to meet the ozone standard. Using the marginal effects, the “average” MSA that adds an additional unit of MPDI is 10 percent less likely to meet the ozone attainment standard. To put this in the context of the MSAs in the sample, if MPDI is increased by one standard deviation (1.24) the “average” MSA

⁴⁰ Relative fragmentation measures the number of governments per unit of population, thus it is only possible to add governments and still maintain the assumption population stays constant.

is 12.4 percent less likely to attain the ozone standard. The Tampa-St. Petersburg MSA has approximately the average value for MPDI, if one-half standard deviation is added, it would have an MPDI value that was similar to an MSA such as New London CT. Only 15 of the 41 MSAs with MPDI values equal to New London's of 6.57 or higher were in attainment in 1997.⁴¹

The results for jurisdictional count (JDCNT) indicate that an MSA, which adds one additional jurisdiction, is 0.14 percent less likely to reach the attainment standard. If jurisdiction count is increased by one-half a standard deviation, (70 jurisdictions) this would decrease the chance of being an attainment by 9.8 percent. This is a prospect that seems unlikely as the average MSA has only 121 jurisdictions. Consider instead an increase in jurisdictions by five units, this would imply the average MSA would be 0.8 percent less likely to attain the standard.

The empirical results suggest that MSAs with higher levels of central city growth are more likely to be in attainment of the ozone standard. Using marginal effects, the "average" MSA that adds an additional unit of central city growth (CCG) is 5.8 percent more likely to meet the ozone attainment standard. The average value for CCG is 5.02. To put this in the context of the MSAs in the sample, if CCG is increased by one-half a standard deviation (3.7) the "average" MSA is 21.5 percent more likely to attain the ozone standard. The Houston, Texas MSA with a CCG value of 4.9, is close to the average value. If one-half a standard deviation is added it would have a CCG value that was similar to an MSA such as Ocala, Florida with a CCG value of 8.8. Of the 31 MSAs

⁴¹ In the probit model marginal effects are not constant, but depend on the data point at which they are calculated. I calculated the marginal effects for the values of MPDI and JDCNT that are used here that are different than the mean values reported in the table. These values are very similar to the mean values. Thus, we will assume constant marginal effects for ease of exposition (see Wooldridge 2000, 538).

with CCG values of 8.8 or higher 24 were in attainment in 1997. Examining the MSAs with values of CCG one-half standard deviation lower than the average includes MSAs such as, Evansville-Henderson, Indiana with a value of 1.2. For the 75 MSAs that have values of CCG of 1.2 or less only 25 were in attainment of the ozone standard.

To try to further understand how CCG impacts the ozone attainment standard, we substituted its two component parts, change in central city population since 1950 and change in central city area since 1950, for CCG into the probit model. Both components have similar statistically significant impacts on attainment. Marginal effects for the average MSA indicate that a one unit increase in the population component of central city growth increases the likelihood of reaching the attainment standard by 9.4 percent. While increasing the area component of central city growth by one unit increases the likelihood of attaining the ozone standard by 6.3 percent. Examining the correlation coefficients of the three measures indicates that while the population portion may have a larger effect on attainment, the land area component is highly correlated with the final central city growth measure. The correlation coefficient for land area and CCG is 0.9 while the population component only has a correlation coefficient of 0.3. Surprisingly, the two components are not very correlated with each other, only having a correlation coefficient of 0.16.

As was shown in an earlier section there are a group of outlier MSAs that have calculated third highest daily maximum values (MAXEPA) that are incongruent with their attainment status. In order to test the effect that these MSAs have on the probit results, the dependent variable of attainment was changed to conform to the MAXEPA value. The results of the revised attainment-model are presented in Table C19 and suggest that only one of the three previously statistically significant fragmentation

variables has a statistically significant impact on MSA "attainment." CCG still has a positive and statistically significant effect on attainment status. The formerly statistically significant variables of MPDI and JDCNT do maintain the same sign as in the previous probit specification, but are not statistically significant. This result suggests that there are additional institutional components involved in reaching "attainment." Fragmentation appears to play a role in some MSAs' ability to coordinate their activities sufficiently to get a desired attainment status for a given ozone reading. MSAs that are less fragmented appear to be able to obtain a designation of attainment, even if their ozone reading should technically put them in nonattainment. While other more fragmented MSAs that should be in attainment based on ozone readings are unable to coordinate their regulatory response in a sufficient manner to rebut the incorrect classification of nonattainment. Before presenting results from the IV regression, we first discuss results for covariates other than fragmentation.

Control Variables

Of the five preference and demographic variables, college (COLLEGE), less than 25 (LESS25), and gross metropolitan product (GMP) all have a statistically significant effect on the attainment of the ozone standard. Percent democrat (PERDEM) and percent white (WHITE), do not have a statistically significant effects on attainment of the ozone standard.

The estimated effect for COLLEGE is counterintuitive. For the average MSA with 24 percent of its population college graduates, adding an additional one percentage point to COLLEGE indicates that the MSA is seven percent less likely to attain the ozone

standard. It is possible that this counterintuitive result is because of simultaneity bias. This will be examined in the discussion of the IV results. For the percent of population under age 25, a one percent increase in this variable indicates the MSA is seven percent less likely to be in attainment. Increasing GMP by \$1 billion indicates an average MSA is two percent more likely to be in attainment, holding all else constant.

Six urban form variables were included in the models.⁴² Density, commute time (COMTIME), and percent single-family (PRCNT1FAMILY) did not have a statistically significant impact on the attainment of the ozone standard. The MSAs presence in a CMSA had a large statistically significant impact on attainment. The marginal effect for CMSA indicates that MSAs located in CMSAs are 68 percent less likely to attain the ozone standard than those MSAs not within a CMSA.

DVMT has a statistically negative effect on attainment. If an additional million miles is added to the average MSA's DVMT, it is 2.6 percent less likely to attain the ozone standard. The transit variable, fare per mile of transit routes (FAREPERMI), also has a statistically significant impact on the attainment status of an MSA. The results suggest that an increase in FAREPERMI decreases the likelihood that an MSA will be in attainment. This is another anomalous result and will be further examined in the IV section.

Three variables are included in the category of economic activity. Only manufacturing employment (MFGAVGT) has no statistically significant effect on attainment. Employment growth (EMPGROWTH) has a positive and statistically

⁴² Regional authorities are not included in final empirical model. F-tests suggest that the coefficient values are not statistically different from zero in the probit specification for the three models of interest here, MPDI, JDCNT and CCG. Furthermore, only 10 MSAs have official regional governments.

significant effect on attainment. If the average MSA increased employment by one percent from 1992 to 1997, it would be four percent more likely to attain the ozone standard.

Point source total emissions have a statistically significant negative effect on the likelihood of reaching attainment. A joint F-test reveals that the null hypothesis that both the point source emissions and point source squared emissions coefficients both equal zero can be rejected at the 10 percent level. The positive coefficient for point source total squared suggests that as emissions increase, the chance of attainment of the ozone standard decreases but at a decreasing rate. For the average MSA adding 1000 tons of additional point source emissions, decreases the chance that an MSA will be in attainment by 0.88 percent. The inflection point for this quadratic function, in which additional point source emissions have zero effect on the chance of attainment for the average MSA, is approximately 138,400 tons of emissions. To put this value in perspective, the median value of point source emissions is 14,083 while the mean is 28,362. Only Cincinnati, Chicago, Detroit, and Houston exceed 138,400 tons of point source emissions annually.

The dummy variables for the presence of dirty industry or power plants were not included in the final empirical specification due to *ceteris paribus* constraints with point source emissions. It is not possible to keep point source emissions constant while making incremental changes to the dummy variable of power plant or the presence of dirty industry. Both power plants and dirty industry are likely to be large point source polluters and would be counted in point source emissions. In order to satisfy the *ceteris paribus* conditions any power plant or dirty industry that is added or subtracted from an MSA

would either have zero point source emissions or the current distribution of point source emissions would have to change to accommodate the new entrant. Neither possibility seems to be a credible assumption.

Seven variables are included in the categories of weather and geography. In the weather category total ozone season rain (TTLRAIN), and July average wind speed (JULYMNWIND) do not have a statistically significant effect on the attainment of the ozone standard. July temperature (JTEMP) does have a statistically significant negative effect on attainment. If the average MSA's July average temperature were to rise by 1°, it would be 4 percent less likely to attain the ozone standard.

In the geography category, the regional variables SOUTH and MIDWEST and the coastal location variable all have a statistically significant effect on the attainment of the ozone standard. The regional variable west does not have a statistically different effect than the default region, north. SOUTH has a large statistically significant positive effect on the attainment of the standard. This result suggests that all else equal, an MSA in the south is 64 percent more likely to attain the ozone standard than an MSA in the north. MIDWEST has a similar effect, indicating a 37 percent greater chance of attainment than a similar MSA in the north. If an MSA is located in a coastal region, it is 33 percent more likely to attain the ozone standard as an MSA located inland (See Table C18).

The lagged ozone value has a very large positive coefficient and is statistically significant. The maximum EPA value for 1992 (MAXEPA1992), suggests that an increase of 0.01 ppm in ozone in 1992 makes it 43.4 percent more likely that an MSA will be in nonattainment in 1997.

Recall, this variable is included as way to control for unobserved heterogeneity when using proxy variables (Wooldridge 2000, 289). The IV probit results are discussed next.

IV Probit Results

In Table C20 the results from the IV probit variables are given. The CCG variable still maintains significance at the 10 percent level and MPDI is marginally insignificant at the 15 percent level while JDCNT is not statistically significant. In the instrumental variables specification, the magnitude of the fragmentation variables increases, but so do the standard errors. This is a common problem when using an instrumental variables' approach to control for potential endogenous repressors (Wooldridge 2000, 475). Because the Newey's efficient two-step estimator had to be used in Stata to get the IV estimates to converge, we were unable to calculate marginal effects.⁴³ Thus, it is not possible to compare the magnitude of the change in effect of the IV estimates and the probit estimates.

To test the possible endogeneity of DVMT and FAREPERMI in the probit model, we conducted a Wald test as well as the two-stage endogeneity test suggested by Wooldridge (2002). The Wald test is computed by Stata. When using the Newey two-step estimator, the residuals from the first stage regression are included in the second stage estimation. The Wald test is a joint test of significance on those residuals' coefficients. The Wald test statistic was 0.34, this is weak evidence against the null hypothesis that DVMT and FAREPERMI are exogenous in equation (5.2).

⁴³ In Stata using Newey's two step estimator, the coefficients' t-statistics can be used to determine statistical significance, but deriving the marginal effects from two-step models such as this one are difficult and not currently available in Stata (Statacorp 2007, see also Wooldridge 2002, section 15.7 for a discussion of a slightly simpler two-step probit estimator and the issues involved in computing the marginal effects).

In an effort to further test for endogeneity and perhaps determine which variable might be exogenous, we computed a form of the augmented regression test suggested by Wooldridge (2002). To perform the test, we ran the OLS regression on the suspected endogenous variable, DVMT, and all other exogenous variables, including relevant instruments and saved the residuals. We repeated this procedure with the second endogenous variable, FAREPERMI. We then used these two residuals from the OLS regression in the probit regression that includes the potentially endogenous variables. The reported t-statistic on the residuals is a valid test of the null hypothesis that the variables, DVMT and FAREPERMI are exogenous (Wooldridge 2002, 474). For the DVMT residual, the test statistic was 0.4. For the FAREPERMI residual, the test statistic was 0.25. When a joint F-test was computed, the test statistic was 0.34. These tests support the assumption of exogeneity DVMT and FAREPERMI. If DVMT and FAREPERMI are exogenous, the IV probit estimator is less efficient than the probit estimator. This results in larger standard errors in the IV estimation (Wooldridge 2000, 483). This is in fact what we find in the results of the IV probit model reviewed below. The results of the remaining independent variables are discussed next

Only those independent variables that were statistically significant, potentially endogenous, or yield theoretically incongruent results in the probit models presented in Table C17 will be discussed in this section. In general, the IV results support the probit results. However, very few of the variables have statistically significant coefficients. Again in this section the general focus will be on the MPDI model. However results tend to be consistent across the three fragmentation models of interest MPDI, JDCNT, and CCG.

For the demographic and preference variables, the percent of college graduates living in an MSA has a statistically significant effect on the attainment of the ozone standard (see Table C20). For the IV probit model, the magnitude of the college effect is greater than the probit result. Because marginal effects are not available, the percent change on the likelihood of attainment for the average MSA cannot be estimated. However, as the IV probit coefficient is larger than the probit coefficient it is possible that the probit model underestimates the effect.

There are several variables of interest in the urban form group. The results of the IV probit regression suggest that MSA location in a CMSA has a statistically significant negative effect on attainment of the ozone standard. The magnitude of the CMSA effect on attainment is greater in the IV specification than in the probit model. This suggests that CMSAs are likely to have a negative effect on attainment. The two potentially endogenous explanatory variables DVMT and FAREPERMI are discussed next.

The IV probit regression results suggest that higher values of daily vehicle miles traveled (DVMT) decrease the likelihood of attainment. The IV probit estimate for DVMT has a greater magnitude on the coefficient estimate than the probit model but a larger standard error. Thus, the IV estimates offer evidence that the probit model accurately estimates the negative effect DVMT has on attainment.

For the variable FAREPERMI, the IV probit results still show a negative effect on attainment although it is not statistically significant. This is contrary to the intuition that greater amounts of public transit should contribute to the attainment of the ozone standard. This result will be revisited in the discussion section. A joint F-test on the four variables CMSA, DVMT, FAREPERMI, DENSITY and COMTIME indicate that the

null hypothesis that they all equal to zero cannot be rejected.

In the weather and geography group, the results of the IV probit model suggest that higher July average temperature has a marginally statistically significant impact on the attainment of the ozone standard. The magnitude of the coefficient is approximately the same as the probit estimate. This suggests that the probit model accurately estimates the effect of July temperatures on the likelihood of attainment of the ozone standard. The positive effects of being in the south and midwest are also generally supported in the IV specification (see Table C20). The magnitude of the lagged ozone value increases and remains highly statistically significant.

OLS Results

Table C21 shows the results for the six fragmentation measures using the OLS specification. In this specification the dependent variable is the calculated third highest daily maximum EPA ozone value (MAXEPA). While the attainment status is determined by the MAXEPA value, attaining the ozone standard and maintaining low ozone levels are not necessarily congruent goals. Henderson (1996) shows that overall ozone levels tend to rise under the one-hour ozone standard over time even though more counties reached attainment. Only those MSAs in nonattainment have an incentive to reduce ozone. As long as an MSA's MAXEPA value does not cross the threshold, an MSA faces no sanctions if its ozone level rises.

While the attainment of the ozone standard is what matters to MSAs, using the value of MAXEPA as the dependent variable has several advantages. First, MAXEPA is continuous. As discussed earlier, there is limited variation in attainment status over time.

This is problematic for a panel data fixed effects approach. Using MAXEPA allows for comparisons of results between the cross-sectional approach and the panel approach.

Second, MAXEPA results may be able to help us in the understanding of some of the anomalous probit results. The specification for the OLS estimation is the same as for the probit models. The fragmentation variables will be discussed first followed by the other independent control variables.

OLS Fragmentation Variables

The MPDI variable which had a statistically significant effect on attainment of the ozone standard only has a marginally significant effect on MAXEPA. If MPDI were to increase by one unit, the MAXEPA value would increase by 0.0008 ppm. Increasing MPDI by one standard deviation increases the ozone value by 0.0012 ppm. To try and gauge the magnitude of this effect, we determine how many MSAs would cross the 0.12 ppm threshold for attainment if 0.0012 was added or subtracted from its MAXEPA value. Only three MSAs in attainment would cross the 0.12 ppm threshold, decreasing the number of attaining MSAs by 2.6 percent. Seven MSAs in nonattainment would fall below the threshold, decreasing the number of nonattaining MSAs by 9.6 percent.

The empirical results suggest that MSAs with greater values for JDCNT are more likely to have higher values of MAXEPA. Adding an additional jurisdiction increases MAXEPA by 0.000014 ppm. If an MSA were to increase its number of jurisdictions by one-half standard deviation, MAXEPA would be expected to increase by 0.00085 ppm. This effect is of a lesser magnitude than the MPDI result.

The CCG variable also had a statistically significant effect on attainment of the

ozone standard in the probit models, but has only a marginally significant effect on MAXEPA. If an MSA were to add one unit of CCG, the MAXEPA value would be expected to decline by 0.00018 ppm. Again, using the one-half standard deviation value used in the probit analysis, MAXEPA would decline by 0.0007 ppm. This is a smaller effect than that for MPDI and would only cause three nonattaining MSAs to cross over the attainment threshold. The other independent control variables are discussed next.

OLS Control Variables

This section will focus on the model including the MPDI as the measure of fragmentation, as did the probit section. The MPDI is the most interesting fragmentation measure that is also available to test in the panel framework. As in the probit specification, the results across the three models of interest MPDI, JDCNT, CCG are fairly consistent. As the EPA technically determines MSA attainment status from the MAXEPA value, one would expect that MAXEPA and attainment status should be correlated. However, as was discussed earlier, that is not the case. The general empirical theory remains the same for both dependent variables. Independent variables that should make it less likely to reach the attainment of the ozone standard should also lead to increases in the value of MAXEPA. The following section discusses the four independent variable groups, demographic and preference variables, urban form, economic activity, and weather and geography.

None of the Demographic and preference variables have a statistically significant effect on the MAXEPA ozone value. Even the college variable which had a statistically significant impact in both probit and IV probit specifications does not even have a

marginally significant effect on the MAXEPA ozone value.

Of the six urban form variables, only CMSA has a statistically significant impact on the MAXEPA ozone value. If an MSA is part of a CMSA, it can be expected to have .0054 ppm higher ozone value than an MSA not in a CMSA, all else equal (see Table C21).

The results for the two endogenous variables DVMT and FAREPERMI differ from the results of the probit model. The results in Table C21 indicate that DVMT has no statistically significant effect on MAXEPA. This is contrary to the negative effect found in the probit model. These differences will be further analyzed in the panel data section.

FAREPERMI has a negative effect on MAXEPA. However, the result is not statistically significant. This result is in contrast to the probit result, which found that higher values of FAREPERMI made it more likely that an MSA would be in nonattainment. These incongruent results could be due to the nature of MAXEPA in nonattainment MSAs. In nonattainment MSAs with high values for FAREPERMI, the value of MAXEPA tends to be lower than the MAXEPA value for other nonattainment MSAs with lower values of FAREPERMI. For instance, New York City with the highest value for FAREPERMI of 516,642 and has a MAXEPA value of 0.137. While Houston, TX has a relatively modest value for FAREPERMI of 15,696, but has a MAXEPA value of 0.189. In fact, the top-five MSAs in FAREPERMI have an average FAREPERMI value of 183,595 and average MAXEPA value of 0.13. While the five MSAs with the highest MAXEPA values, that are not in the top-twenty for FAREPERMI, have an average FAREPERMI value of 10,690 and an average MAXEPA value of 0.18.

The OLS results for economic activity differ slightly from the probit results. The

variables, manufacturing employment and point source total emissions have a statistically significant impact on MAXEPA. However employment growth (EMPGROWTH) does not have a statistically significant effect on MAXEPA. Manufacturing employment has a negative effect on MAXEPA. As there is a large variation in the MSA manufacturing employment, we will compare the effects using one-half standard deviation of 45,615.⁴⁴ For an MSA that increases its manufacturing employment by one-half a standard deviation, it would decrease MAXEPA by 0.0024 ppm.

Point source total emissions have a statistically significant positive effect on MAXEPA. The marginally statistically significant negative value for point source total squared suggests that the effect of point source emissions on MAXEPA increases as emissions increase at a decreasing rate. The inflection point for this quadratic function, in which additional point source emissions have zero effect on MAXEPA, is approximately 149,000 tons of emissions. This value is similar to the value of 138,400 tons of emissions for the average MSA in the probit model.

The seven geography and weather variables have a similar effect on MAXEPA ozone as they did on attainment status. Two of the weather variables have a statistically significant effect on MAXEPA. Total ozone season rain has a statistically significant negative effect on MAXEPA. If one standard deviation of total rain were added, 9.34 inches, then MSA would be expected to have 0.002 ppm lower values of MAXEPA.⁴⁵

July average wind also has a positive statistically significant effect on MAXEPA. This effect is unexpected and contrary to ozone formation theory. This result is examined further in the IV section. July temperature has a marginally statistically

⁴⁴ The mean value for manufacturing employment is 61,177 while the median is 28,008.

⁴⁵ The average total July rain is 18.4 inches while the median is 19.3 inches.

significant positive effect on MAXEPA.

The four geography variables do not appear to have a statistically significant effect on MAXEPA. Only the regional variable south has a marginally statistically significant effect on MAXEPA. The results suggest that an MSA in the south can be expected to have a lower level of MAXEPA than an MSA in the north all things equal. This is in agreement with the probit result. However a joint F-test on the four variables COASTAL, SOUTH, MIDWEST, and WEST indicate that the null hypothesis that they all equal zero cannot be rejected.

In the OLS specification the lagged variable MAXEPA in 1992 has a very large positive coefficient and is statistically significant. The results suggest that if an additional 0.01 ppm is added to the 1992 MAXEPA value, it will increase the 1997 MAXEPA value by 0.0065 ppm.

IV OLS Results

In order to accurately interpret the estimates from the IV specification one must first determine the likelihood that the suspected variables are indeed endogenous. To test the possible endogeneity of DVMT and FAREPERMI in the OLS model, we used the augmented regression test suggested by Wooldridge (2000) for OLS. We ran the OLS regression on the suspected endogenous variable, DVMT, and all other exogenous variables, including relevant instruments and saved the residuals. We repeated this procedure with the second endogenous variable, FAREPERMI. We then used these two residuals from the OLS regression in the full OLS model that includes the potentially endogenous variables. The reported t-statistic on the residuals is a valid test of the null

hypothesis that the variables, DVMT and FAREPERMI, are exogenous (Wooldridge 2000, 484).

For the DVMT residual, the test statistic was 0.25. For the FAREPERMI residual, the test statistic was 0.69. When a joint F-test was computed, the test statistic was 0.06. This is an odd result. The individual t-tests suggest that neither variable is endogenous, while the joint test shows that there is fairly strong evidence that at least one of the variables is endogenous. One potential explanation for this could be multicollinearity in the residuals. It is possible that multicollinearity among the two residuals results in the t-test not having sufficient evidence to sort out the separate effects of each residual. However, the two residuals still have a substantial combined effect on the sum of squared errors which is what is used in the F-test.

A VIF test, run after the augmented regressions, produces VIF factors for the DVMT and FAREPERMI residuals of 53 and 20 respectively. These high values suggest that multicollinearity is present among the two residuals. Thus, the evidence of endogeneity in the OLS model is somewhat mixed. It is possible that either DVMT or FAREPERMI is endogenous. However, the evidence for the existence of endogeneity is not overwhelming. Thus, the IV OLS estimators may be less efficient than the OLS estimator. This will produce larger standard errors if both variables are exogenous. The next section will discuss the results of the IV OLS regression.

In Table C22 the results from the instrumental variables regression are given for MAXEPA. These results differ from the OLS fragmentation variable estimates. Only the CCG variable maintains statistical significance at the 15 percent level. The standard errors are larger; however, the signs on the coefficients remain the same.

The results for the other control variables are also presented in Table C22 for the IV OLS specification. Once again, the focus will be on the variables that were statistically significant in the OLS specification. Generally, the IV results support the OLS results. Once again, the IV specification yielded fewer statistically significant coefficients than the OLS specification. The four groups of independent control variables will be discussed briefly next.

None of the demographic and preference variables have a statistically significant effect on the MAXEPA ozone value. For the urban form group, the inclusion of an MSA in a CMSA raises the value of MAXEPA compared to stand alone MSAs. However, it is not statistically significant.

In the economic activity group manufacturing employment still has a negative effect on MAXEPA, but the effect is not statistically significant. While, greater point source total emissions increases MAXEPA ozone values and is marginally statistically significant. The signs on both coefficients support the OLS results.

For the geography and weather group, the IV results generally support the anomalous OLS results. July average wind maintains a positive statistically significant effect on MAXEPA. Examining the regional differences in Table C4 suggests a possible explanation for this anomaly. Western MSAs have the highest average value for MAXEPA of 0.123, they also have the highest average July wind at 9.7 miles per hour. This average wind speed for the region is 1.3 miles per hour higher than the second place region, the midwest. Perhaps the unique topography of mountain ranges and valleys found in some western MSAs overcomes the usual effect that higher winds have on ozone formation.

July temperature no longer has a statically significant effect on MAXEPA in the IV specification. The effect of total rain lessens the value of MAXEPA by about the same magnitude as the OLS result however, the standard error increases.

For the geographical variables, only the regional variable SOUTH has a marginally statistically significant effect on MAXEPA. The results suggest that an MSA in the south can be expected to have higher levels of MAXEPA than an MSA in the north all things equal. This result does not agree with the probit result. However a joint F-test on the four variables COASTAL, SOUTH, MIDWEST, and WEST indicates that the null hypothesis that they all equal zero cannot be rejected.

The lagged MAXEPA value is still positive and highly statistically significant. The magnitude of the coefficient is about the same as the OLS value only increasing to 0.0067.

Discussion I

The cross sectional model provides evidence that fragmentation hinders an MSA's ability to reach the attainment of the ozone standard. However this effect is an economically modest one. The model of primary interest is that of the attainment status of the MSAs rather than the levels of ozone. Ultimately it is being in attainment of the ozone standard that provides MSAs with incentives to reduce ozone levels. Thus, the probit results are the more relevant than the OLS. Three of the six fragmentation variables were statistically significant in the probit model. They were MPDI, JDCNT, and CCG. For the OLS model only one fragmentation variable was statistically significant, CCG.

In the probit model an incremental increase in MPDI for the “average” MSA decreased the likelihood of attainment by 10 percent. This change (a one unit increase in MPDI) is very similar to the standard deviation for MPDI of 1.24. For the average MSA that increased MPDI by one standard deviation from approximately 5.23 to 6.37 it would be 12.4 percent less likely to be in attainment of the ozone standard. The two MSAs mentioned previously, Tampa-St. Petersburg and New London, CT illustrate the influence of expenditures and jurisdiction count on the variable MPDI. New London has an MPDI value of 6.57; it has 124 jurisdictions and expenditures of approximately \$463 million. The Tampa-St. Petersburg MSA has fewer jurisdictions with 90 and almost eight times the expenditures of New London with \$ 3.7 billion. However, it has a lower MPDI value of 5.16. This highlights the effect that consolidation of expenditures can have on MPDI and potentially attainment of the ozone standard.

The results for jurisdictional count (JDCNT) indicate that the “average” MSA, which adds ten additional jurisdictions, is 1.4 percent less likely to reach the attainment standard. Again examining the MSA of New London CT, it has 124 jurisdictions which is close to the average of 121. If it were able to consolidate some of its 18 townships, six cities, or 100 special districts it could conceivably decrease its jurisdiction count by 35 units (one-quarter of a standard deviation). This would increase the likelihood of attainment of the ozone standard by 4.9 percent, a modest impact.

The “average” MSA that adds an additional unit of central city growth (CCG) is 5.8 percent more likely to meet the ozone attainment standard. The average value for CCG is 5.02 and one half-standard deviation is 3.7. Thus, an MSA like Houston, TX which has approximately the average value for CCG would be 21.5 percent more likely

to attain the ozone standard if it could increase its CCG value by one-half a standard deviation. For Houston, CCG would increase by one-half a standard deviation if Houston central city expanded its land area by approximately 30 percent and if its central city population grew by approximately 30 percent.⁴⁶ This type of consolidation seems rather unlikely to occur.

The cross-sectional model provides evidence that fragmentation has an effect on the attainment of the ozone standard. The probit model provides the strongest evidence of the effect while the OLS results are only modestly supportive. This difference in results is reasonable when considering the different nature of the dependent variable in each specification. The OLS specification measures a continuous variable for which governments that are in attaining MSAs have little incentive to lower. Thus, for the 114 MSAs in attainment, it is a poor approximation of jurisdictional behavior. The probit model more accurately approximates the behavior of jurisdictions in all MSAs. Those jurisdictions in MSAs that are in attainment have incentives to stay in attainment, while those jurisdictions in nonattaining MSAs have incentives to try to reach the ozone standard. Thus, the probit model offers the correct measure of the environmental good, “attainment of the ozone standard.”

As described in Chapter 2, Foster (1993) and Nelson and Foster (1999) introduced three fragmentation variables that measured local government structure: central city dominance, special district dominance, and county primacy. These three measures were included in the analysis here and they did not have a statistically significant effect in any of the models. This result is fairly consistent with the literature. Foster (1993) only

⁴⁶ Any combination of central city land area expansion and central city population expansion that equaled approximately 60 percent would result in a 3.07 increase in CCG.

found special district dominance to be a consistent statistically significant predictor of population growth. While, Nelson and Foster (1999) found that central city dominance was a statistically significant predictor of population growth.

In comparing the statically significant measures of government fragmentation to the insignificant measures, two key differences are apparent. First, population levels and location do not appear to play a significant role in determining attainment of the ozone standard. Central city dominance (CCD) and county primacy (CP) are both measures of population distribution within an MSA, and neither is ever statistically significant. The statistically significant variable, CCG measures the change in central city population from 1950 to 2000 and incorporates growth in land area. The ability to expand the land area of a central city and attract additional population appears to be a better indicator of the power the central city has to influence ozone policy, rather than population levels. MPDI is another statistically significant fragmentation measure that measures the concentration of expenditures in the MSA. MPDI is not correlated with CCD or CP, further illustrating the relative lack of importance population distribution seems to play in determining attainment of the ozone standard.

It also appears that the specific purpose of an additional jurisdiction may not be relevant for determining attainment of the ozone standard. Comparing SDD with the statistically significant variable, JDCNT, it appears that general government fragmentation plays a more important role in attainment of ozone standard than if that jurisdiction is a general purpose or special purpose government.

Additional Cross-Sectional Models

Several other specifications of equation 5.1 were formulated to test the robustness of both the probit and OLS results discussed above. In an effort to determine whether MSAs that are far from the one-hour attainment standard behave differently from MSAs that are close to the standard, an interaction term was added. For all MSAs, the absolute value of the difference between the one-hour ozone standard of 0.12 ppm and the 1997 MAXEPA value was calculated. All MSAs that were within 0.02 ppm of the ozone standard were assigned the dummy variable of one. This corresponded to 119 MSAs. This dummy was interacted with the three statistically significant fragmentation variables, MPDI, JDCNT, and CCG in both the probit and OLS specifications.

The probit models produced no statistically significant effects for the interaction term. In the OLS specification, the CCG interaction term was statistically significant, while jurisdiction count was marginally significant at the 12 percent level. For CCG, the result suggests that the effect of increasing CCG by one unit for MSAs within 0.02 absolute value of the standard decreases MAXEPA by 0.000042 ppm as compared to a decrease of 0.000592 ppm for MSAs that are not within 0.02 ppm of the standard. This result remains statistically significant in the IV specification as well. The results suggest that MSAs that are closer to the standard benefit less from reductions in fragmentation as measured by CCG.

In an effort to explain the unexpected positive sign on the college variable, we tested several different model specifications. A quadratic term was added for the college variable, and several different age and race terms were substituted in place of less than 25 and percent white. The college coefficient remained negative and statistically significant

throughout all the different variations in the age and race variables such as percent Hispanic, percent Black, percent over 65, and percent between 25 and 64. The quadratic term had a positive coefficient but was not statistically significant. Further analysis of the college variable will be undertaken in the panel data section.

Overall, the covariates that were statistically significant had the appropriate signs. In the probit model, FAREPERMI, had an unexpected sign suggesting that MSAs with greater transit, were more likely to be in nonattainment. FAREPERMI was not statistically significant in the OLS model. In the IV probit specification FAREPERMI maintains its negative sign but it is not statistically significant. Controlling for the possible endogeneity of FAREPERMI is further complicated by the potential for transit to be used historically to try and alleviate automobile congestion. Often, these efforts were made before the clean air act required MSA action to reduce ozone. In most cases, traffic congestion persisted even after transit was built. In the panel model it is possible to control for these historical correlations.

Another anomalous result is that of DVMT in the OLS model. While DVMT was not statistically significant, it has the incorrect negative sign, suggesting that MSAs with more daily vehicle miles traveled are likely to have lower ozone readings. In the IV OLS specification DVMT maintains its negative sign but is not statistically significant. This result will be explored further in the panel model.

While endogeneity may be present in the ozone levels model (the cross section OLS model), in the key model of interest, the attainment model, the assumption of exogeneity of both DVMT and FAREPERMI seems to be reasonable.

Given the lack of clear evidence, we next explore a subset of the models presented in this section for which panel models may be estimated.

Panel Data

A key benefit of panel data is to be able to control for unobserved heterogeneity when one or more of the independent variables is correlated with an unobservable. If the unobservable characteristics are assumed to be fixed over time, the fixed effects estimator can be used to produce unbiased estimates.

In the cross-sectional model recall two methods are utilized to control for unobserved heterogeneity. The first is the use of proxy variables. The second is the use of the lagged dependent variable. Using the panel data in a random effects probit specification, we can test key variables to determine whether they might be correlated with unobservables. If we find they are not, this serves to bolster the results in the cross-sectional model.

There are several key variables of interest: the statistically significant fragmentation variables MPDI and jurisdiction count (JDCNT), the potentially endogenous variables, and the variables with unexplained results in the cross-section models. Next is a general description of the fixed effects estimator (FE). Consider a general model of the form in equation (5.13),

$$y_{it} = \beta_1 x_{it1} + \beta_2 x_{it2} + \dots \beta_k x_{itk} + a_i + u_{it}, t = 1, 2, \dots, T., \quad (5.13)$$

where y_{it} is a variable measuring air quality and $x_1 - x_k$ are the fragmentation variables

and control variables discussed earlier and a_i is a vector of MSA fixed effects, and u_i is the error term. In order to remove a_i we can average equation (5.13) overtime to get equation (5.14).

$$\bar{y}_i = \beta_1 \bar{x}_{i1} + \beta_2 \bar{x}_{i2} + \dots \beta_k \bar{x}_{ik} + a_i + \bar{u}_i, \quad (5.14)$$

where $\bar{y}_i = T^{-1} \sum_{t=1}^T y_{it}$, $\bar{x}_i = T^{-1} \sum_{t=1}^T x_{it}$ and so on. Subtracting (5.14) from (5.13) yields equation (5.15),

$$\dot{y}_{it} = \beta_1 \dot{x}_{it1} + \beta_2 \dot{x}_{it2} + \dots \beta_k \dot{x}_{itk} + \ddot{u}_{it}, t = 1, 2, \dots, T. \quad (5.15)$$

Where $\dot{y}_{it} = y_{it} - \bar{y}_i$ is the time demeaned data on y and $\dot{x}_{it} = x_{it} - \bar{x}_i$ is the time demeaned data on x and so on. If the explanatory variables are assumed to be exogenous, the fixed effects estimator is unbiased. The fixed effects estimator allows for the explanatory variables to be correlated with the unobserved fixed effects, a_i . However, if the dependent variable y_{it} is a binary variable that represents MSA attainment status and does not change over the three periods of panel data, it too will be removed by subtracting (5.14) from (5.13) (Green 1993 and Baltagi 1999). This is the case for 136 of the MSAs in the sample, 75 are always in attainment and 61 are always in nonattainment in the three panel periods. Thus the fixed effects specification is helpful for the continuous dependent variable MAXEPA but not the binary dependent variable of attainment status. The random effects (RE) model allows for the inclusion of such fixed variables and as such, it is discussed next.

Random effects allows for the inclusion of all the observations in the model regardless of whether the dependent variable changes over time. The general random effects model is as follows. Suppose equation (5.16) is an unobserved effects model similar to equation (5.13),

$$y_{it} = \beta_0 + \beta_1 x_{it1} + \beta_2 x_{it2} + \dots \beta_k x_{itk} + a_i + u_{it}, t = 1, 2, \dots, T., \quad (5.16)$$

An intercept is included here so that a_i can be assumed to have zero mean. However for the RE model, we also assume that a_i is uncorrelated with all independent variables.

Rewriting equation (5.16) with the composite error term $v_{it} = a_i + u_{it}$ gives equation (5.17)

$$y_{it} = \beta_0 + \beta_1 x_{it1} + \beta_2 x_{it2} + \dots \beta_k x_{itk} + v_{it}, t = 1, 2, \dots, T. \quad (5.17)$$

Since a_i is in the composite error for each time period in equation (5.17), the composite errors v_{it} are serially correlated as expressed in equation (5.18),

$$Corr(u_{it}, v_{is}) = \sigma_a^2 / (\sigma_a^2 + \sigma_u^2), t \neq s. \quad (5.18)$$

General least-squares (GLS) can be used to resolve the serial correlation that is necessarily present in random effects (Wooldridge 2000, 450). Wooldridge defines the necessary transformation to estimate the serial correlation in the errors as equation (5.19),

$$\lambda = 1 - [\sigma_a^2 / (\sigma_a^2 + \sigma_u^2)]^{1/2}, \quad (5.19)$$

where Lambda is between zero and one. The transformed equation is shown in (5.20),

$$y_{it} - \lambda \bar{y}_i = \beta_0(1 - \lambda) + \beta_1(x_{it1} - \lambda \bar{x}_{i1}) + \dots + \beta_k(x_{itk} - \lambda \bar{x}_{ik}) + (v_{it} - \lambda \bar{v}_i) = 1, 2, \dots, T. \quad (5.20)$$

A more general way to think of the random effects estimator is that it is a combination of the fixed effects estimator and a λ -weighted value of the between estimator. Recall that the between estimator is defined in equation (5.14).

The random effects estimator crucially depends on a_i being uncorrelated with any independent variable. If the random effects estimator is used when a_i is correlated with the independent variables, the estimates are generally inconsistent (Wooldridge 2000, 453). Hausman 1978 devised a test to check this condition of the random effects model. The Hausman test compares the results from fixed effects and random effects models and tests if they are equal. However, in my data is not possible to conduct the fixed effects estimation on the full sample. Thus the Hausman test is not practical.

In a test suggested by Gould (2001) one uses the relationship of the between estimator (BE) and the fixed effects estimator to determine whether the random effects estimator is biased. The intuition behind the test is similar to that of the Hausman test. If all of the independent variables are uncorrelated with a_i , the fixed effects estimates should be equivalent to the random effects estimates. Since the random effects estimator is a matrix weighted average of the fixed effects and the between estimator, it can be shown that if the random effects assumptions are satisfied the fixed effects estimates are equivalent to the between estimates (Gould 2001).

The test requires that the random effects estimator be broken down to its

component parts of the fixed effects estimator and between estimator for each independent variable for which we think there is a possible correlation with a_i . An F-test can be used for each variable's two components, the fixed effects estimate and the between estimate. The null hypothesis is that the fixed effects estimate equals the between estimate. If the null hypothesis cannot be rejected at a reasonable level of statistical significance, it suggests evidence that the selected variable is not correlated with a_i . To fully simulate a Hausman test, one must run a joint F-test on all the independent variables. However if there are variables that appear to be correlated with a_i , one can leave them out of the Joint f-test and test whether the remaining variables are uncorrelated with a_i .

The Gould test has several benefits for my analysis. Because the test is run within the random effects framework, it allows for comparisons using the full sample. Also unlike the Hausman test, which tests all independent variables at once, the Gould test allows for selective testing of individual dependent variables. Thus the Gould test can serve as an additional endogeneity test for key variables in the cross-sectional models. If it can be shown that the independent variable is not correlated with a_i in the panel model, it is suggestive evidence that the variable is not correlated with unobservables in the cross-sectional model. As was discussed earlier, the effects of endogeneity or unobserved heterogeneity have similar results on regression estimates and are controlled for in similar manner. For some of the variables in the cross-sectional analysis, the IV technique was used to try and control for potential endogeneity. However, not all variables had suitable instruments. Thus, if unobserved heterogeneity is not present in the panel model it bolsters the claims for exogeneity in the cross-sectional models.

Panel Results for the Dependent Variable of Attainment

Table C23 shows the panel probit specification results for two of the three fragmentation measures that had explanatory power in the cross-section models.⁴⁷ The dependent variable is the binary variable, attainment of the ozone standard. The number of observations is 187 MSAs, the same as the cross-sectional model. The models are generally weaker overall with fewer statistically significant variables.

The empirical results suggest that MSAs with higher values of MPDI and jurisdiction count (JDCNT) are less likely to meet the ozone standard. The results for the model with the metropolitan power diffusion index (MPDI) indicate that an MSA which adds one additional unit of MPDI, is 20 percent less likely to reach the attainment standard. The random effects result also supports the probit result in the cross-sectional model, but it is approximately twice as large.

Using the marginal effects, the “average” MSA that adds an additional unit of jurisdictional count (JDCNT) is 0.2 percent less likely to reach the attainment standard. This result is in general agreement with the cross-sectional results that found the marginal effect of jurisdiction count to be 0.14 percent. This result provides additional support for the cross-sectional model.

In order to determine the validity of the random effects estimates, we conducted the Gould test on both models. In model 1 that contains MPDI, college and MPDI variables had statistically significant F-statistics at the 1 percent level. This suggests that these variables may be correlated with unobservables. To test this prediction, we conducted a joint F-test in model 1 with all variables included. This produced an F-

⁴⁷ Recall, that one of the measures, central city growth (CCG) is only available in the cross-sectional model and thus is not included in table C23.

statistic with a p-value of 0.0003, indicating that one could reject the null hypothesis that all pairs of estimates were equal. A second F-test was conducted, dropping the likely correlated variable college. The resulting F-statistic had a p-value of 0.16. This is weak, suggestive evidence that the remaining variables of interest are not correlated with unobservables. If COLLEGE and MPDI are dropped, the resulting F-statistic had a p-value of 0.65. This is considerably stronger evidence that the remaining variables are not correlated with unobservables.

Thus, the results of the random effects estimates for the variables MPDI and COLLEGE should be viewed cautiously. It is also possible that the remaining variables are also inconsistent if they are correlated with the either MPDI or COLLEGE (Wooldridge 2000, 166).⁴⁸ Examining the correlation coefficients for COLLEGE, it appears to be relatively uncorrelated with any of the other variables in the estimation equation. MPDI has correlation coefficients between 0.4 and 0.6 with several of the other control variables, including employment, gross metropolitan product, manufacturing employment, DVMT and point source total emissions. Thus, the estimates in model 1 should be viewed cautiously.

In model 2 which uses JDCNT as the fragmentation measure, only COLLEGE had statistically significant F-statistic at the one percent level. In model 2 a joint F-test without COLLEGE generated an F-statistic with a p-value of 0.54. As COLLEGE appears to have little correlation with the other control variables, the results for other covariates in model 2 are not as likely to be inconsistent. These results for models 1 and 2

⁴⁸ If any independent variable is correlated with u_i , generally all estimators are inconsistent. If only x_1 is correlated with u_i than $\hat{\beta}_1$ will be inconsistent. If x_1 and x_2 to are correlated, $\hat{\beta}_2$ will also be inconsistent. However, if x_1 and x_2 are uncorrelated $\hat{\beta}_2$ will not be inconsistent (Wooldridge 2000, 166).

and their implications on the cross-sectional model will be discussed in greater detail in the summary section. Next we will examine the other covariates of interest.

The demographic and preference variable, COLLEGE, has a statistically significant positive effect on attainment in both random effects models 1 and 2. This is in contrast to the results in the cross-sectional probit model which found a statistically significant negative effect on attainment. As was noted earlier, the college variable is likely correlated with unobservables in both models 1 and 2 and thus is inconsistent. Due to this correlation, a fixed effects approach is recommended. The COLLEGE variable will be revisited in the next section discussing MAXEPA in which fixed effects estimation is available.

The urban form variable of DVMT was found to be exogenous in the cross-sectional probit model. That result is supported by the random effects panel model as DVMT is unlikely to be correlated with unobservables in the random effects panel model. However, DVMT is not a statistically significant predictor of attainment in either model 1 or 2.

The economic activity variables were judged to be exogenous by economic intuition in the cross-sectional probit model. The assertion is bolstered by the results of the Gould test for both models 1 and 2. None of the economic activity variables, log employment, manufacturing employment, or point source total emissions were found to be likely correlated with unobservables in the random effects specification. Neither log employment nor manufacturing employment is statistically significant in either model. Point source total emissions have a marginal statistically significant negative effect at the 15 percent level on attainment of the ozone standard. This result supports the result found

in the probit cross-sectional specifications.

The weather variables of July temperature (JTEMP) and total ozone season rain (TTLRAIN) offer mixed support for the results of the probit cross-sectional model. TTLRAIN has a positive and statistically significant effect on the attainment of the ozone standard in both models 1 and 2. While total rain did not have a statistically significant effect in the probit cross-section model, the random effects result is in agreement with ozone formation theory.

July temperature (JTEMP) does have a statistically significant positive effect on attainment in the random effects model 2 and a marginally insignificant positive result at the 15 percent level in model 1. This is contrary to the result found in the cross-sectional probit model as well as contrary to ozone formation theory. This result will be revisited in the section discussing the dependent variable MAXEPA in which a fixed effects approach can be utilized.

Results for the dependent Variable MAXEPA

Table C24 shows the results for the two fragmentation measures using the random effects estimator and the panel fixed effects estimator with the dependent variable of MAXEPA. The variable MAXEPA is a continuous variable thus no observations are dropped due to lack of variation. If the random effects estimator is unbiased, it is preferred as it has greater efficiency than the fixed effects estimator. The random effects estimator will be discussed first.

The random effects results from Table C24 indicate that MPDI has a positive but statistically insignificant effect on MAXEPA. This result is similar to that of the OLS

cross-section results. In model 2 JDCNT has the incorrect sign and is highly insignificant.

In order to determine the validity of the random effects estimates, we conducted the Gould test on both models. In model 1 that contains MPDI, the variables of DVMT, Density, and GMP had statistically significant F-statistics at the one-percent level. This suggests that these variables may be correlated with unobservables. To further explore this proposition, we conducted a joint F-test in model 1 with all variables included. This produced an F-statistic with a p-value of 0.004, indicating that one could reject the null hypothesis that all pairs of fixed effects and between estimates were equal. Additional F-tests were conducted including different combinations of the three variables. All generated statistically significant F-statistics. Only dropping all three variables DVMT, DENSITY, and GMP generated a reasonable F-statistic with a p-value of 0.32, which suggests that the remaining control variables are not correlated with unobservables. Model 2 generated similar results as model 1.

DVMT, DENSITY, and GMP are reasonably correlated with other covariates in the model. Thus, the random effects estimates presented in Table C24 are all likely to be inconsistent. As such, we will focus the remainder of the discussion on the fixed effects estimates in Table C24.

The fixed effects results from Table C24 indicate that as MPDI increases MAXEPA also increases however, the effect is not statistically significant. In model 2 JDCNT also has a positive effect on MAXEPA but is not statistically significant. Both results offer modest support of the OLS cross-sectional model. We next examine the other covariates of interest; the urban form variable DVMT, will be addressed last.

The college variable has a positive effect on MAXEPA but is not statistically

significant. This is suggestive evidence that MSAs that increase the percentage of residents with a college degree have higher levels of MAXEPA, all else equal. The July temperature variable also has a positive but insignificant effect on MAXEPA.

One of the covariates that have inconsistent results is the variable COLLEGE. It has a highly statistically significant negative effect on attainment of the ozone standard in the cross-sectional probit models, but is not statistically significant in any of the OLS cross-sectional models. To further explore this inconsistency in the models, we interacted COLLEGE with attainment status. The results indicate that COLLEGE has a very small negative effect on MAXEPA but it is not statistically significant, while the interaction term has a larger positive statistically significant effect of 0.0003 on MAXEPA. This suggests that adding college graduates to attaining MSAs increases MAXEPA by a greater amount than nonattainment MSAs. A joint F-test produced a statistically significant p-value at the one percent level. As the 95 percent confidence interval for the COLLEGE estimate is between -0.00065 and 0.00053, the overall effect is unknown. However, it is likely that adding additional college graduates to nonattainment MSAs has almost zero effect on MAXEPA, while adding college graduates to MSAs in attainment has a small positive effect on MAXEPA.

The incongruence of the COLLEGE estimates in the cross-sectional results and random effects results is thus likely due to two factors. First the COLLEGE variable is correlated with unobservables and is inconsistent. However, as college is uncorrelated with the other covariates, this bias should not contaminate the other coefficient estimates. Second, COLLEGE seems to affect MSAs in attainment differently from those in nonattainment.

In the OLS cross-sectional models DVMT was not statistically significant. In the fixed effects specification DVMT has a negative and statistically significant effect on MAXEPA. This suggests that as DVMT increases MAXEPA decreases. This result is contrary to ozone formation theory. As was discussed earlier, automobile emissions are a major source of ozone precursor emissions that have a direct link to vehicle miles traveled. The fixed effects results rely on the assumption of exogenous independent variables. If DVMT is indeed endogenous this could bias the results. In order to control for the potential endogeneity of DVMT, we conducted an IV panel regression with the same instruments for DVMT, as used in the cross-sectional model; state level gas tax's and drivers' licenses. DVMT still maintains its negative effect on MAXEPA however, now it is not statistically significant. The other covariates maintain the same signs however the standard errors generally increase.

In order to further evaluate the DVMT variable, we interacted DVMT with attainment status. The results indicate that DVMT has a negative effect on MAXEPA but that effect is not statistically significant. However, the interaction term has a positive and statistically significant effect. A joint F-test yields a statistically significant p-value at the ten percent level. These results indicate that additional DVMT affects MSAs in attainment differently from those in nonattainment.

An additional cofounder for the DVMT variable is its trend relative to area total emissions. From 1992 until 2002 DVMT has increased by 27 percent. While area total emissions have decreased by 24 percent. This suggests that while DVMT had been increasing the amount of ozone precursor pollutants being emitted has been decreasing. A lower level of precursor emissions is likely to lower MAXEPA levels.

Finally, using the panel data fixed effects model, we find suggestive evidence to support the contention that attainment status is the more important motivator than ozone levels (MAXEPA) for MSAs. We added an interaction term of attainment status and fragmentation to the fixed effects model. The result for the MPDI term yield a positive coefficient of 0.0003 and a p-value 0.8, the interaction term generates a coefficient of 0.00091 and statistically significant p-value of 0.009. A joint F-test yields a statistically significant p-value of 0.02. This is suggestive evidence that MSAs in attainment behave differently than those in nonattainment. Adding an additional unit of MPDI to an MSA in attainment increases its MAXEPA level by almost 0.001 ppm more than an MSA in nonattainment. Thus, MSAs in attainment are likely to have greater increases in ozone levels due to increases in MPDI all else equal. A similar effect was found for jurisdiction count. This is suggestive evidence that MSAs in attainment are not as concerned with MAXEPA levels as long as they remain below the attainment threshold.

Discussion II

The panel data model's primary purpose is that of a robustness check on the cross-sectional results. As such, the panel data model offers four important benefits. First, it provides a way to test for unobserved heterogeneity. Second, it allows for a robustness check of the estimates of marginal effects for two fragmentation variables of interest. Third, it is useful to clarify the results from covariates that are potentially endogenous, or generated estimates that switched signs in various specifications, or were contrary to economic theory. Fourth, it is possible to verify the appropriateness of the probit specification versus the OLS specification.

One of the key benefits of the panel data specification is the ability to control for unobserved heterogeneity as well as test for its presence. Using Gould's variation on the Hausman test, we were able to test two of the individual fragmentation variables as well as many of the important covariates correlations with a_i , an unobserved effect. The results generally support the main cross-sectional probit results which are the models of interest.

In model 1 in the random effects specification with MPDI as the fragmentation variable, recall that the marginal effect of an additional unit of MPDI was approximately a 20 percent decrease in the likelihood of attainment of the ozone standard. However, the MPDI variable was found to be correlated with unobservables, thus its estimate is inconsistent. If MPDI is positively correlated with a_i , then we can infer that the value of the MPDI estimate is biased upward. However, a_i is unobservable, thus it is difficult to assess the direction of the potential correlation. But we do have several useful points of reference as well as economic intuition that can give some guidance as to the direction of the correlation. The possibility that MPDI is negatively correlated with a_i is not a great concern. If that were the case, it indicates that the 20 percent value generated in the random effects model is biased toward zero, thus the actual effect is larger. In addition, the cross-sectional value of 10 percent would also be biased downwards, and thus be a minimum value. A negative correlation would suggest that MPDI has a very large negative effect on the likelihood of attainment. This seems unlikely given the data. MPDI has held fairly constant over the 10 year period, while 51 MSAs have reached attainment.

The primary concern is the effect a positive correlation would have on the estimate of MPDI. If MPDI is positively correlated with a_i , the estimates of MPDI will be

biased upward, away from zero. If this bias is large enough, the actual effect MPDI has on attainment could be close to zero. What is a reasonable upper limit on the effect MPDI has on attainment? This is a difficult question to answer. If the random effect estimate is inconsistent, the cross-sectional estimate is also likely to be inconsistent. Thus, the consistent value estimate is likely to be less than the marginal effect of 10 percent.

A reasonable range for the estimate might be determined whether we could estimate a lower bound for MPDI. MPDI is highly correlated with jurisdiction count. Jurisdiction count was found to be uncorrelated with a_i in the random effects model. We might be able to use the relationship between jurisdiction count and MPDI to get a reasonable estimate on the lower bound of the MPDI effect.

Again referring to the example used in the cross-sectional discussion, Tampa-St. Petersburg has approximately the average value for MPDI of 5.16 and has 90 jurisdictions, while New London Connecticut has an MPDI value of 6.57, approximately one-half a standard deviation greater than Tampa-St. Petersburg. New London has a jurisdiction count of 124. This difference of 34 jurisdictions is approximately equal to one-quarter of a standard deviation for the variable JDCNT. Recall increasing jurisdiction count by one-quarter of a standard deviation decreased the likelihood of attainment by approximately 5 percent. This suggests that the lower bound for the MPDI effect might be approximately 5 percent. Thus, a likely range for the effect MPDI has on the attainment of the ozone standard is that an increase of one unit of MPDI, decreases the likelihood of attainment of the ozone standard by more than five percent but less than 10 percent.

It is possible for MSAs to change their value of MPDI by one-half a standard

deviation. In the period from 1992-2002, nine MSAs changed MPDI by approximately 1.24, one increased its MPDI, while eight decreased by approximately 1.24 or more. This indicates that it is possible for MSAs to change their MPDI to a degree that is statistically relevant for ozone formation. In addition, this list includes several large MSAs, in which if the ozone standard was obtained, could potentially benefit several million people. This list includes Detroit, Newark, St. Louis, and Philadelphia.

The jurisdiction count results from the random effects model support the results from the cross-sectional probit model. The random effects results indicate that jurisdiction count has a negative statistically significant effect on the attainment of the ozone standard. The marginal effects estimate for the random effects model is a 0.2 percent decrease in the likelihood of attainment compared to 0.14 percent decrease for the probit cross-sectional model.

Using the Gould test, jurisdiction count was found to be uncorrelated with unobservables. Thus, the results from both random effects model and the cross-sectional probit model are likely to be consistent. Recall the example of an MSA that decreases its jurisdiction count by one-quarter standard deviation, 35 jurisdictions, is approximately 5 percent more likely to reach attainment.

To determine whether this is a likely occurrence for MSAs, we examined the panel data. Nine MSAs increased their jurisdiction count by 35 or more, while one decreased its jurisdiction count by 35 or more. Again, some large MSAs are in this list. Those MSAs that increased by 35 jurisdictions or more include Chicago, Nassau Suffolk, Atlanta, and Denver, only Philadelphia decreased by 35 or more. Another large MSA, Baltimore, decreased by 26 jurisdictions. Once again due to the populations of these

larger MSAs, millions of people could potentially be affected if the changes in the number of jurisdictions facilitated a change of attainment status for the ozone standard.

The results from the panel data generally confirmed the cross-sectional results in determinations of endogeneity as well as clarifying some enigmatic results from other covariates. An important consideration in the empirical specification is the potential endogeneity of DVMT. Using the augmented regression tests in the cross-sectional probit model indicated that DVMT was not endogenous in that specification. However, running the Durbin, Watson, Hu augmented regression test in the OLS specification indicated that DVMT was endogenous.

The results from the Gould test on DVMT in both the attainment specification and the MAXEPA specification support the cross-sectional endogeneity tests. DVMT is found to be uncorrelated with unobservables in the attainment specification. This is suggestive evidence that DVMT is not endogenous. However, in the MAXEPA specification, which coincides with the OLS specification in the cross-sectional tests, DVMT was found to be correlated with unobservables. This result supports the finding of endogeneity in the cross-sectional OLS specification.

The DVMT results overall are hard to interpret. In the cross-sectional probit model, DVMT has a statistically significant negative effect on attainment. This is the theoretically expected result. That result is generally not supported in the random effects model. In model 2, which contains jurisdiction count, DVMT has a statistically significant positive effect on attainment. In the cross-sectional OLS specification, DVMT has a negative effect on MAXEPA, but it is not statistically significant. In the fixed effects specification, DVMT has a statistically significant negative effect on

DVMT. This suggests that as DVMT decreases MAXEPA values increase.

In an effort to further explore these conflicting results several different fixed effects specifications were utilized. First a fixed effects instrumental variable regression was run. The results for the IV fixed effect specification indicate that DVMT still has a negative effect on MAXEPA, but it is not statistically significant. DVMT was also interacted with attainment; the interaction term suggests that additional DVMT has different effects on MSAs depending on attainment status. While the total effect of increasing DVMT is uncertain, an MSA in attainment will likely experience a greater increase in MAXEPA levels due to increases in DVMT than a similarly situated MSA in nonattainment. As was noted earlier, MSAs in attainment seem to behave differently from those in nonattainment with regard to ozone levels. The DVMT result may be further evidence of this dichotomy.

In addition trends in DVMT, emissions, and attainment may also contribute to these results. DVMT is increasing in the period of 1992 to 2002, while area total emissions are decreasing. Also 51 MSAs reached the ozone attainment standard during the period. While no MSAs that started the period in attainment, ended it in nonattainment. The decoupling of DVMT and ozone levels is also supported by the fact that a small segment of the nation's automobile fleet account for a large portion of ozone forming emissions (Kahn, 2001).

Another covariate with unexpected results in the cross-sectional specification was the college variable. In the cross-sectional probit model college has a statistically significant negative effect on attainment. In the random effects model college is found to have a statistically significant positive effect on attainment. However, college was found

to be correlated with unobservables. Thus, the results in both cross-sectional and random effects models are likely to be inconsistent. Once again, this inconsistency may be due to the differences in behavior for MSAs in attainment or nonattainment.

In the fixed effects model an interaction term of college and attainment was added. The results suggest that adding additional college graduates to an MSA in attainment increases the value of MAXEPA, while adding college graduates to nonattainment MSAs has almost zero effect on MAXEPA levels. This result suggests that the overall effect on attainment is likely to be minimal.

Summary

In summary three fragmentation variables were found to have statistically significant effects on MSA attainment of the ozone standard in the cross-sectional model. Higher levels of MPDI and jurisdiction count were found to hinder attainment of the ozone standard, while greater values of central city growth aided in reaching the attainment standard. The panel data results generally support the results from the cross-sectional models, as well as help to resolve some important estimation issues. MPDI was found to be correlated with unobservables in the random effects model, indicating that the cross-sectional results for MPDI may be biased as well. However, no such problem was found with the jurisdiction count variable. MPDI and jurisdiction count are highly correlated and this relationship was used to estimate a reasonable range for the effect MPDI has on the attainment of the ozone standard. MPDI is a nuanced measure of fragmentation, incorporating several elements of the other fragmentation variables such as jurisdiction count and a form of central city dominance. However, it appears that the

simple measure, jurisdiction count, is a reasonable proxy for the effect MPDI has on an MSA's ability to attain the ozone standard. The implications these results have for environmental quality, as well as local government form decisions will be discussed next in the concluding chapter.

CHAPTER 6

CONCLUSION

This dissertation contributes to two bodies of literature, that of environmental federalism and that of urban growth and local government form. In the area of environmental federalism this dissertation extends the collective action model to include local governments. An empirical framework is developed that includes cross-sectional and panel data. In the urban growth and local government form literature, this dissertation comprehensively tests many existing measures of local government fragmentation within an environmental policy framework. It also modifies and extends some of the fragmentation variables. The results suggest that local government fragmentation does hinder MSAs from attaining of the ozone standard.

The remainder of this chapter will address the following. First, the contributions this dissertation has made to the environmental federalism literature are reviewed, followed by a discussion of the contributions made to the urban growth and local government form literature. Next, we review the basic empirical estimation structure and results. Some policy implications of the results will then be discussed and finally some areas of future research will be offered.

The environmental federalism literature has traditionally focused on jurisdictions as environmental standard setting entities. In this context, the literature consists primarily of theoretical inquiries on the outcomes of subnational governments such as states, setting environmental standards (See Oates and Schwab 1988). In this framework, environmental goals are endogenous for the decision-making agents. This

dissertation extends the literature to include how the number of local jurisdictions within the borders of an MSA affects its ability to meet exogenously set air quality standards.

Another usual assumption in the environmental federalism literature is that decisions made by one jurisdiction do not affect the environmental quality of another jurisdiction. In particular, it is assumed that pollution does not spillover across borders. However for an MSA that includes many jurisdictions in close geographic proximity, clearly decisions made by one jurisdiction will have effects on its neighbors. Thus, the effects of border spillovers are important to incorporate into a model of local government fragmentation and environmental quality.

We find the collective action model is well suited for modeling why environmental quality may be under provided in an MSA composed of many jurisdictions when spillovers are present. The collective action model seeks to explain why individual rationality does not guarantee an outcome that is rational for the group (Olson 1965). In some cases, such as the provision of public goods, individual rationality predicts an outcome that is clearly at odds with the Pareto efficient outcome for the group. This notion is embodied in the Samuelson social welfare function (Samuelson 1954). Mueller (1989) showed that for Cobb Douglas utility functions that Olson's notion that increased N would lead to larger departures from an efficiency standard was true. In this dissertation, we adapt the Mueller framework to describe jurisdictional choice over voluntary decisions to increase levels of environmental quality by taking costly actions.

The empirical literature on urban growth and local government form is predominantly concerned with population growth and economic development of a region. In particular, researchers examine whether fragmentation measures can explain observed

growth patterns in metropolitan areas. This literature attempts to resolve the question of whether fewer larger centralized local governments or many smaller decentralized local governments are the most conducive to growth and development.

In the urban growth and local government form literature the variables used to measure local government fragmentation can be grouped as follows. First, “simple” counts of governments, such as jurisdiction count and relative fragmentation (JDCNT RELFRAG see table 4.1 for a description), these are used by Razin and Rosentraub (2000) and Carruthers and Ulfarsson (2002). Razin and Rosentraub find that relative fragmentation does not have a statistically significant effect on urban sprawl. The urban sprawl dependent variable is an index based on various population and housing density measures. Carruthers and Ulfarsson found that higher levels of relative fragmentation are associated with lower population densities and higher property values. No direct effect on public service expenditures was found. Less fragmented metropolitan areas also tended to cover more land.

Second some researchers have focused on local government structure and created the measures of special district dominance, central city dominance, and county primacy, (SDD, CCD, and CP see table 4.1 for a description). They were initially used by Foster (1993) and then Nelson and Foster (1999). Foster found that special district dominance had a statistically significant negative effect on population growth. While Nelson and Foster found that central city dominance had a statistically significant positive effect on MSA income growth and special district dominance was marginally statistically significant and negative.

Additional measures created in the past research include the metropolitan power diffusion index (MPDI see Table C3 for a description) developed by Miller (1999) and central city elasticity used by Rusk (1995). These measures are more complex and try to capture the more nuanced relationships between the jurisdictions of the MSA. The MPDI attempts to measure the political effects of fragmentation based on jurisdictional fiscal power. The goal of the central city elasticity measures is to try and capture the effect of a dynamic growing central city on a metropolitan area population and economic growth. The measure we use, central city growth (CCG see Table C3 for a description) is computed differently from Rusk's, but the intent is the same.

Miller found that MSAs have become more diffuse since 1972. He also found that the MPDI was correlated with the absolute number of municipal governments but uncorrelated with population growth. Rusk (1995) compares different pairs of metropolitan areas and finds that the metropolitan areas with more elastic central cities had higher rates of population and economic growth.

This dissertation extends the literature by examining the effect that local government fragmentation has on regional environmental quality. In addition, it extends the use of the computationally complex measure of MPDI to include additional local government expenditures as well as additional years of panel data. This dissertation also comprehensively tests all of the above listed fragmentation measures to determine which might affect regional environmental quality.

Two empirical estimation strategies were implemented, a cross-sectional approach and a panel data approach. The cross-sectional approach estimates the effects

that long-term changes in local government structure have on attaining the ozone standard by measuring differences across MSAs. Several key econometric issues had to be resolved in order to successfully estimate the cross-sectional model. First, suitable proxy variables had to be found to estimate the price of the public good, which is unobservable. Second, the potential endogeneity of the public transit variable, fare per mile (FAIRPERMI) as well as daily vehicle miles traveled (DVMT) had to be controlled for with an instrumental variables approach. Third, unobserved heterogeneity had to be controlled for by using a lagged dependent variable.

The panel data model's primary purpose was that of a robustness check on the cross-sectional results. As such, the panel data model served several important functions. First, it provided a way to test for unobserved heterogeneity. Due to the lack of variation in the binary dependent variable ATTAIN (whether or not an MSA is in attainment of the ozone standard), fixed effects estimation was not possible, nor was a traditional Hausman test available. Using a procedure developed by Gould (2001), we were able to determine whether key variables were correlated with unobservables. Second, it allowed for a robustness check of the estimates of marginal effects for two fragmentation variables of interest, MPDI and JDCNT. Third, it was useful to clarify the results from covariates that were potentially endogenous such as DVMT. Fourth, it was possible to verify the appropriateness of the probit specification versus the OLS specification.

Three of the six tested fragmentation variables were found to have statistically significant effects on MSA attainment of the ozone standard in the cross-sectional model. Higher levels of MPDI and jurisdiction count were found to hinder attainment of the ozone standard, while greater values of central city growth aided in reaching the

attainment standard. Generally, the panel data results' supported the results from the cross-sectional models. In addition, the panel model resolved some important estimation issues. MPDI was found to be correlated with unobservables in the random effects model, indicating that the cross-sectional results for MPDI may be biased as well. This was not an issue for the variable jurisdiction count. MPDI and jurisdiction count are highly correlated with each other and this relationship was used to estimate a reasonable range for the effect MPDI might have on the attainment of the ozone standard. This range suggests that a one unit increase in the MPDI, for an MSA, is likely to lead to a decrease in the chance of attainment of the ozone standard by greater than five percent but less than ten percent.

MPDI is a nuanced measure of fragmentation as it quantifies the entire power structure among all the MSA's jurisdictions. It is the sum of the square root of each jurisdictions ratio of its expenditures to total MSA expenditures. Local jurisdiction budgets are very fungible and as such it is likely that MPDI captures the political will and local residential tastes and preferences. Thus, it is not surprising that MPDI might be correlated with unobservables. Jurisdiction count, while "simple," is not nearly as dynamic a measure as MPDI. It takes many years and sometimes decades to create a new city. The amount of counties in the country has not changed much in 50 years. Special districts are more easily created but the number of special districts still has considerably less variation than jurisdictional expenditures. Thus, it seems reasonable that JDCNT was not found to be correlated with unobservables. In the next section we explore the results from the cross-sectional probit model highlighting the effect that changes in the three

statistically significant fragmentation variables of MPDI, JDCNT and CCG, would have on a selected group of populous MSAs.

Changes in Fragmentation and Attainment of the Ozone Standard

This section presents illustrative examples of how fragmentation might hinder attainment of the ozone standard in a select group of MSAs. Table C25 shows the ten most populous MSAs within 0.01 ppm of the ozone standard. Only MSAs not in CMSAs and that are not considered outliers were considered. Also the MSA of Atlanta is included. From these 11 MSAs, we selected one MSA that had close to the average value for each of three variables of interest (MPDI, JDCNT, and CCG) to focus on in my discussion. The three MSAs chosen are Tampa-St. Petersburg for MPDI, Phoenix for JDCTN, and Columbus, Ohio for CCG. Again, Atlanta will also be discussed in detail as it is of local interest. Next, using these four MSAs, we discuss the effects that changes in the three variables would have on the likelihood of attainment of the ozone standard.

In order to determine the effect of changing MPDI, we calculated the incremental effect that the average county, city, town, or special district would have on MDPI for each MSA.⁴⁹ For instance, in the MSA of Atlanta there are 20 counties, 107 cities, and 106 special districts. The average expenditure for a county is approximately \$126 million, the average expenditure for a city is \$18 million, and the average expenditure for a special district is \$19 million. To determine the effect of consolidation, we calculate how the likelihood of attainment would change if the MSA were to consolidate an additional ten percent of its cities and 20 percent of its special districts. For ease of

⁴⁹ This calculation differs from the actual MDPI slightly due to the uneven distribution of jurisdictional expenditures. This variation is not present when using average effects.

exposition, we will refer to this as the “standard consolidation.” If Atlanta were to consolidate ten percent of its cities and 20 percent of its special districts, this would decrease its MPDI by 0.86. Using approximately the average value of the estimated range for the MPDI marginal effect on attainment of the ozone standard of 8 percent, this consolidation translates into a 6.9 percent increase in the likelihood of attainment of the ozone standard. The standard consolidation of jurisdictions in Atlanta would imply approximately 32 jurisdictions are eliminated from JDCNT. This would translate into approximately a 4.5 percent increase in the likelihood of attainment using the JDCNT estimated marginal effect on ozone attainment of 5 percent. We will next do similar calculations for the three MSAs highlighted above for each of the three fragmentation variables.

The MSA of Columbus, Ohio is in attainment. It has six counties, 75 cities, 79 towns, and 46 special districts. The average expenditure for a county is approximately \$137 million, the average expenditure for a city is \$18 million, the average expenditure for a town is \$1.1 million, and the average expenditure for each special district is \$4.9 million. Since Columbus is in attainment of the ozone standard, the fragmentation effect of interest is not consolidation but rather the impact of additional jurisdictions. If Columbus were to *add* ten percent more towns and cities and 20 percent more special districts (we call this the “standard expansion”), this would have an effect of increasing MPDI by approximately 0.3.⁵⁰ Assuming the MPDI marginal effect of 8 percent, this would decrease the likelihood of attainment by roughly 2.3 percent. In terms of jurisdiction count, Columbus would gain approximately 25 jurisdictions from the

⁵⁰ For MSAs with many cities, towns, and special districts the effect of consolidation is almost equal to the effect of expansion. However in the case of counties, some MSAs have only two or three counties and the effects of consolidation versus expansion can differ by a nontrivial amount.

standard consolidation. The estimated marginal effect from model 2 in Table C18 would imply a decrease in the likelihood of attainment by 3.4 percent.⁵¹

The MSA of Phoenix, Arizona is in nonattainment for 1997. It has two counties, 32 cities, and 94 special districts. The average expenditure for a county is approximately \$723 million, the average expenditure for a city is \$93 million, and the average expenditure for a special district it is approximately \$14 million. The standard consolidation would generate a decrease in MPDI of approximately 0.7. This would increase the likelihood of attainment by 5.4 percent. In terms of jurisdiction count, the standard consolidation would reduce the number of jurisdictions by approximately 22 and would increase the likelihood of attainment by 3.1 percent.

The MSA of Tampa-St. Petersburg is in attainment. It has four counties, 35 cities, and 51 special districts. On average, each county spends approximately \$549 million, each city spends \$32.2 million, and each special district spends \$6.9 million. The standard expansion of cities and special districts yields an increase in MPDI of approximately 0.4. This would decrease the likelihood of attainment by 3.1 percent. In terms of jurisdiction count the standard expansion would increase the number of jurisdictions by approximately 14, and would decrease the likelihood of attainment by 1.9 percent.

The effects of central city consolidation are likely to be smaller than that of JDCNT and MPDI. The central city growth variable is measured over a span of 50 years. Thus, any changes that would occur over the span of several years will likely have a small effect on that variable. In the period 1990 to 2000 six of the 11 MSAs had

⁵¹ Columbus is the only MSA of the 11 that has a greater JDCNT effect than MPDI effect. This is due to the small average expenditure level of towns relative to cities and special districts.

approximately zero central city land area growth, thus we only consider how changes in central city population change CCG. The average growth rate for the 11 central cities selected from 1990-2000 is approximately 12 percent. If central cities were to grow in population by 10 percent, this would have a relatively minor effect on CCG. For the MSAs of Atlanta, Columbus, and Tampa-St. Petersburg, the effect of increasing central city population by 10 percent results in a 0.24 percent increase in CCG or less. A 0.24 percent increase in CCG makes it 1.4 percent more likely that an MSA will be in attainment. A 10 percent increase in population has the largest impact on CCG for Phoenix, and results in an increase in the likelihood of attainment by 7.4 percent.

It is also possible for counties and central cities to merge. A merger of the central city and its surrounding county would have a dramatic effect on central city growth. For example, if the city of Atlanta was to merge with all of Fulton County or some portion of Fulton County and was to increase its population by 50 percent and its land area by 50 percent, this would generate a value for CCG of 5.24 and would increase the likelihood of attainment by 14 percent.

Table C25 illustrates the effect that modest changes in the three fragmentation variables of interest can have on selected MSAs. For those MSAs in nonattainment the standard, contraction in the number of cities, towns, and special districts can have a modest though potentially meaningful effect on the likelihood of attainment. For the ten MSAs within 0.01 ppm of the standard, the standard contraction had the greatest effect on Salt Lake City and Louisville, increasing their likelihood of attainment by approximately three to six percent. For the MSA of Atlanta this range was slightly higher, increasing its likelihood of attainment by approximately five to seven percent. For those MSAs in

attainment the effect of the standard expansion of the number of cities, towns, and special districts is smaller. The standard expansion had the greatest effect on Columbus and Tampa-St. Petersburg, decreasing their likelihood of attainment by approximately two to three percent.

Modest changes in CCG generally had smaller effects on the likelihood of attainment. This effect tended to be smaller for MSAs in nonattainment with the exception of Phoenix. For those MSAs in nonattainment, Salt Lake City experienced the highest increase in the likelihood of attainment of 0.5 percent. For MSAs in attainment, Raleigh-Durham had the greatest decrease in the likelihood of being in attainment of 2.5 percent.

As these examples illustrate the effects of changing the variables of MPDI, JDCNT, and CCG on the likelihood of attainment are modest. However, if only one MSA in the sample were to come into attainment or maintain its attainment status through measures that decrease one of these three variables, it could potentially benefit millions of MSA residents. Potential future research is discussed next.

Future Research

Several areas of future research are contemplated. The first is a more integrated treatment of the urban form variables. This dissertation uses several variables to control for the effect that urban form has on attainment of the ozone standard as well as levels of ozone (MAXEPA). One of the key variables in the urban form category is DVMT. The results for the DVMT variable are not in keeping with the theoretical model for the OLS MAXEPA specification. The OLS results suggest that higher values of DVMT lead to lower levels of ozone. As was discussed earlier, Kahn (2001) suggests a potential reason

for this is a small segment of the nation's automobile fleet account for a large portion of ozone forming emissions. However, it would be helpful to obtain actual automobile emissions at the MSA level and use that in place of DVMT in the models. If the automobile emissions results follow the predictions of the theoretical model, this would confirm the difficulty of using DVMT as a proxy for automobile emissions in some MSAs.

Three other variables in the urban form category are not statistically significant in the cross-sectional probit model. They are commute time, density of the population per square mile, and percent single-family homes. These measures attempt to control for the effects of urban sprawl on the attainment of the ozone standard. These measures may be too coarse to capture some important yet subtle differences in urban form among MSAs. Several sophisticated sprawl indices have been constructed by Razin and Rosentraub (2000) and Ewing, Pendall, and Chen (2002), that might better capture the relationship between sprawl and attainment of the ozone standard, however, they do not include all the MSAs in my sample. Extending these indices to include the full sample may add some additional explanatory power to the model.

The second area of future research we consider focuses on the estimation of the models. Two particular areas that may be improved are controlling for the unobserved heterogeneity bias in the random effects probit model and/or estimating the magnitude of the bias on the MPDI estimate. In the panel random effects probit model, it was determined that MPDI is likely correlated with unobservables, while jurisdiction count was not. As was discussed earlier, this has an intuitive explanation due to the dynamic qualities of the jurisdictional level expenditure components of MPDI. This correlation

induces the random effects probit estimate to be biased. Estimating the amount of bias or attempting to add additional variables to the random effects model to alleviate the unobserved heterogeneity is another area of future research.

The panel model may also be extended through the addition of new data. The 2007 census of governments will be available sometime in 2008. However, during this time, the U.S. EPA changed the ozone standard. The EPA issued the 8-hour ozone standard in 1997 which is 0.08 ppm. The new standard was adopted due to concerns that the 1-hour standard was inadequate for protecting public health. Due to litigation, the 8-hour standard was not implemented until 2004. In 2002, Sixty-six MSAs were in nonattainment of the 1 hour standard. The EPA currently lists over 100 MSAs that are currently in nonattainment of the 8-hour standard. If the 2007 year of panel data is added, the regulatory standard to which the municipalities are reacting has changed. However, if the supposition is true that MSAs are most concerned with the “binary outcome” of either being in attainment or not in attainment, then adding the 2007 panel could add important variation in to the data.

A final area of potential future research would be to extend this framework into the area of water quality. Water quality presents interesting modifications to the model, as upstream and downstream effects would need to be considered. In addition MSAs can be composed of several watersheds, which could pose problems of spatial autocorrelation. Border effects may also need to be considered in that watersheds often originate outside the MSA borders. In the case of water quality, the directional nature of water and pollution flows would require modification of both the theoretical approach and the empirical approach.

However, water quality might be more conducive variable than air quality to analyze the effects that fragmentation has on local government efforts to meet an exogenously set environmental standard. Local jurisdictions have more authority in controlling nonpoint source water pollution than they do for nonpoint source air pollution. Automobiles are the primary source of nonpoint source emissions for air pollutants. However, tailpipe emissions as well as automobile inspection policy is usually set at the state level. The source of nonpoint water pollution is often runoff from local impervious surfaces such as streets and parking lots, construction site runoff, as well as lawn and agricultural runoff. Local jurisdictions have more options to control these sources of runoff such as, stream buffer requirements, best management practices for construction sites, as well as general land use planning authority. In addition, local jurisdictions are more likely to benefit directly from investments to improve water quality. River sheds tend to be smaller than air sheds, thus benefits are more localized. In addition, the nature of rivers suggests that jurisdictions only need to get cooperation from their upstream neighbors to reap the benefits of their actions. The additional incentives localized benefits provide to jurisdictions are not present for air quality. Any improvements to air quality generated by a jurisdiction mix homogenously throughout the MSA air shed, and are available to all jurisdictions.

APPENDIX A:

DEFINING METROPOLITAN STATISTICAL AREAS AND CONSOLIDATED METROPOLITAN STATISTICAL AREAS:

The Census Defines Metropolitan Statistical Areas as follows:

Each metropolitan statistical area must have at least one urbanized area of 50,000 or more inhabitants

Under the standards, the county (or counties) in which at least 50 percent of the population resides within urban areas of 10,000 or more population, or that contain at least 5,000 people residing within a single urban area of 10,000 or more population, is identified as a "central county" (counties). Additional "outlying counties" are included in the CBSA if they meet specified requirements of commuting to or from the central counties. Counties or equivalent entities form the geographic "building blocks" for metropolitan and micropolitan statistical areas.

If specified criteria are met, a metropolitan statistical area containing a single core with a population of 2.5 million or more may be subdivided to form smaller groupings of counties referred to as "metropolitan divisions."

CMSAs- An area that meets these requirements for recognition as an MSA but also has a total population of one million or more may be recognized as a CMSA if: (1) separate component areas can be identified within the entire area by meeting specified statistical criteria, and (2) local opinion indicates there is support for the component areas. If recognized, the component areas are designated PMSAs, and the entire area becomes a CMSA. If no PMSAs are recognized, the entire area is designated an MSA.

Urbanized areas are defined by the census as follows:

For Census 2000, the Census Bureau classifies as "urban" all territory, population, and housing units located within an urbanized area (UA) or an urban cluster (UC). It delineates UA and UC boundaries to encompass densely settled territory, which consists of:

- core census block groups or blocks that have a population density of at least 1,000 people per square mile and
- surrounding census blocks that have an overall density of at least 500 people per square mile

In addition, under certain conditions, less densely settled territory may be part of each UA or UC.

APPENDIX B:

LAND AREA CHANGES

The Phoenix MSA is made up of two counties Maricopa and Pima. The total area of the MSA is 14,598 square miles. A substantial amount of this land area is desert. The city of Phoenix is located primarily in the center of Maricopa County. The county is 9,224 square miles in area. In order to capture the population centers, we measured the distance to the outlying municipalities from the central city of Phoenix. The relevant radius used for Phoenix was 60 miles around the city of Phoenix. This radius captures the far flung municipalities of Eloy, Globe, and Wickensburg.

The Las Vegas MSA is made up of two Nevada counties: Clark and Nye and one Arizona county: Mohave. The total three county area is 39,720. This area has a very large desert component. The city of Las Vegas is located in Clark County. The county is 8,091 miles in area. we measured the distance to the outlying municipalities from the central city of Las Vegas. The farthest municipality is Boulder city which gives the relevant radius used for the Las Vegas MSA of 40 miles from the center city.

The Riverside-San Bernardino MSA is made up of two counties: Riverside and San Bernardino. The total county area is 27,408 square miles which is mostly desert. San Bernardino County is the largest county in the continental U.S. measuring 20,105 square miles. we measured the distances to outlying municipalities from the central city of San Bernardino. The relevant radius used for the San Bernardino MSA was 45 miles around the city of San Bernardino. This captures Palm Springs and Yucca Valley.

For Duluth-Superior we adjusted the area of St. Louis county Minnesota, which has over 2,000 square miles covered by dense forest or lakes. Since Duluth borders Lake

Michigan a radial measure was not appropriate. Instead we estimated an area that included the population centers of the county. The most populous area came out to be approximated 1,234 square miles. The adjusted area for Duluth-Superior then becomes 1,909 square miles.

APPENDIX C:

TABLES

Table C1

Hypothetical calculation of Metropolitan Power Diffusion Index (MPDI)^a

MSA Region A			MSA Region B		
Jurisdiction count	Jurisdiction Expenditure	Power Index	Jurisdiction count	Jurisdiction Expenditure	Power Index
1	\$900,000	0.948683	1	\$900,000	0.94868
2	\$20,000	0.141421	2	\$9,091	0.09535
3	\$20,000	0.141421	3	\$9,091	0.09535
4	\$20,000	0.141421	4	\$9,091	0.09535
5	\$20,000	0.141421	5	\$9,091	0.09535
6	\$20,000	0.141421	6	\$9,091	0.09535
Total Exp.	\$1,000,000		7	\$9,091	0.09535
	MPDI	1.65579	8	\$9,091	0.09535
			9	\$9,091	0.09535
			10	\$9,091	0.09535
			11	\$9,091	0.09535
			12	\$9,091	0.09535
			Total Exp.	\$1,000,000	
				MPDI	1.9975

^a From Miller (2002)

Power Index = square root of (jurisdiction expenditure/total expenditure)

MPDI = Sum of all jurisdictions Power Index

Table C2
Accounts included in MPDI variable definitions

Variable Specification ^b	Variable Specification ^c	Municipal Expense account Description
MPDI1	MPDI2	Financial Administration
MPDI1	MPDI2	Fire Protection
MPDI1	MPDI2	Judicial and Legal Services
MPDI1	MPDI2	Central Staff Services
MPDI1	MPDI2	General Public Buildings
MPDI1	MPDI2	Health Services
MPDI1	MPDI2	Own Hospitals
MPDI1	MPDI2	Other Hospitals
MPDI1	MPDI2	Regular Highways
MPDI1	MPDI2	Toll Highways
MPDI1	MPDI2	Housing and Community Development
MPDI1	MPDI2	Libraries
MPDI1	MPDI2	Natural Resources
MPDI1	MPDI2	Parking Facilities
MPDI1	MPDI2	Parks and Recreation
MPDI1	MPDI2	Police Protection
MPDI1	MPDI2	Welfare, Federal Categorical Assistance Programs
MPDI1	MPDI2	Welfare, Cash Assistance
MPDI1	MPDI2	Welfare, Vendor Payments for Medical Care
MPDI1	MPDI2	Welfare, Vendor Payments for Other Purposes
MPDI1	MPDI2	Welfare Institutions
MPDI1	MPDI2	Welfare
MPDI1	MPDI2	Sewerage
MPDI1	MPDI2	Solid Waste Management
MPDI1	MPDI2	General
MPDI1	MPDI2	Water Utilities
MPDI1	MPDI2	Electric Utilities
MPDI1	MPDI2	Gas Utilities
MPDI1	MPDI2	Transit Utilities
	MPDI2	Air Transportation
	MPDI2	Miscellaneous Commercial Activities, NEC
	MPDI2	Corrections
	MPDI2	Elementary and Secondary Education
	MPDI2	Other Higher Education
	MPDI2	Social Insurance Administration
	MPDI2	Private Transit Subsidies
	MPDI2	Protective Inspection and Regulation, NEC
	MPDI2	Sea and Inland Port Facilities
	MPDI2	Liquor Stores
	MPDI2	Interest on Debt

^b These accounts are included in Miller's definition of MPDI. (Miller 2001).

^c These accounts were suggested to be included by
Professor David Sjoquist of Georgia State University .

Table C3
Variable Definitions

Variable Name	Variable Definition	Data Source
Dependent Variables		
attain1997	Dummy variable =1 if Ozone standard met, =0 otherwise	EPA Green book http://www.epa.gov/oar/oaqps/greenbk/index.html
maxepa	Third Highest Ozone Monitor Reading as averaged across MSA monitors	EPA http://www.epa.gov/ttn/naaqs/ozone/areas/aqdata.htm
areattl	Area total emissions for NOX & VOC in an MSA in 1997	EPA's National Emissions Inventory ftp://ftp.epa.gov/pub/EmisInventory/nei_criteria_summaries/
MSA Income Demographic and Taste Variables		
pi	MSA Per capita personal income, 1992, 1997, 2002	Bureau of Economic Analysis http://www.bea.gov/regional/index.htm
MSAGMP	Gross metropolitan product 1992, 1997, 2002	Bureau of Economic Analysis http://www.bea.gov/regional/index.htm
msapop	MSA population 1992, 1997, 2002	Census of Governments, The Inter-univ. Consortium for Political and Social Research (ICPSR 2006) http://www.icpsr.umich.edu/index.html
perdem	Percent of votes in the MSA congressional elections between 1997 and 1999 cast for a democratic candidate or against a republican candidate	Places Rated Almanac, 1999
age		
less25	Percent of MSA population less than 25 1992, 1997, 2002	U.S. Census Bureau, Population Estimates, County Population datasets, http://www.census.gov/popest/datasets.html
btw2564	Percent of MSA population between 25 and 64 1992, 1997, 2002	
over65	Percent of MSA population 65 and over 1992, 1997, 2002	

Table C3
Variable Definitions

Variable Name	Variable Definition	Data Source
MSA Income Demographic and Taste Variables		
white	Percent of MSA population that is white 1992, 1997, 2002	U.S. Census Bureau, Population Estimates, County Population datasets, http://www.census.gov/popest/datasets.html
black	Percent of MSA population that is black 1992, 1997, 2002	
hispanic	Percent of MSA population that is hispanic 1992, 1997, 2002	
asian	Percent of MSA population that is asian 1992, 1997, 2002	
college	Percent of MSA population that graduated college 1992, 1997, 2002	U.S. Census Bureau, Education attainment by state, http://www.census.gov/population/www/socdemo/educ-attn.html
Fragmentation Variables		
jdcnt1997	See Ch 3 for detailed description	All Fragmentation variables from: Census of Governments, The Inter-univ. Consortium for Political and Social Research (ICPSR 2006) http://www.icpsr.umich.edu/index.html
relfrag1997	See Ch 3 for detailed description	
ccd1997	See eq 3-3 in Ch 3 for detailed description	
sdd1997	See eq 3-1 in Ch 3 for detailed description	
cp1997	See eq 3-4 in Ch 3 for detailed description	
cgc	See eq 4-4 in Ch 4 for detailed description	
mpdi1 1997	See eq 3-5 in Ch 3 for detailed description	
mpdi2 1997	See eq 3-5 in Ch 3 for detailed description	

Table C3
Variable Definitions

Variable Name	Variable Definition	Data Source
Price of Public Good		
<i>Urban Form</i>		
prcntlfamily	Percent of single family homes	Census of Governments American Housing Survey (AHS) http://www.census.gov/hhes/www/housing/ahs/access.html
dvmt1997	MSA Daily Vehicle Miles Traveled 1992, 1997, 2002 (in thousands of miles)	Federal Highway administration (FHA 2006) http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm
comtime	MSA average commute time to work in minutes	Places Rated Almanac, 1999
trackmi	Total public transit train track miles	All public transit variables from: National transit database (NTD 2006) http://www.ntdprogram.com/ntdprogram/data.htm
tranrte	Total public transit train and bus route miles	
sumfares	Total Fares received from public transit in 1997 (in thousands)	
CMSA	Dummy variable =1 if MSA in CMSA, =0 otherwise	U.S. Bureau of the Census 2006 Density
reggov	Presence of Regional Government Dummy variable =1 if Regional gov. in MSA =0 otherwise	Regionalism on Purpose, 2001
density	MSA population density (population 1997 divided by total MSA land area)	U.S. Bureau of the Census 2006 Density http://www.census.gov/population/www/censusdata/density.html
<i>Economic Activity</i>		
emp	MSA Total Employment 1992, 1997, 2002	BLS and the economic census for 1992, 1997 and 2002 (U.S. Bureau of the Census 2006, BLS 2006).
mfgavg	MSA Employment in only the Manufacturing sector 1992, 1997, 2002	http://www.bls.gov/cew/ http://www.census.gov/epcd/ec97/us/US000_22.HTM
ptscctl	MSA point-source total emissions 1992, 1997, 2002	EPA's National Emissions Inventory ftp://ftp.epa.gov/pub/EmissionInventory/nei_criteria_summaries/

Table C3
Variable Definitions

Variable Name	Variable Definition	Data Source
dirtyind	Dummy variable=1 if there are Chemical, Nonmetallic mineral product, Petroleum & coal products, Plastics & rubber products, or Primary metal manufacturing plants within the MSA, =0 otherwise	U.S. Bureau of the Census 2006 Census of Industry http://www.census.gov/epcd/ec97/us/US000_22.HTM
utlity	Dummy variable=1 if there is a Fossil fuel power generation facility within the MSA, =0 otherwise	U.S. Bureau of the Census 2006 Census of Industry http://www.census.gov/epcd/ec97/us/US000_22.HTM
<i>Weather</i>		
ttlrain	MSA total rainfall from May 1st - Sept 30th 1992, 1997, 2002	All Weather Data is from: US National climate data service (NCDS 2006) http://lwf.ncdc.noaa.gov/oa/climate/normal/usnormals.html
jrain	Total rainfall in just July 1992, 1997, 2002	
jtemp	July mean temperature 1992, 1997, 2002	
julymaxtemp	July Maximum temperature 1997	
julymnwind	July mean wind speed in 1997	
<i>Geography</i>		
south	Dummy variable =1 if MSA in region,	U.S. Bureau of the Census 2006
midwest	=0 otherwise	
west	see table 4-2 for a list of states and regions	U.S. Bureau of the Census 2006
north		
Coastal	Dummy variable =1 if If MSA is located on a great lake or ocean, =0 otherwise	

Table C4
Region Definitions, MSAs and CMSAs

Region	MSAs	CMSAs	Number of MSAs in attainment	Avg. MAXEPA
south	77	5	61	0.113
midwest	39	5	30	0.107
west	37	6	12	0.123
north	34	3	5	0.120
total MSAs	187	19	108	
The states included in the four regions are as follows:				

North: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York,
Pennsylvania, Rhode Island, and Vermont.

Mid West: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri,
Nebraska, N. Dakota, Ohio, S. Dakota, and Wisconsin.

South: Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi,
N. Carolina, Oklahoma, S. Carolina, Tennessee, Texas, Virginia, and W. Virginia.

West: Arizona, Californian, Colorado, Idaho, Montana, Nevada,
New Mexico, Utah, Oregon, Washington, and Wyoming.

Table C5
Summary Statistics

Variable Name	Obs	Mean	Std.Dev	Min	Max
Dependent Variables					
attain1997	187	0.61	0.49	0.00	1.00
maxepa1997	187	0.11	0.02	0.07	0.22
areattl1997	187	105,455	111,743	18,193	722,606
MSA Income and Taste variables					
pi1997	187	25,043	4,321	12,056	47,190
Msagmp1997 (in \$billions)	187	32.7	46.4	4.7	355.0
msapop1997	187	1,013,357	1,291,955	201,775	9,127,751
perdem	187	52.09	71.48	4.8	100
white1997	187	75%	16%	12%	97%
black1997	187	11%	9%	0.3%	43%
hispanic1997	187	10%	14%	0.5%	87%
asian1997	187	3%	3%	0.3%	21%
less25	187	35%	3%	25%	48%
btw2564	187	52%	2%	43%	58%
over65	187	13%	3%	8%	30%
Fragmentation Variables					
jdcnt1997	187	121	140	10	1,103
relfrag1997	187	1.55	1.15	0.16	8.16
ccd1997	187	0.39	0.21	0.00	0.90
sdd1997	187	1.77	2.27	0.03	13.44
cp1997	187	4.76	23.31	0.00	250.00
cgc	187	5.10	7.51	-0.58	52.61
mpdi21997	187	5.23	2.47	1.70	17.62
Price of Public Good					
Urban Form					
prcntlfamily	187	0.61	0.08	0.40	0.77
dvmt1997 (1000s)	187	18,025	25,849	1,320	209,816
comtime	187	24.06	3.71	17.1	38.9
trackmi	187	52.65	218.82	0	1706.2
tranrte	187	903.36	1349.21	0	8448
sumfares (1000s)	187	36,000	196,000	0	2,490,000
farepermi	187	14,093	40,815	0	516,643
sqmiles	187	2,564	3,729	46	39,370
density	187	648	1,203	31	11,974
CMSA	187	0.28	0.45	0	1
reggov	187	0.04	0.20	0.00	1.00

Table C5
Summary Statistics

Variable Name	Obs	Mean	Std.Dev	Min	Max
Economic Activity					
emp1997	187	444,593	599,390	61,063	3,855,812
empgrowth	187	0.13	0.09	-0.12	0.46
mfgavgt1997	187	61,177	91,232	2,407	653,005
ptscctl1997	187	28,362	36,929	0	224,877
powerplant	187	0.66	0.48	0	1
dirtyind	187	0.29	0.45	0	1
Weather					
ttlrain1997	187	18.41	9.34	0.41	51.32
jrain1997	187	3.84	2.61	0.00	14.59
jtemp1997	187	75.86	5.98	61.38	91.30
julymaxtemp	187	86.14	6.39	71.10	104.20
julymnwind	187	8.13	1.68	4.80	13.60
Geography					
south	187	0.41	0.49	0.00	1.00
midwest	187	0.21	0.41	0.00	1.00
west	187	0.16	0.36	0.00	1.00
north	187	0.18	0.39	0.00	1.00
coastal	187	0.26	0.44	0	1
Lagged value of Dependent variable					
maxepa1992	187	0.12	0.03	0.07	0.30
areattl1992 (in tons)	187	122,388	132,677	23,879	858,942

Table C6
Correlation Coefficients

	attain	maxepa	areattl	pi	msagdp	gm pcap	perdem	jd cnt	mpdi l	msapop	fare
	1997	1997	1997	1997	1997	1997		1997	1997	1997	permi
attain1997	1.00	-0.58	-0.28	####	-0.30	-0.29	-0.04	-0.31	-0.37	-0.02	-0.20
maxepa1997	-0.58	1.00	0.45	0.25	0.46	0.30	0.02	0.30	0.32	0.19	0.17
areattl1997	-0.28	0.45	1.00	0.29	0.92	0.33	0.12	0.74	0.62	0.26	0.46
pi1997	-0.27	0.25	0.29	1.00	0.42	0.86	0.09	0.29	0.30	-0.06	0.28
msagdp1997	-0.30	0.46	0.92	0.42	1.00	0.41	0.15	0.63	0.50	0.18	0.68
gm pcap1997	-0.29	0.30	0.33	0.86	0.41	1.00	0.06	0.25	0.23	-0.02	0.28
perdem	-0.04	0.02	0.12	0.09	0.15	0.06	1.00	0.11	0.11	-0.05	0.17
jd cnt1997	-0.31	0.30	0.74	0.29	0.63	0.25	0.11	1.00	0.90	0.19	0.21
relfrag1997	-0.08	-0.16	-0.21	####	-0.23	-0.13	0.07	0.24	0.36	-0.08	-0.15
ccd1997	0.04	0.08	0.21	0.09	0.28	0.14	0.06	-0.02	-0.21	0.14	0.22
sdd1997	-0.14	0.09	-0.08	####	-0.03	-0.04	-0.07	0.01	-0.07	0.14	-0.05
cp1997	-0.06	0.00	-0.07	0.19	-0.04	0.19	-0.15	-0.10	-0.11	0.03	-0.03
ccg	0.23	-0.12	-0.12	####	-0.13	-0.17	-0.10	-0.23	-0.31	-0.10	-0.12
mpdi21997	-0.37	0.30	0.61	0.30	0.50	0.23	0.11	0.89	0.99	0.13	0.09
mpdi l1997	-0.37	0.32	0.62	0.30	0.50	0.23	0.11	0.90	1.00	0.14	0.09
MSApop1997	-0.30	0.48	0.93	0.34	0.99	0.31	0.14	0.63	0.51	1.00	0.61
density	-0.27	0.24	0.31	0.39	0.46	0.34	0.20	0.08	0.05	0.43	0.58
prcnt1family	0.32	-0.22	-0.27	####	-0.38	-0.46	-0.05	-0.09	-0.08	-0.35	-0.36
dvmt1997	-0.28	0.48	0.93	0.31	0.94	0.34	0.11	0.61	0.48	0.96	0.49
comtime	-0.36	0.43	0.51	0.45	0.58	0.41	0.12	0.26	0.23	0.56	0.47
totrksmb	-0.26	0.24	0.65	0.26	0.76	0.24	0.14	0.49	0.35	0.73	0.77
totrowsmb	-0.29	0.37	0.79	0.35	0.81	0.33	0.18	0.59	0.52	0.82	0.44
sumfaresb	-0.19	0.17	0.47	0.24	0.69	0.24	0.15	0.22	0.11	0.63	0.98
farepermi	-0.20	0.17	0.46	0.28	0.68	0.28	0.17	0.21	0.09	0.61	1.00
emp1997	-0.30	0.44	0.95	0.38	0.97	0.35	0.14	0.69	0.56	0.98	0.56
mfgavgt1997	-0.24	0.41	0.90	0.34	0.87	0.31	0.12	0.68	0.59	0.89	0.36
mfgper1997	0.05	0.00	-0.01	0.00	-0.03	0.00	-0.07	0.06	0.14	-0.03	-0.08
ptscctl1997	-0.17	0.34	0.65	0.12	0.49	0.17	0.06	0.56	0.46	0.50	0.19
drty_ind	-0.01	0.06	0.01	####	-0.06	-0.17	-0.03	0.15	0.27	-0.03	-0.10
power_plant	-0.15	0.32	0.33	0.22	0.28	0.19	0.17	0.27	0.32	0.29	0.14
ttlrain1997	0.23	-0.18	-0.03	####	-0.10	-0.15	-0.06	-0.07	-0.09	-0.10	-0.03
jrain1997	0.04	-0.08	0.01	####	-0.04	-0.10	-0.10	-0.03	-0.02	-0.05	0.08
jtemp1997	0.12	0.15	0.01	####	-0.06	-0.30	-0.15	-0.19	-0.28	-0.02	-0.07
julymnwind	-0.05	-0.03	0.02	0.25	0.08	0.22	0.12	0.10	0.12	0.05	0.04
coastal	-0.05	0.11	0.19	0.33	0.28	0.18	0.17	0.01	0.00	0.27	0.24
cmsa1y	-0.38	0.39	0.36	0.55	0.43	0.54	0.14	0.23	0.23	0.40	0.27
south	0.30	-0.04	-0.09	####	-0.16	-0.24	-0.13	-0.33	-0.42	-0.15	-0.13
midwest	0.16	-0.16	0.06	0.04	0.01	0.04	0.04	0.23	0.23	0.01	-0.04
west	-0.10	0.08	0.00	0.09	0.07	0.09	0.03	-0.04	-0.08	0.08	-0.01
maxepa1992	-0.59	0.87	0.47	0.21	0.50	0.22	0.01	0.25	0.28	0.54	0.18
areattl1992	-0.30	0.50	0.99	0.29	0.93	0.32	0.13	0.70	0.59	0.95	0.47

Table C7
Ozone attainment, Population, Vehicle miles traveled and GMP per capita

Lowest ten in Class											
MSA NAME	ST.	attain ^a	MSAPOP ^c	MSA NAME	ST.	attain ^a	DVMT ^b	MSA NAME	ST.	attain ^a	GMP/cap ^d
Waco	TX	1	201,775	Johnstown	PA	0	1,320	McAllen-Edinburg-Mission	TX	1	\$15,504
Springfield	IL	1	204,130	Salinas	CA	1	1,321	Ocala	FL	1	\$20,510
Lynchburg	VA	1	205,559	Visalia-Tulare	CA	0	1,691	Visalia-Tulare-Porterville	CA	0	\$20,742
Longview-Marshall	TX	1	206,732	Boulder-Longmont	CO	0	1,728	El Paso	TX	0	\$20,835
Wilmington	NC	1	206,738	Yakima	WA	1	1,778	Daytona Beach	FL	1	\$21,448
Asheville	NC	1	210,042	Longview-Marshall	TX	1	1,850	Huntington-Ashland	WV	1	\$21,479
Green Bay	WI	1	213,072	Fayetteville-Springdale	AR	1	2,119	Pensacola	FL	1	\$21,499
Evansville-Henderson	IN	0	214,538	Fort Collins-Loveland	CO	1	2,172	Mobile	AL	1	\$21,644
Yakima	WA	1	216,234	Santa Cruz-Watsonville	CA	1	2,246	Lakeland-Winter Haven	FL	1	\$21,652
Brazoria	TX	0	220,854	Odessa-Midland	TX	1	2,295	Johnstown	PA	0	\$21,672
Highest ten in Class											
MSA NAME	ST.	attain ^a	MSAPOP ^c	MSA NAME	ST.	attain ^a	DVMT ^b	MSA NAME	ST.	attain ^a	GMP/cap ^d
Los Angeles-Long Bch.	CA	0	9,127,751	Los Angeles-Long Beach	CA	0	209,816	New Haven-Meriden	CT	0	\$56,438
New York-Newark	NY	0	8,958,529	Chicago	IL	0	142,004	Washington	DC	0	\$55,186
Chicago	IL	0	7,078,564	New York-Newark	NY	0	123,115	Wilmington-Newark	DE	0	\$51,413
Boston-Brockton	MA	0	5,327,463	Atlanta	GA	0	89,530	San Jose	CA	1	\$42,974
Detroit	MI	1	4,415,628	Detroit	MI	1	87,621	Oakland	CA	1	\$42,500
Houston	TX	0	3,791,921	Washington	DC	0	80,171	San Francisco	CA	1	\$42,500
Philadelphia	PA	0	3,789,278	Boston-Brockton	MA	0	79,177	Nassau-Suffolk	NY	0	\$39,637
Atlanta	GA	0	3,541,230	Houston	TX	0	77,018	Newburgh	NY	0	\$39,637
Nassau-Suffolk	NY	0	3,209,124	Philadelphia	PA	0	74,956	New York-Newark	NY	0	\$39,637
Dallas	TX	0	3,047,983	Dallas	TX	0	70,050	Odessa-Midland	TX	1	\$39,227
187 MSA sample mean			1,013,357				18,024				\$29,974
187 MSA sample median			523,307				8,057				\$28,932

^aattain= 0 if MSA failed to meet 1997 one-hour ozone standard

attain= 1 if MSA met 1997 one-hour ozone standard

all data for the year 1997

^bDVMT = dailey vehicle miles traveled

^cGMP/cap= MSA Gross Metropolitan Product per capita

^dMSAPOP = MSA population

Table C8
Ozone attainment and Selected Fragmentation variables

Lowest ten in Class											
MSA NAME	ST.	attain ^a	JDCNT ^b	MSA NAME	ST.	attain ^a	MPDI ^c	MSA NAME	ST.	attain ^a	RELFRAG ^d
Fayetteville	NC	1	10	Fayetteville	NC	1	1.7	Miami	FL	1	0.16
Amarillo	TX	1	12	Ocala	FL	1	2.04	New York-Newark	NY	0	0.17
Roanoke	VA	1	13	Lubbock	TX	1	2.11	New Orleans	LA	1	0.18
Jersey City	NJ	0	15	Tucson	AZ	1	2.12	Springfield	IL	1	0.25
Lynchburg	VA	1	15	Amarillo	TX	1	2.16	Norfolk-Va Bch-Newpt Ns	VA	0	0.27
Ocala	FL	1	15	Roanoke	VA	1	2.17	Jersey City	NJ	0	0.27
Odessa-Midland	TX	1	15	El Paso	TX	0	2.2	Baltimore	MD	0	0.30
Lubbock	TX	1	16	Tallahassee	FL	1	2.3	Los Angeles-Long Beach	CA	0	0.30
Tallahassee	FL	1	16	Albuquerque	NM	1	2.37	El Paso	TX	0	0.35
Pensacola	FL	1	19	Asheville	NC	1	2.45	Fayetteville	NC	1	0.35
Highest ten in Class											
MSA NAME	ST.	attain ^a	JDCNT ^b	MSA NAME	ST.	attain ^a	MPDI ^c	MSA NAME	ST.	attain ^a	RELFRAG ^d
Chicago	IL	0	1103	Boston-Brockton	MA	0	17.62	Johnstown	PA	0	8.16
Boston-Brockton	MA	0	747	Chicago	IL	0	15.72	Peoria-Pekin	IL	1	6.18
Pittsburgh	PA	0	692	St. Louis	MO	0	14.98	Duluth-Superior	MN	1	6.06
St. Louis	MO	0	653	Pittsburgh	PA	0	14.18	Davenport-Moline	IA	1	5.00
Philadelphia	PA	0	643	Philadelphia	PA	0	12.24	Rockford	IL	1	4.27
Houston	TX	0	522	Minneapolis-St. Paul	MN	1	10.65	Omaha	NE	1	4.24
Minneapolis-St. Paul	MN	1	434	Scranton--Wilkes-Barre	PA	0	10.65	Scranton--Wilkes-Barre	PA	0	4.11
Kansas City	MO	1	396	Harrisburg-Lebanon	PA	0	9.48	Fort Wayne	IN	1	4.08
Denver	CO	0	384	Detroit	MI	1	9.06	Utica-Rome	NY	1	3.68
Nassau-Suffolk	NY	0	311	Riverside-San Bernardino	CA	0	8.78	Harrisburg-Lebanon	PA	0	3.66
187 MSA sample mean			121				5.2				1.54
187 MSA sample median			77				4.67				1.25

^aattain= 0 if MSA failed to meet 1997 one-hour ozone standard

attain= 1 if MSA met 1997 one-hour ozone standard

all data for the year 1997

^bJDCNT= Jurisdiction count

^cMPDI= Metropolitan Power Diffusion Index 2

^dRELFRAG= Relative Fragmentation

Table C9
Summary Statistics for Two groups of MSAs

	<u>MSAs in non-attainment 1997</u>			<u>MSAs in attainment 1997</u>		
	mean	min	max	mean	min	max
maxepa1997	0.13	0.09	0.22	0.10	0.07	0.14
Emarea1997	144,290	26,275	722,606	81,142	18,193	482,756
Empoint1997	36,258	235	224,877	23,625	1,019	196,007
Emttl1997	180,548	31,423	906,628	105,158	19,270	678,763
emm/cap	0.12			0.15		
jdcnt1997	175	15	1,103	87	10	434
mpdisj1997	6.39	2.20	17.62	4.50	1.70	10.65
relfrag1997	1.66	0.17	8.16	1.48	0.16	6.18
msapop1997	1,493,977	214,538	9,127,751	712,447	201,775	4,415,628
emp1997	668,654	66,526	3,855,812	304,312	61,063	1,929,365
sqmiles	2,319	46	27,270	2,160	445	39,370
density	1,056	47	11,974	399	31	3,595

Table C10
Total Emissions of NOX and VOC (in tons)

Attainment MSAs		Total	Area	Point-source	NonAttainment MSAs		Total	Area	Point-source
MSA NAME	ST	emissions	emissions	emissions	MSA NAME	ST	emissions	emissions	emissions
Bremerton	WA	19,270	18,193	1,077	Dutchess County	NY	31,423	30,398	1,025
Santa Cruz	CA	20,256	18,823	1,432	Johnstown	PA	32,324	31,189	1,135
Yakima	WA	24,835	23,595	1,240	Visalia-Tulare	CA	32,636	32,401	235
Killeen-Temple	TX	28,437	27,418	1,019	Modesto	CA	33,318	32,040	1,279
Lubbock	TX	29,327	25,315	4,012	Salem	OR	33,794	33,555	239
Ocala	FL	29,919	28,650	1,269	Hamilton-Middletown	OH	34,954	26,275	8,679
Tallahassee	FL	30,238	28,202	2,035	Reno	NV	36,909	36,286	623
Fort Collins-Loveland	CO	32,108	25,301	6,807	Boulder-Longmont	CO	37,040	31,076	5,964
Fayetteville	NC	33,086	30,971	2,115	Santa Barbara	CA	37,488	33,953	3,535
Springfield	IL	33,832	22,074	11,758	Portland	ME	38,513	33,117	5,397
10 MSA mean		28,131	24,854	3,276	10 MSA mean		34,840	32,029	2,811

Attainment MSAs		Total	Area	Point-source	NonAttainment MSAs		Total	Area	Point-source
MSA NAME	ST	emissions	emissions	emissions	MSA NAME	ST	emissions	emissions	emissions
Detroit	MI	678,763	482,756	196,007	Chicago	IL	906,628	722,606	184,022
Minneapolis-St. Paul	MN	446,618	329,859	116,759	Boston-Brockton	MA	682,536	601,253	81,283
New Orleans	LA	323,744	186,371	137,373	Los Angeles-Long Beach	CA	648,119	604,084	44,035
Tampa-St Pete	FL	315,262	216,070	99,192	Houston	TX	612,848	387,970	224,877
Cleveland-Lorian	OH	302,493	244,878	57,615	New York-Newark	NY	548,511	497,691	50,820
Greensboro-Win Sal	NC	291,443	157,003	134,440	Philadelphia	PA	528,010	412,099	115,912
Kansas City	MO	290,178	236,195	53,983	Atlanta	GA	497,684	413,117	84,567
Seattle-Bellevue	WA	240,849	223,317	17,533	Washington	DC	486,112	407,958	78,154
Memphis	TN	229,042	168,333	60,709	St. Louis	MO	340,938	224,116	116,822
Indianapolis	IN	214,426	193,307	21,119	Cincinnati-Hamilton	OH	335,769	191,245	144,523
10 MSA mean		333,282	243,809	89,473	10 MSA mean		558,715	446,214	112,502

all Data for 1997

Table C11
Emissions Ratios

Attainment MSAs		Area	Point-source	NonAttainment MSAs		Area	Point-source
<u>MSA NAME</u>	<u>ST</u>	<u>emissions</u>	<u>emissions</u>	<u>MSA NAME</u>	<u>ST</u>	<u>emissions</u>	<u>emissions</u>
Bremerton	WA	94%	6%	Dutchess County	NY	97%	3%
Santa Cruz	CA	93%	7%	Johnstown	PA	96%	4%
Yakima	WA	95%	5%	Visalia-Tulare	CA	99%	1%
Killeen-Temple	TX	96%	4%	Modesto	CA	96%	4%
Lubbock	TX	86%	14%	Salem	OR	99%	1%
Ocala	FL	96%	4%	Hamilton-Middletown	OH	75%	25%
Tallahassee	FL	93%	7%	Reno	NV	98%	2%
Fort Collins-Loveland	CO	79%	21%	Boulder-Longmont	CO	84%	16%
Fayetteville	NC	94%	6%	Santa Barbara	CA	91%	9%
Springfield	IL	65%	35%	Portland	ME	86%	14%
10 MSA mean		89%	11%	10 MSA mean		92%	8%

Attainment MSAs		Area	Point source	NonAttainment MSAs		Area	Point source
<u>MSANAME</u>	<u>ST</u>	<u>emissions</u>	<u>emissions</u>	<u>MSANAME</u>	<u>ST</u>	<u>emissions</u>	<u>emissions</u>
Detroit	MI	71%	29%	Chicago	IL	80%	20%
Minneapolis-St. Paul	MN	74%	26%	Boston-Brockton	MA	88%	12%
New Orleans	LA	58%	42%	Los Angeles-Long Beach	CA	93%	7%
Tampa-St Pete	FL	69%	31%	Houston	TX	63%	37%
Cleveland-Lorian	OH	81%	19%	New York-Newark	NY	91%	9%
Greensboro-Win Sal	NC	54%	46%	Philadelphia	PA	78%	22%
Kansas City	MO	81%	19%	Atlanta	GA	83%	17%
Seattle-Bellevue	WA	93%	7%	Washington	DC	84%	16%
Memphis	TN	73%	27%	St. Louis	MO	66%	34%
Indianapolis	IN	90%	10%	Cincinnati-Hamilton	OH	57%	43%
10 MSA mean		74%	26%	10 MSA mean		78%	22%

all Data for 1997

Table C12
Outliers

[illegible]

Table C13
Panel Year Means

	1992	1997	2002	% chg 92-02
Area total emissions	122,388	105,455	93,305	-24%
maxepa ozone	0.116	0.114	0.111	-4%
MSA population	943,485	1,013,275	1,079,685	14%
MSA GMP* (in millions)	27,642	32,665	37,319	35%
Metro Power diffusion index2	4.75	5.23	4.61	-3%
Jurisdiction count	121.3	120.9	128.0	6%
Central city dominance	0.39	0.39	0.40	2%
Special District dominance	1.74	1.77	1.85	7%
County Primacy	3.92	4.81	5.09	30%
Relative Fragmentation	1.64	1.54	1.55	-5%
Employment	394,109	444,593	508,651	29%
MFG. employment	64,454	61,177	51,722	-20%
Point-source total emissions	33,028	28,362	22,330	-32%
July Rain	3.86	3.84	3.20	-17%
Total Ozone season rain	17.28	17.62	16.89	-2%
July Temperature	75.53	75.86	75.73	0.3%

*ADJ TO 1997 DOLLARS

Table C14
Panel Group Means

	Never in Attainment	Change in Attainment	Always in Attainment
Area total emissions	153,472	121,287	59,612
maxepa ozone	0.13	0.11	0.10
MSA population	1,597,370	1,094,880	479,911
MSA GMP* (in millions)	54,405	34,498	13,406
Metro Power diffusion index2	5.99	5.06	3.81
Jurisdiction count	179.8	127.3	74.9
Central city dominance	0.376	0.407	0.404
Special District dominance	2.34	1.45	1.57
County Primacy	6.99	1.44	4.82
Relative Fragmentation	1.68	1.39	1.63
Employment	712,240	485,029	210,692
MFG. employment	90,482	67,947	27,604
Point-source total emissions	36,196	34,117	16,942
July Rain	3.08	3.61	4.10
Total Ozone season rain	15.63	18.27	17.91
July Temperature	75.06	73.85	77.49

* All values adjusted to 1997 dollars

Table C15
Correlations Sensitivity

	outliers	w/o outliers
	attain1997	attain1997
maxepa1997	-0.58	-0.77
areattl1997	-0.28	-0.41
	areattl1997	areattl1997
maxepa1997	0.45	0.49

Table C16
Variable Definitions

Variable Name	Variable Definition
Dependent Variables	
attain1997	Dummy variable =1 if Ozone standard met, =0 otherwise
maxepa	Third Highest Ozone Monitor Reading as averaged across MSA monitors
areattl	Area total emissions for NOX & VOC in an MSA in 1997
MSA Income Demographic and Taste Variables	
pi	MSA Per capita personal income, 1992, 1997, 2002
MSAGMP	Gross metropolitan product 1992, 1997, 2002
msapop	MSA population 1992, 1997, 2002
perdem	Percent of votes in the MSA congressional elections between 1997 and 1999 cast for a democratic candidate or against a republican candidate
age less25	Percent of MSA population less than 25 1992, 1997, 2002
btw2564	Percent of MSA population between 25 and 64 1992, 1997, 2002
over65	Percent of MSA population 65 and over 1992, 1997, 2002
MSA Income Demographic and Taste Variables	
white	Percent of MSA population that is white 1992, 1997, 2002
black	Percent of MSA population that is black 1992, 1997, 2002
hispanic	Percent of MSA population that is hispanic 1992, 1997, 2002
asian	Percent of MSA population that is asian 1992, 1997, 2002
college	Percent of MSA population that graduated college 1992, 1997, 2002
Fragmentation Variables	
jdcnt1997	See Ch 3 for detailed description
relfrag1997	See Ch 3 for detailed description
ccd1997	See eq 3-3 in Ch 3 for detailed description
sdd1997	See eq 3-1 in Ch 3 for detailed description
cp1997	See eq 3-4 in Ch 3 for detailed description
cgc	See eq 4-4 in Ch 4 for detailed description
mpdi1 1997	See eq 3-5 in Ch 3 for detailed description
mpdi2 1997	See eq 3-5 in Ch 3 for detailed description

Table C16
Variable Definitions

Variable Name	Variable Definition
Price of Public Good	
<i>Urban Form</i>	
prent1family	Percent of single family homes
dvmt1997	MSA Daily Vehicle Miles Traveled 1992, 1997, 2002 (in thousands of miles)
comtime	MSA average commute time to work in minutes
trackmi	Total public transit train track miles
tranrte	Total public transit train and bus route miles
sumfares	Total Fares received from public transit in 1997 (in thousands)
CMSA	Dummy variable =1 if MSA in CMSA, =0 otherwise
reggov	Presence of Regional Government Dummy variable =1 if Regional gov. in MSA =0 otherwise
density	MSA population density (population 1997 divided by total MSA land area)
<i>Economic Activity</i>	
emp	MSA Total Employment 1992, 1997, 2002
mfgavgt	MSA Employment in only the Manufacturing sector 1992, 1997, 2002
ptsecttl	MSA point-source total emissions 1992, 1997, 2002
dirtyind	Dummy variable=1 if there are Chemical, Nonmetallic mineral product, Petroleum & coal products, Plastics & rubber products, or Primary metal manufacturing plants within the MSA, =0 otherwise
utlity	Dummy variable=1 if there is a Fossil fuel power generation facility within the MSA, =0 otherwise
<i>Weather</i>	
ttlrain	MSA total rainfall from May 1st - Sept 30th 1992, 1997, 2002
jrain	Total rainfall in just July 1992, 1997, 2002
jtemp	July mean temperature 1992, 1997, 2002
julymaxtemp	July Maximum temperature 1997
julymnwind	July mean wind speed in 1997
<i>Geography</i>	
south	Dummy variable =1 if MSA in region, =0 otherwise see table 4-2 for a list of states and regions
midwest	
west	
north	Dummy variable =1 if If MSA is located on a great lake or ocean, =0 otherwise
Coastal	

Table C17: Results of Probit Regression

Model	(1) mpdi		(2) jdent		(3) ccd		(4) sdd		(5) cp		(6) ccg	
	expected sign (-)		expected sign (-)		expected sign (+)		expected sign (-)		expected sign (+)		expected sign (+)	
	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)
Frag Var.	-0.285**	(0.02)	-0.00390**	(0.05)	0.352	(0.75)	0.0252	(0.83)	-0.00785	(0.18)	0.177***	(0.00)
college	-19.60***	(0.00)	-16.92***	(0.00)	-17.52***	(0.00)	-17.46***	(0.00)	-18.12***	(0.00)	-17.07***	(0.00)
less25	-19.58**	(0.01)	-14.94**	(0.03)	-14.36**	(0.03)	-14.21**	(0.04)	-15.75**	(0.03)	-18.57**	(0.05)
msagdp ^{kk}	0.0000530*	(0.08)	0.0000417	(0.12)	0.0000339	(0.18)	0.0000336	(0.20)	0.0000374	(0.15)	0.0000487*	(0.07)
perdem	-0.00729	(0.41)	-0.00699	(0.42)	-0.00820	(0.36)	-0.00775	(0.38)	-0.00888	(0.34)	-0.0104	(0.28)
white	-1.440	(0.41)	-1.698	(0.36)	-1.553	(0.38)	-1.638	(0.34)	-1.934	(0.28)	-1.576	(0.46)
cmsaly	-2.008***	(0.00)	-1.700***	(0.01)	-1.425**	(0.01)	-1.407**	(0.02)	-1.470**	(0.01)	-1.286**	(0.02)
comtime	0.102	(0.18)	0.0646	(0.39)	0.0669	(0.37)	0.0486	(0.54)	0.0378	(0.62)	0.0462	(0.54)
density ^k	0.000393	(0.34)	0.000127	(0.78)	0.000313	(0.50)	0.000344	(0.46)	0.000230	(0.64)	0.000177	(0.76)
dvmt ^k	-0.0710**	(0.04)	-0.0528	(0.10)	-0.0574*	(0.06)	-0.0547*	(0.08)	-0.0579*	(0.07)	-0.0741**	(0.02)
farepermi ^k	-0.0343*	(0.07)	-0.0240	(0.20)	-0.0305	(0.11)	-0.0299	(0.12)	-0.0308	(0.11)	-0.0195	(0.27)
prcnt1 family	0.440	(0.89)	-0.179	(0.96)	-0.428	(0.90)	-0.723	(0.83)	-1.186	(0.73)	0.797	(0.83)
empgrowth	11.00***	(0.00)	9.704***	(0.00)	9.666***	(0.00)	9.705***	(0.00)	10.31***	(0.00)	10.76***	(0.00)
mfgavg ^t ^k	0.00494	(0.49)	0.00482	(0.49)	0.00277	(0.69)	0.00263	(0.70)	0.00181	(0.79)	-0.00276	(0.70)
ptscttl ^k	-0.0243*	(0.07)	-0.0253**	(0.04)	-0.0270**	(0.03)	-0.0262**	(0.03)	-0.0287**	(0.02)	-0.0269**	(0.03)
ptscttlsq	8.80e-08	(0.27)	9.64e-08	(0.20)	1.21e-07	(0.11)	1.16e-07	(0.12)	1.32e-07*	(0.09)	1.63e-07**	(0.03)
coastal	1.102*	(0.06)	1.082*	(0.08)	1.198**	(0.05)	1.180*	(0.06)	1.265**	(0.04)	1.300**	(0.03)
jtemp	-0.121**	(0.03)	-0.113**	(0.04)	-0.107**	(0.04)	-0.105**	(0.05)	-0.116**	(0.02)	-0.201***	(0.00)
julymnwind	0.146	(0.22)	0.125	(0.29)	0.127	(0.30)	0.130	(0.29)	0.121	(0.33)	0.338**	(0.02)
ttlrain	-0.00287	(0.94)	0.0108	(0.78)	-0.00992	(0.79)	-0.00924	(0.81)	-0.0151	(0.71)	0.0238	(0.55)
south	2.223**	(0.02)	2.402***	(0.01)	2.808***	(0.00)	2.885***	(0.00)	3.031***	(0.00)	3.030***	(0.00)
midwest	1.383*	(0.05)	1.464**	(0.05)	1.568**	(0.03)	1.621**	(0.02)	1.685**	(0.02)	1.565**	(0.02)
west	-0.923	(0.19)	-0.436	(0.50)	-0.474	(0.52)	-0.459	(0.55)	-0.253	(0.72)	-2.006**	(0.02)
maxepa92	-119.8***	(0.00)	-118.0***	(0.00)	-115.8***	(0.00)	-116.7***	(0.00)	-118.0***	(0.00)	-108.3***	(0.00)
_cons	31.98***	(0.00)	29.21***	(0.00)	28.39***	(0.00)	28.88***	(0.00)	31.60***	(0.00)	32.96***	(0.00)
N	187		187		187		187		187		187	

p-values in parentheses
* p<0.10 ** p<0.05 *** p<0.01
k- Coefficients scaled by 1,000
kk- Coefficient scaled by 1,000,000

Table C18: Marginal Effects from Probit Regression for Models 1,2 and 6

Models	(1)		(2)		(6)	
	mpdi dy/dx	p(z)	jdcnt dy/dx	p(z)	ccg dy/dx	p(z)
Frag Var.	-0.1032 **	0.02	-0.0014 **	0.05	0.0578 ***	0.00
college	-7.0953 ***	0.00	-6.2415 ***	0.00	-5.5657 ***	0.00
less25	-7.0884 **	0.01	-5.5111 **	0.02	-6.0563 **	0.04
msagdp ^{kk}	0.000019 *	0.07	0.00002	0.11	0.00002 *	0.07
perdem	-0.0026	0.40	-0.0026	0.41	-0.0034	0.28
white	-0.5215	0.41	-0.6262	0.36	-0.5140	0.47
cmsa1y	-0.6845 ***	0.00	-0.6044 ***	0.00	-0.4540 **	0.01
comtime	0.0370	0.18	0.0238	0.40	0.0151	0.54
density ^k	0.00014	0.33	0.00005	0.78	0.0001	0.76
dvm ^k	-0.0257 **	0.04	-0.0195	0.11	-0.0242 **	0.02
fareperm ^k	-0.0124 *	0.07	-0.0089	0.20	-0.0063	0.27
prcnt1family	0.1595	0.90	-0.0662	0.96	0.2599	0.83
empgrowth	3.9826 ***	0.00	3.5789 ***	0.00	3.5088 ***	0.00
mfgavgt ^k	0.0018	0.49	0.0018	0.50	-0.0009	0.70
ptscttl ^k	-0.0088 *	0.06	-0.0093 **	0.04	-0.0088 **	0.03
ptscttlsq	0.00000003	0.27	0.00000004	0.19	0.0000001 **	0.03
coastal	0.3346 *	0.02	0.3391 *	0.03	0.3288 **	0.01
jtemp	-0.0437 **	0.03	-0.0416 **	0.04	-0.0654 ***	0.00
julymnwind	0.0530	0.22	0.0460	0.30	0.1103 **	0.02
ttlrain	-0.0010	0.94	0.0040	0.78	0.0078	0.55
south	0.6422 **	0.00	0.6881 ***	0.00	0.7221 ***	0.00
midwest	0.3772 *	0.00	0.4038 **	0.00	0.3484 **	0.00
west	-0.3532	0.18	-0.1677	0.51	-0.6833 **	0.00
maxepa92	-43.3742 ***	0.00	-43.5056 ***	0.00	-35.3219 ***	0.00

p-values in parentheses

* p<0.10 ** p<0.05 *** p<0.01

k- Coefficients scaled by 1,000

kk- Coefficient scaled by 1,000,000

Table C19: Results of Revised Probit Regression

	(1) mpdi expected sign (-)		(2) jdcnt expected sign (-)		(6) ccg expected sign (+)	
	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)
Frag Var.	-0.144	(0.24)	-0.00168	(0.50)	0.154*	(0.06)
college	11.49	(0.12)	12.83	(0.11)	19.49*	(0.05)
less25	-27.56	(0.10)	-25.46	(0.14)	-42.15*	(0.06)
msagdp ^{kk}	-0.0000123	(0.76)	-0.00000995	(0.80)	-0.00000525	(0.90)
perdem	0.0241*	(0.07)	0.0213	(0.10)	0.0179	(0.20)
white	-1.593	(0.60)	-1.618	(0.60)	-4.802	(0.20)
cmsa1y	-0.849	(0.42)	-0.663	(0.52)	-0.495	(0.62)
comtime	0.0568	(0.64)	0.0329	(0.78)	0.0410	(0.75)
density ^k	-0.00257***	(0.00)	-0.00248***	(0.00)	-0.00310***	(0.00)
dvm ^k	-0.0457	(0.37)	-0.0474	(0.35)	-0.0898	(0.16)
farepermi ^k	-0.0800**	(0.02)	-0.0751**	(0.02)	-0.0959**	(0.01)
prcnt1family	-16.40**	(0.02)	-15.58**	(0.03)	-16.85**	(0.02)
empgrowth	-6.978	(0.12)	-6.743	(0.14)	-10.83**	(0.04)
mfgavg ^k	0.0210*	(0.07)	0.0193*	(0.08)	0.0208*	(0.09)
ptscttl ^k	-0.0761***	(0.00)	-0.0722***	(0.00)	-0.0835***	(0.00)
ptscttlsq	0.000000361***	(0.00)	0.000000346***	(0.00)	0.000000455***	(0.00)
coastal	3.181***	(0.00)	3.014***	(0.01)	4.021***	(0.01)
jtemp	-0.145**	(0.02)	-0.152**	(0.02)	-0.183***	(0.01)
julymnwind	-0.264	(0.16)	-0.270	(0.16)	-0.260	(0.22)
ttlrain	0.0495	(0.26)	0.0572	(0.19)	0.0617	(0.17)
south	0.988	(0.42)	1.276	(0.33)	1.169	(0.27)
midwest	0.219	(0.84)	0.351	(0.75)	0.857	(0.43)
west	0.795	(0.52)	1.325	(0.30)	0.216	(0.86)
maxepa92	-261.9***	(0.00)	-262.3***	(0.00)	-300.3***	(0.00)
_cons	64.02***	(0.00)	62.71***	(0.00)	77.63***	(0.00)
N	187		187		187	

p-values in parentheses

="* p<0.10 ** p<0.05 *** p<0.01"

k- Coefficients scaled by 1,000

kk- Coefficient scaled by 1,000,000

Table C20: Results of Probit Regression with Two IV's

Model	(1) mpdi		(2) jdcnt		(3) ccd		(4) sdd		(5) cp		(6) ccg	
	expected sign (-)		expected sign (-)		expected sign (+)		expected sign (-)		expected sign (+)		expected sign (+)	
	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)
Frag Var.	-0.725	(0.18)	-0.00829	(0.24)	0.104	(0.61)	0.743	(0.75)	-0.0104	(0.61)	0.225*	(0.10)
college	-29.14**	(0.03)	-28.60*	(0.06)	-28.28*	(0.09)	-28.24*	(0.08)	-24.70*	(0.08)	-46.26	(0.19)
less25	-17.02	(0.23)	-10.04	(0.49)	-9.464	(0.49)	-10.86	(0.42)	-11.96	(0.33)	-8.724	(0.77)
msagdp ^{kk}	0.000280	(0.35)	0.000317	(0.40)	0.000204	(0.62)	0.000252	(0.54)	0.000115	(0.74)	0.000882	(0.30)
perdem	-0.00842	(0.61)	-0.0115	(0.53)	-0.0114	(0.47)	-0.0121	(0.48)	-0.0123	(0.41)	-0.0202	(0.61)
white	-5.824	(0.36)	-6.996	(0.37)	-4.944	(0.56)	-6.358	(0.47)	-3.584	(0.62)	-17.78	(0.32)
cmsaly	-2.499*	(0.05)	-2.071*	(0.09)	-1.481	(0.13)	-1.632	(0.13)	-1.415*	(0.10)	-2.222	(0.32)
comtime	0.121	(0.39)	0.0424	(0.77)	-0.0223	(0.89)	0.0160	(0.91)	-0.00232	(0.99)	-0.0960	(0.77)
density ^k	0.000775	(0.35)	0.000902	(0.38)	0.000921	(0.43)	0.000862	(0.43)	0.000475	(0.63)	0.00224	(0.30)
dvm ^k	-0.353	(0.39)	-0.389	(0.45)	-0.235	(0.67)	-0.308	(0.58)	-0.119	(0.80)	-1.167	(0.31)
fareperm ^k	-0.144	(0.25)	-0.163	(0.30)	-0.110	(0.51)	-0.135	(0.42)	-0.0728	(0.60)	-0.368	(0.28)
prcnt1family	-3.580	(0.59)	-5.286	(0.50)	-4.109	(0.59)	-4.498	(0.56)	-2.781	(0.70)	-11.73	(0.46)
empgrowth	5.983	(0.36)	4.010	(0.60)	5.276	(0.54)	4.183	(0.64)	7.382	(0.32)	-3.532	(0.83)
mfgavgt ^k	0.000405	(0.97)	-0.00525	(0.73)	-0.00855	(0.65)	-0.00878	(0.64)	-0.00583	(0.74)	-0.0332	(0.41)
ptscttl ^k	0.0104	(0.83)	0.00235	(0.96)	-0.0130	(0.78)	-0.00914	(0.84)	-0.0235	(0.56)	0.0479	(0.61)
ptscttlsq	-1.29e-08	(0.66)	-7.96e-08	(0.79)	-2.74e-08	(0.93)	-5.49e-08	(0.87)	5.92e-08	(0.83)	-4.42e-07	(0.50)
coastal	0.0183	(0.99)	-0.108	(0.95)	0.288	(0.87)	0.239	(0.89)	0.779	(0.61)	-1.811	(0.60)
jtemp	-0.192	(0.12)	-0.192	(0.17)	-0.146	(0.29)	-0.174	(0.24)	-0.129	(0.27)	-0.498	(0.12)
julymnwind	0.113	(0.60)	0.0383	(0.88)	0.0520	(0.84)	0.0115	(0.97)	0.0773	(0.74)	0.0109	(0.98)
ttlrain	0.0393	(0.59)	0.0553	(0.49)	0.0499	(0.53)	0.0483	(0.55)	0.0266	(0.69)	0.146	(0.38)
south	2.094	(0.17)	3.255	(0.14)	3.236	(0.21)	3.549	(0.17)	2.766	(0.22)	8.175	(0.14)
midwest	1.951	(0.22)	2.495	(0.24)	1.934	(0.37)	2.182	(0.31)	1.489	(0.41)	5.463	(0.23)
west	-0.376	(0.79)	0.961	(0.65)	0.449	(0.85)	0.954	(0.68)	0.324	(0.88)	2.284	(0.66)
maxepa92	-125.6***	(0.00)	-132.4***	(0.00)	-128.6***	(0.00)	-127.5***	(0.00)	-122.6***	(0.00)	-149.3***	(0.00)
_cons	46.24**	(0.03)	45.36**	(0.05)	39.74	(0.11)	42.88*	(0.09)	36.31	(0.10)	84.26	(0.11)
N	187		187		187		187		187		187	

p-values in parentheses

* p<0.10 ** p<0.05 *** p<0.01

k- Coefficients scaled by 1,000

kk- Coefficient scaled by 1,000,000

Table C21: Results of OLS Regression

Model	(1) mpdi		(2) jdcnt		(3) ccd		(4) sdd		(5) cp		(6) ccg	
	expected sign (+)		expected sign (+)		expected sign (-)		expected sign (+)		expected sign (-)		expected sign (-)	
	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)
Frag Var.	0.000793	(0.16)	0.0000141*	(0.08)	-0.00290	(0.62)	0.000169	(0.71)	-0.0000314	(0.45)	-0.000180	(0.18)
college	-0.0113	(0.57)	-0.0143	(0.45)	-0.0151	(0.43)	-0.0153	(0.43)	-0.0147	(0.45)	-0.0164	(0.39)
less25	-0.00122	(0.97)	-0.00606	(0.85)	-0.00166	(0.96)	-0.00581	(0.85)	-0.00676	(0.83)	0.00512	(0.87)
msagdp ^{kk}	1.17e-07	(0.31)	1.17e-07	(0.30)	1.59e-07	(0.18)	1.52e-07	(0.18)	1.59e-07	(0.16)	1.48e-07	(0.19)
perdem	2.95e-06	(0.94)	3.89e-06	(0.92)	5.84e-06	(0.89)	7.33e-06	(0.86)	9.77e-06	(0.98)	6.18e-06	(0.88)
white	0.00600	(0.54)	0.00564	(0.56)	0.00588	(0.54)	0.00596	(0.53)	0.00583	(0.54)	0.00836	(0.37)
cmsaly	0.00543*	(0.05)	0.00532*	(0.05)	0.00500*	(0.07)	0.00492*	(0.07)	0.00494*	(0.07)	0.00447*	(0.10)
comtime	0.000396	(0.29)	0.000449	(0.21)	0.000429	(0.31)	0.000482	(0.19)	0.000479	(0.19)	0.000524	(0.13)
density ^k	-0.00000117	(0.20)	-0.00000120	(0.21)	-0.00000125	(0.15)	-0.00000135	(0.13)	-0.00000137	(0.13)	-0.00000124	(0.17)
dvm ^k	-0.000133	(0.34)	-0.000152	(0.28)	-0.000156	(0.25)	-0.000162	(0.24)	-0.000170	(0.22)	-0.000161	(0.24)
fareperm ^k	-0.0000115	(0.80)	-0.0000172	(0.71)	-0.0000338	(0.47)	-0.0000338	(0.47)	-0.0000356	(0.44)	-0.0000333	(0.47)
prcnt1family	0.0180	(0.19)	0.0185	(0.18)	0.0186	(0.18)	0.0179	(0.21)	0.0171	(0.22)	0.0160	(0.26)
empgrowth	0.00888	(0.37)	0.00894	(0.37)	0.00971	(0.36)	0.00889	(0.38)	0.00945	(0.36)	0.00819	(0.44)
mfgavgt ^k	-0.0000519**	(0.03)	-0.0000502**	(0.03)	-0.0000507**	(0.04)	-0.0000474*	(0.06)	-0.0000496**	(0.04)	-0.0000443*	(0.06)
ptscttl ^k	0.000171***	(0.00)	0.000183***	(0.00)	0.000200***	(0.00)	0.000205***	(0.00)	0.000202***	(0.00)	0.000188***	(0.00)
ptscttlsq	-5.71e-10*	(0.05)	-6.63e-10**	(0.03)	-6.73e-10**	(0.03)	-7.01e-10**	(0.03)	-6.74e-10**	(0.03)	-6.26e-10**	(0.04)
coastal	0.000145	(0.94)	0.000169	(0.94)	-0.000168	(0.94)	-0.000385	(0.86)	-0.000368	(0.86)	-0.000445	(0.83)
jtemp	0.000290	(0.15)	0.000281	(0.17)	0.000297	(0.16)	0.000288	(0.16)	0.000287	(0.16)	0.000361*	(0.08)
julymnwind	0.00166***	(0.01)	0.00171***	(0.00)	0.00182***	(0.00)	0.00177***	(0.00)	0.00175***	(0.00)	0.00164***	(0.00)
ttlrain	-0.000228**	(0.04)	-0.000241**	(0.04)	-0.000229*	(0.05)	-0.000224*	(0.06)	-0.000240**	(0.05)	-0.000237**	(0.03)
south	0.00450	(0.22)	0.00385	(0.27)	0.00236	(0.49)	0.00214	(0.53)	0.00219	(0.53)	0.00275	(0.42)
midwest	0.000501	(0.86)	0.000145	(0.96)	-0.0000899	(0.98)	-0.000185	(0.95)	-0.000260	(0.93)	-0.000159	(0.96)
west	-0.00307	(0.36)	-0.00394	(0.25)	-0.00427	(0.16)	-0.00533	(0.17)	-0.00476	(0.15)	-0.00283	(0.40)
maxepa92	0.653***	(0.00)	0.662***	(0.00)	0.654***	(0.00)	0.656***	(0.00)	0.656***	(0.00)	0.646***	(0.00)
_cons	-0.0245	(0.37)	-0.0208	(0.45)	-0.0211	(0.45)	-0.0207	(0.46)	-0.0187	(0.49)	-0.0281	(0.30)
N	187		187		187		187		187		187	

p-values in parentheses

* p<0.10 ** p<0.05 *** p<0.01

k- Coefficients scaled by 1,000

kk- Coefficient scaled by 1,000,000

Table C22: Results of OLS Regression with Two IV's

Model	(1) mpdi		(2) jdcent		(3) ccd		(4) sdd		(5) cp		(6) ccg	
	expected sign (+)		expected sign (+)		expected sign (-)		expected sign (+)		expected sign (-)		expected sign (-)	
	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)
Frag Var.	0.000141	(0.92)	0.00000749	(0.72)	0.000224	(0.66)	-0.000141	(0.99)	-0.0000557	(0.36)	-0.000180	(0.17)
college	-0.0230	(0.52)	-0.0292	(0.43)	-0.0246	(0.59)	-0.0231	(0.59)	-0.0204	(0.63)	-0.0180	(0.67)
less25	-0.00708	(0.84)	-0.00629	(0.86)	-0.00878	(0.81)	-0.00787	(0.83)	-0.0118	(0.74)	0.000611	(0.99)
msagdp ^{kk}	6.40e-07	(0.48)	7.67e-07	(0.50)	6.58e-07	(0.57)	6.37e-07	(0.57)	5.77e-07	(0.56)	4.31e-07	(0.67)
perdem	-6.67e-06	(0.89)	-9.73e-06	(0.86)	-4.18e-06	(0.94)	-6.03e-06	(0.91)	-1.28e-06	(0.82)	-1.31e-06	(0.98)
white	-0.00443	(0.83)	-0.00729	(0.77)	-0.00476	(0.86)	-0.00426	(0.87)	-0.00319	(0.90)	0.00208	(0.93)
cmsaly	0.00427	(0.22)	0.00438	(0.23)	0.00419	(0.20)	0.00417	(0.20)	0.00428	(0.17)	0.00387	(0.18)
comtime	0.000505	(0.26)	0.000469	(0.29)	0.000501	(0.29)	0.000524	(0.28)	0.000501	(0.26)	0.000575	(0.15)
density ^k	-8.04e-07	(0.65)	-3.76e-07	(0.88)	-7.84e-07	(0.79)	-8.71e-07	(0.75)	-1.03e-07	(0.69)	-1.16e-06	(0.66)
dvmt ^k	-0.000995	(0.41)	-0.00116	(0.45)	-0.00102	(0.51)	-0.000991	(0.52)	-0.000913	(0.50)	-0.000714	(0.59)
farepermi ^k	-0.000177	(0.62)	-0.000232	(0.60)	-0.000184	(0.69)	-0.000175	(0.70)	-0.000150	(0.71)	-0.0000971	(0.81)
prcnt1 family	0.0124	(0.54)	0.0108	(0.66)	0.0112	(0.65)	0.0126	(0.59)	0.0105	(0.65)	0.0122	(0.55)
empgrowth	0.00318	(0.86)	0.000592	(0.98)	0.00274	(0.91)	0.00347	(0.88)	0.00520	(0.79)	0.00575	(0.77)
mfgavg ^{tk}	-0.0000356	(0.31)	-0.0000446	(0.31)	-0.0000330	(0.57)	-0.0000339	(0.52)	-0.0000322	(0.54)	-0.0000228	(0.64)
ptscttl ^k	0.000242	(0.12)	0.000251	(0.11)	0.000254*	(0.07)	0.000247*	(0.07)	0.000243**	(0.05)	0.000215*	(0.07)
ptscttl ^{sq}	-9.93e-10	(0.28)	-1.10e-09	(0.26)	-1.06e-09	(0.28)	-1.00e-09	(0.28)	-9.61e-10	(0.24)	-8.19e-10	(0.31)
coastal	-0.00202	(0.66)	-0.00236	(0.67)	-0.00232	(0.67)	-0.00205	(0.69)	-0.00202	(0.67)	-0.00153	(0.73)
jtemp	0.000104	(0.78)	0.0000672	(0.88)	0.000101	(0.82)	0.000105	(0.82)	0.000125	(0.76)	0.000236	(0.56)
july ^{mn} wind	0.00155**	(0.02)	0.00148*	(0.06)	0.00156*	(0.07)	0.00158*	(0.07)	0.00155*	(0.06)	0.00153**	(0.04)
ttl ^{rain}	-0.000175	(0.24)	-0.000167	(0.33)	-0.000172	(0.33)	-0.000176	(0.31)	-0.000209	(0.19)	-0.000209	(0.19)
south	0.00715	(0.17)	0.00816	(0.28)	0.00694	(0.42)	0.00674	(0.40)	0.00663	(0.38)	0.00631	(0.38)
midwest	0.00350	(0.52)	0.00402	(0.59)	0.00359	(0.63)	0.00337	(0.63)	0.00313	(0.63)	0.00257	(0.67)
west	-0.000776	(0.84)	-0.0000648	(0.99)	-0.00175	(0.81)	-0.00107	(0.86)	-0.00143	(0.82)	-0.000228	(0.97)
maxepa92	0.674***	(0.00)	0.672***	(0.00)	0.675***	(0.00)	0.676***	(0.00)	0.678***	(0.00)	0.670***	(0.00)
_cons	0.00256	(0.97)	0.0110	(0.88)	0.00493	(0.95)	0.00254	(0.97)	0.00404	(0.96)	-0.0146	(0.83)
N	187		187		187		187		187		187	
p-values in parentheses					k- Coeffecients scaled by 1,000							
* p<0.10	** p<0.05	*** p<0.01	kk- Coefficient scaled by 1,000,000									

Table C23: Results of Random Effects Probit Regression

Model	(1)		(2)	
	mpdi		jdcnt	
	expected sign (-)		expected sign (-)	
	Coef.	p(z)	Coef.	p(z)
Frag	-0.729***	(0.00)	-0.0107***	(0.00)
white	1.740	(0.17)	1.402	(0.29)
less25	-14.64***	(0.01)	-18.85***	(0.00)
college	0.373***	(0.00)	0.451***	(0.00)
density	-0.00286***	(0.00)	-0.00406***	(0.00)
dvm	0.000000962	(0.98)	0.0000712**	(0.02)
lnemp	-1.682***	(0.00)	-1.406***	(0.00)
gmpi	3.73e-08	(0.26)	4.85e-09	(0.79)
mfgavg	0.00000583	(0.24)	-0.00000106	(0.80)
ptsttl	-0.0000649***	(0.00)	-0.0000543***	(0.00)
ptsttlsq	1.97e-10**	(0.01)	1.43e-10*	(0.06)
ttlrain	0.114***	(0.00)	0.113***	(0.00)
jtemp	0.150***	(0.01)	0.147***	(0.00)
_cons	8.357	(0.12)	3.585	(0.50)
lnsig2u				
_cons	3.178***	(0.00)	3.171***	(0.00)
N	561		561	

p-values in parentheses

* p<0.10

** p<0.05

*** p<0.01

Table C24: Results of Random Effects and Fixed Effects OLS Regression

Model	(1) Random Effects		(2) Random Effects		(1) Fixed Effects		(2) Fixed Effects	
	mpdi		jdcnt		mpdi		jdcnt	
	expected sign (+)		expected sign (+)		expected sign (+)		expected sign (+)	
	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)	Coef.	p(z)
Frag	0.000849	(0.22)	-0.00000134	(0.92)	0.000707	(0.55)	0.0000110	(0.79)
white	-0.00929	(0.41)	-0.00636	(0.57)	0.0309	(0.25)	0.0294	(0.28)
less25	0.0896**	(0.03)	0.0894**	(0.03)	0.0932	(0.18)	0.0879	(0.20)
college	-0.000124	(0.52)	-0.000108	(0.58)	0.000320	(0.27)	0.000333	(0.25)
density	0.00000315**	(0.02)	0.00000285**	(0.03)	-0.0000162*	(0.05)	-0.0000162**	(0.05)
dvm	2.42e-08	(0.86)	6.15e-10	(1.00)	-0.000000671***	(0.01)	-0.000000670***	(0.01)
lnemp	0.00315	(0.20)	0.00374	(0.13)	0.00523	(0.39)	0.00415	(0.49)
gmpi	-7.22e-11	(0.30)	-5.86e-11	(0.41)	-8.83e-11	(0.48)	-7.76e-11	(0.53)
mfgavg	5.82e-08**	(0.02)	6.79e-08***	(0.01)	-7.33e-08	(0.14)	-6.27e-08	(0.19)
ptsttl	0.000000208***	(0.00)	0.000000219***	(0.00)	0.000000280***	(0.00)	0.000000277***	(0.00)
ptsttlsq	-5.08e-13	(0.14)	-5.31e-13	(0.12)	-8.54e-13**	(0.04)	-8.28e-13*	(0.05)
ttlrain	-0.000136	(0.31)	-0.000128	(0.34)	0.0000595	(0.79)	0.0000768	(0.73)
jtemp	0.000256	(0.30)	0.000209	(0.40)	-0.000524	(0.31)	-0.000492	(0.34)
_cons	0.0229	(0.60)	0.0201	(0.65)	0.0433	(0.65)	0.0580	(0.54)
N	561		561		561		561	

p-values in parentheses

* p<0.10

** p<0.05

*** p<0.01

Table C25: The effects of Changes in MPDI, JDCNT, CCG on the Likelihood of Ozone attainment

MSA NAME	attain ^a	MSAPOP ^b	JDCNT	MPDI	CCG	Percent Change in likelihood of attainment due to increase/decrease in the variable of: ^c		
						$\Delta\%$ JDCNT	$\Delta\%$ MPDI	$\Delta\%$ CCG
Atlanta, GA	0	3,541,230	233	8.57	2.83	4.47%	6.89%	0.75%
Louisville, KY	0	991,765	251	6.00	0.25	4.59%	5.73%	0.42%
Phoenix-Mesa, AZ	0	2,746,703	128	4.63	38.14	3.08%	5.40%	7.42%
Salt Lake City, UT	0	1,217,842	135	6.82	0.85	3.12%	6.08%	0.50%
Columbus, OH	1	1,447,646	206	6.66	5.23	-3.44%	-2.32%	-1.14%
Greensboro-Win Sal, NC	1	1,141,238	77	4.84	6.76	-1.33%	-2.55%	-1.81%
Jacksonville, FL	1	967,286	41	2.80	26.60	-0.83%	-2.15%	-2.16%
New Orleans, LA	1	1,632,175	29	3.25	-0.24	-0.38%	-0.63%	-0.51%
Oklahoma City, OK	1	1,026,657	101	4.95	12.03	-1.72%	-3.66%	-1.25%
Raleigh-Durham, NC	1	1,025,253	64	4.68	12.62	-1.29%	-3.00%	-2.52%
Tampa-St Petersburg, FL	1	2,199,231	90	5.16	6.33	-1.92%	-3.09%	-1.46%

all data for the year 1997

^aattain= 0 if MSA failed to meet 1997 one-hour ozone standard

attain= 1 if MSA met 1997 one-hour ozone standard

^bMSAPOP = MSA population

^c If an MSA is in nonattainment of the ozone standard, the standard consolidation is used which decreases the number of cities and towns by 10% and the number of special districts by 20%.

if an MSA is in attainment of the ozone standard, the standard expansion is used which increases the number of cities and towns by 10% and the number of special districts by 20%.

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VITA

Peter Stuart Bluestone was born on October 18, 1964, in Rochester, New York. The family moved to Brighton, New York, a suburb of Rochester, in 1968. Peter graduated from Brighton high school in 1983. He completed his college education at Georgia Institute of Technology where he graduated with a Bachelor of Arts in Industrial Engineering in 1987.

In the fall of 1988, Peter enrolled at Georgia State University Law School. He graduated in 1991 and successfully set for the Georgia state bar exam. He practiced in several areas of law including, public interest environmental litigation and commodities and securities law. In the fall of 2000 he entered the doctoral program in Economics at Georgia State University. His areas of concentration were Environmental and Natural Resource Economics, Urban Economics, and State and Local Public Finance.

As a graduate research assistant, Peter worked on a variety of projects such as: The economic and legal consequences of Georgia school districts being declared unitary under current federal court guidelines. He conducted an economic and spatial analysis of local option sales taxes in Georgia counties and updated state level economic data for the Governor's office. In October 2004, Peter became a Research Associate at the Fiscal Research Center, at the Andrew Young School of Policy Studies, Georgia State University. His responsibilities include, preparing fiscal notes for the Georgia State Legislature and writing policy reports on state and local fiscal policy. He graduated with a Doctor of Philosophy degree in Economics in December 2007.