Trading Equity for Efficiency in Environmental Protection?
Environmental Justice Effects from the SO_2 Allowance Trading Program[1]

Evan J. Ringquist
School of Public and Environmental Affairs
Indiana University
Bloomington, IN 47405
eringqui@indiana.edu

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[1] Direct all correspondence to Evan Ringquist, School of Public and Environmental Affairs, Indiana University. 1315 E. 10th Street, Bloomington, IN 47404. 812.855.0732. eringqui@indiana.edu.

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Abstract

Objective: Arthur Okun made plain the fundamental conflict between efficiency and equity that arises in the pursuit of policy goals (Okun 1974). While Okun was speaking about government tax and spending policy, the potential conflict between efficiency and equity is also manifest at the nexus of two of the most far reaching changes in the environmental policy arena; the adoption of market-like tools for pollution control and the quest for environmental justice. The paper assesses this potential tradeoff by determining whether the pursuit of efficiency through the Clean Air Act Amendment's (CAA) sulfur dioxide allowance trading program (ATP) inadvertently transfers pollution into poor and minority communities.

Methods: I employ Probit, Tobit, and GLS models using data for all SO_2 trading activity between January 1995 and March 2009 to estimate whether allowance trading concentrates SO_2 emissions in poor communities and communities of color. When using these models I control for sample selectivity and for possible bias stemming from the modifiable areal unit problem.

Results: The ATP does not concentrate sulfur dioxide emissions in black or Hispanic communities. To the contrary, communities with high percentages of black and Hispanic residents experience fewer imports of sulfur dioxide. Allowance trading does transfer SO_2 emissions into poorly educated communities.

Conclusions: There is no inherent tradeoff between efficiency and equity when using market based instruments for pollution control. Policy makers, however, might make an effort to design and implement future emissions trading programs in a manner that reduces the monitoring costs of tracking emissions trading. By reducing monitoring costs, policy makers may prevent the concentration of emissions in poorly educated communities while preserving the efficiency benefits of these instruments.

1.0 Introduction

A generation ago Arthur Okun made plain the fundamental conflict between efficiency and equity that arises in the pursuit of policy goals (Okun 1974). While Okun was speaking about government tax and spending policy, the potential conflict between efficiency and equity is also manifest at the nexus of two of the most far reaching changes in the environmental policy arena; the adoption of market-like tools for pollution control and the quest for environmental justice. Environmental economists and environmental justice advocates both offer legitimate critiques of current and past practice in environmental regulation. This paper focuses upon one prominent place where these two critiques intersect, the sulfur dioxide allowance trading program (ATP) created by the 1990 Clean Air Act (CAA) amendments. The primary concern of environmental justice advocates, and the focus of my investigation, is whether by pursuing the efficient control of pollution the ATP transfers pollution into poor and minority communities. By examining all SO_2 trading activity between January 1995 and March 2009, I conclude that the ATP does not concentrate sulfur dioxide emissions in black or Hispanic communities, but that trading does transfer significant SO_2 emissions into poorly educated communities.

The remainder of the paper proceeds in five stages. Section 2 discusses the potential tradeoff between efficiency and equity in pollution control; i.e., the argument that market mechanisms for pollution control might inadvertently concentrate pollution in poor and minority communities. This section also reviews the limited empirical evidence on the topic. Section 3 describes the creation, content, and current experience with sulfur dioxide allowance trading within the federal acid rain program. Section 4 describes how I use the EPA's allowance trading and compliance databases to create three measures of the propensity and magnitude of SO_2 trading, and the effect that these trades have on the transfer of sulfur dioxide emissions. Section 5 describes the modeling approaches employed and discusses the results of several empirical models of SO_2 allowance trading behavior. Section 6 concludes.

2.0 Efficiency vs. Equity in Environmental Policy

Environmental protection policy is a quintessential example of the new social regulation that became common at the federal level during the 1960s and the early 1970s (Eisner 1993). In environmental protection, policymakers identified an important market failure (negative externalities), and addressed this failure using "command and control" regulations. These regulations were supposed to reduce pollution, while the associated improvements in environmental quality -- a public good -- were to benefit all citizens more or less equally. Over the past thirty years, policy analysts have questioned both of these aspects of pollution control policy. These criticisms have crystallized into two of the most significant changes in the environmental policy area. The first criticism took aim at the economic aspects of command and control regulation. Beginning in the mid-1970s, economists charged that traditional environmental regulations were inefficient and ineffective (see Tietenberg 1985 for a good review). These analysts argued that economic incentive approaches to pollution control would produce greater improvements in environmental quality at far lower costs. A second, more recent criticism of environmental policy has been leveled by "environmental justice" advocates who argue that environmental regulations have not benefited all citizens equally. These critics cite evidence that poor and minority communities suffer disproportionate exposures to environmental contaminants and levels of environmental risk. Concerns over environmental equity have drawn the attention of political scientists and sociologists, much as concerns over efficiency in environmental regulation drew the attention of economists over a decade earlier. Moreover, environmental justice advocates seek to reorient federal environmental policy to emphasize social justice, much as economists lobbied to reorient policy toward efficiency.

2.1 The Economic Critique of Environmental Regulation

From an economic perspective, the central drawback of command and control regulations is that they do not recognize unequal marginal costs of pollution control across firms. Firm A may be able to reduce pollution at half the cost of firm B, yet command and control regulations require both firms to meet identical pollution reduction goals. A more efficient approach would recognize heterogeneous marginal costs of control and allow firms for whom control comes more cheaply to reduce their pollution more, while firms for whom reductions are costly can reduce their pollution less. In this way, we get the same reduction in pollution at a lower cost.

Economic incentive approaches for environmental protection can be grouped into three categories; pollution taxes, subsidies, and emissions trading. The most common of these is emissions trading. Under emissions trading, the government sets the desired level of environmental quality and allocates only as many pollution permits or credits as is compatible with this predetermined level. No source can emit pollution without a permit or credit. The government then allows firms (or other actors such as environmental groups) to purchase these permits through market transactions. Firms with low costs of control will reduce their pollution more than necessary so that they can sell their permits, and high control cost firms will purchase permits rather than reduce their pollution. Emissions trading has several advantages: (i) it requires firms to reveal their marginal costs of pollution control (i.e., the price they are willing to pay for a pollution permit), (ii) it recognizes differences across firms in the marginal cost of control, and allows for varying levels of pollution reduction; (iii) because of (i) and (ii), emissions trading produces the desired level of environmental quality at lower cost; and (iv) promotes technological innovation in pollution control as firms seek ways to reduce pollution so that they can sell their pollution credits.

2.2 The Environmental Justice Critique of Environmental Regulation

Environmental justice advocates claim that traditionally disadvantaged communities are further disadvantaged in that they must endure disproportionately high levels of exposure to environmental risks. For some critics, the critical causal factor is race: higher levels of environmental risk in communities of color are one more example of institutional racism in the U.S. (Bullard 1990). For other observers, race is less important than class -- traditionally disadvantaged lower classes are targeted to receive higher levels of pollutants because they are politically unmobilized and pose less threat of opposition and delay in siting environmentally hazardous facilities (Szasz 1994). The concerns of environmental justice advocates are backed by significant empirical evidence (see Ringquist 2005 for a review).

Federal policymakers responded quickly to the concerns of environmental justice advocates. The Environmental Protection Agency (EPA) initiated its environmental justice efforts in 1990 with the creation of the Environmental Equity Workgroup. Acting on the recommendations of the workgroup, the agency created the Office of Environmental Equity (OEE, 1992), placed environmental justice coordinators in all regional offices (1993), and expanded the OEE into the Office of Environmental Justice (1994). Finally, President Clinton signed Executive Order 12898 requiring all federal agencies to conduct environmental justice evaluations of their programs, and develop plans to remedy any race and class biases in their regulatory decision making. EO 12898 is still in effect.

2.3 The Potential Conflict between Efficiency and Equity in Environmental Protection

These two developments in environmental protection policy are related. Economic incentive approaches emphasize efficiency, but policies that focus on efficiency may ignore equity (Okun 1974). Emissions trading in particular may have significant distributional consequences. Under trading, some facilities sell credits (i.e., reducing pollution more than required, making the surrounding area cleaner) while other facilities purchase credits (allowing these facilities to avoid reducing pollution and perhaps even increase emissions). Emissions trading programs embody the same goal as benefit-cost analysis – maximizing present net benefits at the firm and the societal level. While economic incentive approaches to pollution control may reduce the overall marginal costs of pollution reduction, this gain in efficiency may come at the cost of less obvious inequities in the distribution of pollution and environmental risk.

There are two links in the causal story connecting emissions trading to inequities in the distribution of pollution. First, pollution control costs are typically highest for older facilities, so newer facilities are likely to sell emission credits while older facilities are likely to purchase them. Therefore, pollution declines near new facilities and remains high or increases near older facilities. Second, many older facilities are located near the former industrial heart of cities. Over the past several decades, these areas have experienced a large influx of poor and minority residents as wealthier, white residents moved to the suburbs. Consequently, if older facilities purchase emission credits, this may transfer pollution from outlying communities into communities of the poor and people of color. In this manner, emissions trading may exacerbate existing environmental inequities (for a more complete discussion of the potential conflicts between emissions trading and environmental justice, see Chinn (1999) and Kaswan (2008)).

2.4. Previous Research

A handful of studies have examined the equity consequences of emissions trading. When studying the distributional effects of the national sulfur dioxide allowance trading program, Ringquist (1998) and Corburn (2002) find that the ATP does not transfer SO_2 into minority neighborhoods; Shadbegian, Gray, and Morgan (2007) conclude that the monetized benefits from the ATP are distributed equally across racial and ethnic groups; and the US EPA (2005) concludes that the health benefits from the ATP are distributed equally across racial, ethnic, and income categories. When studying California's

NOX trading system under the RECLAIM program, Fowlie, Howland, and Mansur (2009) conclude that changes in emissions do not vary significantly with neighborhood demographic characteristics.

If the extant literature is unanimous in concluding that there are no meaningful environmental inequities stemming from emissions trading programs, why do we need to study this question further? The results from the previous literature are suggestive but not conclusive. All previous studies of the equity effects of the ATP examine a very small number of years early in the history of the emissions trading program, and/or examine a small number of participating facilities. For example, Shadbegian et al (2007) examine the first year, Ringquist (1998) examines the first two years, and Corburn (2002) examines the first three years of trading behavior under the ATP.

Focusing on early implementation of the ATP has at least three consequences. First, all studies examine the trading behavior of only a small number of firms. Phase I of the ATP, described in greater detail below, ran from 1995 through 1999 and included only 110 electric generating facilities east of the Mississippi River. By contrast, Phase II of the ATP (2000-2010) covered nearly 2000 polluting facilities nationwide. By restricting their analysis to the first three years of ATP implementation, Ringquist (1998), Corburn (2002), and Shadbegian et al. (2007) exclude the trading behavior of over 90% of the facilities covered by the ATP. Second, the level of allowance trading was relatively low in 1995-1997 (see figure 1). Between 1995 and 2008, over 255 million allowances were traded under the ATP, but only 49 million of these occurred before 1998. Previous research, then, excludes information from 80% of allowances traded under the ATP. Third, during the early years of the ATP, more than 70% of allowances were traded between different generating units at the same physical location (i.e., different boilers at the same power plant). These trades cannot transfer pollution spatially. By contrast, after 1998 fewer than 50% of trades were intra-facility transactions. Over 87 percent of allowance trades that had the effect of transferring pollution spatially occurred outside of the temporal window considered in previous studies. Therefore, conclusions from these studies may not be representative of the ATP overall.

[Figure 1 About Here]

In addition, several studies examine equity effects at the regional level (Fowlie et al 2009) or examine the long range transport of sulfates (Shadbegian et al. 2007; US EPA 2005), rather than the localized concentrations of SO_2 emissions. By examining the local concentration of sulfur dioxide attributable to emissions trading between 1995 and 2009, I hope to provide more conclusive evidence regarding any equity effects from emissions trading.

3.0 The Sulfur Dioxide Allowance Trading Program

The Acid Rain Program (ARP) was established in Title IV of the 1990 Clean Air Act Amendments. The goal of the ARP is to reduce sulfur dioxide emissions by 50 percent from 1980 levels by 2010 (i.e., by about 8 million tons). The goal of a 50 percent emission reduction is to be attained in two phases. In Phase I (1995-1999), the 1990 CAA placed new emissions limits on the 110 dirtiest coal fired utilities in 21 eastern and Midwestern states. Beginning in 1995, each of these Phase I power plants had to meet increasingly stringent emissions limitations. Electric power generators regulated under the ARP had several options for meeting the new emission limits; they might install more effective pollution control equipment, switch to a different electrical generation process, switch to a less polluting fuel, or purchase pollution allowances from other sources. The last option, of course, has received the most attention from scholars and the media, and is increasingly popular among utilities. An allowance is essentially a permit or a coupon, and each allowance entitles the owner to emit one ton of sulfur dioxide. The EPA gave allowances equal to 5.7 million tons of sulfur dioxide to Phase I power plants free of charge, allocating them based upon each unit’s baseline fuel consumption and emission levels during 1985-87. Each year EPA reduced the allowances allocated to each Phase I power plant; thus, the plants either reduced their emissions or purchased additional allowances from other sources. Phase I utilities could also meet these emissions targets by reducing emissions at other “substitution” or “compensating” generating stations.

Phase II of meeting the emissions reduction goal began in 2000 when all fossil fuel fired power plants and other industrial electrical generating stations were brought in to the ARP. Beginning in 2000, EPA began allocating pollution allowances to each of the more than 2000 facilities covered by Phase II. Facilities that began operation after 1996 were ineligible to receive allowance allocations from EPA, and instead had to purchase these allowances on the open market or from the EPA. Allowances for all Phase II facilities were reduced each year until the number of allowances equaled the sulfur dioxide emissions goal of 8.95 million tons in 2010. Like Phase I facilities, after 2000 Phase II utilities had to either reduce their emissions or purchase additional pollution allowances to meet these increasingly stringent emission requirements (US EPA 1998). Finally, any utility, independent power producer, or industrial generating facility that is not required to participate in the ATP may “opt-in” to the program and receive sulfur dioxide allowances (a unit may choose to opt in if it feels it can reduce its emissions cheaply and sell the extra allowances at a profit). Each Phase I, Phase II, and opt-in unit must obtain an acid rain permit from the EPA and file a compliance plan outlining how it will meet emissions requirements. Regulated facilities whose emissions exceed their allowances are fined $2,000 per ton of excess emissions, adjusted for inflation (currently, the fine is roughly $3500 per ton). Regardless of how many allowances are held by the owners of a particular facility, emissions from this facility may not exceed the standards established by Title I of the 1970 CAA or by relevant state regulations.

Electric utilities and other units regulated under the ARP can obtain additional allowances through at least six methods. First, additional allowances may be purchased from the EPA at annual allowance auctions. In Phase I, EPA auctioned 150,000 additional allowances each year from an allowance reserve fund held by the agency. In Phase II, EPA auctions 200,000 additional allowances each year.[2] From 1995-2006 these auctions were managed by the Chicago Board of Trade, but they are now administered directly by EPA. EPA allowance auctions are always over-subscribed. Second, buyers may purchase additional allowances placed for sale by others on the Chicago Board of Trade. Third, buyers may purchase additional allowances from one of the many allowance brokers that purchase and hold allowances for resale. Fourth, buyers may purchase allowances directly from other utilities and regulated units. Fifth, allowances can be transferred between generating units within the same utility or utility holding company though intra-utility transfers (EPA stopped monitoring these intra-facility transfers in 2006). Finally, if a utility invests in energy conservation or the production of energy from renewable sources, it may obtain allowances for a portion of the sulfur dioxide emissions avoided through these investments from the EPA’s conservation and renewable energy allowance reserve. Allowance sales, however, are not limited to electrical generating units regulated under the ARP. Nearly anyone can buy or sell emission allowances. Permits to emit sulfur dioxide have been purchased by smelters, factories, environmental groups -- even elementary school students. According to officials at the EPA, "A guiding principle of the Acid Rain Program has been for EPA to minimize its role in the allowance market" (Solomon 1994, 12). This means that EPA places no geographic,

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[2] A smaller number of allowances is available for direct purchase from the EPA. These allowances, however, are generally reserved for new independent power producers.

temporal, or other restrictions on allowance trading. Moreover, unlike previous market incentive approaches in air pollution control, the EPA plays no role in approving or disallowing allowance sales.

The EPA has two tools with which to monitor compliance with the ARP. First, the agency monitors allowance trading activity through the Allowance Tracking System (ATS). The ATS is an automated system that tracks the sale, purchase, trade, and retirement of pollution allowances. Each allowance has a unique 12 digit identification number to facilitate tracking transactions. In effect, the ATS acts much like a bank where each regulated entity has an account and where the EPA maintains several general accounts (e.g., the conservation and renewable energy reserve). Initially, reporting allowance transactions to the ATS was voluntary, but reporting has been mandatory since 1998.[3] Second, under the ARP any electric generation unit larger than 25 MW and all new generating units smaller than 25 MW that use high sulfur fuels must continuously monitor their emissions of sulfur dioxide and other pollutants. These emissions data, aggregated hourly, are reported to EPA on a quarterly basis and stored in the Emissions Tracking System, EPA's largest database. The EPA can easily compare the number of allowances in facility ATS accounts with the emissions record in the ETS to determine if emissions exceed allowances.

The acid rain program will be fully implemented in 2010. Moreover, the Clean Air Interstate Rule (CAIR) embodies significant changes in the ARP. Beginning in 2010, regulated utilities in the Eastern U.S. will have to surrender two allowances for each ton of sulfur dioxide released to the atmosphere. In 2015, these same utilities must surrender 2.86 allowances for each ton of sulfur dioxide emissions. Given these important changes, this is an especially opportune moment to study the effects of the acid rain program.

4.0 Measuring SO_2 Transfers under the ATP

4.1 Measuring SO_2 Transfers

I obtained allowance trading records for all facilities participating in the sulfur dioxide allowance trading program between January 1995 and March 2009 (the end of the 2008 program year). When measuring allowance transfers it is important to distinguish between *vintage years* and *program years.* Allowances are issued for vintage years and redeemed during program years. For example, under the ARP Facility A may be entitled to 50,000 SO_2 allowances each year between 2000 and 2010. EPA will

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[3] EPA believes that the vast majority of early allowance transactions were reported to the ATS (US EPA 1998).

allocate to Facility A 50,000 vintage year 2000 allowances, 50,000 vintage year 2001 allowances, etc. Facilities can use allowances for the current and previous vintage years to settle emissions accounts in the current program year, but cannot use allowances from future vintage years to settle accounts in the current program year. That is, firms may bank or carry forward allowances from previous vintage years, but they may not borrow allowances from future vintage years.

I calculate the net transfer of sulfur dioxide allowances from this data set using the following formulas.

[1] A_{itv} = Allowances allocated to facility i for vintage year t.

[2] R_{itp} = Allowances redeemed by facility i in program year t.

[3] B_{itp} = $A_{itv} - R_{itp}$ where v=p

Allowances banked by facility i in program year t

$B_{itp} >= 0$, because if $R_{itp} > A_{itv}$, the remainder must come from purchased allowances or previously banked allowances. Negative values of B_{itp} cannot be carried over to new program years.

[4] T_{itp} = $A_{itv} + \sum^{v}_{t=1} B_{itp} - R_{itp}$

Net allowance transfers

Equation 4 shows that net allowance transfers for any facility are the sum of allocations for the current vintage year and all banked allowances from previous vintage years, minus allowances redeemed in the current program year. An example might help clarify this calculation. Assume facility A receives an initial allocation of 50,000 allowances for vintage years 1, 2, and 3 (i.e., A_{itv} = 50,000 for tv=1, 2, and 3). If facility A redeems 40,000 vintage year 1 allowances in program year 1(R_{i1}=40,000), it can bank the remaining allowances ($B_{i1} = \sum^{v}_{t=1} B_{it} = 10{,}000 = T_{i1}$). In program year 2, facility A redeems 45,000 allowances, banking the remaining 5,000 allowances, so that now B_{i2}=5000 and $T_{i2} = \sum^{v}_{t=1} B_{itp} = 15{,}000$. In program year 3, facility A increases capacity and/or output and redeems 70,000 allowances (R_{i3}). With an initial allocation of only 50,000 allowances for vintage year 3 (A_{i3}), facility A must redeem an additional 20,000 allowances; 15,000 of these will be drawn from allowances banked from previous vintage years ($\sum^{v}_{t=1} B_{itp}$, or T_{i2}), with the remaining 5,000 being purchased from EPA, brokers, or other facilities. In program year 3, then, T_{i3} = -5,000, and $\sum^{v}_{t=1} B_{itp}$ =0 going in to program year 4. Note that T_{itp} is negative if a facility imports pollution to its location. Our discussion will be easier to follow if net imports of pollution receive positive values, so our measure of net pollution transfers employs the following transformation:

$$[5] \qquad SO_2 \text{ Imports} \quad = \quad (T_{itp}) * (-1)$$

With this transformation, negative values for SO_2 imports represent allocated allowances that a facility has not redeemed. These allowances may be banked or sold by the facility, but we do not distinguish between these two potential outcomes. In this paper I only measure the difference between levels of pollution that a facility *could* have released given its allocation of allowances, and the pollution that *was* released as measured by the redemption of allowances.

Figure 2 shows that the distribution of SO_2 imports is centered around 0 (most facilities in most years redeem almost all of their allocated allowances), with a strong negative skew. Far more facilities bank or sell allowances than import them. This distribution is consistent with the general conclusion that the sulfur dioxide allowance trading program has produced significant reductions in overall SO_2 emissions (Ellerman et al. 2000).

[Figure 2 about here]

4.2 Three Dependent Variables

I use the measure of SO_2 imports from equation [5] to craft three dependent variables. First, I simply examine whether a facility is a net importer of sulfur dioxide. To answer this question, I dichotomize SO_2 imports so that facilities that import and redeem allowances in program year t receive a value of 1, and facilities that do not receive a value of 0. This variable takes on a value of 1 in roughly 37 percent of facility-years.

The central question is whether facilities in poor and/or minority communities redeem SO_2 allowances in excess of their allocations. The second dependent variable, then, simply measures the magnitude of SO_2 imported by a facility. This variable takes on a value of zero for all facilities where imports are less than or equal to zero, and takes on the value from equation [5] where imports are greater than zero. We observe 3402 facility-years in which net SO_2 imports are positive. Imports are positively skewed. The mean number of allowances imported in a particular year is 2177, with a median of 10 allowances and a maximum value of 255313 allowances. We observe 1373 facility-years where imports exceed 1000 allowances.

Finally, we may be interested in net SO_2 imports arising from the allowance trading program, not simply which facilities import pollution. That is, we might be interested in the difference between actual and potential SO_2 emissions for all facilities in all years in our sample, regardless of whether this difference is positive or negative (i.e., the entire range of values on the variable calculated in equation [5]). When using this variable, however, we need to take care when interpreting negative values. Negative values arise when allocations exceed redemptions during any particular period. The remaining allowances can be banked or sold, but we do not know which. Therefore, it is important to view these negative values as a measure of unrealized pollution potential, rather than as a measure of allowances banked or sold. We observe some level of SO_2 trading in 6202 facility-years, or in roughly 63 percent of the 9565 facility-years where trading might take place. Summary statistics for this variable reflect the predominance of banking/sales behavior over allowance importation: the mean value for this variable is -31629 allowances, the median is -2315, and the minimum value is -1,923,077 allowances. The maximum value for this variable is 255313, the same maximum value from the second dependent variable.

Appendix 1, included for reviewers, illustrates that allowance trading under the ATP is a nationwide phenomenon. Virtually all states contain facilities that import and bank or export substantial volumes of SO_2 allowances.

5.0 Modeling SO_2 Imports under the ATP

5.1 Model Construction

5.1.1. Defining "Affected Community" in Environmental Justice Research. The central question for this study is whether the ATP has the effect of importing SO_2 emissions into poor and minority communities. There is significant debate among environmental justice scholars regarding the appropriate spatial definition of "affected community." Commonly used levels of spatial aggregation include counties, ZIP codes, census tracts, and circular areal units defined using facility latitude-longitude coordinates and GIS software. Early research encouraged the use of smaller spatial units in an effort to avoid aggregation bias (e.g., Anderton et al. 1994). A meta-analysis of the environmental justice literature, however, showed no systematic differences in measures of inequity attributable to spatial aggregation (Ringquist 2005).

I define affected community in two ways. First, consistent with much of the previous work on environmental justice, I define a spatial community using five-digit residential ZIP codes. Second, I define a spatial community using 1 and 3 mile radii centered upon facilities engaging in emissions trading under the ATP. I employ this second definition of affected community because the most important lesson from the work of Mohai and Saha (2007) is that using *any* administrative unit -- county, ZIPcode, census tract, etc. – to define affected community runs the risk of introducing bias into estimates of environmental equity. I use the areal apportionment method to measure the characteristics of the population residing within one and three miles of facilities engaging in pollution trading.

5.1.2. Selection Issues in Estimating Equity Effects of the ATP. With these two definitions of community, we can refine the central question as whether facilities in ZIP codes/1 mile radius circles/3 mile radius circles with large percentages of black, Hispanic, and/or poor residents are more likely to import SO_2 allowances. One method of answering this question is to treat the polluting facility as the unit of analysis, employ a measure of net SO_2 allowance trading as the dependent variable in a general linear model, and predict this dependent variable using the demographic and economic characteristics of communities surrounding these facilities. The few studies examining this question have approached it in just this manner (Ringquist 1998; Corburn 2002; US EPA 2005).

The allowance trading program cannot concentrate SO_2 emissions in a community if the community does not have a facility eligible to participate in the ATP. A drawback of the empirical approach described in the previous paragraph is that it assumes that facilities eligible to participate in the ATP are distributed independently of the racial and class characteristics of communities. If polluting facilities are distributed in part based upon the characteristics of the surrounding community – that is, if polluting facilities are concentrated in poor or minority communities – the approach employed in previous work will produce biased and inconsistent estimates of the equity effects of allowance trading (e.g., Moffitt 1991). The assumption that facility location is independent of the demographic and economic characteristics of neighborhoods is at odds with most of the research in environmental justice (e.g., Ringquist 2005; Mohai and Saha 2007). Therefore, we should model the effects of allowance trading as conditional upon the location of polluting facilities; i.e., they are jointly determined.

The standard solution for this problem is to employ a two-equation model where the first equation predicts whether a community contains a facility eligible to participate in the ATP (the selection model) and the second equation predicts the outcome or effect of allowance trading (the structural model) (Heckman 1979; Puhani 2000). Controlling for sample selection in this manner requires a unit of analysis that is defined prior to the assignment of units to treatment and control groups. Moreover, all observations must be able to be assigned to either the treatment group or the control group. For example, if one wants to examine the effect of school vouchers on educational attainment, one first has to predict which students receive a voucher and which do not, and then condition estimates of the effect of vouchers on the probability that a student receives a voucher. We define the unit of analysis – the student – before assigning students to treatment and control groups using the receipt of vouchers, and the sample is fully defined by students that receive and do not receive vouchers. By the same token, if we want to examine whether SO_2 trading concentrates pollution in poor and minority communities, we need to predict which communities will contain an ATP eligible facility, and condition estimates of the effects of facility trading on the probability that a community contains such a facility. In this example, we define the unit of analysis – e.g., ZIP codes – before assigning units to "treatment" and "control" groups based upon whether they contain an ATP eligible facility, and the sample is fully defined by ZIP codes that contain and do not contain these facilities. When defining affected communities using the GIS areal apportionment method, however, the unit of analysis is defined simultaneously with the treatment group. While treatment group communities are defined as residents living within 1 or 3 miles of an ATP eligible facility, there is either (a) no corresponding control group (i.e., no pre-determined set of areas that do not contain facilities), or (b) an infinitely large control group made up of all possible 1 and 3 mile circles in the US that do not contain eligible facilities. In either case, it is impossible to estimate a selection equation.[4]

Therefore, I use two modeling strategies. To control for potential bias arising from the nonrandom distribution of polluting facilities I estimate two equation sample selection models where

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[4] Mohai and Saha (2007) establish control groups by identifying a number of 1, 2, and 3 mile radii circles not containing facilities equal to the number of facilities defining treatment groups. This approach arbitrarily excludes an infinite number of potential control group communities and large areas of the United States, with unknown effects on model results.

affected communities are defined using 5 digit residential ZIP codes. To control for potential bias arising from the unit-hazard coincidence problem (i.e., from using ZIP codes) I estimate structural models where affected communities are defined using GIS areal apportionment.

5.1.3. The Structural Model. To estimate the effect that allowance trading has on SO_2 emissions in communities of color, I use variables measuring the percentage of black households and the percentage of non-white Hispanic households in each community. To estimate any class biases in the effects from allowance trading I use a variable measuring the percentage of households in a community with incomes below the poverty line. If allowance trading concentrates sulfur dioxide emissions in poor communities and communities of color, parameter estimates for these variables will be positive. Note that these hypotheses are not causal – we do not expect the race, ethnicity, or economic resources of area residents to influence facility trading behavior. Any significant correlations should be interpreted as unintended equity effects from allowance trading that is motivated by efficiency.

Allowance trading behavior on the part of firms may be influenced by the ability of area residents to monitor and mobilize against the large scale importation of pollution (e.g., Hamilton 1995). Therefore, in addition to the race, ethnicity, and poverty variables, the structural model includes two variables measuring the capacity to engage in monitoring and political action: the percentage of adult residents that do not have a high school diploma, and the percentage of dwellings that are owner-occupied. Poorly educated residents have a lower capacity to monitor firm trading behavior, while both education and home ownership are strongly related to political activity (Rohe, van Zandt, and McCarthy 2002). If firm trading behavior is affected in the manner hypothesized here, SO_2 imports should be positively related to the proportion of residents without a high school diploma (where residents have lower monitoring capability) and negatively related to the proportion of owner occupied homes (where residents are more politically active).

Finally, the structural model includes four control variables. First, firms may seek to limit public opposition to pollution emissions and/or minimize pollution exposure to the surrounding population. To account for this possibility, I include a variable measuring the population density of affected communities. Second, the supply of allowances (A_{itv}) may affect the propensity of a firm to engage in allowance trading and the volume of these trades. Third, the propensity to import pollution and the level of imports should be positively related to the pollution intensity of the facility. I measure pollution intensity as the pounds of sulfur generated each year per megawatt of electricity generating capacity at the facility.[5] Ceteris paribus, facilities with a larger supply of allowances will be more likely to sell them, while pollution intensive facilities will be more likely to purchase allowances, thereby importing pollution. Finally, figure 1 shows that allowance trading has increased over time. To control for the maturation of the SO_2 allowance market, I include a time counter variable.

5.1.4. The Selection Model. Not all ZIP codes contain polluting facilities, so the dependent variable in the selection model takes on a value of 1 for ZIP codes containing these facilities and 0 for ZIP codes without them. Ringquist (2008) proposes that environmental justice research ought to consider multiple explanations for the location of noxious facilities. Following this advice, the selection model predicts the distribution of polluting facilities using variables representing market forces (property values, measured by the median housing value); the potential political power of area residents (measured by the percentage of adult residents without a high school diploma, median household income, and median household income squared); and the racial and ethnic characteristics of communities (measured as the percentage of black households and non-white Hispanic households). These are standard predictors of facility location in the environmental justice literature. Note that the median household income and median housing value variables are unique to the selection model, which substantially improves the predictions from the structural model (Wooldridge 2002).

5.2 Modeling the Propensity to Import SO_2

I model the propensity of a facility to import sulfur dioxide in any year utilizing the structural model described in section 5.1.3 and the dichotomous dependent variable described in section 4.2. When defining affected community using residential ZIP codes I also utilize the selection model described in section 5.1.4, and parameter estimates are obtained using a bivariate Probit model with sample selection estimated using full information maximum likelihood (Heckman 1979; Pulani 2000). When affected communities are defined using GIS areal apportionment, parameter estimates are obtained using a standard Probit model. Results are reported in table 1.

[Table 1 about here]

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[5] These data were obtained from FERC form 826.

The selection model demonstrates that the location of facilities eligible to participate in the ATP – mostly electric generating plants and large industrial facilities -- is strongly related to the racial and ethnic character of communities. Specifically, the probability that a ZIP code contains a facility engaging in allowance trading increases substantially with the percentage of black and Hispanic households. Market forces also matter, as ZIP codes with high property values are significantly less likely to contain these facilities. Finally, the potential political power of area residents is significantly related to the distribution of polluting facilities, as these facilities are more likely to be located where large percentages of residents do not have high school diplomas. The selection equation also shows the curvilinear relationship between income and facility location that is so common in environmental justice research: the probability that a ZIP code contains a polluting facility first increases and then decreases with income (i.e., polluting facilities tend to be located in working class communities, but not in exceptionally poor or wealthy communities).

The ZIP code structural model presents no evidence that the probability a facility will import SO_2 is positively related to the racial or ethnic characteristics of the community. Parameter estimates for the black and Hispanic household variables are negative, with the Hispanic parameter significantly different from zero. If there is an equity effect from allowance trading in this model, it works to the advantage of communities of color; e.g., a ten percent increase in the percentage of Hispanic households in a ZIP code is associated with a 4.1 percent decrease in the probability that a facility in that ZIP code will import SO_2 allowances (see figure 3). On the other hand, the probability that a facility will import sulfur dioxide allowances is negatively related to the education level of area residents; a 10 percent increase in the percentage of adult residents without a high school diploma is associated with a 5.6 percent increase in the probability that a facility will import pollution. Somewhat unexpectedly, there is also a positive relationship between the percentage of homeowners in a ZIP code and the probability that a facility will import sulfur dioxide allowances; a ten percent increase in the former is associated with a 4.5 percent increase in the latter. The control variables generally display coefficient estimates in the expected directions; facilities in densely populated areas are less likely to import pollution, facilities with large supplies of allowances are less likely to import them; and the probability of SO_2 imports increases over time. Pollution intensity is independent of the propensity to import SO_2 in specification 1.

[Figure 3 About Here]

Surprisingly, the error terms of the selection and structural models in table 1 are only weakly correlated, suggesting that there are no unobserved factors causing the location of pollution facilities and the decision to import SO_2 allowances to be jointly determined. In this situation, there is little risk of bias in the Probit parameters from the GIS areal apportionment models. The results from these models are consistent with those from the ZIP code model. Most importantly, there is no evidence that facilities in poor or minority communities are more likely to import SO_2. Parameters for the black and Hispanic household variables are negative, as is the parameter for the percentage of households in poverty. The parameter estimate for Hispanic households is significantly different from zero when defining affected communities using 3 mile and 1 mile radii, while the parameter for black households is significantly different from zero only when defining affected communities using a 1 mile radius. The size of these effects is small: a 10 percent increase in the proportion of black or Hispanic households within 1 mile of a facility is associated with a 0.8 percent and 3.2 percent reduction in the probability that the facility will import SO_2 allowances, respectively. In the GIS models we again find that the probability that a facility will import SO_2 allowances increases with the percentage of poorly educated residents. For example, a 10 percent increase in the proportion of residents without a high school diploma within 3 miles of a facility is associated with an 8.9 percent increase in the likelihood that the facility imports SO_2.[6]

5.3 Modeling the Magnitude of SO_2 Imports

The second analysis predicts the importation of SO_2, measured in tons, by any facility during any year. The structural model described in section 5.1.3 is used to predict the positive definite (left censored) dependent variable described in section 4.2. When defining affected communities using residential ZIP codes, I also use the selection model described in section 5.1.4. Parameter estimates are obtained using Tobit for the structural equations and Probit for the selection equation (Wooldridge 2002). Results are reported in table 2.

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[6] Standard practice in environmental equity research is to obtain separate estimates of equity effects for black, Hispanic, and poor residents. Independent effects are interesting in their own right, and are most relevant for policy makers since race and ethnicity define protected classes eligible to seek remedy for discriminatory practices while income status does not. Nevertheless, these factors are often highly correlated, so estimating their effects independently may underestimate overall inequities attributable to race, ethnicity, and income. Therefore, I combined the black, Hispanic, and poverty variables into a single standardized summed index and entered this variable into the structural equations in table 1. The parameter estimate for this variable was uniformly negative and significantly different from zero, indicating no meaningful aggregate inequities stemming from allowance trading.

[Table 2 About Here}

Parameter estimates for the selection equation in table 2 differ from those in table 1, but they tell a similar story. ZIP codes with large percentages of black and Hispanic residents are more likely to contain polluting facilities. ZIP codes with high property values are significantly less likely to contain these facilities, and the income of area residents has a parabolic relationship with the probability of facility location. One substantial difference is that the percentage of area residents without a high school diploma is not an important predictor of facility location in table 2. A second difference is the larger and significant correlation between the error terms in the selection and structural equations, validating the choice to estimate the equity effects of allowance trading as conditional upon the location of polluting facilities.

[Figure 4 About Here]

The results for the structural equation using ZIP codes are also similar to those from table 1. The percentage of black and Hispanic residents is inversely related to the magnitude of sulfur dioxide imports, and both parameter estimates are significantly different from zero. A ten percent increase in black households is associated with a 410 ton reduction in pollution imports, while a ten percent increase in Hispanic households is associated with an 816 ton reduction (see figure 4). A ten percent increase in the percentage of residents without a high school diploma, however, increases SO_2 allowance imports by 1072 tons. Home ownership continues to display a counter-intuitive relationship; a 10 percent increase in the number of homeowners in a ZIP code is associated with a 351 ton increase in SO_2 imports. Poverty levels are independent of pollution imports. The control variables in table 2 have a different effect on the magnitude of sulfur dioxide imports than they do on the propensity to import pollution. As expected, the magnitude of SO_2 imports is positively associated with pollution intensity, and sulfur dioxide imports increase over time. On the other hand, population density is independent of SO_2 imports, and contrary to expectations, facilities with large allowance allocations import more allowances.

The statistically significant correlation between the errors from the selection and structural equations means that we ought to take care when interpreting the results from the two structural models defining affected communities using the GIS areal apportionment method. Since the magnitude of this correlation is small, however (0.26), any bias in the parameters from the GIS models is likely to be small as well. When we define affected communities using residents within 1 or 3 miles of polluting facilities, the results are consistent with those from the ZIP code model. Most importantly, the GIS models in table 2 provide no evidence that imports of SO_2 allowances are larger for facilities surrounded by large percentages of black or Hispanic residents. Once again, the parameter estimates for the percentage of black and Hispanic households is negative and significant, suggesting that facilities in minority communities import less SO_2. Moreover, the magnitude of this negative relationship is larger than we find in the ZIP code model: e.g., a 10 percent increase in black and Hispanic residents living within 3 miles of a polluting facility is associated with 703 and 2151 ton reductions in SO_2 imports, respectively.[7] While poverty also has a negative relationship with SO_2 imports, this parameter is statistically different from zero only in the 3 mile radius model. Finally, the GIS models show a positive relationship between SO_2 allowance imports and the percentage of poorly educated residents. For example, a 10 percent increase in the proportion of residents without a high school diploma within 3 miles of a facility is associated with a 6628 ton increase in allowance imports.[8]

5.4 Modeling Net SO_2 Imports

The final analysis models net SO_2 allowances imports, measured in tons, by any facility during any year. I model net SO_2 imports utilizing the structural model described in section 5.1.3 to predict the continuous, uncensored dependent variable described in section 4.2. When defining affected communities using ZIP codes I also use the selection model described in section 5.1.4. Parameter estimates are obtained using OLS for the structural equations and Probit for the selection equation (Heckman 1978). Results are reported in table 3.

[Table 3 About Here]

Parameter estimates for the selection equation in table 3 tell a story identical to that from table 2, so the discussion here will focus on the results from the structural model. The percentage of black and Hispanic residents in a ZIP code is inversely related to net SO_2 imports, and both parameter estimates

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[7] The larger coefficients may be an artifact of uncontrolled selection bias.

[8] I also combined the black, Hispanic, and poverty variables into a single standardized summed index and entered this variable into the structural equations in table 2. The parameter estimate for this variable was uniformly negative and significant, indicating no meaningful aggregate inequities stemming from allowance trading.

are significantly different from zero. A ten percent increase in black households is associated with a 10,010 ton reduction in net imports, while a ten percent increase in Hispanic households is associated with a 15,196 ton reduction (see figure 5). Consistent with what we saw in tables 1 and 2, rather than concentrating SO_2 in areas with high percentages of minority residents, allowance trading appears to work to the advantage of these areas. On the other hand, we see again that allowance trading has the effect of concentrating SO_2 emissions in poorly educated communities. A 10 percent increase in the percentage of adult residents is associated with a 3833 ton increase in net SO_2 imports. In addition, table 3 reports the first evidence that allowance trading may concentrate pollution in poorer communities; a 10 percent increase in the percentage of households below the poverty line is associated with a 325 ton increase in net allowance imports. We should be careful when interpreting this parameter estimate as evidence of environmental inequity. Recall that the mean value for the net SO_2 import variable is -31629 tons. Holding all other independent variables at their mean values, then, a 10 percent increase in the percentage of households in poverty does not increase pollution in an absolute sense – it is simply associated with smaller reductions in emissions. Home ownership is unrelated to net sulfur dioxide imports in table 3, and the control variables again largely conform to expectations. As expected, facilities with large allowance allocations import fewer allowances, pollution intensive facilities are more likely to import SO_2 allowances, and net SO_2 imports have increased over time. Somewhat unexpectedly, population density is positively related to net SO_2 imports 3.

[Figure 5 About Here]

The correlation between the selection and structural models in table 3 is very large (-0.91) and statistically significant. The correlation indicates that unmeasured factors *increasing* the probability a ZIP code will contain a polluting facility also *decrease* net SO_2 allowances traded. A large a negative correlation between the selection and structural models suggests that estimating the structural model alone is likely to produce badly biased parameters that are often of the wrong sign. This is exactly the situation we observe in table 3. When controlling for selection bias in the ZIP code models, we estimate a negative relationship between the race and ethnicity of area residents and net imports of SO_2. In the GIS models that do not control for selection bias, however, we estimate a positive relationship between the percentage of black residents and net SO_2 imports. In fact, most of the parameters from the GIS models are signed opposite to those from the ZIP code models. To be clear, this is not a result of using different spatial definitions of affected community. Estimates from the ZIP code and GIS models in tables 1 and 2 – where the selection and structural equations are only weakly correlated -- are fully comparable. Moreover, if we estimate only the structural ZIP code model in table 3, the results are biased in the same way as those from the GIS models (e.g., the parameter for the percentage of black residents is 251.76). Differences between the ZIP code and GIS results in table 3 are driven wholly by the inability to control for selection bias using GIS areal apportionment. The results from the GIS models in table 3 serve as an example of the potential consequences of failing to control for sample selection where it exists.[9] [10]

6.0 Discussion and Conclusions

Several observers have raised concerns about the equity effects of market based environmental policy instruments in general and emissions trading systems in particular (e.g. Chinn 1999). A handful of previous studies have investigated this question and found that emission trading has not created pollution "hot spots" within poor and minority communities. While these studies offer some reassurance that there is not an inevitable tradeoff between efficiency and equity in environmental protection, their conclusions should be viewed as provisional because they focus on very short periods of time immediately following the inception of pollution markets (e.g., Ringquist 1998, Corburn 2002; Shadbegian et al. 2007), on small-scale pollution markets (e.g., Fowlie, et al. 2009), study the trading behavior of a small number of polluting facilities (e.g., Corburn 2002; US EPA 2005), or examine equity effects at a regional rather than a local level (US EPA 2005).

By contrast, this analysis focuses on the largest emissions trading market in the United States (the ATP), examines the trading behavior of nearly two thousand polluting facilities over a 14 year period, and investigates potential environmental inequities at the local level. From this analysis I conclude that the sulfur dioxide allowance trading program does not produce the unintended consequence of

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[9] I also combined the black, Hispanic, and poverty variables into a single standardized summed index and entered this variable into the structural equations in table 3. The parameter estimate for this variable was uniformly negative, indicating no meaningful aggregate inequities stemming from allowance trading.

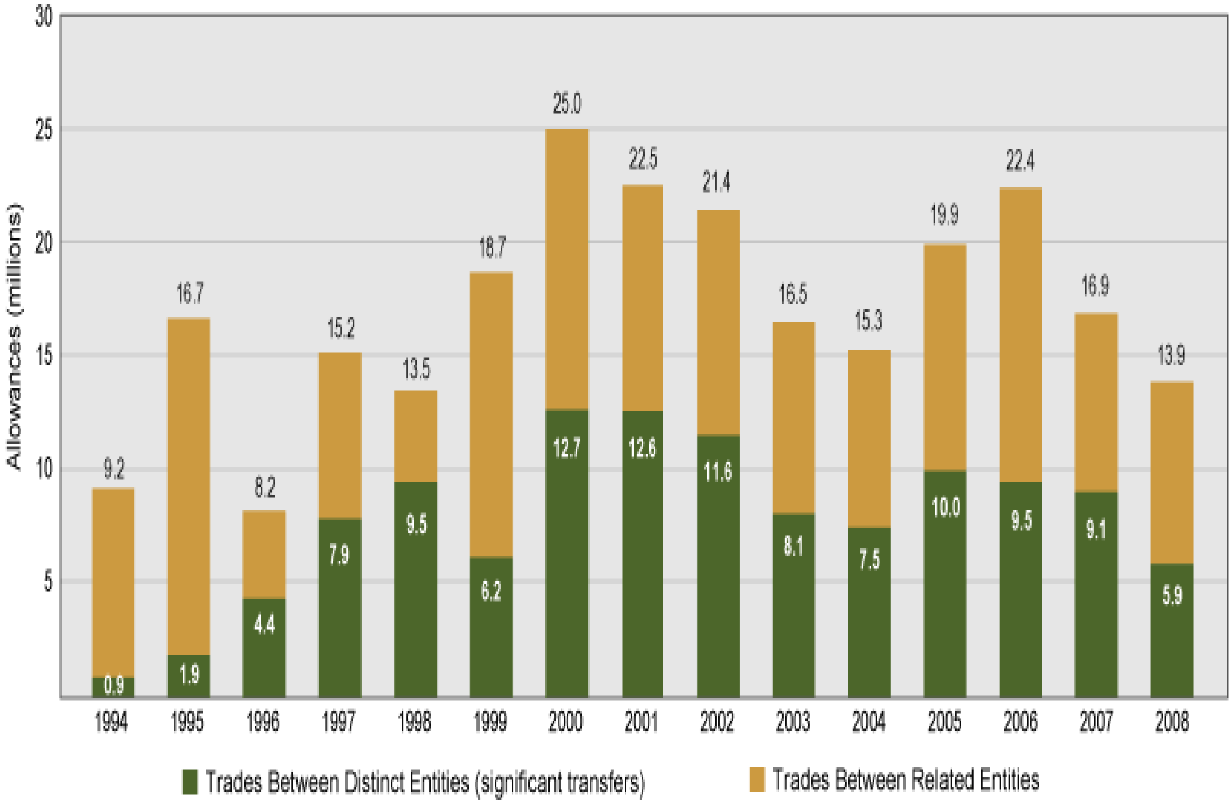
[10] Net allowance trades are highly skewed, so the results in tables 1-3 may be driven by a few facilities importing large numbers of allowances. To test for this, I re-estimated all models using only those observations below the 90th percentile of allowance imports. All statistical results remain unchanged.

concentrating SO_2 emissions in black and Hispanic neighborhoods; i.e., emissions trading does not produce racial or ethnic environmental inequities. In fact, there is a negative relationship between the percentage of black and Hispanic households in a community and the probability that polluting facilities will import SO_2 and the magnitude of these imports. The ATP pollution market, it seems, may play a role in remedying existing environmental inequities. These results are robust across different dependent variables, different definitions of affected community, and different model specifications. There is also scant evidence that markets for sulfur dioxide concentrate pollution in poor communities.

The SO_2 allowance market is the oldest and largest pollution market in the US, but it is not the only one. Similar national markets exist for oxides of nitrogen (NOx), and regional markets exist for a number of pollutants including volatile organic compounds (in California) and carbon dioxide (CO_2) (in New England). Moreover, markets have been proposed as mechanisms to control domestic mercuty pollution, and most observers believe that an international market for CO_2 trading is likely to be a central part of any agreement to address climate change. A natural question, then, is whether the results regarding the equity consequences of SO_2 trading apply to other allowance trading programs. There is a growing literature in environmental economics that assesses what types of environmental problems are best suited to emissions trading (e.g., Richards 2000), but further research is required to determine whether such trading may generate inequities in the distribution of these pollutants.

Finally, the analysis uncovers one potentially problematic result; allowance trading appears to concentrate SO_2 emissions in communities having large percentages of adults without a high school diploma. This effect is generally smaller than the positive effects associated with race and ethnicity, and this result may be less relevant for public policy since the poorly educated are not a protected class under the 1964 Civil Rights Act and its associated regulations. If additional research examining other emissions trading programs establishes the generalizability of these results, policy makers might make an effort to design and implement future emissions trading programs with an eye toward minimizing the costs of monitoring pollution trading on the part of area residents. By reducing monitoring costs, policy makers may provide safeguards against concentrating emissions in poorly educated communities while preserving the efficiency benefits of these instruments.

Figure 1: SO_2 Allowance Trading Activity 1994-2008



Source: http://www.epa.gov/airmarkets/progress/ARP_4.html

Figure 2: Net Imports of SO_2 Allowances by ZIP Code

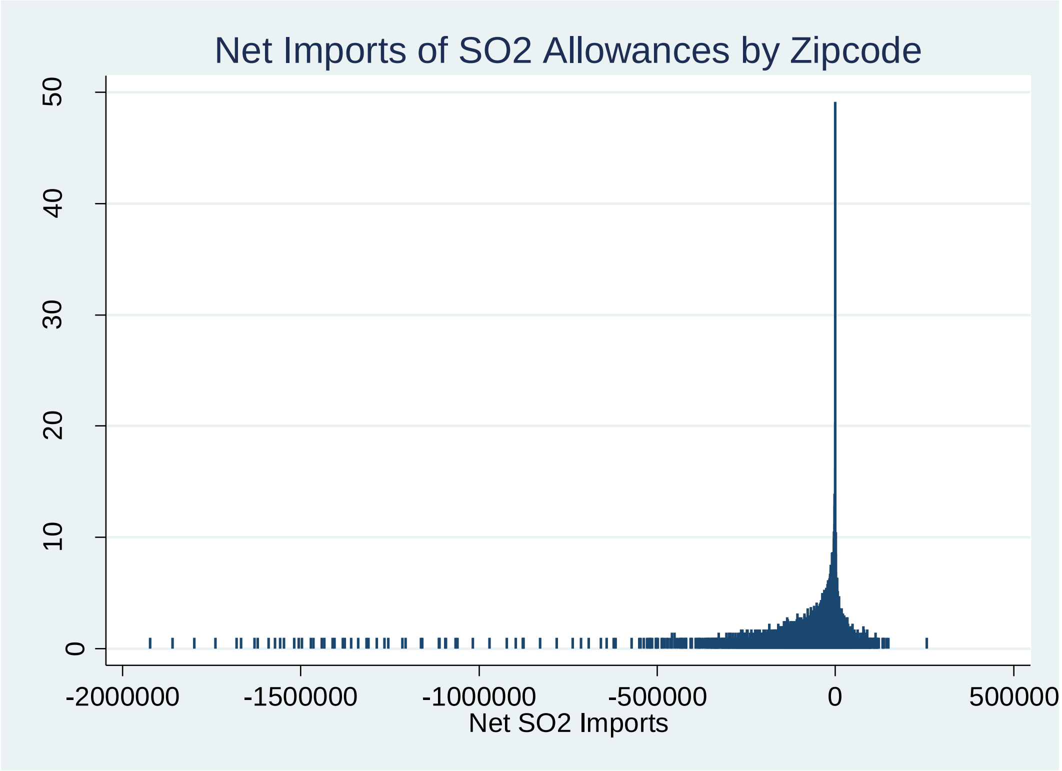


Figure 3: Effect of Race, Ethnicity, and Education on the Propensity to Import SO_2

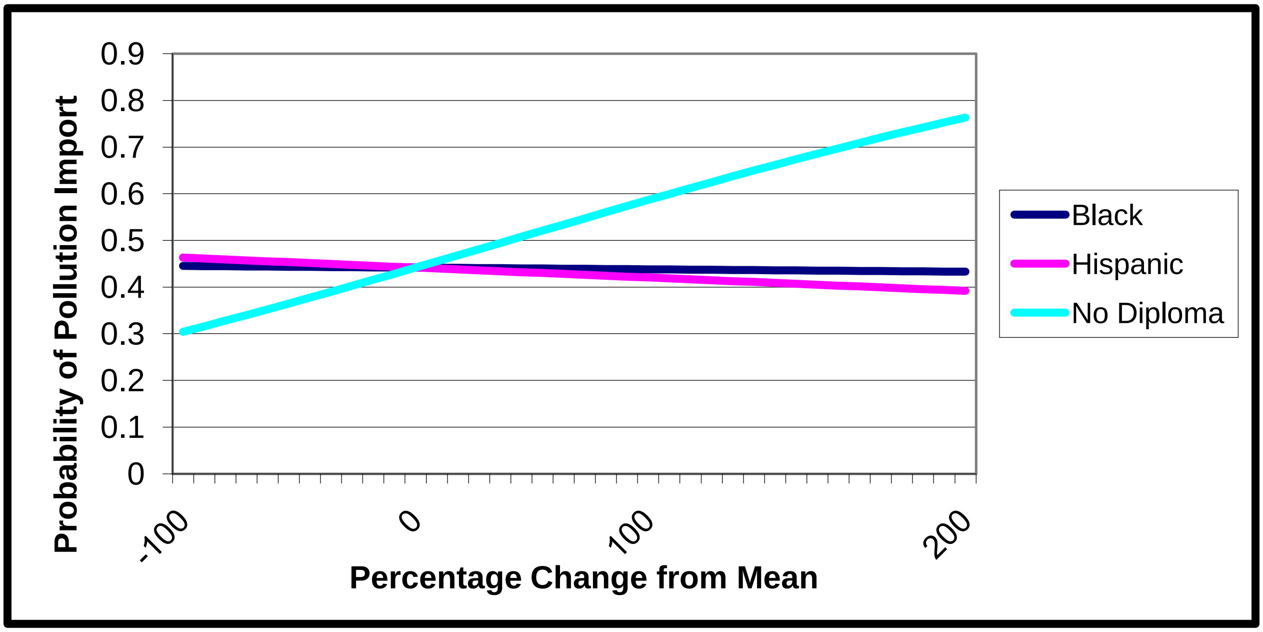


Figure 4: Effect of Race, Ethnicity, and Education on Magnitude of SO_2 Imports

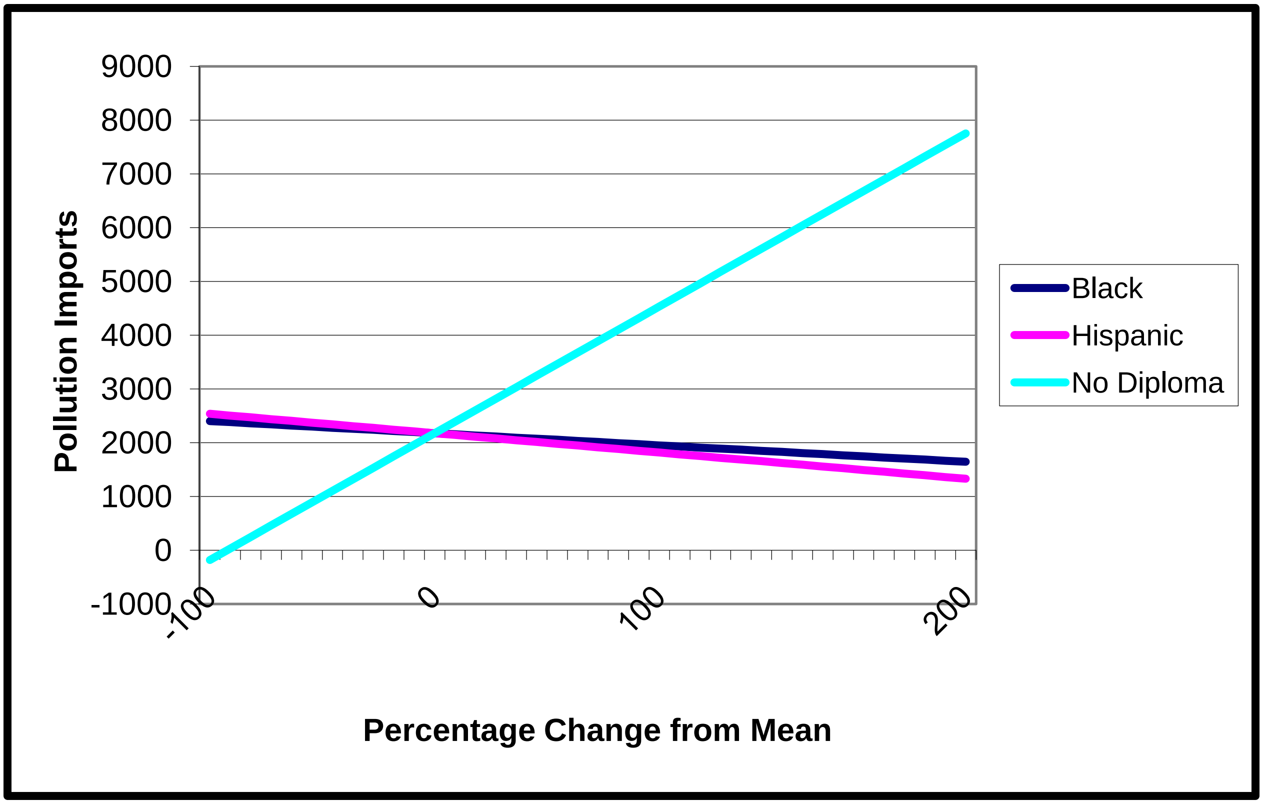


Figure 5: Effect of Race, Ethnicity, Class, and Education on Net SO_2 Imports

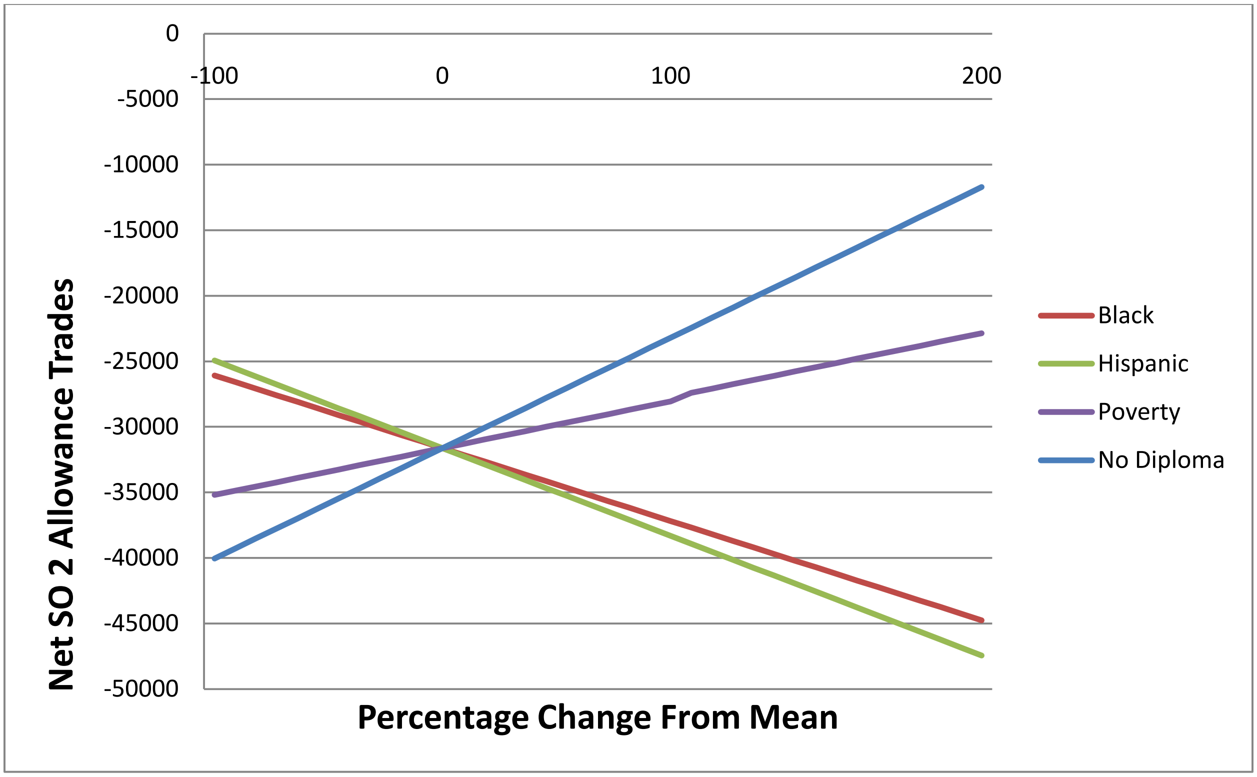


TABLE 1. Predicting the Decision to Import SO_2 Allowances

Independent Variables	ZIP Code Model[a]	3 Mile GIS Model[b]	1 Mile GIS Model[c]
Structural Model			
%African American	-0.0017	-0.0014	-0.0022**
	(0.0016)	(0.0013)	(0.0011)
% Hispanic	-0.0123***	-0.0095***	-0.0094***
	(0.0021)	(0.0014)	(0.0013)
% Poverty	0.0037	-0.0092**	-0.0012
	(0.0031)	(0.0036)	(0.0030)
% No Diploma	0.0166***	0.0389***	0.0258***
	(0.0020)	(0.0040)	(0.0034)
% Home Ownership	0.0134***	0.0154***	0.0106***
	(0.0014)	(0.0015)	(0.0011)
Population Density	-0.0147***	0.0069**	0.0099
	(0.0049)	(0.0027)	(0.0070)
Allowance Allocation	-0.0000***	-0.0000***	-0.0000***
	(0.0000)	(0.0000)	(0.0000)
Pollution Intensity	-0.0004	0.0011	0.0015*
	(0.0008)	(0.0008)	(0.0008)
Year	0.0914***	0.0952***	0.0955***
	(0.0034)	(0.0034)	(0.0033)
Constant	-184.57***	-192.61***	-192.67***
	(6.83)	(6.75)	(6.70)
Selection Model			
%African American	0.0106***		
	(0.0004)		
% Hispanic	0.0134***		
	(0.0007)		
Median Housing Value	-0.0013***		
	(0.0002)		
Median Household Income	0.0602***		
	(0.0032)		
Median Household Income^2	-0.0000***		
	(0.0000)		
% No Diploma	0.0048***		
	(0.0008)		
Constant	-2.2989***		
	(0.0829)		
Wald χ^2	1129.49***	1261.41***	1201.57***
Psuedo-R^2	na	0.14	0.14
rho	0.07	na	na
Number of Cases	40470	9956	9956

[a] figures are coefficients from bivariate Probit model with sample selection, robust standard errors in parentheses

[b] figures are coefficients from Probit model, robust standard errors in parentheses

[c] figures are coefficients from Probit model, robust standard errors in parentheses

*p<.10; **p<.05 ; ***p<.01, one-tailed tests

TABLE 2. Predicting Imports of SO_2 Allowances

Independent Variables	ZIP Code Model[a]	3 Mile GIS Model[b]	1 Mile GIS Model[c]
Structural Model			
%African American	-41.02***	-70.26***	-52.76***
	(10.09)	(23.40)	(20.68)
% Hispanic	-81.56***	-215.07***	-187.02***
	(15.07)	(28.07)	(24.97)
% Poverty	- 9.57	-109.53**	-41.86
	(12.21)	(63.57)	(53.46)
% No Diploma	107.20***	662.79***	475.40***
	(8.62)	(67.79)	(57.88)
% Home Ownership	35.07***	194.90***	151.18
	(7.85)	(26.12)	(19.74)
Population Density	0.0230	0.2946*	0.1636
	(0.0233)	(0.1578)	(0.1363)
Allowance Allocation	0.0628***	-0.0709***	-0.0681***
	(0.0023)	(0.0144)	(0.0144)
Pollution Intensity	2.99**	116.14***	121.95***
	(1.36)	(13.18)	(13.15)
Year	0.49**	1430.16***	1443.46***
	(0.24)	(68.18)	(68.20)
Constant	-6608.62***	-2901614***	-2922827***
	(880.37)	(136787)	(136814)
Selection Model			
%African American	0.0024***		
	(0.0004)		
% Hispanic	0.0036***		
	(0.0007)		
Median Housing Value	-0.0009***		
	(0.0001)		
Median Household Income	0.0398***		
	(0.0018)		
Median Household Income^2	-0.0000***		
	(0.0000)		
% No Diploma	-0.0004		
	(0.0007)		
Constant	-1.5007***		
	(0.0528)		
Wald χ^2 or F	55.00***	928.41***	877.71***
rho	0.26**	na	na
Number of Cases	41703	9956	9953

[a] figures are coefficients from Tobit model with Probit sample selection model, robust standard errors in parentheses

[b] figures are coefficients from Tobit model, robust standard errors in parentheses

[c] figures are coefficients from Tobit model, robust standard errors in parentheses

*p<.10; **p<.05 ; ***p<.01, one-tailed tests

TABLE 3. Predicting Net SO_2 Allowance Trading

Independent Variables	ZIP Code Model[a]	3 Mile GIS Model[b]	1 Mile GIS Model[c]
Structural Model			
%African American	-1009.88***	306.08***	235.73***
	(71.95)	(60.90)	(46.64)
% Hispanic	-1519.60***	- 31.41	- 39.07
	(98.55)	(52.66)	(42.70)
% Poverty	324.82**	-960.33***	-778.87***
	(136.16)	(244.13)	(200.61)
% No Diploma	383.33**	610.65***	579.74***
	(137.14)	(212.19)	(184.34)
% Home Ownership	57.73	287.56***	141.21***
	(38.90)	(48.19)	(33.83)
Population Density	0.1715***	-0.1623	-0.0122
	(0.0445)	(0.4626)	(0.3766)
Allowance Allocation	-0.3822**	- 2.27***	- 2.27***
	(0.1303)	(0.11)	(0.11)
Pollution Intensity	217.63***	-499.85***	-496.48***
	(63.95)	(114.82)	(115.01)
Year	207.09	-3333.28***	-3327.85***
	(110.39)	(274.14)	(275.40)
Constant	-265215	6663411***	6662386***
	(221869)	(550476)	(553451)
Selection Model			
%African American	0.0061***		
	(0.0004)		
% Hispanic	0.0085***		
	(0.0005)		
Median Housing Value	-0.0038***		
	(0.0006)		
Median Household Income	0.0107***		
	(0.0017)		
Median Household Income^2	-0.0000***		
	(0.0000)		
% No Diploma	0.0014		
	(0.0007)		
Constant	-1.1571***		
	(0.0517)		
Wald χ^2	444.22***	na	na
rho	-0.91***	na	na
R^2	na	0.27	0.27
Number of Cases	40470	9956	9953

[a]figures are coefficients from OLS model with Probit sample selection model, robust standard errors in parentheses

[b]figures are coefficients from OLS model, robust standard errors in parentheses

[c]figures are coefficients from OLS model, robust standard errors in parentheses

*p<.10; **p<.05 ; ***p<.01, one-tailed tests

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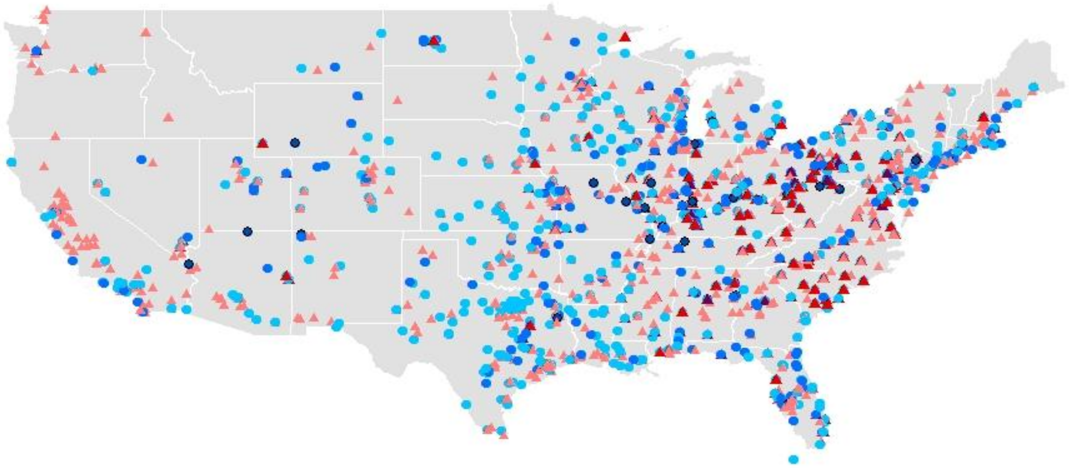
Appendix 1: Distribution of Net Allowance Trading Under the ATP



Red triangles represent facilities that import SO_2 allowances, with darker shades of red representing greater imports. Blue circles represent facilities that export or bank SO_2 allowances, with darker blue representing greater exports or banking.