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Emissions trading and environmental justice: distributive fairness and the USA's Acid Rain Programme

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Summary

As emissions trading regimes become increasingly popular mechanisms for environmental pollution control around the world, environmentalists are asking whether market-based programmes meet their promise of both efficient and equitable pollution reductions. The emissions trading regime of the USA's Acid Rain Programme (ARP) is investigated in order to determine whether the programme has concentrated sulphur dioxide (SO_2) pollution disproportionately for the poor and people of colour. While the USA emissions trading regime has been hailed as a success for cost-efficiently reducing pollution in the aggregate, critics contend that the programme is insufficiently attentive to the localized concentrations of harmful SO_2 that trading can create. Further, advocates of environmental justice question whether emissions trading might exacerbate the disproportionate pollution burdens already facing the poor and people of colour. Stack emissions and pollution allowance holdings for all 110 power plants participating in Phase I of the trading programme are correlated with income and racial demographic characteristics of the people living around each plant to determine whether the ARP might raise distributive environmental justice concerns. Using USA Census data at the tract level, income and racial demographics around plants that increased and decreased their emissions as well as plants that were net purchasers and sellers of pollution allowances over the first three years of the programme are compared. For the first few years of the ARP, the emissions trading regime does not appear to have been concentrating SO_2 pollution disproportionately for the poor and racial minority populations.

Keywords: emissions trading, distributive fairness, acid rain, environmental justice, sulphur dioxide

Introduction

The tradable emissions allowance system of the USA's Clean Air Act Acid Rain Programme (ARP) began in 1995 and has been hailed as a success by the electric power industry, the US Environmental Protection Agency (US EPA), and environmental advocacy groups (Stavins 1997; Burtraw 1998; US EPA 1998*a*; Svendsen 1999; Environmental Defense 2000; Ellerman *et al*. 2000). For example, according to the US EPA (1998*a*), annual emissions of SO_2 declined to less than 13 million tonnes in 1997, down from almost 16 million in 1990, reductions in SO_2 emissions produced over US$ 10 billion in health benefits in 1997, and compliance costs are almost 50% lower under the allowance-trading scheme than they would have been under a command and control (CAC) regime. By these accounts, the Programme is a successful example of market-based environmental policy, because it has reduced pollution in a cost-efficient manner. However, one challenge to tradable emission regimes and market-based environmental policy generally is that they are not sufficiently attentive to the distributive fairness of pollution distributions resulting from market transactions. More specifically, one aspect of this challenge is whether tradable emission regimes might contribute to pollution concentrations in areas where poor and minority populations reside, a key concern for the environmental justice movement. This paper empirically tests whether SO_2 pollution from power plants participating in the ARP is disproportionately burdening poor and minority populations. This investigation is important for environmental policy since pollution-trading schemes have gained salience across environmental media, from controlling greenhouse gases under the Kyoto Protocol to New Zealand's Fisheries License Trading Programme, but the distributive fairness of these policies can often be overlooked.

Most studies of the ARP have examined the distributive mechanism for the allocation of the initial permits (Joskow & Schmalensee 1996) or the efficacy and efficiency of the trading regime itself (Joskow *et al*. 1998), but few have examined the actual distribution of SO_2 emissions since the programme went into effect. While the few studies that have investigated the distribution of SO_2 emissions from the trading programme have not found any pollution hot spots (Burtraw & Mansur 1999; Solomon & Lee 2000; Swift 2000), these studies aggregated emissions only by state or region and none combined emissions data with income and racial demographic data. This study seeks to fill this void by comparing emissions and allowance data from 1995 through 1997 for each plant in the trading programme with income and racial

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demographic data for the populations surrounding each of these plants.

Advocates of environmental justice claim that traditionally disadvantaged groups and communities are further disadvantaged because they must endure disproportionately high levels of exposure to environmental contaminants (Bullard 1990; Institute of Medicine 1999; Ringquist 2000). For some critics, the critical causal factor is race; high levels of environmental risk in communities of colour are one more example of institutional racism in the USA (Bullard 1990). For other observers, class is the dominant determining factor and traditionally disadvantaged lower classes are targeted to receive higher levels of pollutants because they are politically inactive and pose less threat of opposition and delay in locating environmentally noxious facilities (Bryant 1993; Lazarus 1993). While pinpointing the interrelating causes of the disparity remains challenging, empirical evidence leaves little doubt that the poor and people of colour experience greater risks from exposures to most environmental contaminants (US EPA 1992; Brown 1995; Pulido 1996; Institute of Medicine 1999). Importantly, empirical studies reveal that disproportionate exposures exist for air pollution (Wernette & Nieves 1992; Gelobter 1993; Sexton *et al*. 1993; Morello-Frosch 2001) and environmental-justice concerns have been raised against the Regional Clean Air Incentives Market (RECLAIM), an air pollution emission-trading programme in California (Bae 1997; Chinn 1999; Drury *et al*. 1999). Finally, New York and other eastern states of the USA have challenged the distributive fairness of emissions trading, noting that power plants of the mid-western USA participating in the ARP are not required to reduce their emissions, which disproportionately impact the health of downwind communities (Zaffrann 1999; Wald 2001).

Analysing the potential localized concentrations of SO_2 is important, since this pollutant does not mix uniformly in the atmosphere, resulting in concentrations of SO_2 that vary both regionally and locally; generally there are greater concentrations of SO_2 near the source (Boubel *et al*. 1994; Manuel 1995; de Kluizenaar *et al.* 2001). Acute exposure to SO_2 has been shown to contribute to wheezing, chest tightness, asthma attacks and premature death (Dockery *et al*. 1993; Pikhart *et al.* 2000). Localized SO_2 also contributes to fine particulate matter and often forms sulphate aerosols, both of which are detrimental to human health (Partti-Pellinen *et al*. 1996; Kramer *et al*. 1999; Moolgavkar 2000).

Emissions trading combines government regulation with market incentives. Before any emissions trading regime can be established, government first sets a cap or overall limit on pollution, such as the total number of tonnes of a given pollutant that may be emitted nation-wide in a year. A pool of permits that reflects the amount of pollution allowed under the cap is then created and a scheme is derived to allocate these permits to the relevant firms. Polluting firms are then required to hold permits for all of their emissions. Market-based trading programmes allow firms to choose the means of compliance that is cheapest for them, including buying permits from firms that can more cheaply reduce emissions and thus have excess permits to sell (Freeman 2000; Tietenburg 1992).

The SO_2 emissions trading programme was outlined in Title IV of the 1990 USA Clean Air Act Amendments (Stavins 1997; Ellerman *et al*. 2000). The overriding goal of the programme was a 10 million tonne per year reduction in SO_2 emissions, based on 1980 levels, by the year 2000. In Phase I (1995–1999) of the programme, the 263 dirtiest generating units located at 110 electricity power plants were required to reduce their emissions by roughly 3.5 million tonnes per year. In Phase II (2000 and beyond), virtually all fossil-fuel electric utilities become subject to the national cap on aggregate annual SO_2 emissions (Burtraw 1998; Ellerman *et al*. 2000). This study is concerned with evaluating the measurable effects of Phase I of the programme.

In Phase I, each utility was freely given tradable pollution allowances and each allowance equals one tonne of SO_2 emissions for a particular year or a specified tenure (Joskow *et al*. 1998). Allowances could also be banked and held for future use. At the end of each year, electric utilities submitted the allowances necessary to cover their annual emissions to the US EPA. Utilities are left to decide what combination of emissions reductions and allowance transactions they will employ to meet their emissions requirements. The US EPA plays no role in approving or disallowing allowance trades (Joskow *et al*. 1998).

In order to ensure compliance, the programme established a continuous emissions monitoring (CEM) system. The CEM system records data for SO_2 emissions every 15 minutes, with consolidated data reported hourly. Emissions data is reported to EPA on a quarterly basis and stored in the Emissions Tracking System (ETS). The EPA monitors the 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 (US EPA 1998*b*).

Stack emissions and pollution allowance holdings for each of the 110 power plants in Phase I of the ARP are compared to income and racial demographic characteristics of the people living within 1.6 km, 8.0 km and 16.1 km radial zones of impact around each plant. The study tests for distributive fairness by comparing census tract demographic data around each plant with USA averages, averages of all USA states that house at least one Phase I power plant and all the USA counties that house at least one Phase I plant. The different comparison demographics were used to sensitize the study to the ongoing debate in the environmental justice literature over whether census tracts, counties or zip codes are the appropriate aggregation to measure disproportionate impact (Anderton *et al*. 1994; Hamilton 1995; Been 1997). In addition, as the comparisons represent dramatically different aggregations, it is possible to test for inequity using different comparison groups. The objective of the study was to investigate whether SO_2 pollution from plants participating in the ARP is concentrating in communities of poor and people of colour.

Six questions tested whether the ARP is distributing greater pollution burdens to poor and minority populations: (1) Where are all the Phase I electric power plants located? (2) Which plants increased/decreased their SO_2 emissions under the ARP from 1995 to 1997? (3) Are plants that increased emissions located in poor communities of colour and are plants that decreased emissions located in whiter, wealthier areas? (4) Does comparing the percentage of each plant's increase/decrease to community demographics alter the findings? (5) Are plants that purchased allowances located in poor communities of colour and are plants that sold allowances located in whiter, wealthier areas? (6) Are the findings significantly different at the state as opposed to national level?

Methods

Complete data is available on the location, annual emissions and allowance holdings for all power plants in Phase I of the programme because these facilities and these plants were determined by the USA Congress in Title 42 Chapter 85, Subchapter IV, Table A of the Clean Air Act as the dirtiest plants in the country. Annual emission and allowance data were used because units are required to comply with the programme on an annual basis. The data were obtained from the National Allowance Tracking System (ATS) and Emissions Data Reports (EDR) from the US EPA (1998*a,b,c*). Stack emissions and pollution allowance holdings were calculated for each of the 110 power plants in Phase I of the ARP and compared to income and demographic characteristics of the people living within 1.6, 8.0 and 16.1 km radial zones of impact around each plant. The distance aggregations were chosen based on assumptions over local variation in SO_2 concentrations derived from standard Gaussian plume models for smokestack emissions and the Pasquill-Gifford model, which estimates localized smokestack impacts occurring between 2 and 20 km (Flagan & Seinfeld 1988; Boubel *et al*. 1994; Manuel 1995).

Within each radial zone, income and racial characteristics were derived from the 1990 USA Census Data, Population and Housing, Summary Tape file 3a and 3b, at the tract level (US Bureau of the Census 1990). This provided the median household income, percentage of the total population in poverty, and total population of white, black, Asian/Pacific Islander, other, and Hispanic (total), within each radial zone surrounding all 110 power plants. The census tract demographics were compared to USA averages, averages of all USA states that house at least one Phase I power plant and all the USA counties that house at least one Phase I plant. The demographic analysis was combined with annual SO_2 allowance emissions data for each of the 110 power plants.

In order to complete this analysis, each plant was plotted in a geographic information system (GIS) using the plant's longitude and latitude coordinates as the centre point. The locations of plants were then linked to the 1990 US Bureau of the Census data. The demographic data within each radial zone were calculated by taking the mean values for all demographic categories for all the census tracts that fell within the specified radius. If only a part of the census tract fell within the specified radius, the entire tract was counted in the calculation. Weighted averages were not used. Thus, throughout the study 'community' and 'area' around each power plant should be considered synonymous and represent the population residing within each radial zone and the additional population that may be outside the zone, but within the census tracts that comprise each zone.

The raw annual emissions data (tonnes) were used to calculate which power plants increased and which decreased their emissions. The total SO_2 emissions for each plant from 1995 to 1997 and total change in emissions from 1995 to 1997 were calculated. The percentage of emission change was based on plant emissions in 1995, the inaugural year of the programme. The percentage increase/decrease was divided into five percentage ranges, namely 1–5, 6–10, 11–20, 21–40 and 40+. These ranges were chosen because there was a wide variability within the raw emission data, and percentage change might help reveal any significant variability between plants with low percentage emission changes and those with very high percentage changes. In addition to these comparisons, the raw annual emissions (tonnes SO_2) for all plants were plotted with each demographic category for each of the radial zones. The idea was to display visually emissions data for all 110 power plants along with demographic data in each radial zone.

In addition to emissions data, allowance holdings for each plant were calculated. The allowance data provided by the US EPA were aggregated by allowances issued, allowances traded and allowances carried over from the previous year. In order to compare allowances across all plants, the net allowance holdings for each Phase I plant were recorded on an annual basis. Annual net-allowance holdings ($A_{net,}$ where A = allowances) were defined as the remainder of a plant's total allowance allocations from the US EPA for a given year, minus the total allowances used in that year, plus the total allowances carried over from the given year to the next (i.e. banked allowances). The following formula determined each plant's annual net allowances:

$$A_{net} = (A_{allocated} - A_{used}) + A_{banked} \quad (1)$$

Calculating the net allowances for all 110 Phase I plants for the years 1995, 1996, and 1997 gave the total net allowances for each plant for these years.

Comparisons of emissions and allowance data were conducted at the USA national level since the ARP is a national programme. However, an equally valid design might define inequity in terms of intra-state comparisons, where significance is based upon deviation from each state's means. The difference can be substantial. For example, in Alabama a radial zone that has a 21% black population is significant when compared with the national black population average of 12%. However, the mean black population in Alabama is 25%, making this radial zone an area with a lower than average number of black residents when compared to the state of Alabama as a whole. Therefore, the Phase I plants were aggregated by state and the mean demographics in census tracts for all Phase I plants in a particular state calculated and these findings compared to the means for each demographic within each state. Instead of analysing each plant to particular demographics, all the plants were grouped in their respective states, and only the plants within each state compared to their state's demographic means.

Results

Where are the Phase I plants located?

The power plants in Phase I of the ARP are located primarily in the mid-western and mid-Atlantic sections of the country (Fig.1). The 110 power plants are located in 21 states ranging from New Hampshire to Florida to Wisconsin. However, 60% of the plants are located in six states (8 in Illinois, 15 in Indiana, 10 in Kentucky, 8 in Missouri, 15 in Ohio and 9 in Pennsylvania).

The median population within a 1.6 km radius of all Phase I plants is 8825 and within a 16.1 km radius the median population is 72 273. Within all the plants' 16.1 km radial zones, 18 of the 110 plants have populations over 200 000 and only five have populations over 500 000. Thus, it is clear that the majority of the plants are not located in densely populated areas.

The census tracts within a 16.1 km radial zone of each plant have median household incomes of US$ 26 731, an average of 12.4% of the population is in poverty, an average of 96.3% is white, 2.6% black and 0.7% Hispanic (Table 1). Compared to USA national averages, the median household income surrounding each plant is lower than the national average of US$ 30 056, as are the percentage in poverty (13.1%), percentage black (12%) and percentage Hispanic (8.8%). The percentage of whites in the census tracts surrounding the plants is higher than the national average (80.3%). Within the 1.6, 8 and 16.1 km radial zones around each plant, the median household income and percentage of the population in poverty, black and Hispanic, do not exceed the USA national average. However, the percentage of white population exceeds the national average in all three radial zones. Thus, the plants seem to be located in areas with moderate to low household incomes and predominantly white populations.

When radial zone demographics are compared to averages found in all the states and counties that house a Phase I plant,

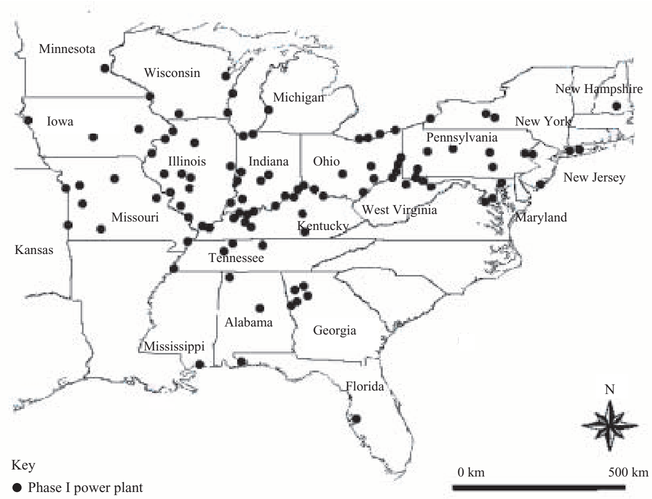

Figure 1 Locations of all Phase I power plants in Acid Rain Programme. Source: US EPA (1998*c*).

Table 1 All Phase I plants, change in emissions 1995–1997, and US demographic data. Source: EPA (1998*c*); US Bureau of the Census (1990).

	Census tracts in radial zone	*All plants (110)*	*Emissions reduced (37 plants)*	*Emissions increased (73 plants)*	*Total USA national average*	*Averages in all states with Phase I plants*	*Averages in all counties with Phase I plants*
Mean median household income (US$ yr^{-1})	1.6 km	26 626	24 948	27 215	30 056	28 955	26 843
	8 km	25 818	24 213	27 732			
	16.1 km	26 731	25 371	27 568			
Mean % in poverty	1.6 km	12.1	12.7	11.9	13.1	13.2	13.3
	8 km	12.5	13.6	11.9			
	16.1 km	12.4	13.0	12.1			
Mean % white	1.6 km	98.4	98.6	98.2	80.3	82.7	83.6
	8 km	97.1	97.5	96.8			
	16.1 km	96.3	96.6	95.9			
Mean % black	1.6 km	0.9	0.9	0.9	12	13.4	13.7
	8 km	1.6	1.9	1.5			
	16.1 km	2.6	2.2	3.0			
Mean % Hispanic	1.6 km	0.5	0.5	0.5	808	4.8	0.6
	8 km	0.6	0.5	0.6			
	16.1 km	0.7	0.6	0.7			

we arrive at similar results (Table 1). The mean median household income and percentage in poverty for all radial zones does not significantly differ from the state or county averages, and thus we see a similar non-significant result. In addition, as with the national average comparison, the percentage black and Hispanic populations in the states and counties housing a Phase I plant was significantly more than we found in all radial zones surrounding the plants.

Which plants increased/decreased their SO_2 emissions under the ARP from 1995–1997? Are plants that increased emissions located in poor communities of colour and are plants that decreased emissions located in white, wealthy areas?

Of the 110 plants in Phase I, 37 reduced their emissions from 1995 to 1997 and 73 increased their emissions. Table 1 displays the results of comparing the demographics surrounding all the plants that increased their emissions to those that decreased, to national averages, averages within all states with a Phase I plant and all counties with a Phase I plant.

The a priori expectation, in part drawing from the environmental justice literature, was that plants in which emissions increased would be in poor communities of colour, and the plants that reduced their emissions would be in wealthier white communities. However, the demographics in the census tracts surrounding the plants that increased emissions and those that decreased emissions were not significantly different. For example, in the 1.6 km radial zone, the median household income for plants that decreased their emissions was US$ 24 948, and US$ 27 215 for plants that increased their emissions. These data run counter to expectation. However, since both sets of income data are below national means, it is difficult to determine whether the wealthier are benefiting. It is clear that there is not a disproportional relationship between low incomes and high SO_2 emissions. Similarly, there does not appear to be an inequitable distribution for those in poverty. In the 1.6 km radial zone around each plant, the percentage of all persons in poverty where emissions increased is 11.9% and 12.7% where emissions decreased. There was no significant difference in the percentage of white, black and Hispanic populations in the 1.6, 8 and 16.1 km radial zones where plants increased or decreased emissions.

This analysis shows that Phase I plants that increased their emissions compared to those that reduced their emissions do not have significantly different income and racial characteristics in the census tracts within the 1.6, 8 or 16.1 km radial zones surrounding each plant. To further display the lack of any significant correlation between the changes in emissions from 1995 to 1997 at all Phase I plants and the demographics surrounding each plant, all 110 plants were plotted on a graph (Fig. 2). The change in plant emissions appears as an ‘S’ curve along the y-axis. If there were a correlation between the change in emissions and income, we would

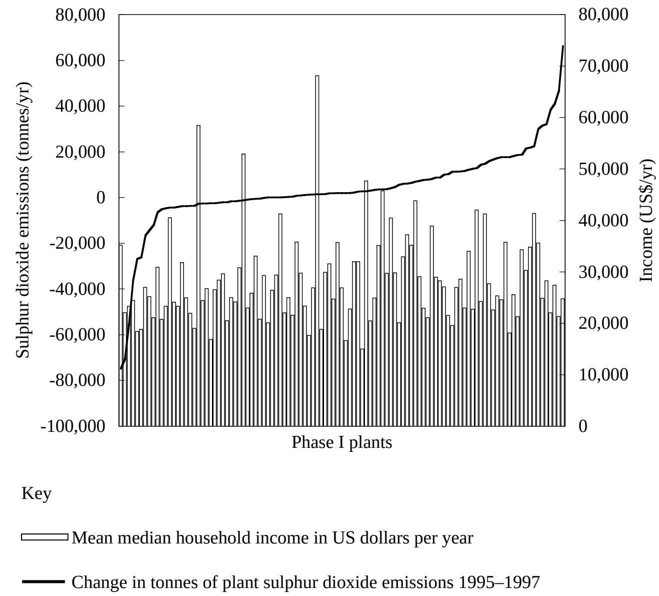

Figure 2 All Phase I plants: emissions change 1995–1997 and household income in 1.6 km radial zone, all Census Tracts. Sources: US EPA (1998*c*); US Bureau of the Census (1990).

expect to see an inverted S curve when plotting median household income with change in emissions. This means that where emissions decreased, we might expect income to be high and where emissions increased we expect income to be lower. However, the graph shows no discernible or consistent relationship between change in emissions and income.

Similar graphs of all plants and their change in emissions from 1995 to 1997, and the percentage of the population in poverty and percentage of the population that was black were plotted for all radial zones. These graphs did not reveal any consistent relationships that indicated that there might be significant inequities in pollution burdens.

Does comparing the percentage increase/decrease alter the findings?

The emission reduction/increase in Table 1 was calculated as a raw number (tonnes SO_2). The change in emissions ranged from decreases of over 74 000 tonnes to increases of over 64 000 tonnes; these changes were compared to the demographics. A scenario similar to the one observed with the raw emissions change was observed when comparing the percentage of emissions increased and decreased for each plant from 1995 to 1997. The expectation, if there were an inequitable distribution, was that plants with a high percentage increase in emissions would be in relatively poor communities of colour. Following this logic, as the percentage of a plant’s emissions decreases, the areas surrounding these plants should move from predominantly poor to wealthy, and minority to white. Thus, the areas surrounding plants that experienced the largest percentage increase of emissions (40%+) are expected to be poor communities of colour and the areas surrounding plants that experienced the largest percentage emission reduction (40%+) are expected to be well-off and have the smallest percentage of African-Americans and Latinos. The data comparing the percentage of a plant's emission increase or decrease with the surrounding demographics shows an inverse relationship from that expected. For example, in the 1.6 km radial zone, the plants with the largest percentage emissions reduction (40% or more) had the lowest median household income and lowest percentage of African-Americans (0.2%). The plants with the largest percentage increase in emissions had the highest median household income (US$ 35 612) and the lowest percentage in poverty (5.6%) of all ranges of percentage emissions increase or decrease in the 1.6 km radial zone. The percentage of African-Americans is below the national average for all percentage emissions reductions or increases, except in the 8 and 16.1 km radial zones, where plants reduced emissions by between 21% and 40%.

The central concern in questions two, three and four was whether Phase I power plants are concentrating SO_2 emissions in poor and minority communities. The answer to this concern is most probably no. There are no clear relationships between the concentration of African-Americans and Latinos and an increase in a Phase I power plant's SO_2 emissions. There does not seem to be any relationship between the concentration of low-income populations and an increase in a Phase I power plant's SO_2 emissions. In fact, in all radial zones the median household incomes were higher and percentage population in poverty lower for plants that increased SO_2 emissions from 1995 to 1997.

Are plants that purchased allowances located in poor communities of colour and are plants that sold allowances located in white, wealthy areas?

In addition to plant emissions, the allowance trading system must be closely assessed to understand whether the ARP is burdening the poor and communities of colour. A plausible causal story outlining how trading allowances might concentrate pollution in poor communities of colour might suggests that older electric utilities are more likely to be located in central cities. Therefore, the areas surrounding these power plants might contain high populations of the poor and people of colour. In addition, since older power plants are thought to have outdated technology and higher pollution control costs, these facilities should produce more pollution. Under an allowance-trading scheme, polluters with lower pollution control costs will sell their allowances to polluters with higher pollution control costs. Thus, utilities selling allowances are likely to be newer facilities in outlying areas and utilities buying pollution allowances are likely to be older facilities in urban areas. In this story trading results in pollution allowances being transferred from wealthier communities who can sell to the poorest communities.

The results of the net allowance calculation revealed that of the 110 power plants, 19 had negative net allowances between 1995 and 1997, and 91 plants had positive net allowances in the same time period. Plants with negative net allowances are termed purchasers, because these plants require additional allowances to comply with the programme. Plants with positive net allowances are termed sellers, since they hold an excess of allowances.

Table 2 displays the mean values for the demographic characteristics in the census tracts within the 1.6, 8 and

Table 2 Acid Rain Programme: Phase I plant purchasers/sellers of allowances 1995–1997 and US demographic data. Source: US EPA (1998*b*); US Bureau of the Census (1990).

	Census tracts in radial zone	*Purchasers (19 plants)*	*Sellers (91 plants)*	*USA national averages*	*Averages in all states with Phase I plants*	*Averages in all counties with Phase I plants*
Mean median household income (US$ yr^{-1})	1.6 km	27 023	26 108	30 056	28 955	26 843
	8 km	24 722	26 084			
	16.1 km	26 368	26 839			
Mean % in poverty	1.6 km	11.3	11.2	13.1	13.2	13.3
	8 km	12.3	12.1			
	16.1 km	12.1	12.2			
Mean % white	1.6 km	98.6	98.3	80.3	82.7	83.6
	8 km	98.0	96.6			
	16.1 km	97.2	95.9			
Mean % black	1.6 km	0.7	0.9	12.0	13.4	13.7
	8 km	1.4	1.8			
	16.1 km	2.2	2.7			
Mean % Hispanic	1.6 km	0.5	0.5	8.8	4.8	0.6
	8 km	0.5	0.7			
	16.1 km	0.5	0.7			

16.1 km radial zones of the plants that were purchasers and those that were sellers of allowances from 1995 to 1997. The allowance data for each plant are compared to income and racial demographics, again using USA national averages, averages in all states with a Phase I power plant and averages in all counties with a Phase I power plant. If trading allowances has the effect of transferring pollution to areas with large numbers of poor and minority residents, then we would expect to see significantly higher incomes and lower percentages of the population in poverty, or of African-American and Latino origin in seller radial zones. For the same reason, we would expect to see lower incomes and higher percentages of the population in poverty and minority racial groups in census tracts in the radial zones surrounding purchaser power plants. Median household incomes are slightly lower in the 1.6 km radial zone, slightly higher in the 8 km radial zone, and almost identical in the 16.1 km radial zone for sellers and purchasers of allowances. However, none of the differences in income is large enough to be statistically significant. For all other demographics, including the percentage of the population in poverty, white, black and Hispanic, the results are nearly identical for purchasers and sellers in all radial zones. Compared to USA national means and the means in states and counties with Phase I power plants, the median household incomes and the percentages in poverty are slightly lower for both sellers and purchasers. The percentage of whites is higher and the percentage of blacks and Hispanics is significantly lower than national means for both sellers and purchasers.

Does averaging all the plants into net purchasers or sellers disguise some interesting and perhaps significant cases? The

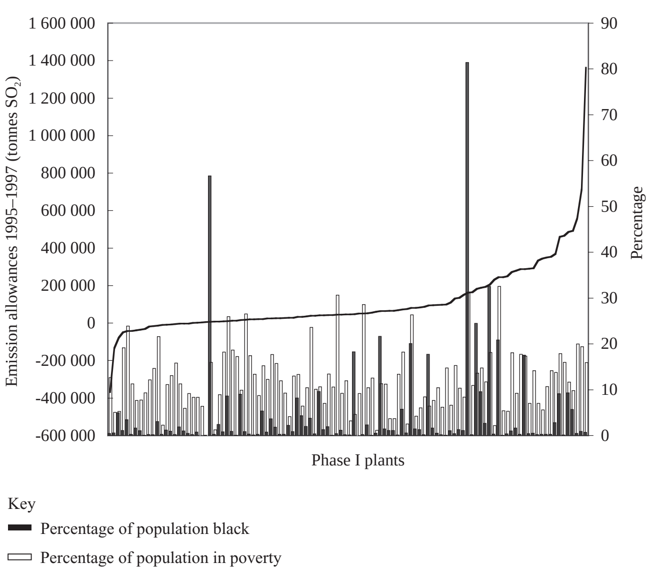

Figure 3 All Phase I plants: net allowances 1995–1997, percentage in poverty and black in the 1.6 km radial zone, all Census Tracts. Sources: US EPA (1998*b*); US Bureau of the Census (1990).

net allowances held by each Phase I plant plotted against the percentage of the population in poverty and percentage African-American within each radial zone do not reveal any significant cases. Figure 3 shows the graph for the 1.6 km radial zone. The expectation, as stated above, was that if the ARP is transferring allowances inequitably from the white and wealthy to the poor and African-American, we would observe an inverse trend with respect to allowances held and percentage in poverty and African-American. Stated another way, the plants with negative net allowances (purchasers) should have a high percentage of the population in poverty and African-American, while the plants with positive net allowances (sellers) should have a low percentage of the population in poverty and African-American. However, the graph does not display any clear or consistent relationship between net allowances and percentage of the population in poverty or African-American. The conclusion from the analyses of net allowances at all Phase I plants is that the ARP is not resulting in allowance trades from white, wealthy communities to poor communities of colour.

Are the findings significantly different at the state as opposed to national level?

Twenty-one states contain all 110 Phase I power plants. Of the 21, seven had net reductions in SO_2 emissions from all the Phase I plants in the state. Of the seven states with net emission reductions, three had statistically significant differences between state means and the means within the census tracts surrounding the Phase I plants. For example, in Alabama, the percentage of the population in poverty in the 8 and 16.1 km radial zones is 23.6% and 23.1% respectively, compared to a state mean of 18.3% for the percentage of the population in poverty. In the same radial zones in Alabama, the percentage of African-Americans is 45.8% and 41.4%, compared to a state mean of 25.2%. Since Alabama is a net reducer of emissions, these findings run counter to the expectation of inequitable burdens for African-Americans. In New York, the median household incomes in the 1.6, 8 and 16.1 km radial zones (US$ 40 829, US$ 39 577, US$ 39 699 respectively) are significantly greater than the state mean (US$ 32 965). Since New York was a net reducer of emissions, these findings support the expectation that the more affluent are benefiting from pollution reductions. However, the racial demographics do not support the inequity conclusion for New York. The average percentage of African-American population in the 1.6, 8 and 16.1 km radial zones are 1.4%, 2.4% and 2.4%, respectively, while the average percentage of African-Americans in New York State is 15.9%. All of these findings, however, can be challenged because of the small number of Phase I plants in each state (two in Alabama and five in New York state).

Of the 14 states that had net increases in SO_2 emissions from Phase I plants between 1995 and 1997, all but Kansas, Minnesota and Wisconsin, had lower percentages of their population in poverty in the radial zones surrounding the

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Phase I plants than state means. Of the same 14 states, only Kansas and Minnesota had a higher percentage of African-Americans in the radial zones surrounding the Phase I plants than state means. Generally, the comparison of radial zone census tract demographics to state rather than national means does not alter the overall findings of this study that poor communities of colour do not appear to be bearing a larger burden of SO_2 pollution from Phase I plants in the ARP.

Discussion

This analysis shows that there do not appear to be significant differences in income and racial demographics within census tracts surrounding Phase I power plants that increased or decreased their emissions from 1995 to 1997. There is no strong evidence suggesting that SO_2 emissions from Phase I power plants are concentrated in poor communities of colour. In addition, there is little evidence that the allowance trading system has the unintended consequence of transferring SO_2 pollution to poor communities of colour. These conclusions hold true for all the census tracts within the 1.6 km, 8 km and 16.1 km radial zones surrounding each plant. There was no significant difference when analysing the change in emissions as a raw number (i.e. tonnes of SO_2) or as a percentage change from 1995 emissions. Further, the differences in demographic data are not statistically significant when compared to either USA national or state means, or the means of states or counties that house a Phase I plant.

These findings are consistent with prior studies investigating the potential distributive fairness of the ARP. One study showed the geographic pattern of emissions trading between states from the inception of the programme until June 1997 (Solomon & Lee 2000). In this study, no distinct patterns were revealed to suggest environmental injustice. A second study aggregated pollution by state, geographic region (i.e. mid-west, middle Atlantic, south-east, and north-east) and by individual plants, and found no strong correlation between emissions trading and concentrations of pollution (Swift 2000). A key limit of both of these studies was that all Phase I plants were grouped together either by state or region (e.g. mid-west). In addition, while the study by Swift (2000) did analyse plant specific data, only the 18 largest polluters were used for analysis. Despite these limits, the findings here are consistent with Swift (2000, p. 955), who notes: 'In practice, trading may be expected to have little relation to hot spots … for several reasons. First, the potential for hot spots must be evaluated in the total regulatory context of the pollutant: for SO_2 this includes both the existing ambient limits on SO_2 emissions and the major added reduction made under the Acid Rain Programme. The second consideration is the relative importance of trading in relation to other factors of an economic, circumstantial, and operational nature that are likely to have far greater influence on local pollution levels than the operation of a regulatory programme.'

The findings also appear to be consistent with those from the RECLAIM operating in the Los Angeles, California air basin. This programme differs significantly from the ARP in that it is on a regional, intra-state scale. It also allows participants to gain stationary pollution allowance credits by retiring a mobile emission source, such as an old polluting automobile (Drury *et al*. 1999). The mobile-stationary emissions trading scheme has been one of the most controversial aspects of the programme and the focus of an environmental injustice claim against the programme (Chinn 1999; Drury *et al*. 1999). The environmental justice advocates note that inequities arise because trading occurs across different pollutants where, for example, retiring a NO_x polluting automobile gives emissions credits to a benzene emitting industrial polluter operating in a poor Latino neighbourhood (Bae 1997; Drury *et al*. 1999). However, under RECLAIM the region has been divided into two zones and facilities are limited with whom they can trade according to the zone where they are located (Drury *et al*. 1999). If adverse trading patterns are found, the regional air pollution control agency has the authority to make corrective changes, unlike the US EPA under the ARP. Thus, procedural safeguards exist to address any injustices that may result from the RECLAIM trading programme. A recent audit of trading patterns under RECLAIM has not revealed any distinct shift in the geographical distribution of emissions to poor or people of colour populations (Luong *et al*. 2000).

Clearly there are limits to these findings and analyses. A factor not considered in this study that warrants additional attention before any definitive policy implications can be drawn are substitution or compensating units. Under Phase I, utilities are allowed to meet their emission reduction requirements by reducing emissions at other generating sources. These sources are called substitution units and vary from year-to-year. For example, there were 182 substitution and compensating units in 1995, 161 in 1996 and 153 in 1997 (US EPA 1998*b*). These units constituted less than 12% of all Phase I emissions in any given year from 1995 to 1997. Further, only 57 of the 182 (30%) in 1995, 40 of the 161 in 1996 (24%) and 31 of the 153 in 1997 (20%) of these substituting and compensating units were located at plants distinct from the 110 designated Phase I plants. The remaining substituting and compensating units were located at existing Phase I plants and were additional generating units, often with separate stacks, to those covered under the Clean Air Act Table A for Phase I units. When these units were located at plants separate from the 110 Phase I plants, the units generally did not constitute an entire power plant. In other words, the substitution and compensating units were often one or a few of many units that make up an entire power plant. Thus, including these units presents a problem for comparing plants to units. The substitution and compensating sources were also not evaluated in this analysis because complete emission data were not available for all units and since they vary from year-to-year, comparison from 1995 through 1997 was not possible.

This study should be seen as an initial attempt to build an evaluation of the distributive character of emissions trading. There may be several reasons why we do not see the distributive inequity anticipated by the environmental justice critique of market-based environmental policy. The first possibility is that the inequity in pollution distributions might be a consequence of the original facility location process, not the programme's operation. An investigation into this hypothesis would require analysis of the demographics and other decision variables at the time the facility location was selected. Assuming there was inequity in the location decision, distributive equity from current plant operations may be altered because the demographics have changed since the facility's construction.

A second, perhaps more compelling hypothesis is that it may be too early in the programme to tell. The power plants achieved the largest emissions reductions early, in the first year or two of the programme. The electric utility firms may have been preparing throughout the 1980s for the oncoming Clean Air Act Amendments in 1990, and delayed any technology upgrades, such as scrubbers, or switching to cleaner-burning low-sulphur coal, until the Programme commenced in 1995.

Munton (1998) suggests that one major change in the coal-power-generating industry was the increased availability of low sulphur coal to the large power-generating facilities in the mid-western USA. According to Munton (1998), almost all the coal-fired power plants in the mid-west used high-sulphur coal that was in close proximity to their operation in order to reduce transportation costs. This meant that the plants primarily used coal from coalmines in Appalachia. However, in the late 1980s, the railway infrastructure was being completed that made it possible to deliver low sulphur coal from Wyoming's Powder River Basin to the large power plants in the mid-west (Munton 1998).

While these explanations are preliminary and speculative, they suggest that more investigation is warranted into the causal factors of the distributive characteristics of SO_2 emissions. These hypotheses suggest further questions for study. In order to ever say definitively whether the trading regime is shifting emissions burdens inequitably, these and other questions must be addressed.

Conclusions

Preliminary findings suggest that environmental policy may not have to trade efficiency for equity. While clearly not definitive, the findings show that in the first three years of the ARP, the regime does not appear to have shifted pollution burdens inequitably to poorer communities or communities of colour. Further study is required to make this claim with greater confidence.

At least three additional factors might contribute to a more definitive analysis. First, the substitution and compensating units must be incorporated. Second, more investigation is needed into the factors underlying the initial distribution of power plants. For example, further analysis might show that property values, employment characteristics and political power (i.e. wealth, education, group organization, participation in politics, etc.) influenced the original location of power plants. Third, a more inclusive definition of environmental justice might reveal unfairness in, for example, participation in programme design or allowance allocation. Further studies must expand the scope of environmental injustice beyond distributional characteristics and explore procedural justice concerns.

The hypothesis was that there might be an antagonistic relationship between economic efficiency and environmental equity that would be exposed by the workings of the USA Acid Rain Programme. An analysis of the ARP, produced no evidence that SO_2 emissions from Phase I power plants are being distributed inequitably, specifically that emissions are concentrated in poor communities or communities of colour. The allowance trading system has not had the unintended consequence of transferring pollution allowances to poorer communities or communities of colour, at least not to date. The inequities that result from noxious facilities being located in poor communities of colour do not appear to carry over into the local distribution of risks from Phase I power plants.

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