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Assessing the US sulfur reduction program in Massachusetts from an environmental justice framework: Is there evidence of disproportionality?

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Abstract:

This study reviews the impact of a sulfur cap-and-trade program on distributions of sulfur within Massachusetts from 1990 thru 2014. The results indicate that sulfur reductions occurred throughout Massachusetts that were proportional, including a targeted study area within the state that meets the operational definition of a marginalized community. While the target study community disproportionately produced more sulfur emissions than surrounding communities, the reductions through cap-and-trade were consistent throughout the entire state. Other factors, beyond cap-and-trade, are identified as possible reasons why all areas of the state saw proportional reductions. But aside from those additional factors, the results indicate that cap-and-trade resulted in substantial and proportional reductions of sulfur throughout Massachusetts. This result informs more recent studies at the national level in the United States which show cap-and-trade programs have the potential to create disproportional impacts, particularly when looking at sulfur emission distributions.

Keywords:

Cap and trade, Disproportionality, Marginalization, Massachusetts, Sulfur Emissions

Introduction

The concept of *disproportionality* has become an important measure for the success, or lack thereof, of environmental policies. This is particularly true when viewing disproportionality through an environmental justice framework. The fundamental question at issue in this kind of inquiry can be stated as such: As society industrializes and modernizes, are reductions in environmental harm that normally coincide with economic development shared proportionately among the entire population? Or, in the alternative, is there evidence that environmental policies of modern societies are distributed disproportionately – unequally – among the population?

Focusing on the distribution of reduced environmental harm is important because it highlights, and thus exposes, a fundamental question of fairness that is at the heart of environmental justice research; when we take measures to reduce environmental harm and are successful in doing so, are those reductions applied evenly across the population? Or, is there a level of unevenness in environmental harm when it is created and when it is reduced through government intervention? From this perspective, environmental justice seeks to understand the distributional nature of environmental harm in its creation and regulation from varied perspectives: demographically, socioeconomically, politically, etc.

An implied assumption in most environmental policy work is that environmental harm is proportional to economic wellbeing. That is, there is implied proportionality between increases (or decreases) in environmental harm and other aggregate factors such a population size, national wealth, and overall level of technological advancement. Basic historical works on externalities (Coase 1960), collective action (Hardin 1968; Olson 1971; Ostrom 1990), and aggregate environmental impacts (Ehrlich & Holdren 1971; Commoner 1972) all highlight the cumulative aspects of environmental problems. Emerging from this work came the following equation representing the major considerations when trying to identify and quantify environmental impact: Impact (I) = Population (P) x Affluence (A) x Technology (T), or I = PAT. This equation presents a kind of large scale thinking supported by an implied assumption of proportionality. Behind this equation lies the inherent assumption that *all* increases in population and affluence negatively impact the environment *equally*. (Note: technology is seen to reduce environmental harm in this equation.) And this assumption then frames the way in which government interventions are measured. For example, a reduction of ten percent of unwanted emissions will impact all emitters equally, and also result in benefits that accrue equally.

Recent work has challenged this underlying assumption of proportionality (Fisher & Freudenburg 2004; Freudenburg 2005, 2009; Collins, Munoz & JaJa 2016). Empirical applications have shown clear indicators of disproportionality. Abel (2008) showed that marginalized residents of Saint Louis, Missouri lived disproportionately closest to industrial polluters and, thus, experienced a disproportionate amount of local air pollution. Ash and Boyce (2011), in looking at the worst corporate polluters, found that the top ten percent exposed marginalized communities to disproportionate impacts. In this nascent literature, there is a call to better understand the dynamics between polluters and patterns of distribution. As Grant et al. (2010) suggest, research should seek to discern patterns of disproportionality by nuanced examination of pollution distribution patterns.

This paper adds to the developing literature on disproportionality by providing an analysis of sulfur dioxide (SO2) distribution patterns on a local scale, measuring those patterns before and after the implementation of a major federal policy aimed at reducing overall levels of sulfur emissions. The goal is to see how a specific federal policy – cap-and-trade – impacts distribution patterns of sulfur. Under a disproportionality assumption, one would expect to find sulfur emissions that are reduced overall, but distribution patterns that are unequal: some areas will have less reductions, or even local increases, compared to decreases measured elsewhere. And the areas seeing increases or less reductions would be those described in environmental justice literature as marginalized communities: communities with higher proportions of minorities, lower educational attainment, and lower socioeconomic status (Fisher & Freudenburg 2004).

Our findings for Massachusetts show that sulfur emissions declined significantly throughout the Commonwealth, with an overall reduction amount of approximately 98% state-wide between 1990 and 2014. That overall reduction was consistent between county-level units. In terms of disproportionality, our focus county (Bristol County) showed the same 98% overall reduction in sulfur emissions, even though Bristol County exhibits clear indicators of marginalization in comparison to the rest of Massachusetts (higher unemployment, lower educational attainment, etc.). Bristol County also historically bore the brunt of sulfur emissions throughout the Commonwealth, averaging approximately 50% of total sulfur emissions between 1990 and 2014. Thus, our findings show the federal program to reduce sulfur emissions through cap-and-trade disproportionately *benefitted* Bristol County, because Bristol saw equivalent proportional reductions of sulfur emissions from 1990 to 2014 (approximately 98%), but this occurred in an area that was a major source of overall sulfur emissions for the entire state. Thus, at least for Bristol County in terms of sulfur emissions, the cap-and-trade program resulted in substantially lower emissions to an area that can be defined as traditionally marginalized. This shows that while disproportionality certainly does occur (and may be one reason Bristol County had historically borne a higher percentage of sulfur emissions before cap-and-trade), it does not automatically result in concentrations of higher emissions to marginalized areas, at least under the confines of this particular study.

US Sulfur Reduction Program

For various reasons (*see* Glass et al. 1982), the US government opted in 1990 to introduce a cap-and-trade program to reduce overall sulfur emissions resulting from, primarily, the burning of coal to produce electricity. Rather than rely on traditional command-and-control regulations, Title IV of the Clean Air Act Amendments of 1990 developed a sulfur allowance trading program. As detailed by Schmalensee and Stavins (2017, 61-62), the multiphase program worked by establishing a cap on total sulfur emissions from commercial electric utility generators. The cap was based on a baseline percentage of total recorded emissions. It decreased in phases over time, and allotted pollution permits to each coal-burning power plant based on actual prior emissions. For example, a cap of 80% of previous sulfur emissions would allot permits totaling that 80% to emitters based on their prior emissions. Generators could then determine the financially best means of electricity production. They could use all of the permits they had, buy additional permits from those who did not use all of their permits, or reduce emissions by installing sulfur pollution controls and bank the additional permits for financial gain. Market conditions dictated the relative costs and benefits of each of these actions.

The program was by most measures a success. Sulfur emissions from electric power plants decreased 36% between 1990 and 2004 (US EPA 2014). And this reduction occurred even as coal-burning power plant electricity production increased 25% over the same period of time (US EIA 2012). In addition, most estimates show the total reductions in sulfur emissions were achieved in an economically efficient manner (Popp 2003; Bellas & Lange 2011), with estimates ranging from between 15% and 90% cheaper than the costs of traditional command-and-control regulation (Carlson et al. 2000). There are other factors that impacted the overall success of the sulfur cap-and-trade program (*see* Schamalensee & Stavins 2013), but it is apparent the program itself provided a market-based policy that efficiently created meaningful overall reductions in sulfur concentrations in a manner that was well received by the regulated industry.

While the vast majority of evidence has suggested the Clean Air Act Amendments of 1990 have successfully reduced *overall* sulfur concentrations, less work has been done to determine the distributional effects, if any, on sulfur emissions. Ellerman and Montero (2000) and Swift (2004) both found that large-scale distribution patterns were consistent with overall sulfur reductions. But the scale of these studies were at the regional-to-national level. Considering most of the large-scale coal-burning that produces significant amounts of sulfur occurs east of the Mississippi River (Ellerman & Montero 2000), larger scale comparisons (state or higher) may fail to discern distributional patterns within a given state. Our work here attempts to address this issue by looking at sulfur distribution patterns at a resolution level within the Commonwealth of Massachusetts before and after enactment of the 1990 Clean Air Act Amendments.

Disproportionality

The concept of disproportionality, as the term is used in this study, is operationally meant to define distributional effects of environmental policies. In the context of cap-and-trade, disproportionality looks at how changes in concentrations occur via the "trading" aspect of the policy. While the cap results in overall reductions in the amount of an undesired byproduct – an identified "pollutant" – the trade allows for market forces to determine distributions. As research has shown, by focusing on distribution patterns, one can identify redistributions that result in greater local concentrations even with reductions in total pollutant output (Freudenburg 2005; Collins 2011). And the characteristics of those communities with localized increases in pollution tend to contain traits associated with marginalization. “Marginalization” in this context means, relative to immediately surrounding areas, characteristics including: higher unemployment, lower educational attainment, higher consumption of means-tested public services, and often greater demographic diversity (Fisher & Freudenburg 2004).

Disproportionality, then, attempts to measure how environmental policies redistribute pollution, and pays specific attention to redistributions where concentrations of pollution increase after the policy implementation. If higher concentrations are found, then the characteristics of that community are observed. Evidence of disproportionality is observed where the community shows characteristics of marginalization and it has relatively higher concentrations of a targeted pollutant after implementing an environmental policy. Thus, disproportionality is positive when a marginalized community shows relatively higher proportions of a regulated environmental harm after policy implementation. Alternatively, it can be said to be negative when a community that exhibits traits of disproportionality shows relatively lower proportions of a regulated environmental harm after policy implementation.

Research Question

Our primary research question can be stated as follows:

- Is there evidence of disproportionality in the application of the US federal sulfur reduction program (Clean Air Act Amendments of 1990) as it relates to communities within Massachusetts?

Subsequent to answering this question, we also ask the following:

- What factors may be influencing the observance, or lack thereof, of disproportionality?
- What policy implications arise from this analysis?

Our goal here is to put the question of disproportionality to the test at a more nuanced level of resolution for an environmental policy – sulfur emission cap-and-trade – that has been widely deemed a success.

When identifying and analyzing disproportionality, we also take notice that cap-and-trade can potentially create disproportions in where pollution is produced, and also how it is distributed (Collins 2011). Using the same framework questions as utilized by Collins, Munoz & Jaja (2016), we seek a before-and-after analysis of polluter and exposure disproportionality to determine:

- Whether producer disproportionalities are present across the study area?
- If disproportionalities are found, what is the demographic makeup of those communities and are they consistent?

We thus are looking at outputs of sulfur emissions at the state and county levels over time.

Methods

Community Choice

We have chosen to look at reductions in total sulfur output from commercial electric utility generators wholly within the geopolitical boundaries of the Commonwealth of Massachusetts before and after the passage of Title IV of the Clean Air Act Amendments of 1990. And within the Commonwealth, we have chosen county level data for comparison purposes. Bristol County was selected as the area of individual disproportionality comparison for two main reasons. First, from 1990 to 2014, it produced essentially half of all sulfur emissions in the Commonwealth (data provided in *Results* section). And the sulfur emissions of Bristol County, on a per unit basis, are higher than sulfur emissions from other counties in the Commonwealth. Second, Bristol County contains traits consistent with marginalization. It is demographically diverse, has higher rates of unemployment, lower educational attainment, and higher rates of means-tested public assistance utilization. These observed demographic traits are consistent with studies that have looked at Bristol County generally, linking its history of industrial activity – particularly textile manufacturing – with macroeconomic trends that has seen most of this industry move to other countries with lower labor costs and other factors (See Barrow 2000, 2002). Thus, for comparative purposes, Bristol County generates disproportionate amounts of sulfur and it contains the traits of a marginalized community when compared to other counties throughout the Commonwealth.

Further, our choice of state and county level data corresponds to suggestions in the disproportionality literature to look at pollution distributions at finer resolutions than national or regional data. While this can be problematic due to the transient nature of emissions (local reductions in emission outputs might not equate to actual local levels of pollutants due to cross-border transmission), it does provide a more nuanced view of disproportionality from an intrastate perspective. And with regards to sulfur emissions, studies have shown the fate and effects of sulfur emissions are varied depending on numerous factors (Smith & Hunt 1978). Thus, the perspective taken in this analysis is that the generation of sulfur, and not the ultimate deposition of sulfur from endo- or exogenesis sources, is the primary consideration as it relates to the question of disproportionality. In effect, if a community has characteristics of marginalization and it is a disproportionately significant source of sulfur emissions, then those facts are determinative when engaging in a pre and post environmental policy adoption analysis as is being done here.

Data and Assessment

To analyze emission dynamics under cap-and-trade to decipher evidence, or lack thereof, of disproportionality, sulfur emissions data was provided by the US Environmental Protection Agency National Emissions Inventory (NEI) database (US EPA 2014). The NEI is a comprehensive and detailed estimate of air emissions of criteria pollutants under the Federal Clean Air Act, which includes sulfur emissions. Data is collected from state, local, and tribal air agencies within their reporting requirements under federal law. That data is then supplemented with data developed independently at the federal level. The end result is an integration of data from multiple government sources that result in the NEI database.

The data is reported beginning in 1990 to coincide with the implementation of the Amendments of 1990 that gave rise to sulfur cap-and-trade. The 1990 data sets a baseline of emissions. The federal legislation then had a five-year implementation period. Thus, the next data set available is 1996. The data is then annual between 1996 and 2002, reflecting annual data collection practices. After 2002, the data is provided in 3-year increments beginning in 2005 and reflecting changes to the reporting requirements for the cap-and-trade program. Data presented in this study is current through 2014, the most recent date where data is available. The 2017 inventory is currently in the planning stages and has not yet been finalized at the time of analysis and writing. The data allowed for a direct analysis of sulfur emission changes at the state and county level over time. For each NEI reporting year, the emissions of each county and the state are noted. Numeric and percentage changes in emissions are noted in total and between reporting years. In addition, for five counties identified as major contributors, a rate of change between reporting periods was calculated using the above data to determine any variation in the rates of change between major emitting counties.

To analyze demographic information relevant to defining and understanding marginalized community dynamics, US Census data was utilized for years 1990 and 2000. This provided demographic coverage during the initial implementation of the sulfur cap-and-trade program in 1990 through 2000. In addition, The American Community Survey was utilized for years between 2000 and 2014 to match the NEI reported years. Available metrics of demographics used to measure marginalization include the following: population, unemployment rate, poverty rate, and educational attainment. These metrics were determined at the state and county level for comparison purposes. The goal was to provide a comparison between counties and the state on relative indicators of marginalization. If a county showed indications of marginalization and high rates of sulfur emission, then that county was compared to all other counties. Corresponding changes in marginalization (via the demographic metrics noted) were also examined over time at equivalent intervals for NEI inventory reports in the following reporting years: 1990, 2000, 2005, 2008, 2011, 2014. These years were then averaged and the results provided a comparison of counties on traits of marginalization that corresponded to NEI reporting years of sulfur emissions. Each demographic metric used to measure marginalization was individually compared against sulfur emissions between counties. The results allowed for a detailed analysis of marginalization within the context of sulfur emission generation.

Results

Sulfur Cap-and-Trade Program

Table 1 provides an accounting of total sulfur emissions (in metric tons) in the Commonwealth of Massachusetts, including county output, for reporting years from 1990 to 2014. As noted earlier, the years presented in Table 1 represent the reporting years for the initiation and implementation of the US Clean Air Act cap-and-trade program.

Table 1
Total Sulfur Emissions (Metric Tons), 1990–2014

Year	1990	1996	1997	1998	1999	2000	2001	2002	2005	2008	2011	2014
Barnstable	60,633	15,230	28,379	33,213	27,878	23,848	23,227	22,014	27,095	4,590	128	700
Berkshire	0	4	4	5	3	3	3	0	7	0	4	0
Bristol	95,374	48,402	52,945	51,808	52,876	49,921	45,220	44,118	37,092	32,100	18,755	1,640
Dukes	0	0	0	0	2	2	2	2	4	6	12	1
Essex	42,197	23,827	32,143	34,338	23,865	20,535	18,323	14,154	10,619	4,359	3,612	1
Franklin	0	0	0	0	0	0	0	0	0	0	0	0
Hampden	12,267	7,768	10,301	9,034	7,897	8,641	9,190	5,697	5,355	4,611	266	188
Hampshire	0	0	0	0	0	0	0	0	26	31	16	12
Middlesex	13,389	9,288	19,654	28,283	16,728	9,749	7,795	5,307	5,285	34	12	15
Nantucket	501	103	108	110	43	0	0	0	1	0	0	0
Norfolk	8	30	32	32	0	44	45	23	56	23	27	23
Plymouth	519	8	9	8	8	8	9	15	12	11	10	0
Suffolk	8,779	80	11	9	17	6	7	286	5	813	54	948
Worcester	0	174	162	157	4	4	4	13	21	16	17	16
Massachusetts	233,668	104,916	143,747	156,998	129,322	112,761	103,826	91,628	85,578	46,595	22,912	3,544

Source: U.S. Environmental Protection Agency's National Emissions Inventory, 1990–2014

As Table 1 shows, the total amount of sulfur emissions in Massachusetts was more than halved between 1990 (inception of the sulfur cap-and-trade program) and 1996, the first year of measurement. Sulfur emissions were reduced from 233,668 metric tons in 1990 to 104,916 metric tons in 1996. Then in 1997, an approximately 40% increase from 1996 levels was reported at 143,747 metric tons. This coincided with changes to federal cap-and-trade policy and reporting requirements (Bellas & Lange 2011; Schmalensee & Stavins 2013). 1998 thru 2001 saw a return to regular reductions in sulfur emissions, ending at near-1996 levels by 2001 when 103,826 metric tons of total emissions were reported. More significant reductions were seen from 2001 thru 2005. But then substantial reductions (essentially halving total sulfur emissions) occurred during reporting periods of 2008 and 2011. The most recent reported year, 2014, showed an approximately 7-fold decrease from 2011 emissions, resulting in a total of 3,544 metric tons of sulfur emissions for the entire Commonwealth.

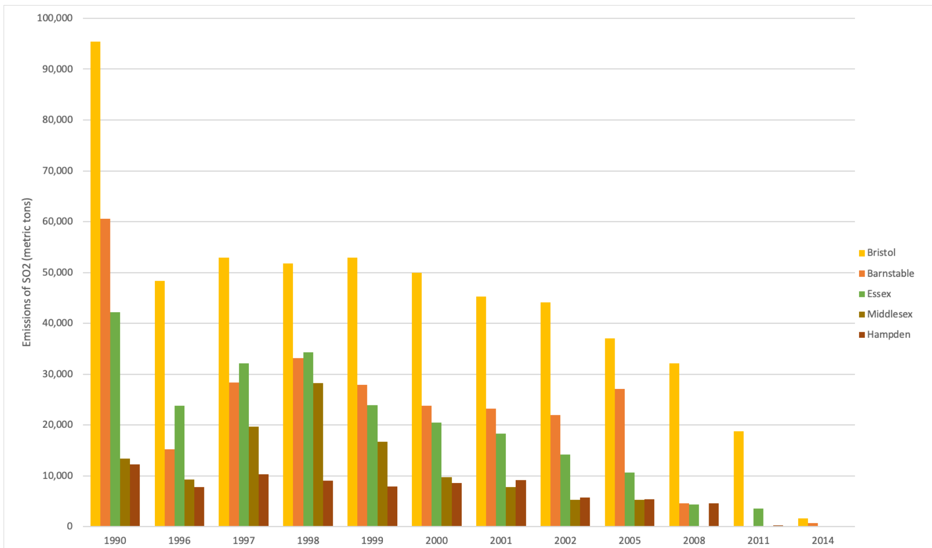
Comparing the fourteen counties in Massachusetts, we see that Bristol County provided a disproportionate amount of sulfur emissions as compared to other counties during the period of 1990 thru 2014. And in particular years during the cap-and-trade program (2008 and 2011), Bristol County's contribution increased proportionately as a percentage of total state contributions, from a background average of about 48% to a high of 82% of total state output.

In addition to Bristol County, four other counties provided the vast majority of the Commonwealth's total sulfur emissions. Barnstable, Essex, Middlesex, and Hampden Counties, when included with Bristol County, represent approximately 96% of the total Massachusetts sulfur emissions reported in 1990: 223,861 of the 233,668 metric tons reported. During subsequent reporting years, the five counties represented 98% or more of Massachusetts's total sulfur emissions, with the exception of 2014 where they represented approximately 72% of total emissions.

Focusing on these five counties, a visual comparison of the emissions data can be provided to determine relative changes in emissions between these counties over time. **Figure 1** provides two comparisons of total emissions over time. Figure 1(a) shows a bar comparison of total emissions during each of the major reporting years. Figure 1(b) provides the same information in line graph format to get a sense of the relative rates of change in emissions between these five counties overall and in-between intervening reporting years. Collectively, these figures provide a proportionate sense of emissions between these major emitting counties during the entire reporting of the sulfur cap-and-trade program, and also a sense of emission reduction (or increase) trajectory between the counties over time.

Figure 1
Sulfur Emissions of Major Counties in Massachusetts Over Time

1(a)



1(b)

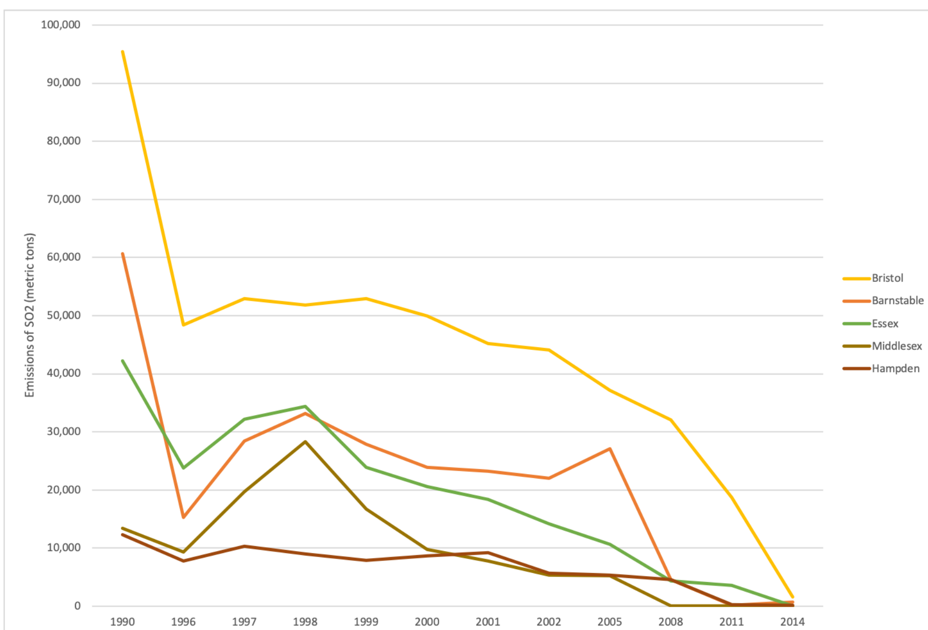


Figure 1 clearly shows Bristol County continued to be the largest source of sulfur emissions from 1990 thru 2014. In addition, as seen most clearly in Figure 1(b), Bristol County had a more moderated rate of lowered sulfur emissions, in comparison to the other counties, mainly between 1998 and 2005. But the rate increased substantially for Bristol County thereafter, ultimately lowering to similar levels of the other counties in 2014. Thus, the data shows that cap-and-trade clearly resulted in all counties having substantially reduced their sulfur emissions by 2014. But the *rate of decrease* was not equivalent between these major emitting counties during at reporting intervals between 1990 and 2014.

The variation among the five major sulfur emitting counties in the rates of change between reporting periods can be teased out by singingly out the variation between reporting periods using the following equation: dc/dt, or change in concentration (dc) over change from immediately preceding reporting period (dt). **Table 2** provides the calculated rates of change in emissions for each of the major sulfur emitters and Massachusetts overall from the immediately preceding reporting period.

Table 2
Rate of Change in Sulfur Emissions From Immediately Preceding Reporting Period

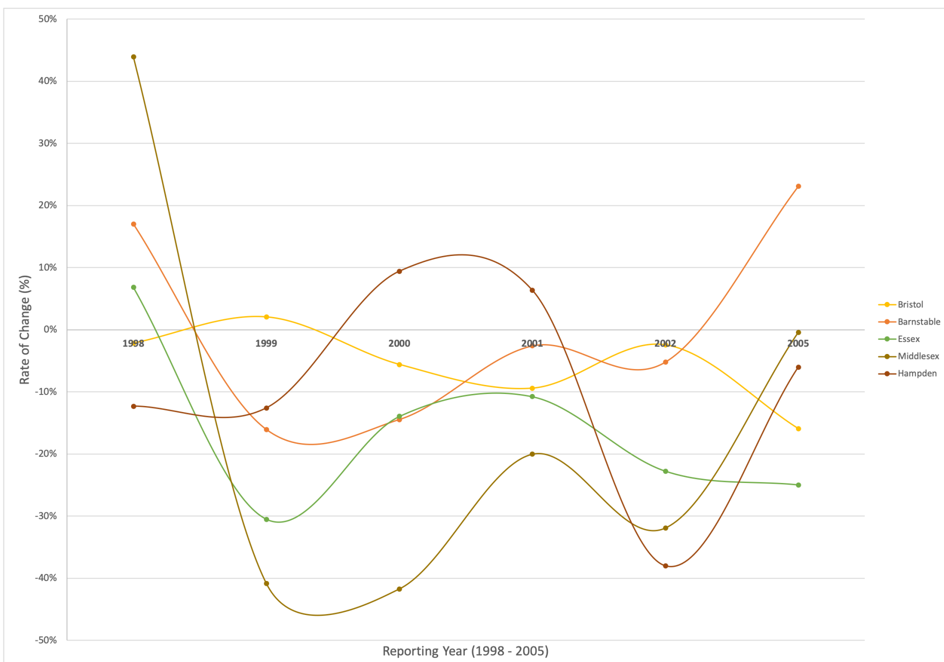
Year	1996	1997	1998	1999	2000	2001	2002	2005	2008	2011	2014
Barnstable	-75%	86%	17%	-16%	-14%	-3%	-5%	23%	-83%	-97%	447%
Bristol	-49%	9%	-2%	2%	-6%	-9%	-2%	-16%	-13%	-42%	-91%
Essex	-44%	35%	7%	-30%	-14%	-11%	-23%	-25%	-59%	-17%	-100%
Hampden	-37%	33%	-12%	-13%	9%	6%	-38%	-6%	-14%	-94%	-29%
Middlesex	-31%	112%	44%	-41%	-42%	-20%	-32%	0%	-99%	-66%	25%
Massachusetts	-55%	37%	9%	-18%	-13%	-8%	-12%	-7%	-46%	-51%	-85%

Source: U.S. Environmental Protection Agency's National Emissions Inventory, 1990–2014

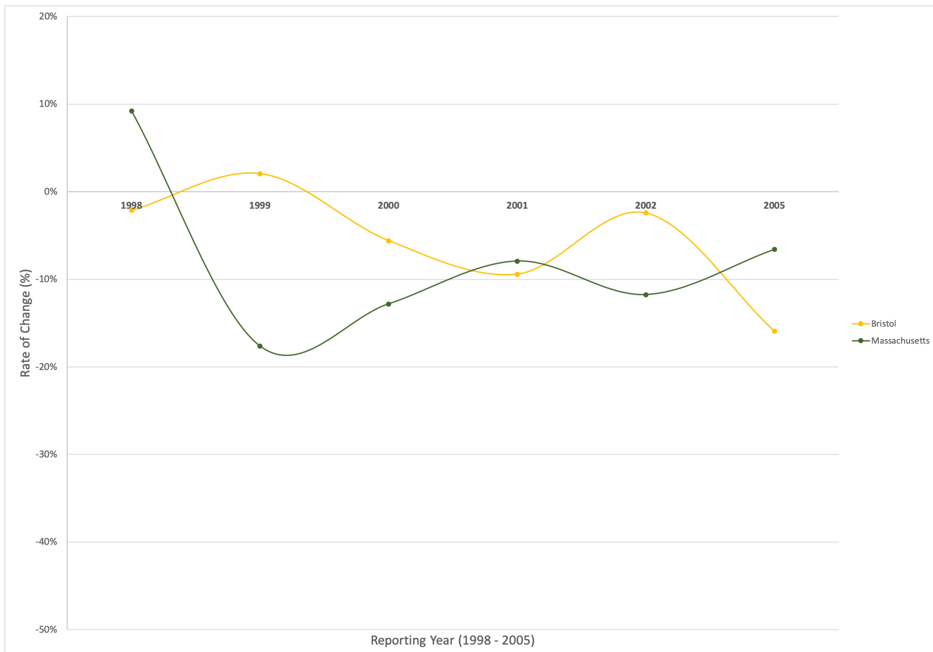
We can map this change visually to discern any differences between the five major sulfur emitting counties over time. **Figure 2** provides two linear graph visualizations for this purpose. Figure 2(a) shows the relative rates of change for the five major emitting counties. Figure 2(b) shows the rates of change for Bristol County and Massachusetts to highlight general trend comparisons. Both figures utilize reporting periods from 1998 thru 2005.

Figure 2
Percentage Rates of Change in Sulfur Emissions of Major Counties in Massachusetts Over Time

2(a)



2(b)

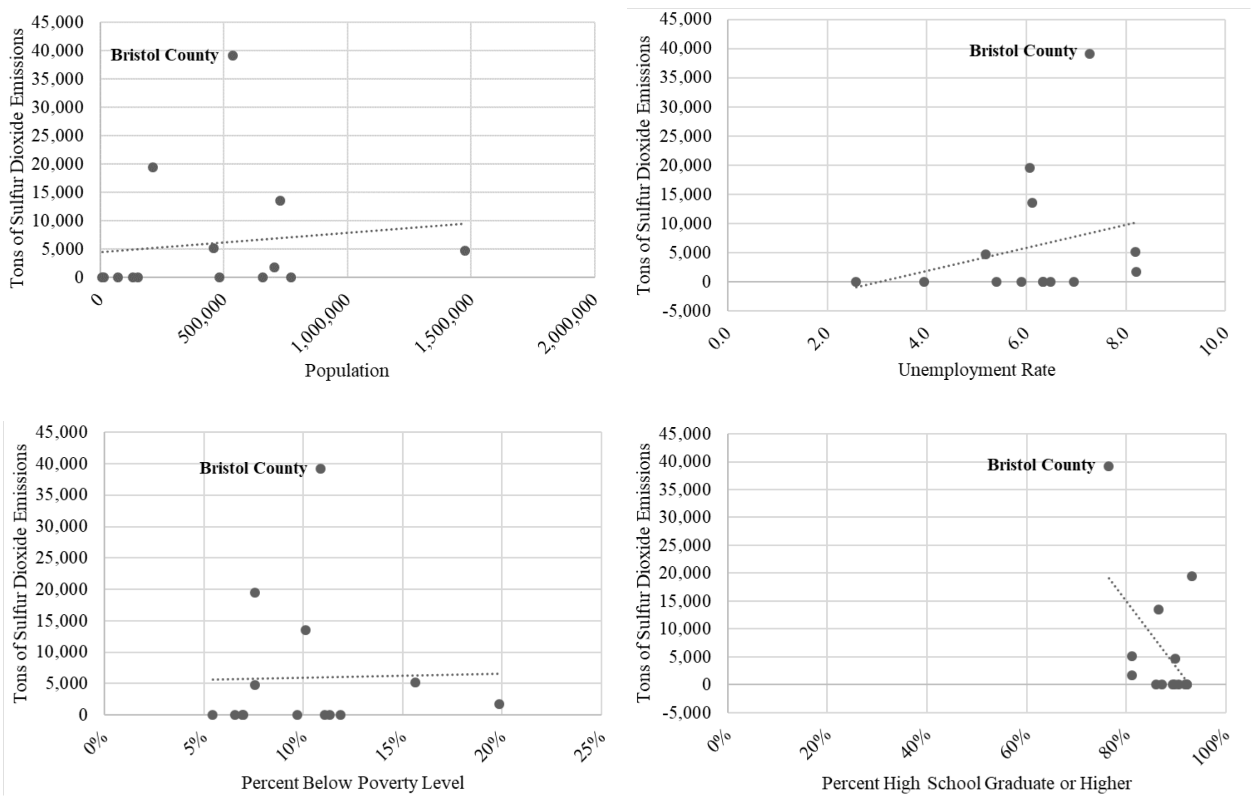


The results from Table 2 represented in Figure 2 show that while Massachusetts and the five major emitting counties saw reductions in sulfur emissions during 1998 thru 2005, those reductions were not consistent between counties. Rather, there were large swings in rates of decrease, and in some instances increases in emission rates between reporting periods, for a number of counties. Bristol County reflected the smallest variance of change between the five major county emitters from one reporting year to the next. In addition, as most clearly seen in Figure 2(b), Bristol County's path of reduced emissions was generally inverse to that of Massachusetts overall from 1998 to 2005.

Disproportionality

In addition to sulfur emissions, disproportionality was also examined. **Figure 3** provides key demographic information for fourteen counties in Massachusetts and compares each demographic to sulfur emissions. Demographics reported include overall population levels, high school graduation rate, rate of unemployment, and rate of poverty for each county. A trend line is provided and our target county for disproportionality, Bristol County, is identified for comparison purposes. The data presented represents average results in each demographic for the following NEI reporting years: 1990, 2000, 2005, 2008, 2011, 2014.

Figure 3
Demographic Indicators Compared to Tons of Sulfur Dioxide Emissions by County, 1990–2014



Source: US EPA National Emissions Inventory, IIPUMS-USA, University of Minnesota, Author's Calculations 1990–2014

The results in Figure 3 show that Bristol County has a high degree of marginalization as measured against the demographic factors indicated. It's disproportionate total average sulfur emissions is positively correlated with higher rates of unemployment and poverty, as well as lower rates of high school and higher graduation.

Discussion/Conclusion

The results obtained in this study provide important insights into the impact of a national sulfur cap-and-trade program on communities of different makeup in the Commonwealth of Massachusetts. It is clear that Bristol County Massachusetts emitted more sulfur emissions than the other counties of Massachusetts: approximately half of total emissions over the entire study period between 1990 and 2014. When we overlay that output of sulfur emissions on variables such as population, educational attainment, unemployment, and poverty, we find that Bristol County rate of sulfur emission generation is disproportionate on all of these factors in comparison to all other counties in Massachusetts (see Figure 3). This finding suggests that Bristol County, with its higher rates of unemployment and poverty, along with lower rates of educational attainment, meets a reasonable definition of a marginalized area. Couple this with the fact that, as a marginalized area, Bristol County continued to provide disproportionate amounts of sulfur emissions during overall reductions in the cap-and-trade program, including the fact that its proportion increased in 2008 and 2011 to a high of 82% of overall emissions, there is positive evidence of disproportionality during cap-and-trade implementation in Massachusetts.

But the finding of disproportionality generally in Bristol County is balanced with the finding that due to overall consistent reductions of sulfur emissions, Bristol County actually enjoyed the largest *numerical reduction* in sulfur emissions of any county in Massachusetts between 1990 and 2014. In terms of actual output, Bristol County reduced its emissions from

95,347 metric tons in 1990 to 1,640 metric tons in 2014: a reduction of 93,707 or over 98% of 1990 output. That percentage is similar to the Commonwealth's overall reduction percentage during the same time period. Effectively, because Bristol County bore a higher burden of overall sulfur emissions, it enjoyed a higher overall reduction in emissions than other counties in Massachusetts. Therefore, based on the analysis presented, Bristol County did not become a hot spot of sulfur emissions as has been found in other contexts (Collins, Munoz & JaJa 2016). Rather, it enjoyed an equivalent percentage of reduction as the Commonwealth which, in numeric terms, resulted in a higher overall reduction of local sulfur emissions when compared to other counties.

The results provided suggest that cap-and-trade programs can be successful at reducing overall emissions levels in a way that does not create outliers (so-called "hotspots") of emissions. Disproportionate sulfur emissions, including the creation of hotspots after cap-and-trade certainly does occur, and has been shown at the national level. And when it does, the areas where the hotspots occur tend to meet accepted definitions of marginalization: they have traits similar to Bristol County. But while Bristol County did in-fact create a disproportionate amount of the sulfur emissions from commercial electricity generation in Massachusetts, reductions brought on by cap-and-trade policy actually created an outsized benefit in comparison to other counties, at least in terms of numerical (metric-ton for metric-ton) reductions.

It can be argued that Bristol County was more of a hotspot for sulfur emissions before the implementation of cap-and-trade. Further, the results of Table 2 and Figure 2, highlighting rates of change between counties and Massachusetts overall, invite questions about cap-and-trade implementation dynamics. Bristol County's movement towards reduced overall emissions was different from the other major emitting counties and Massachusetts. And that difference generally ran counter to the Commonwealth as a whole; when the Commonwealth had higher rates of emissions reductions, Bristol County had lower rates. Only after 2008 did Bristol County show a significant drop in emission rates that allowed it to have effectively the same overall rate of reduction by 2014. This raises potential questions about the path to lowered reductions. For example, did the power producers in Bristol County rely more heavily on purchasing permits to emit while other producers used technology and other means to lower emissions in intervening years of the program? This question should be explored to the extent it can help to elucidate additional political and social factors that can impact intervening rates of emission reductions in cap-and-trade programs for areas that meet operational definitions of marginalization. While examining such questions of disproportionality, again, from the data examined here there is no evidence of disproportionality after full implementation of cap-and-trade, certainly by 2014.

It is important to note this study is limited in a number of ways. For one, it is necessarily limited geographically by design. We wanted to test the hypothesis of disproportionality at a local level, understanding that Southeastern Massachusetts has lagged the rest of the Commonwealth in a number of socioeconomic indicators. We also knew that one of the largest regional coal burning power plants was sited in Bristol County, linking the two factors. Thus, seeing how cap-and-trade affected local policies towards electricity generation in a progressive state provided an important contextual test to this larger problem. What we know from this study is that, at least within the boundaries of Massachusetts, cap-and-trade ultimately has worked to reduce sulfur emissions proportionally between county-level units. And because Bristol County originally had a disproportionate burden of sulfur emission, equivalent percentage reductions across the Commonwealth resulted in substantially less emissions of sulfur, on a per-unit basis, than other counties in the Commonwealth.

Another limitation is that the unique social and political structure of Massachusetts, along with technological innovations, might have aided in the overall substantial reductions of sulfur emissions observed. The sulfur emissions at-issue in this study essentially come from the burning of coal to produce electricity. A concomitant emission from burning coal is carbon, which is an important greenhouse gas that is helping to drive the observed phenomenon of climate change. Massachusetts has long been a proponent of limiting greenhouse gas emissions. For well over the last decade, it has been a member of the New England Regional Greenhouse Gas Initiative, and it has taken on a consistently leading role in lowering its carbon footprint in all areas of human activity. For example, it was the named plaintiff in a suit against the Federal Environmental Protection Agency (EPA) in the mid-2000s that demanded the EPA move forward in listing carbon as a criteria pollutant under the Federal Clean Air Act (Freeman & Vermeule 2007). The desire of the Commonwealth to reduce carbon outputs, along with advances in carbon neutral technologies (solar, wind, hydroelectric) and lower costs for less carbon-intense options (natural gas) have all aided in creating options beyond coal. To the degree these policy choices, technological innovations, and market conditions have aided in reducing sulfur, they provide some potential explanatory factors beyond cap-and-trade for the substantial sulfur reductions observed, particularly from 2011 to 2014.

The limited scope of this study and characteristics of the Massachusetts social-political landscape aside, the results of this study confirm that cap-and-trade policy can have an even-handed impact across geographic areas with varied socioeconomic indicators. To the authors, this represents at least one example that cap-and-trade policy works in terms of total emission reduction (the “cap”) and in terms of equality in how that reduction is distributed (the “trade”). No clear disproportional effects are found in this study. Future work should consider some of the economic, political, and social factors mentioned above (*see* Sze & London 2008). Sulfur reductions may have been easy to achieve because they essentially come from a single source (burning coal), and there are ready-made alternatives for electricity production that are increasingly cost-effective. Like the global efforts to remove hydrofluorocarbons, complimentary factors such as ready-made alternatives can make a solution to a complex problem look deceivingly simple (Velders et al. 2007).

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