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The effects of regulatory uncertainty on the U.S. Acid Rain Program

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THE EFFECTS OF REGULATORY UNCERTAINTY ON THE U.S. ACID RAIN PROGRAM

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ABSTRACT

Title IV of the Clean Air Act Amendments of 1990 (CAAA 1990) created the first large scale cap-and-trade program as a means to control acid rain in the United States. The program regulated the emission of sulfur dioxide (SO_2) and nitrous oxide (NOx) in the atmosphere—the precursor to acid rain. Economists have long argued for the use of market-based incentive approaches as oppose to traditional command-and-control methods for its ability to be efficient and cost-effective. Title IV went into full effect in 1995 and has been lauded among one of the most successful regulation as it was efficient in reducing SO_2 at lower cost than other program.

Market based or incentive based programs work by providing incentives for individuals and firms to alter polluting behavirors by inposing opportunity cost through pricing. The altering of polluting bvehaviors is achieved by changes in the regulatory environment in which firms operate. However, when prices are low there is the potential for the loss of incentive.

Such loss in the regulatory environment occurred in 2008 when the D.C. Circuit overturned the Clean Air Interstate Rule (CAIR) and remanded the dispute to EPA to develop new rules for its replacement. This thesis found regulatory uncertainty to contribute significantly to the decline in the price of emission permits. However, the contribution is relatively small. The adoption of technology appears to be the driving factor behind the decline in the price of emission permits. In the context of the Clean Air Act, there was the expectation of more stringent SO_2 standards and regulation of mercury emissions. Scrubber technology used to control the emission of SO_2 has also shown to be effective in limiting the emissions of oxidized mercury. Since the announcement of these standards there has been a statistically significant increase in the number of control technologies being implemented.

CHAPTER 1: INTRODUCTION

1.1 Introduction

Title IV of the Clean Air Act Amendments of 1990 (CAAA 1990) was designed to deal with the issue of acid rain (formerly acid deposition) reduction. The program regulated the emission of sulfur dioxide (SO_2) and nitrous oxide (NOx) into the atmosphere—the precursor to acid rain. The regulation applied to electricity generating utility plants located in the contiguous United States. As a method of control, the United State Congress broke from the traditional command-and-control methodologies in pollution regulation and created the first large scale market for tradable emission permits—a market/incentive based method.

Economists have long argued for the use of market-based incentive approaches (i.e. market for tradable permits), as oppose to traditional command-and-control methods for its ability to be efficient and cost-effective (Hahn & Stavins, 1992). Title IV (The Acid Rain Program) was fully implemented in 1995 and has been lauded among one of the most successful regulation as it was effective in reducing SO_2 concentration at a lower cost than other program. According to Swift (2005) the strong regulatory framework coupled with cap and trade "is one of the most effective ways to reduce pollution." The program has seen near perfect compliance and has banked significant amount of (unused) permits for future use.

Building upon the successes of the Acid Rain Program, in 2005 the EPA issued the Clean Air Interstate Rule (CAIR). CAIR is a product of the EPA's rulemaking procedure. It was designed to further reduce SO_2 and NO_X emissions in order to meet the National Ambient Air Quality Standards (NAAQS) for criteria pollutant a mandate by the Clean Air Act. CAIR required emission for SO_2 and NO_X to be reduced by 57% and 61%, respectively of 2003 levels to be achieved by 2015 (Sotkiewicz & Holt, 2005). CAIR is tied into the Acid Rain Program by the use of emission permits, where permits allocated under Title IV may be used to comply with the emission reductions mandated by CAIR.

In 2008 several states and utility companies petitioned the U.S. Court of Appeals D.C. Circuit for judicial review of CAIR. The court ruled there were “more than several fatal flaws” with the rule, and the EPA had overstepped the statutory authority granted by the Clean Air Act (Kruse, 2009). The D.C. Circuit vacated the rule and remanded the dispute to EPA to develop a replacement rule that is consistent with the court’s decision.

Market based or incentive based regulations rely on changes in the regulatory framework in order to be effective, thus the overruling of CAIR has left a regulatory void. As a result, the industry faces uncertainty as to decisions for capital investments into control technologies for future compliance; and the individual states face uncertainty about strategies for compliance with NAAQS criteria (Moren, 2009). Regulatory uncertainty is suspected to be the cause of failures in the market for SO_2 permits. Woodward (2010) has shown the price and volume of SO_2 emission permits on a steady decline since the overturning of the rule.

Figure 1-1 shows the price of permits along with events and proposed actions by the EPA which results in changes in the price for SO_2 emission permits. The figure demonstrates an increase in the price following the announcement of tighter standards for particulate matter of size 2.5 microns (PM 2.5). This is followed by a downward trend during the period when CAIR was argued to when courts made its ruling.

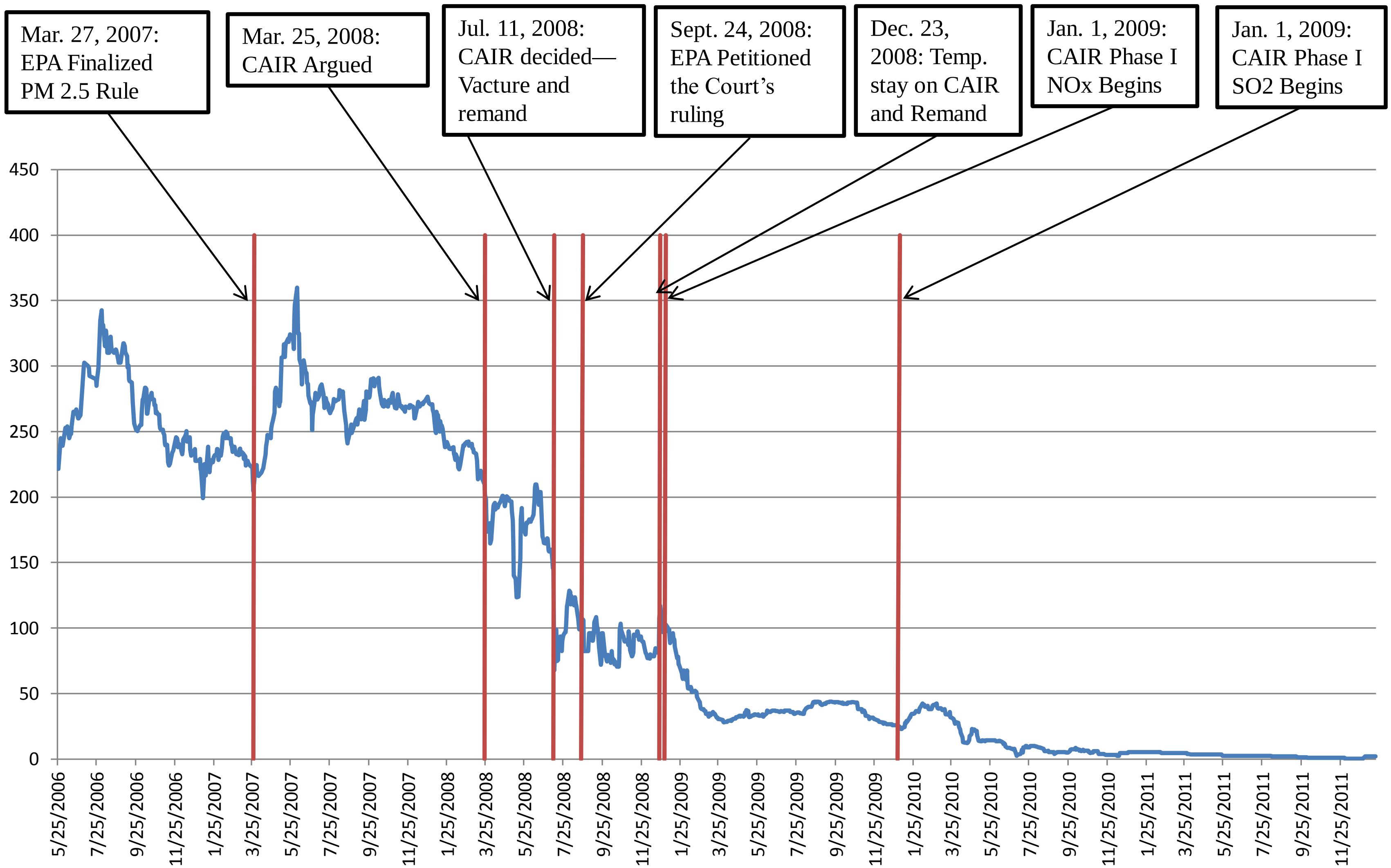


Figure 1-1: Price for Sulfur Dioxide Emission Permits

Also demonstrated in figure 1-1 is the decline in prices after the court's final ruling on CAIR in 2008. Permit prices showed a sharp decline then continued the downward trend. Palmer and Evans (2010) reported spot prices fell from $300 to $80 per permit, when the Circuit court vacated CAIR. Upon temporary reinstatement of CAIR prices rose from $140 to $210 per permit. This is then followed by a steady decline in prices where permits were traded as low as $3.88 at the end of 2010.

The overruling of CAIR created a regulatory void that is cause for concern. Moren (2009) states "The D.C. Circuit's ruling has left a worrisome regulatory gap: downwind states are still enduring the human health and environmental impacts from the upwind pollution, and industry, faced with regulatory uncertainty, is unable to effectively plan for the future." Kruse (2009) commented the decision "bears heavily on future attempts to efficiently deal with pollution." The D.C. Circuit's decision combined with the observed market reaction raises the question: what is the effect of regulatory uncertainty on tradable emission permits?

1.2 Rationale for the Study

Title IV of the CAAA of 1990 has been efficient in reducing the overall level of SO_2 in the atmosphere, and achieved such reductions relatively cost-effectively. As a result, the program has served as a model to control carbon dioxide emission reduction envisioned in the Kyoto Protocol, and European Union Trading Scheme. The objective of the study is to assess the role of regulations with respect to market based incentive policy instrument. This thesis is focused on explaining the dramatic decline in SO_2 permit prices (demonstrated in figure 1-1). It is hypothesized that the decline in prices are due to regulatory uncertainty due to the overruling of the Clean Air Interstate Rule.

Through the use of statistical and econometric models, regulatory uncertainty is analyzed through an examination of the price of SO_2 permits in the context of the electricity production. On the qualitative side, is an examination of the timeline of events, proposed rules and regulatory actions for the Acid Rain Program and CAIR. Because market-based incentive program rely on changes in the regulation which engender a desired behavioral change, a timeline of events provide a context for the analysis.

To understand and analyze the effects of regulatory uncertainty, this analysis is organized by first looking at the theoretical framework of tradable emission permits, then a historic look at air pollution regulations in the United States, followed by description of the Acid Rain Program. I then describe the data and model used followed by the interpretation and discussion of the results.

CHAPTER 2: BACKGROUND/LITERATURE REVIEW

2.1 Sulfur dioxide

Sulfur dioxide (SO_2) is a naturally occurring atmospheric gas; it is formed from the oxidation of elemental sulfur (S). Sulfur dioxide enters the atmosphere through natural and anthropogenic sources. Natural source include the eruption of volcanos, decomposition and combustion of organic matter (Kellog, Candle, Allen, Lazrus, & Martell, 1972). Anthropogenic source is primarily from the combustion of fossil fuel. In the United States, the largest anthropogenic source of SO_2 is from the emission originates from electricity generating power plants (73%) and other industrial facilities (20%) (EPA, 2011). Figure 1-1 below obtained from the EPA shows the total contribution of anthropogenic emissions of SO_2.

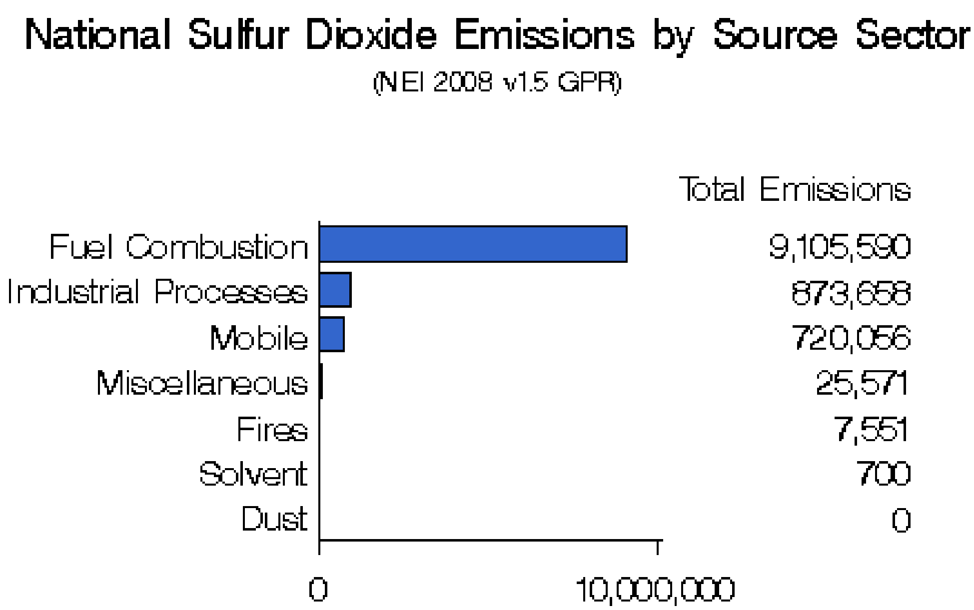


Figure 2 -1: Anthropogenic Sources of Sulfur Dioxide

From point sources, SO_2 is emitted along with other gasses in plumes which mostly remain in the well-mixed layer of the atmosphere. The gas becomes mixed and dispersed horizontally and vertically due to weather and the prevailing wind (Mason, 1992). In the atmosphere, SO_2 becomes oxidized where it is converted to sulfuric acid (H_2SO_4). Figure 1-2 shows the conversion process from SO2 gas emitted from point sources to the formation of sulfuric acid in the atmosphere and final deposition.

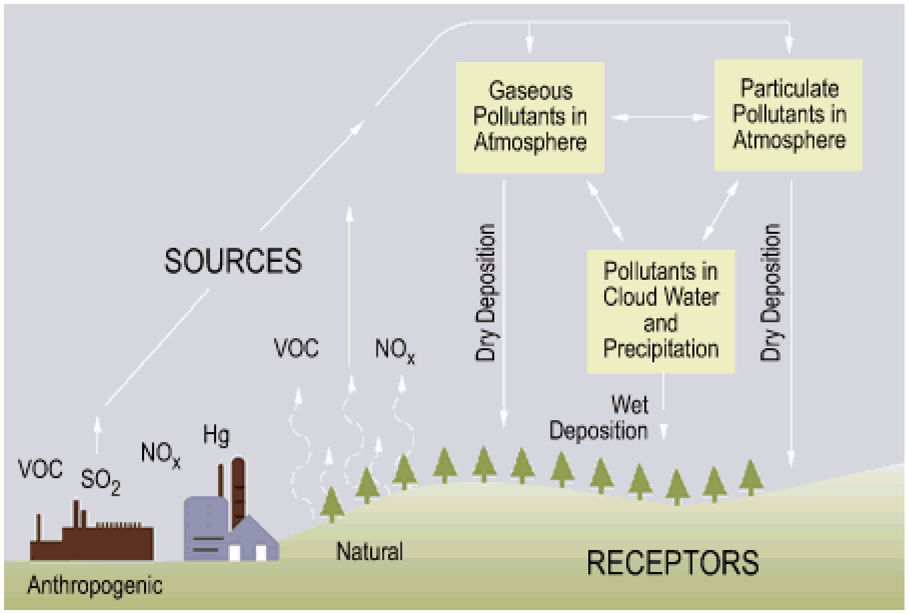


Figure 2-2: Conversion Process of Sulfur Dioxide

The converted sulfuric acid can then exist in “dry” form (gaseous or particulate matter) or “wet” when combined cloud and raindrops. Sulfuric acid is then returned to the Earth’s surface. Dry form can be absorbed by vegetation, and wet is returned in rain, snow or fog (Mason, 1992) (EPA, 2011).

The effects of sulfur dioxide on the environment and human health and are well documented. Sulfuric acid deposited on the Earth’s surface lead to the acidification of freshwater lakes and streams. In soil, it mobilizes naturally occurring metals such as lead, cadmium, mercury and aluminum, which are toxic to humans. In their elemental form these metals are not biologically available, however their solubility increase with decreasing pH. Though acidic deposition is not solely responsible for mobilizing these metals, it increases the uptake rate (Maugh, 1984).

Dry deposition adversely impact human health primarily though inhalation of sulfur dioxide either in gaseous form, particulate form or a combination of both. These compounds attack the respiratory defenses leading to respiratory diseases (Franklin, Burnett, Paolini, & Raizenne, 1985) and may ultimately lead to morbidity or mortality.

2.2 Theoretical Framework of Permit Trading

The goal of environmental public policy is for the protection of human health and ecosystems from harmful levels of pollutants. In the development of public policies, selection of a policy instrument is paramount. Policy instruments can be categorized into two broad areas: (1) "command-and-control" where policymakers typically specify a target reduction and/or technology for abatement and (2) market-based incentives, where policymakers design programs to change the behavior of the polluter.

In developing environmental policy, regulators may claim a singular objective; whereas in reality a single regulation may try to maximize many objectives (Hahn & Stavins, 1992). The criterion for selection of environmental policy instrument as described by Revez and Stavins (2004), and Perman et al. (2003) may include:

1. Effectiveness – the policy achieves the stated target
2. Cost-effectiveness – the target is achieved at the lowest possible cost

3. Information requirement – the policy provides government with information needed to implement the policy
4. Flexibility – the policy is adaptable to changes as new information or technology arises
5. Dynamic incentive – provides incentive for continual research and adoption of abatement technologies
6. Equity – equitable distribution of the costs and benefits
7. Political feasibility – the policy must be feasible to enact and implement

For economists the policy selection criteria should be economic efficiency. The concept of economic efficiency is grounded the concern of utilizing limited societal resources as to maximize utility. In terms of policy, economic efficiency is achieved when net benefit is maximized; where net benefit is equal to the total cost minus total benefits of a proposed regulation (Olmstead, 2010). Figure 2-3 below demonstrates a graphical representation of economic efficiency.

In figure 2-3, the total cost curve increases at an increasing rate. Initial abatement will target pollutants that are the most obvious and easier to remove. As pollution reduction standards become tighter, finer particles are required to be removed. As a result, the cost of compliance will also increase because firms will be required to adopt costly abatement equipment. Benefits on the other hand are continually increasing, however at a decreasing rate. The removal of finer particles of pollution may still have adverse effect on a sensitive portion of the population; this however is a small part of the population. Economic efficiency as determined by maximization of net benefit will be larges positive difference between the total benefit and cost. A criterion for economic efficiency is cost-effectiveness. This is the main criteria discussed. Revesz and

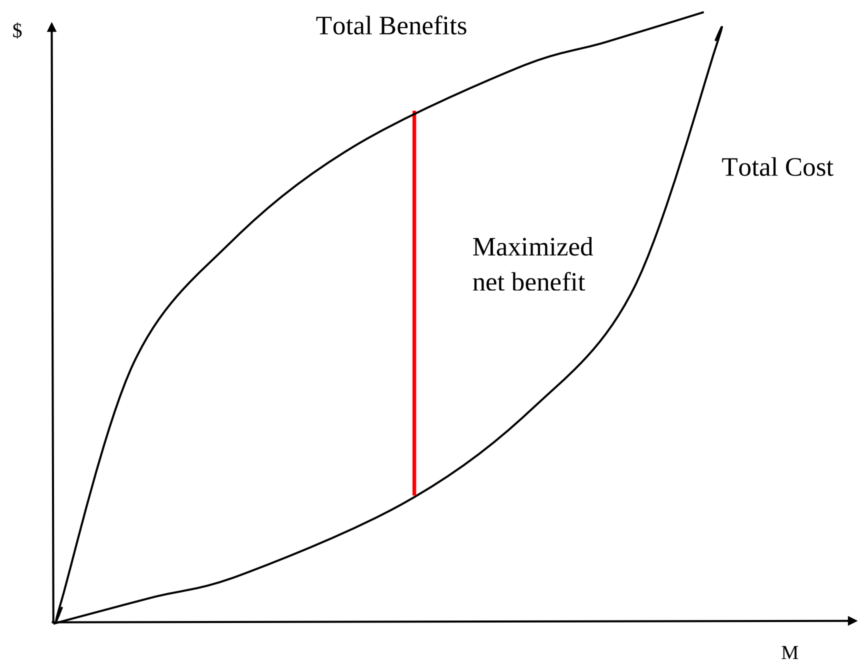


Figure 2-3: Economic Efficiency

Source: adaptation from Olmstead, (2010)
and Perman, et al. (2003)

Stavins (2004) expanded the cost-effectiveness definition to include criterion 1 to 5 referred to earlier.

Historically, environmental regulations have been dominated by "command-and-control" type policy instruments. Typically these regulations define technology based standard, performance based standards and set equivalent shares of control responsibilities among all affected sources (Tietenberg, 2006), (Hahn & Stavins, 1992) (Revesz & Stavins, 2004). Started in the 1970s the federal government began instituting regulations such as the Clean Air Act and the Clean Water Act in response to public concerns of increasing levels of pollution in the environment. The command-and-control instruments used have led to better air and water quality, removal of hazardous substances and protection of biological diversity (Kraft & Vig, 2010).

These instruments have achieved the targeted pollutant reduction, contributed to economic growth through the creation a new economic sector for pollution control and spurred innovation (Press & Mazmanian, 2010). According to Taylor et al. (2005) command and control instruments have led to an increase in technological innovation such as flue gas desulfurization technology, which was in response to the Clean Air Act Amendment of 1970's New Source Performance Standard provision.

Though command-and-control techniques have worked, it has been increasingly criticized because these instruments (1) provide little flexibility for the affected sources to comply as these rules typically dictate a uniform reduction standard or specify control equipment; (2) lacks the ability to provide of dynamic incentives for continual removal of pollutant and technological innovation. As Cook (1988) states, "the incentive under command

and control is simply to conform." Though, Taylor's (2005) study found the instrument spurred technological innovation, the demand for scrubbers from electricity generating utilities remained low. Finally, command and control (3) have been demonstrated not to be cost-effective, where pollution reduction was not achieved at the least cost.

Economists have argued for the use of market based or incentive based policies. Policy instruments that fall under the umbrella of market-based incentives include: emissions charges and taxes, subsidies, liability payments, and tradable emission permits (Perman, Ma, McGilvray, & Common, 2003). This differs from command-and-control where the regulators impose mandatory restrictions or control obligations on the firm.

Market-based instruments change the behavior of the firm through the creation of opportunity costs for each unit of pollutant that is emitted. In an unregulated environment, there are no associated costs incurred to a firm for the emission of pollutants. The behavioral change is achieved when the external cost in the firms' production function has been accounted for, thus internalizing externalities. These instruments provide greater flexibility as regulators do not dictate to firms how the target should be achieved. With the option to freely choose its method of compliance, profit maximizing firms have the incentive to achieve the target reduction at the least cost (Hahn & Stavins, 1992).

Market based instruments and in particular, tradable emission permits are of interest. Environmental resources are by nature public goods, without regulations the affected source has little incentive to reduce its emissions voluntarily. Under a tradable emission permit system, the regulator sets the emission reduction target. A firm, as a profit-maximizer, would rationally choose the least cost option required to meet the target. In a conceptual model, cost-effectiveness can be achieved when the following cost-minimization equation is satisfied:

Equation 1

$$\min_{r_i} C = \sum_{i=1}^{N} c_i(r_i)$$

provided that:

$$\sum_{i=1}^{N} [u_i - r_i] \leq \bar{E}$$

and

$$0 \leq r_i \leq u_i$$

Where: C = aggregate cost of control

$c_i(r_i)$ = cost function for source *i*

r_i = reductions in emissions by source *i*

u_i = uncontrolled emissions by source *i*

$\bar{E}$ = aggregate emissions target imposed by regulator

Source: Revesz & Stavins, (2004), (Tietenberg, 2006).

From the above equation, cost minimization (and thus cost effectiveness) is achieved when the marginal abatement cost has been equalized across all firms (Revesz & Stavins, 2004) (Tietenberg, 2006) (Perman, et al., 2003).

Conversely, for cost-effectiveness to be achieved under a "command-and-control" instrument, emissions levels would have to vary by individual firms according to their unique marginal abatement cost function. Given the state of asymmetric information, regulators generally do not have the appropriate information which would allow them to vary the cost-effective control responsibilities among firms. Additionally, moving from a previously unregulated environment to a regulated one, firms have the incentive to inflate their marginal abatement costs (Tietenberg, 2006) as it would mean lower emission control responsibilities. Thus, policies utilizing command-and-control techniques would fail to achieve the target reduction.

Under a tradable emission permit system, the requisite marginal abatement cost information for the regulator is no longer required. The regulator sets the total permissible level of emissions and the control responsibility is shifted to the individual firms. The control responsibility is then determined by each individual firm's marginal abatement cost function, and through the use of market pricing of emission permits, an efficient allocation will be determined within the industry.

The tradable emission permit system is commonly referred to as a "cap-and-trade" system. The "cap" represents the total permissible level of emissions. The cap is reflected in the number of emission permits that is allocated by the regulator. A permit is the right to emit a unit of pollutant as specified by the regulator (Montgomery, 1972). "Trade" refers to the ability for firms to transfer the right to emit (a predetermined unit of) pollutant. Under a system of tradable emission permits, the regulator sets the level of emissions that is permissible for a given geographic region to be achieved in a time period, where the permissible level is lower that the unrestricted level of emission.

The regulator is additionally required to design monitoring and enforcement systems to ensure compliance (Tietenberg, 2006). The total permissible level, a system of monitoring and enforcement create the incentive to engender the desired behavioral effect, namely less polluting activities.

Prior to any regulation, cost-minimizing firms have the incentive to freely discharge waste into the environment. In a system of tradable emission permits, each unit of pollutant discharged into the environment has an associated cost, which is the cost of the emission permits. As Moren (2009) described, Title IV of the Clean Air Act Amendment of 1990 created *de facto* property rights. Thus where permits can be used either to cover emission by a firm or sold. Thus, the decision for a firm to pollute involves opportunity costs thereby creating the incentive to reduce its emission levels.

Firms across an industry will have varying levels of marginal abatement cost. These costs are dependent upon the age of equipment, production design, physical configuration, and level of technology (Revesz & Stavins, 2004). Thus the valuation of permits will also differ among firms (Tietenberg, 2006). A firm with a high marginal abatement cost will be willing to pay higher prices for additional permits, whereas, firms with low marginal abatement cost will be willing to pay less.

Figure 2-4 demonstrates a stylized model of the marginal abatement cost structure of two firms. In this model, Firm A has a higher marginal abatement cost (MAC) as represented by steeper curve. Firm B on the other hand has a lower MAC depicted by a flatter curve. For a given price *X*, Firm B can achieve larger emission reduction that Firm A. Due to the difference

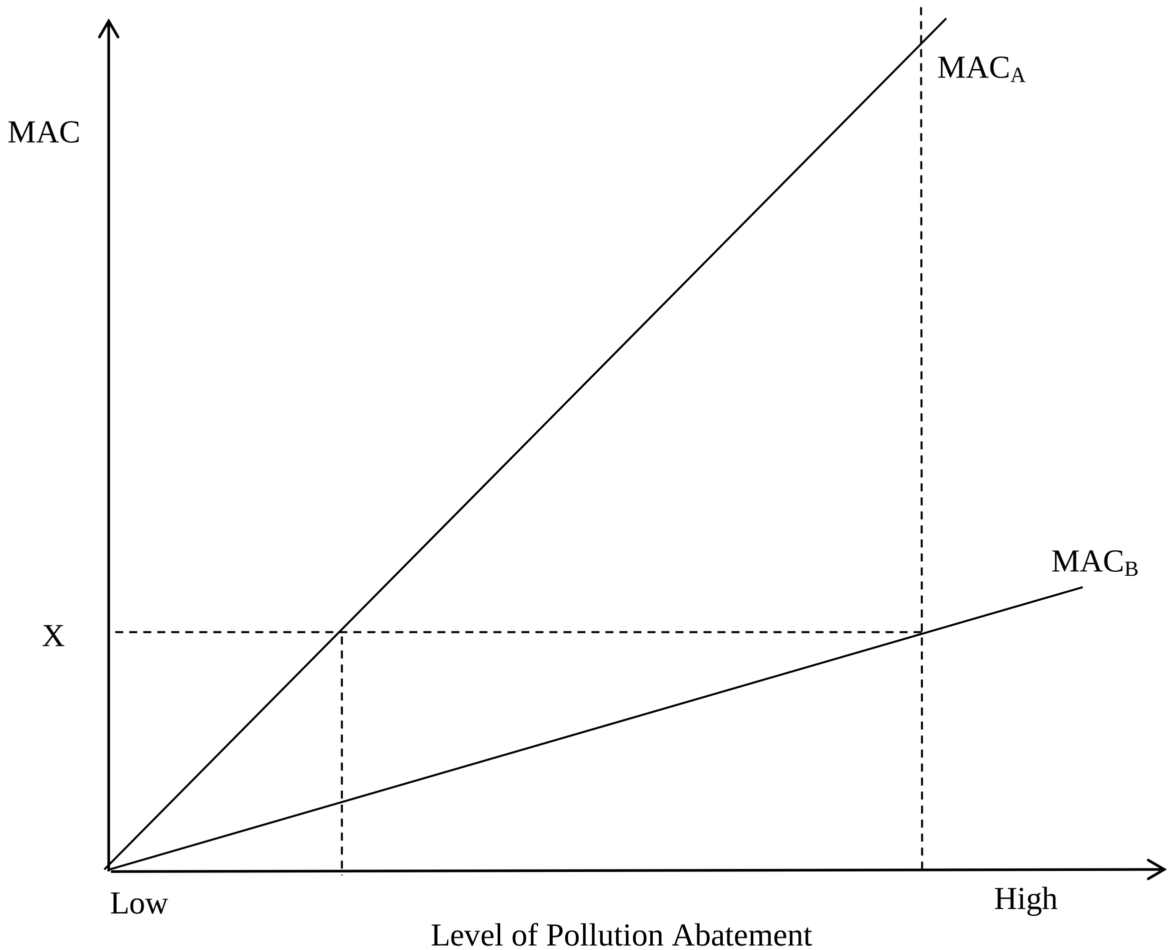


Figure 2-4: Marginal Abatement Cost for Two Firms

Source: Perman, et al. (2003)

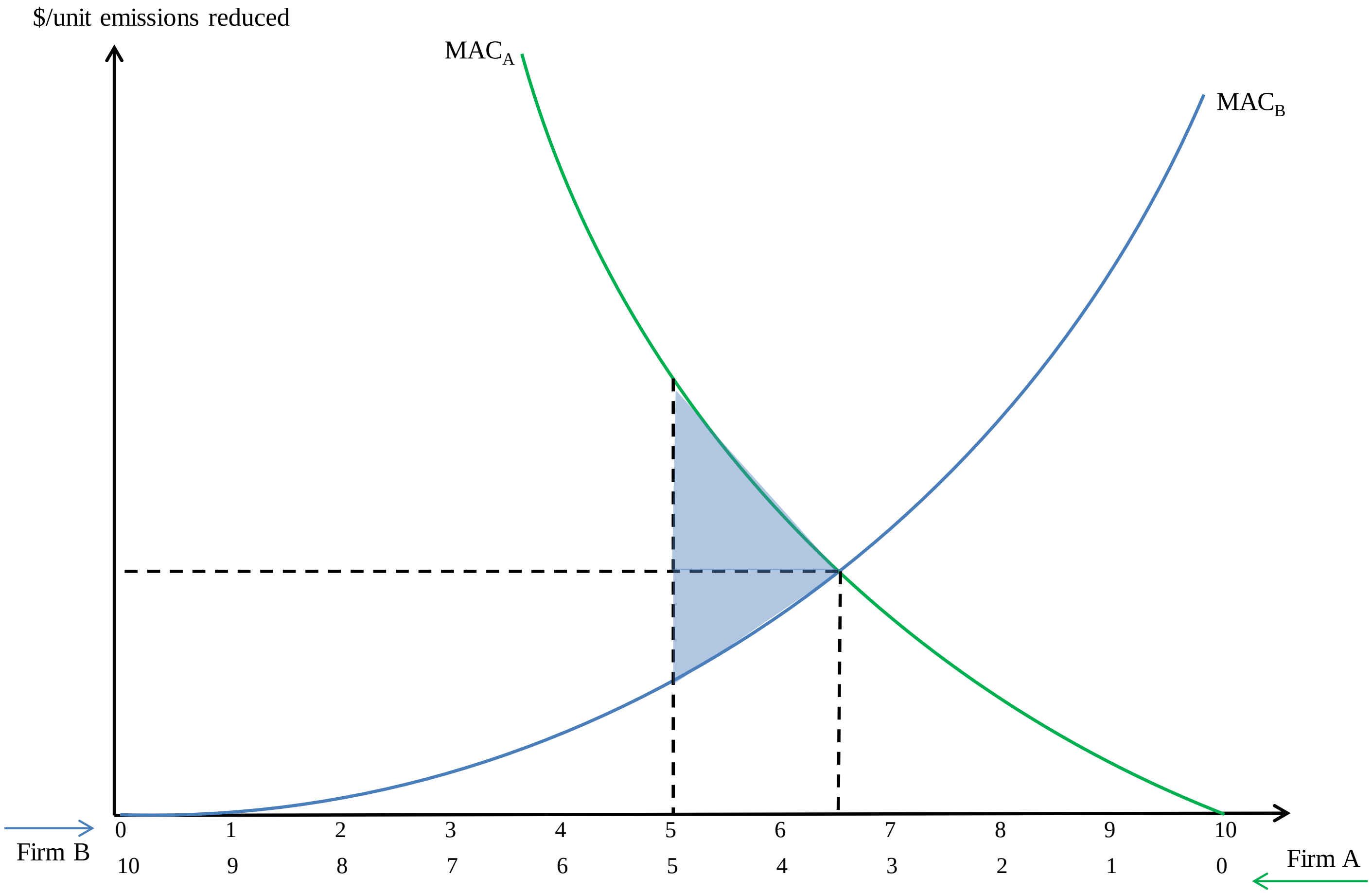
between the two firms' MAC curves, Firm B may find it cost-effective to pursue additional reduction and sell excess permits to Firm A.

Building upon figure 2-4, figure 2-5 shows the efficient allocation of emission control responsibilities for two firms. In this stylized model, the total unrestricted level of emissions is 20 units, where both Firms A and B have maximum emission of 10 units each. The horizontal axis shows the level of emissions for both firm A and B. Note in this model any combination of control responsibilities would yield the regulatory pre-determined 10 units of emission.

As in figure 2-4, the marginal abatement cost is higher for Firm A than for Firm B. As graphically demonstrated in figure 2-5, the efficient allocation of control responsibilities for the two firms is the equilibrium point. At the point where the MAC curves intersects the marginal cost of abatement is equalized between the two firms. This is represented at the point where the MAC for Firm A intersects with the MAC for Firm B.

If both firms were required to reduce their emission by 50%, it would require both firms to reduce 5 units from the unrestricted level. Firm A with a higher MAC would incur higher cost than firm B. Cost-effectiveness can be achieved by the ability to trade the right to emit. Firm B with a lower with a lower marginal abatement cost can take on additional emission reductions while being compensated by Firm A. The efficient allocation of control responsibilities would require Firm A to reduce it emissions approximately by 3.5 units and Firm B 6.5 units. The total gain from trade is represented by the shaded blue area.

An important feature built into a cap and trade system is that a prerequisite for cost-effectiveness is (2) the flexibility firms have to determine its strategies of compliance and (2) the market determine control responsibilities. Since the regulator merely sets the reduction target



Source: adaptation from Tietenberg (2000)

Figure 2-5: Efficient Allocation of Control Responsibility

(the total permissible level of emissions is represented by the number of permits distributed to the affected source), firms can then choose their own method of compliance. Firms have perfect information about their marginal abatement costs, thus as profit-maximizers, firms would (1) rationally choose the least cost abatement method and (2) exploit gains from trade thereby creating a dynamic incentive for continual abatement activities.

As discussed earlier, a tradable emission permit system establishes permits which are the right to emit a unit of pollutant into the environment. Thus, the regulator is required to design systems to monitor the emission of pollutants and enforcement procedures for non-compliance. This is a requirement for the cost-effective criteria (Tietenberg, 2006).

2.2 Regulatory History of Sulfur Dioxide

The Clean Air Act was designed to "protect and enhance the quality of the Nation's air resource so as to promote the public health and welfare and the productive capacity of its population." Since 1955 the act through subsequent amendments has been ever evolving. An understanding of its history can provide some basis for analysis air regulations.

Among the most significant amendments of the Clean Air Act is the 1970 Amendment. The 1970 amendment implemented the basic framework that exists today (Ferrey, 2010). It established national standards for air pollutant and a list of six criteria pollutants to be regulated by the Environmental Protection Agency. Criteria pollutants are naturally occurring atmospheric gasses; however, these gasses in high concentrations can lead to causes adverse effects on human health and the environment.

Sulfur dioxide (SO_2) has been among the list of atmospheric pollutants regulated since the passage of the Clean Air Act Amendment of 1970. According to the EPA, SO_2 emissions lead to the formation of sulfuric acid and particulate matter. This can lead to an array of adverse human health effects including respiratory and cardiovascular diseases and damage to the natural and built environment. Consistent with the objectives articulated in the Clean Air Act, namely for the protection of human health and welfare, the EPA determined standards referred to as the National Ambient Air Quality Standard (NAAQS) for the six criteria pollutants. The standards are scientifically determined level to protect human health with an adequate margin of safety.

The criteria pollutants include ozone, particulate matter, carbon monoxide, nitrogen oxide, sulfur oxide and lead. It should be noted that the original criteria pollutant included hydrocarbons and excluded lead. Hydrocarbons are regulated as a precursor to ground level ozone (Ferrey, 2010). Lead was added to the list of criteria pollutant following *NDRC v. Train* (1975). These NAAQS levels set by the EPA and are the minimum permissible level determined to protect human health with an adequate margin of safety.

The Clean Air Act established a partnership between the federal government and the individual states in order to achieve these air quality standards (Ferrey, 2010). The responsibility for the attainment and maintenance of the nationally uniform standards lies primarily with the individual states (CSR Report for Congress, 2007). The act requires that the individual state outline its procedures that would bring its jurisdiction into attainment in a State Implementation Plan (SIP). SIPs have to be reviewed and approved by the EPA; however the individual states do retain broad discretion as to the strategies that can employ in order to bring their region into compliance (Moren, 2009).

Initially, to comply with the NAAQS SO_2 standards, coal fired electricity generating facilities built tall smokestacks, many of 500 feet in height (Burtraw & Szambelan, 2009). As a result emissions were dispersed higher up in the atmosphere. Emitted SO_2 travel hundreds of miles and react with sunlight and water in the atmosphere to form sulfate which can then be deposited as dry particulate matter or wet when combined with rain, snow or fog.

Installation of tall smokestacks allowed local entities to meet NAAQS criteria. However, since emissions are dispersed higher up in the atmosphere, states continued to experience difficulty in achieving attainment status on a regional level. The failure of states to meet the NAAQS deadlines prompted Congress to impose new control measures.

The Clean Air Act Amendment of 1977 introduced tighter standards for New Source where newly built plants were required to invest in the “Best Available Control Technology” and existing sources to invest in “Reasonable Available Control Technology.” The statue expanded the New Source Performance Standard (NSPS) definition of “new” source to include (1) facilities with construction that began after the New Source Performance Standards were reviewed and (2) modification that were made to existing sources after the revision of NSPS (Brownell, 2009).

These measures were put into place to achieve attainment status and for the prevention of significant deterioration (PSD) of “healthy air” (Ferrey, 2010). The 1977 amendment also introduced the concept of “attainment” and “non-attainment.” An “attainment” designation is for areas in compliance with NAAQS standards, and “non-attainment” is the designation for areas out of compliance.

The designation of "attainment" status continued to be problematic for states to achieve. The Clean Air Act Amendment of 1990 instituted revised controls regulations for SO_2 and NOx. In 1990 the legislative body broke from its traditional command-and-control methods such as technology specifications, and implemented the first market based approach to pollution abatement. This approach is outlined in Title IV of the Clean Air Act Amendment of 1990.

Title IV created the first large scale cap and trade program as a means for pollution control. The program referred to as the Acid Rain Program, controlled sulfur dioxide and nitrous oxide emissions. The statute outlined emission reduction from electricity generating sources as the main contributor of SO_2 and NO_x. The statute here also departs from its predecessors in that it, not only concerned with public health, but rather the larger environment. According to Section 410 the "presence of acidic compounds and their precursors in the atmosphere and in deposition from the atmosphere represents a threat to natural resources, ecosystems, materials, visibility, and public health" Clean Air Act §401 (1990).

CHAPTER 3: THE ACID RAIN PROGRAM

3.1 Overview of the Acid Rain Program

The discussion in the preceding section provided a basic framework of the economic merits of tradable emission permit system, which is the ability to demonstrate efficiency and cost-effectiveness. The theory however, is described in a highly stylized manner with assumption of the absence of market failures. These merits, however, can only be realized based on its implementation, which hinges upon the political process.

The Acid Rain Program created under Title IV of the Clean Air Act Amendment of 1990 established the first large scale system of tradable emission permits. The program was conducted in two phases. Phase I began in 1995 and included the largest emitters of SO_2; this totaled 110 facilities and about 445 units. These units were coal burning facilities primarily located in the Eastern and Midwestern parts of the U.S. The allocation of SO_2 permits for Phase I totaled 5.7 million. Phase II began in 2000, the total allocated permits totaled 9.5 million and included all utilities with a 25 megawatts capacity or greater. Starting in 2010 the EPA instituted a permanent cap of 8.5 million permits (EPA, Acid Rain Program, 2011).

The allocations of permits to existing sources are distributed in two ways (1) grandfathering and (2) through an auction. Existing facilities were grandfathered into the program based on their historic fuel consumption (thereby heat input) and emissions rate (EPA, 2011). Allowances are also distributed through a public auctions conducted by the EPA on a annual basis, usually held in March.

The EPA withholds approximately 2.8% of the yearly allocated permits. The auction is revenue neutral in that the EPA returns the proceeds from the auction to the source where it was initially deducted. The rationale of the auction is to provide price signals to the industry for future trading. It should be noted here from 1993 to 2006 Chicago Board of Trade (CBOT) was designated by the EPA to administer the auction (EPA, 2012), for which they received no compensation.

EPA auctions are open to any registered parties, this includes regulated facilities, individuals, or organizations who wish to participate in the auction (which historically has included Environmental NGOs, University environmental clubs, and brokerage firms). To participate in the auction, the party is required to submit a bid price and the quantity. The Chicago Board of Trade (now the EPA) rank the bid prices from highest to the lowest and auction off the allowances until the supply is exhausted. Holders are also permitted to sell unused permits at auctions. EPA requires the holder specify a minimum price. The agency returns any proceeds from the auction if sold or the permits if unsold.

The program does not allocate allowances to new sources built after 1990. These sources must obtain allowances either through the auction or buy them from other sources. Sources built after 1990 are subject to new source performance standards which require technologies that would control sulfur dioxide emission.

The program allows for greater flexibility for the affected source to comply Title IV regulations. As the EPA touts on its website, the program

> "represents a dramatic departure from traditional command and control regulatory methods that establishes specific, inflexible emissions limitation with which all affected sources must comply. Instead the Acid Rain Program introduces an allowance trading system that harnesses the incentives of the free market to reduce pollution" (EPA, Acid Rain Program, 2011).

Compliance strategies employed by many sources include fuel switching, fuel blending, retrofitting facilities for co-firing and installation of scrubbers (Burtraw, 1996).

Permits have monetary value, thus monitoring and reporting is of importance for a well-functioning market based incentive instrument. The affected source is required by federal law to have continuous emissions monitoring systems (CEMS) installed and the information must be reported in order to ensure compliance. CEMS are required to be in continuous operation and collect data at least every 15 minutes. The EPA describes CEMS data to be "the gold standard to back up the paper currency of emissions allowances" thus accurate monitoring and reporting "instills confidence in allowance transactions…by certifying the commodity being traded" (EPA, 2009).

As it relates to compliance, the affected source is required to surrender allowances to cover its yearly emissions. The EPA grants a 60 day "grace" period where a source may buy or sell allowances. Sources out of compliance after the 60 day grace period face a penalty of an inflation adjusted $2000.00 per ton of SO_2 emitted in excess of permits surrendered. In addition, the affected source is required to offset its emissions. This is done by having it deducted from its yearly allocation or bought on the open market.

Unused permits can be banked (for future use), traded to other electricity generating units, sold to third party (usually a brokerage firm), or sold back to the EPA (EPA, 2009). The Sarbanes-Oxley act of 2002 strengthened the enforcement provision. The act strengthened federal criminal law regarding issues of compliance and document retention (Brownell, 2009).

3.2 Results

3.2.1 Effectiveness

Title IV was effective in that the regulation was able to reduce the intended pollutant—sulfur dioxide and nitrous oxides. In 2009 the industry had emitted 5.7 million tons of SO_2, a 64% reduction compared to 1990 levels and significantly below the 9.5 million tons per year cap. (EPA, 2010). Figure 3-1 below created from data obtained by the EPA demonstrates the decline of SO_2 emissions from 1985 to 2010. As a result sulfate concentration demonstrated in figure 3-2 also declined across the contiguous United States. On the left shows sulfate concentrations in 1985 and on the right shows sulfate concentration in 2009.

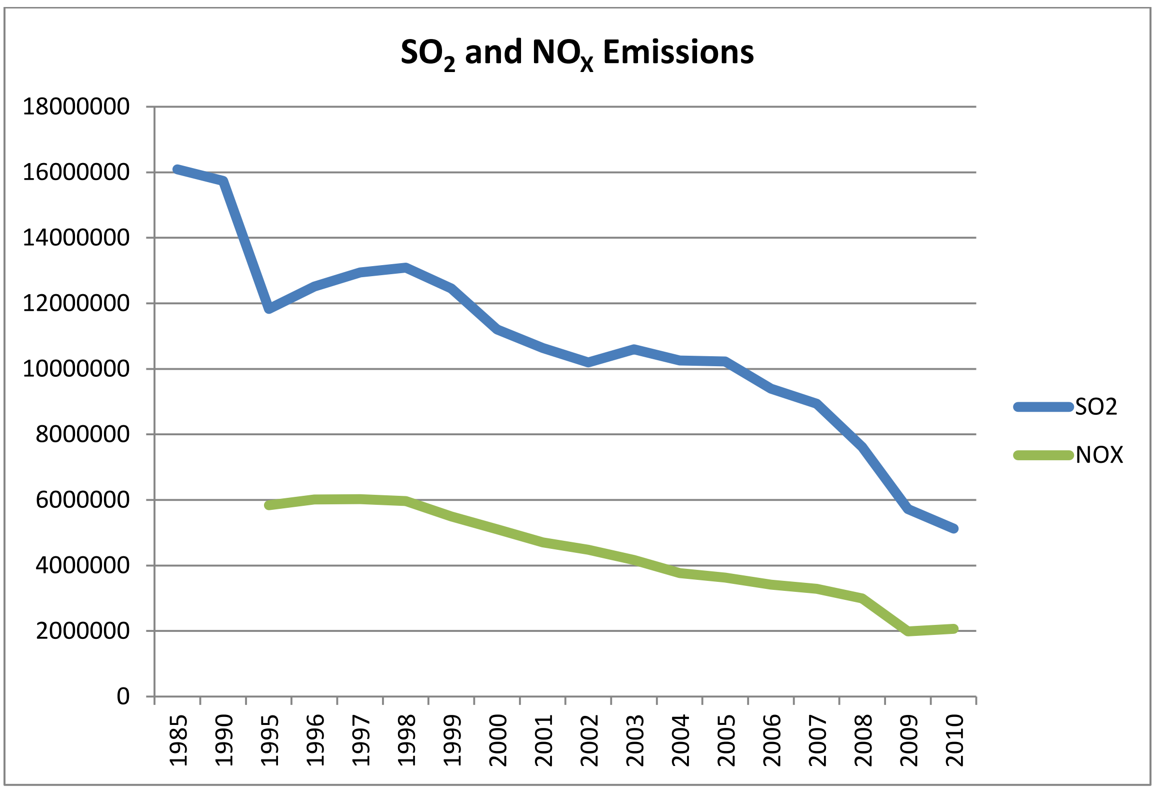


Figure 3-1: Yearly Sulfur Dioxide and Nitrous Oxide Emission (in tons)

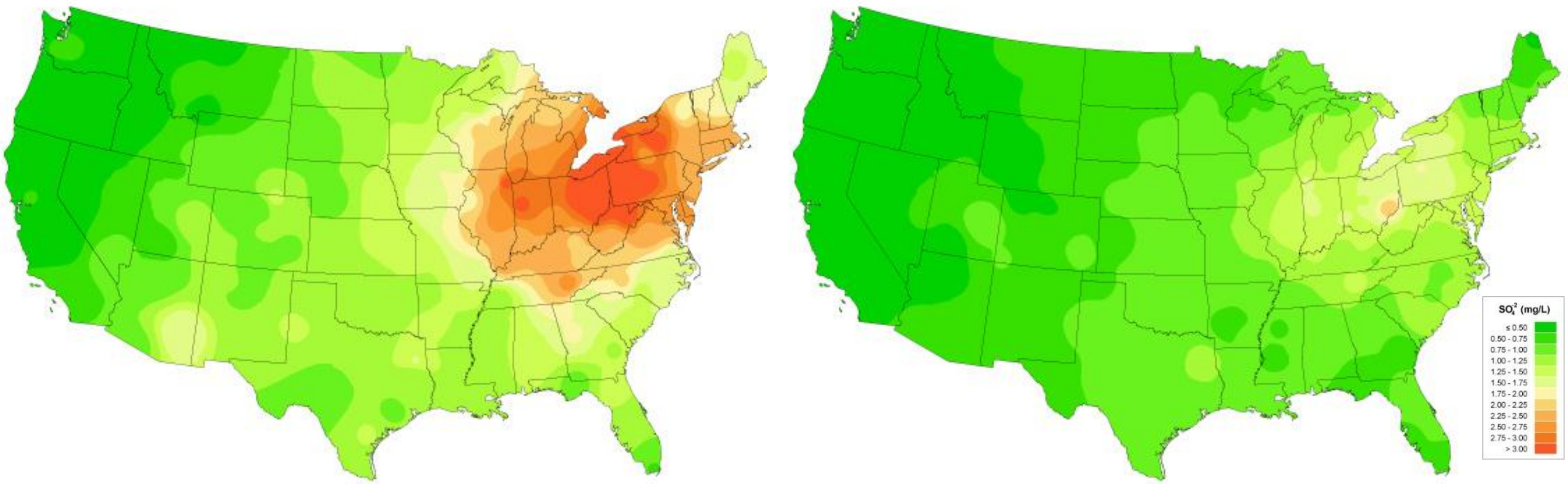


Figure 3-2: Acid Deposition across the U.S. from 1985 - 2008 Source: EPA

As a result of the emissions reduced by the program, the 2005 National Acid Precipitation Assessment Program (2005) report to Congress cited “measurable improvements” in surface water chemistry, sulfate concentration and acidity. Recovery in freshwater lakes and streams have been increasing, where 8% of lakes in the Adirondacks are now considered acidified down from 13%; 5.5% acidified lake in the New England down from 5.6% (an insignificant decrease); less than 1% of acidified lakes in the upper mid-west down from 3%.

The report qualified its finding by stating ecological recovery is a lengthy process and is driven by the hydrological and biogeochemical processes. In some areas recovery may lag behind several decades. Given these limitations, there are is insufficient scientific studies to demonstrate biological recovery of fish in the affected areas, and the recovery of forests. (NAPAP, 2005).

An unintended consequence of the program is the reduction of mercury by 20% (Chestnut & Mills, 2005). Mercury is an environmental pollutant that is harmful to both human and ecosystem integrity. It has been the subject to regulation by the EPA as a hazardous air pollutant. In 2005 the EPA announced the Clean Air Mercury Rule (CAMR) to reduce emissions. The rule however was challenged in New Jersey v. EPA (2008) in the U.S. Court of Appeals D.C. Circuit. The court vacated the rule and remanded it back to the EPA for revisions.

3.2.2 Cost-Effective

The program was relatively cost-effective, here cost-effective is defined as achieving the target reduction at the lowest possible cost. The projected cost for Phase I compliance has been estimated to range between $678 million and $1,511 million (measured in $2000). The actual compliance cost has been now been estimated to be $814 million. Projections for Phase II compliance have been estimated to be around $7.5 billion per year. The actual compliance cost is estimated to be between $1.1 and $1.8 billion per year, significantly lower than projected (NAPAP, 2005).

Lower than expected compliance cost was achieved as a result of the flexibility granted to the utilities to choose their method of compliance. Strategies employed include, fuel blending, fuel switching, installation of flue gas desulfurization equipment (scrubbers) and trading of permits. The literature demonstrates the program could have achieved greater cost saving if it was completely free to choose its method of compliance. Though on the federal level, the program allowed this freedom, state public utility commissions have restricted the options in some states.

Fuel blending and fuel switching have been the most favored approaches to comply with Title IV. Utilities switched from high-sulfur coal to low sulfur coal or used a combination of both high and low sulfur coal. Initial estimates of the cost of compliance were based upon the premise that utilities are designed to use a specific type of coal or a narrow range of coal properties (Shih & Frey, 1995). Utilities however found it cost-effective to retrofit plants with the capacity to utilize different types of coal, a cost that has also been overestimated (Chestnut & Mills, 2005). Without retrofit, utilities could blend up to 40% of low sulfur coal with high sulfur coal (Bohi & Burtraw, 1997).

The industry benefited additional cost reduction due to exogenous factor, particularly the decline in the cost of coal transportation as a result of the Stagger Act of 1980. Low sulfur coal (subbituminous coal) has an average range of 0.5 lb to 1.2 lb of SO_2 per mmBtu. It also has the lowest mine-mouth price (Ellerman, Schmalensse, Bailey, Joskow, & Montero, 2000). However, subbituminous coal is primarily mined in the Powder River Basin located in the northeastern part of Wyoming; geographically located the furthest away from the primary coal markets. Though it had the lowest price, the cost of transportation accounted for a substantial amount of the final cost.

The Stagger Act of 1980 deregulated the railroad industry. This ended the monopoly Burlington Northern Railroad company had out of the Powder River Basin (Ellerman, et al., 2000). As competition in the railroad industry increased, the cost of transportation decreased. The cost of rail transportation in 1979 was 2.0 mills[1] per mile-ton. By 1993 the cost had fallen to 1.0 mill per mile-ton (USDOE, as stated in Ellerman et al. 2000). The reduction in price thus made blending or switching with or to low sulfur coals a viable cost-effective compliance strategy.

The cost of installing and operating scrubber technology also declined as result of Title IV. The decline was not only due to the increased competition among the scrubber vendors, but rather from low-sulfur coal as well (Bohi & Burtraw, 1997). Additionally, scrubber technology became more reliable. Prior to 1990 new sources were required to install scrubbers with 90% efficiency. However there was the lack of incentive for research and development to reduce cost and improve efficiency. The Acid Rain program created such an incentive as utilities can sell unused permits (Popp, 2003).

3.2.3 Correcting for Market Failures

[1] 1 mill is the equivalent to one tenth of a cent

Critical to a well-functioning market based program is the absence of market failure. Such market failures include the lack of information and absence of property rights. Several features of the program which attempts to eliminate the information criterion, this include: (1) EPA auctions and the (2) Clean Air Market Database. As discussed above, the EPA withholds 2.8% of year allocated permits for auction. These auctions were designed to provide price signals to the industry that promote trade. The importance of promoting trade other than an efficient allocation of control responsibilities is the development of "thick" markets which leads to lower transaction costs.

The lack of or asymmetric information is another source of market failure. The Clean Air Market – Data and Map database (now replaced by the Air Market Program Data) maintained by the EPA provides information on:

- Emissions from the national level down to the unit level
- Allowance, transaction history
- Compliance
- facility attributes
- and general market trends

The economic theory posits a well-functioning market will lead to the efficient allocation of goods and services. This implies the costs and benefits accrue only the parties involved in the transaction, thus no externalities (Perman, et al., 2003). Another criterion for the efficient allocation of resources is the absence of market failures, for example, the absence of private property rights. Environmental resources are by nature public goods, where property rights are non-existent or ill defined. One such (environmental) resource is the atmosphere.

Rights are “particular actions that are authorized” by generally agreed upon enforceable prescriptions that require or permit specific actions for the individual (Schlager & Ostrom, 1992). Exploitation of environmental resources stem from the lack of property rights, where individuals have the incentive to use environmental resource because the benefits accrue to the individual, but not the cost (directly). The lack of property rights for environmental resources could be a result from a variety of reasons which include: economic, technological, ecological and cultural (Cole, 2010).

Title IV corrects for this market failure through the creation of permits. Expressed in the Clean Air Act Amendment of 1990, an “allowances” or permit is the “right” to emit 1 ton of sulfur dioxide (SO_2) into the atmosphere. To this end, environmental protection is achieved by the administratively set quota on emissions and by the rules (laid out the CAAA of 1990) that govern its enforcement.

3.2.4 Dynamic Effects

Market based incentive programs in addition to being efficient and cost-effective, will spur innovation in related sectors (Requate, 2005). Title IV has induced innovations particularly in scrubber technology. Technological progress for scrubber has increased 8% a year (Kumar & Managi, 2010).

The program has led to the growth of secondary markets for emission permits. Secondary markets have been developed where brokers act as intermediaries between buyers and seller and determine a market price for permits. As a result, transactions cost declined and more accurate information of market price emerged as brokers publish the bid and sale prices to their clients (Joskow, Schmalensee, & Bailey, 1998).

The economic theory, legal structure and design and implementation of the Acid Rain Program demonstrated the predicted efficiency and cost-effectiveness. There still remains the issue of explaining the dramatic decrease in the price of emission permits. The following section describes the factors influencing the permit prices and the model designed to determine the effects of regulatory uncertainty.

CHAPTER 4: DATA AND METHODS

4.1 Data

Due to the Acid Rain Program's success it has served as a model for other cap-and-trade programs such as those created under the Kyoto Protocol and the European Union for carbon dioxide. The program will continue to serve as a model for the future, thus analysis of the program is useful as a means to improve future models and guide their implementation. In a market based incentive system, changes in the market, whether real or perceived, may have a profound impact on the program's functionality. In this case, regulatory uncertainty is hypothesized to be the reason of the decrease in permit prices.

To analyze the impact of regulatory uncertainty on permits prices, a multiple regression model based on economic theory of price behavior was used. In theory the price of emission permits is a function of supply factors and demand factors. In the case of emission permits the factors are summarized as follows:

A. Supply factors:

1. Initial allocation of permits
2. Permits banked from prior periods

B. Demand factors:

1. Price of fossil fuel input i.e. coal, petroleum, and natural gas
2. Cost of operating scrubbers
3. Electricity generation from fossil fuels
4. Price of Electricity

5. Hydroelectric generation
6. Economic growth
7. State regulations and restriction with respect to trading
8. Periods of regulatory uncertainty

(Boutabba, Beaumais, & Lardic, 2011) (Bohi & Burtraw, 1992) (Shih & Frey, 1995) (Lile & Burtraw, 1998) (Kumar & Managi, 2010) (Schennace, 2000) (Heutel, 2011) (Burtraw, 1996) (Hahn & Stavins, 1992) (Perman, Ma, McGilvray, & Common, 2003) (Revesz & Stavins, 2004) (Tietenberg, 2006) (Jaskow, Schmalensee, & Bailey, 1998) (Arimura, 2002) (Bohi & Burtraw, 1997) (Sotkiewicz & Holt, 2005).

Supply Factors

The supply of permits as discussed in the preceding chapter is relatively stable as there is a fixed allocation from year to year. Changes in the supply however are based upon the stringency of the cap. Such changes occurred during the transition from Phase I to Phase II and then again starting in 2010. The total allocation of permits during Phase I was 5.7 million, Phase II the aggregate allocation increased to 9.5 million and starting in 2010 a permanent cap of 8.9 million was instituted. The price of permits is a function of the supply, thus a reduction in the supply will lead to an increase in the price of permits, all other factors held constant.

Permits banked from previous years provide an additional source of liquidity to the market. In theory, an increase in banked permits will lead to a decrease in the price of permits. Conversely a decrease in the amount of permit banked would reduce the supply and lead to an increase in price of permits. According to Schennach (1998) and Napolitano, et al. (2007), banked permits smooth out volatility in the price of permits. Built up reserved provide utilities with additional insurance for compliance against increased demand for electricity, shocks in the input fuel prices, or regulatory changes.

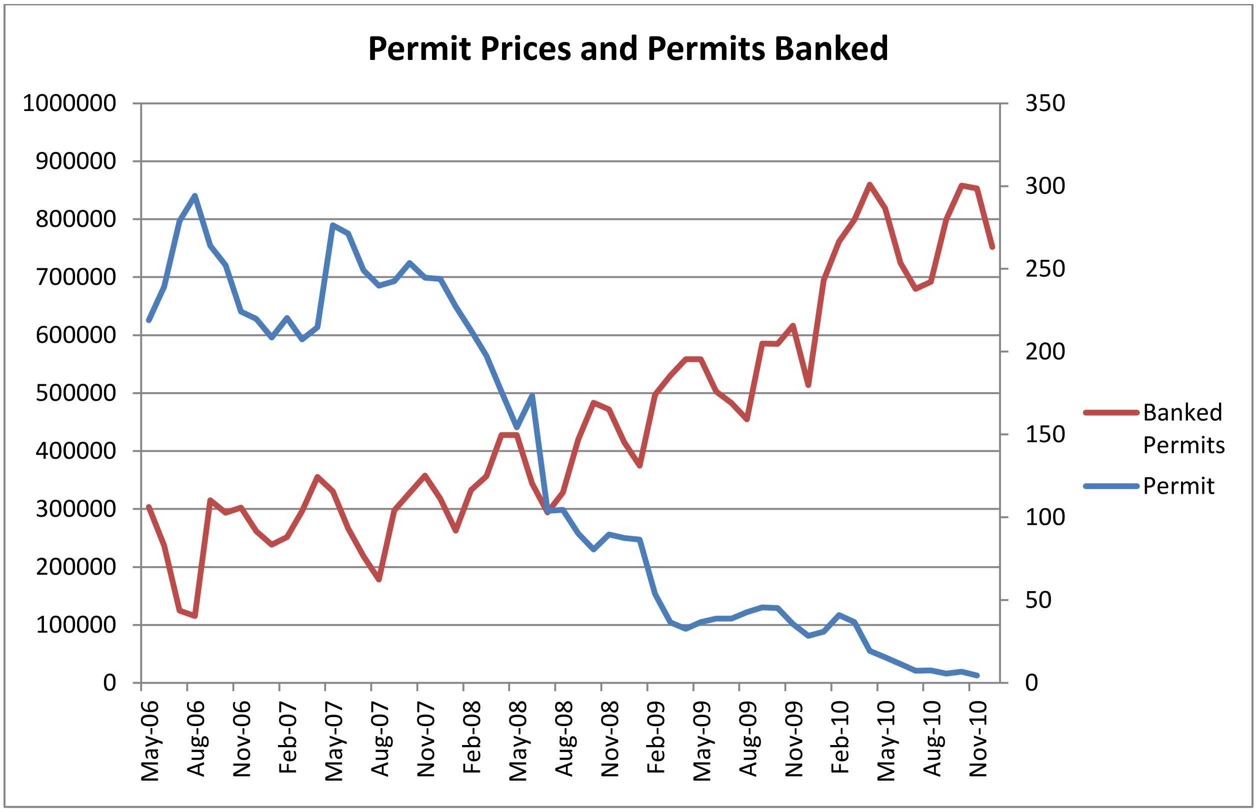


Figure 4-1: SO_2 Permit Prices and Permits Banked

Figure 4-1above demonstrates that relationship between the permit prices and the number of permits banked. Over time, the industry was able to reduce its emissions thus banking increased. Consequently, as the supply of permits banked increased, the price firms are willing to pay will decline.

Demand Factors

The demand for permits is a function of the input fuel (Boutabba, Beaumais, & Lardic, 2011). The three main types of fossil fuel are used in electricity generation are coal, petroleum and natural gas. Of the three groups, coal is associated with the highest level of sulfur content. The three most used coal types are Bituminous, Subbituminous and lignite. Coal is also the cheapest on a per ton and mmBtu basis.

Petroleum has the second lowest sulfur content associated with its combustion. Finally, natural gas has no associated sulfur emission with its combustion. Thus, as the price of high sulfur coal increases relative to other fuel groups the price for permits is expected to decrease as this would induce profit maximizing firms to switch to cheaper fuel. If the price of low sulfur coal increases relative to the price of other fuel groups, the price of permits is expected to increase depending upon the fuel the firm uses as a substitute. The use of high sulfur coal would lead to an increase in the price of permit whereas other fuel groups such as natural gas would lead to a decrease in the price of permits.

Increase in the price of natural gas on the other hand relative to the other fuel groups, the price of permits is expected to increase. Because natural gas has no sulfur emission associated with its combustion, an increase in the price would induce switching to other fuel groups which are associated with sulfur emissions, thus increasing the demand for permits thereby leading to an increase in the price of permits.

The operation of flue gas desulfurization (scrubber) equipment reduces emission of sulfur dioxide in the atmosphere from the combustion of fossil fuel. In the absence of government regulations that mandate the implementation of such control technology, firm will choose to operate scrubbers if the price of permits is higher than its cost of operations. Thus as the cost of operating scrubbers increase, it is expected that the price of permits would also increase.

Electricity generated from hydroelectric sources has no associated sulfur dioxide emissions. It is a substitute for electricity generated from fossil fuel. As the generation from hydrological sources increase, electricity generated from conventional means is expected to decrease. Thus, the price of SO_2 permit is expected to decrease as emissions from sulfur will also decrease with an increase in electricity output.

Economic growth is expected to have a positive effect on the price of emission permits. As economies expand the demand for electricity is expected to increase. The increased pressure for electricity output is expected to increased level of sulfur dioxide emission, thereby higher prices for emission permits.

State and the Public Utility commission's regulations play a large role in determining the price of permits. In accordance with the Clean Air Act, states are required to develop State Implementation Plans (SIP) detailing strategies that will enable their jurisdiction into compliance with the National Ambient Air Quality Standards that is set by the EPA. Thus, consistent with the SIP, states and the public utility commission may mandate how electric generating units comply with Title IV. As a result, states that have high-sulfur coal deposits such as Illinois, Indiana, Ohio, Pennsylvania, Virginia and West Virginia are pro-capital investment. These states encourage the use of scrubber technologies. This is in an effort to protect local economic growth.

On the other hand states like Connecticut, Massachusetts, Michigan, New Hampshire and Washington have state mandated environmental standards which utilities must meet. New York regulations prohibit the sale of allowances based on environmental concerns (Lile & Burtraw, 1998). Restrictions placed by the state laws and PUC influence the price of emission permits based on the goal(s) the state governments try to maximize.

Finally, regulatory uncertainty would play a role in determining the price of permits. In a market setting, prices are affected based on changes that are either real or perceived. As discussed in the conceptual economic framework section in chapter 2, a market based incentive gains efficiency from change in the regulatory framework, typically one that restricts polluting behavior. Under these conditions, the price of permits is expected to increase if there is impending regulations that may further restrict emissions. Prices are expected to decrease if the impending regulation relaxes the stringency.

4.1.1 Variable Description

The price of emission permit was obtained from the Bloomberg database. The prices were reported in a daily format. For this analysis daily close prices were averaged over a one month period. All prices variable in the model were adjusted for inflation where the year 2000 was used as the base year.

The data for fossil fuel used in electricity generation was obtained from EIA-Form 423: Monthly Cost and Quality of Fuel for Electric Plants Data. The form was terminated in 2007 and fuel cost data was consolidated into EIA Form 923 Monthly Utility and Nonutility Fuel Receipts and Fuel Quality Data (schedule 2). The cost of fuel is reported in terms of cents/mmBTU for each unit on a monthly basis.

Banked permits data were obtained from the EPA's Clean Air Market Data and Maps database. The data are available in a yearly format. In order to transform the data into a monthly format, SO_2 emission data which is available in monthly format was used. The variation in

Table 4-1: Data Description

Data	Description	Source
PERMIT	Price of emissions permits as determined by the market	Bloomberg
COAL	The average price of all coal in cents/mmBTU	EIA Form 923 and author's calculations
OIL	The price of petroleum in cents/mmBTU	EIA Form 923 and author's calculations
NGAS	The price of natural gas in cents/mmBTU	EIA Form 923 and author's calculations
BP	The number of permits banked	EPA and author's calculations
RLHS	The relative price of low sulfur coal to high sulfur coal	EIA and author's calculations
HYDRO	Electricity from hydroelectric generation	EIA
SCBR	Cost of scrubber in cents/kwh	EIA Form 767
EGEN	Electricity generation from fossil fuel in million kwh	EIA
ELEC	Average price of electricity	EIA
IPI	Industrial Production Index	Federal Reserve Bank of St. Louis
REG1	Dummy variable where 1=periods of regulatory uncertainty following the announcement of more stringent PM 2.5 standards	
REG2	Dummy variable where 1=periods of regulatory uncertainty from when CAIR was argued in court to when the new rule was announced	
JAN	Dummy variable where 1=January and 0=otherwise	
FEB	Dummy variable where 1=February and 0=otherwise	
MAR	Dummy variable where 1=March and 0=otherwise	
APR	Dummy variable where 1=April and 0=otherwise	
MAY	Dummy variable where 1=May and 0=otherwise	
JUN	Dummy variable where 1=June and 0=otherwise	
JUL	Dummy variable where 1=July and 0=otherwise	
AUG	Dummy variable where 1=August and 0=otherwise	
SEP	Dummy variable where 1=September and 0=otherwise	
OCT	Dummy variable where 1=October and 0=otherwise	
NOV	Dummy variable where 1=November and 0=otherwise	

emission was calculated then using the same rates banked permits were transformed into a monthly format[2]. Scrubber costs were obtained from EIA Form 767. The data is reported in a yearly format. The monthly scrubber costs were calculated based on the monthly variation of electricity generation[3].

Regulatory uncertainty is represented using dummy variables. Using information of the Acid Rain Program timeline, "1" is used to represent periods where there is potential for uncertainty as to the regulation governing the acid rain program. This model contains two periods of regulatory uncertainty. The first period (REG1) represents more stringent standards for particulate matter of size 2.5 microns. The second period (REG2) reflects the period when CAIR was challenged.

As discussed the emissions of sulfur dioxide not only contribute to acid rain, but it also contributes to the formation of sulfuric particulate matter. March 29, 2007 the EPA announced more stringent standards for PM2.5. April 13, 2007 the EPA administrator Stephen Johnson meet with the Canadian minister of Environment John Baird to announce the plans to reduce the flow of pollutants between the two nations. On the markets for emission permits the prices sharply increase when faced with the prospects of more stringent standards. Dummy variable was used to represent the period of unusually high prices.

The second period of regulatory uncertainty is to represent the period when CAIR was challenged in court through its overruling; this runs up to the end of the data set. Regulatory actions included are (1) when CAIR was argues, (2) D.C. Circuit's initial ruling, (3) EPA's petition for a stay on the rule and (4) D.C. Circuit grant a temporary stay with remand.

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[2] There are slight discrepancies in the calculated monthly data. This is due rounding error.
[3] There are slight discrepancies in the calculated monthly data. This is due rounding error.

Table 4-2: Summary of the Expected Signs

Data	Expected Signs
COAL	-
OIL	-
NGAS	+
BP	-
RLHS	-/+
HYDRO	-
SCBR	+
EGEN	+
ELECT	-
IPI	+
REG1	+
REG2	-
JAN	+/-
FEB	+/-
MAR	+/-
APR	+/-
MAY	+
JUN	+
JUL	+
AUG	+
SEP	+/-
OCT	+/-
NOV	+/-

The data ranges from May 2006 through December 2010. The rationales behind the start date are (1) with time individuals and firms behavior will follow economic theory. Since Title IV was the first cap and trade program implemented, it can reasonable assumed that electric generating utilities will be uncertain about the price of permits and their method of compliance. Thus behavior may not follow rational behavior. (2) Period of uncertainty occurred in 2005. In March the EPA announced the Clean Air Interstate Rule which would require further reduction in SO_2 and NOx emissions. Faced with the prospects of more stringent regulations, this can lead to higher permit prices.

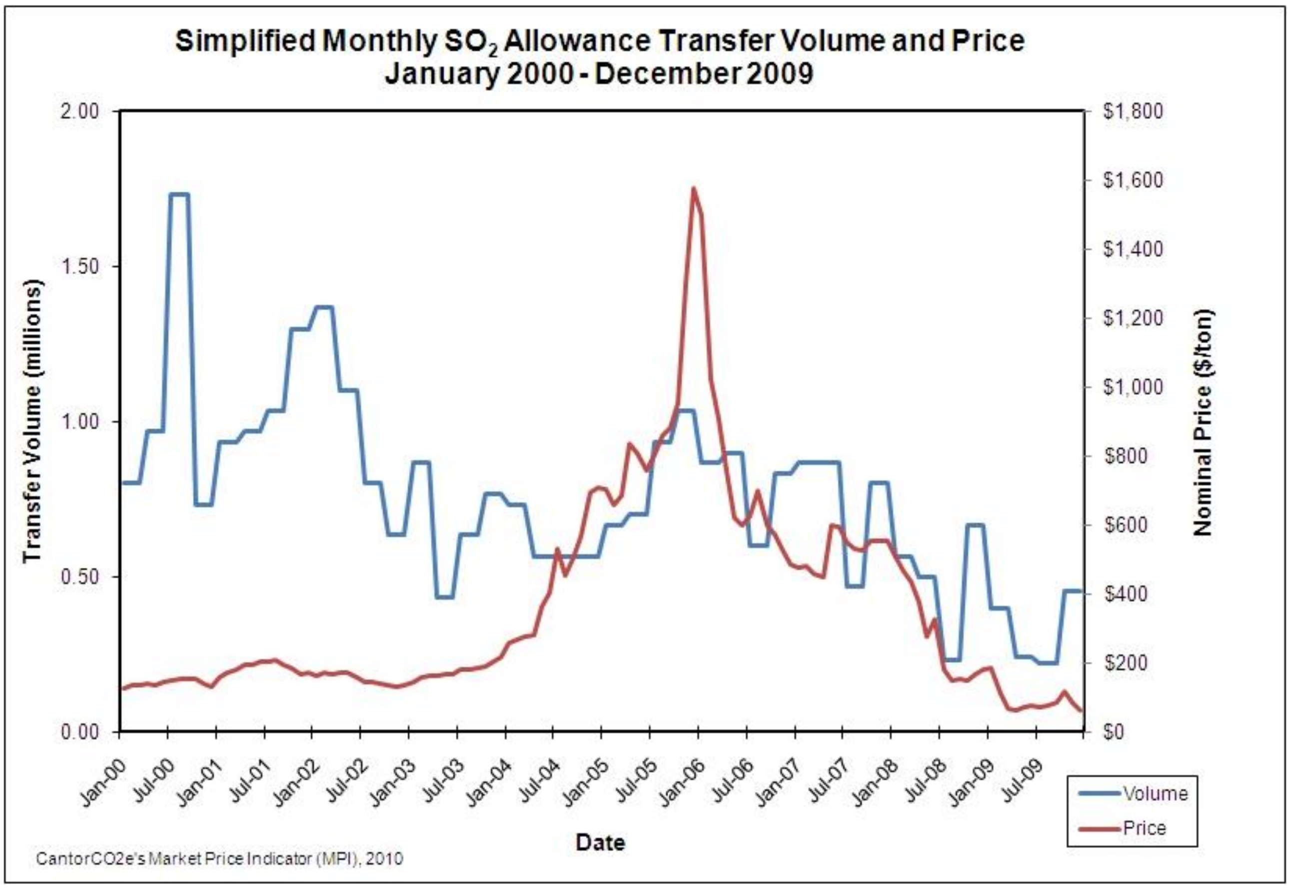

Figure 4-2: Price of Permits and the Volume Traded

In August and September 2005 hurricanes Katrina and Rita, respectively made landfall along the Gulf coast disrupting the supply of natural gas. As a compliance strategy, many utilities switched from coal to natural gas in an effort to comply with the acid rain program. The disruption in natural gas supply lead to an increase in the price of permits upward of $1600/ton of SO_2. Prices increased as firms switched back to coal with has SO_2 emissions associated with its combustion. The figure 4-2 below obtained from the EPA reflects the price of permits starting during Phase II of the acid rain program.

It is unclear from the literature whether either one of these events or a combination is responsible for the rise in prices or the associated impact of each (Boutabba, Beaumais, & Lardic, 2011) (EPA, 2009) (Burtraw & Szambelan, 2009). Regardless, the rise in prices are due to uncertainty be it regulatory uncertainty or otherwise; in this case uncertainty as to the supply of fuel input.

Consistent with the objectives of this study which is to determine the effects of regulatory uncertainty, that entire period was eliminated. By the start of 2006 natural gas service had been restored and the volatility in the price of permits had decreased. The time frame used for this analysis captured both periods of certainty and regulatory uncertainty while other factors which determine the price of permits were relatively stable. Table 4-3 provides the descriptive statistics for the variables used in the model.

.

Table 4-3: Descriptive Statistics

	PERMIT	COAL	OIL	GAS	BP	RLHS	SCBR	EGEN
Mean	129.8624	228.4686	1486.119	640.1897	455403.3	0.589104	0.152608	242085.7
Median	97.04294	251.8072	1462.800	620.5420	417298.2	0.580912	0.150410	236853.6
Maximum	294.1284	287.1732	2268.596	1093.706	859819.5	0.667776	0.194581	319791.5
Minimum	3.888986	176.5797	1033.670	425.7594	115191.6	0.515190	0.119703	190658.1
Observations	56	56	56	56	56	56	56	56

	ELEC	HYDRO	IPI	REG1	REG2
Mean	9.151519	21783.17	93.64880	0.160714	0.589286
Median	8.830058	21412.61	94.48130	0.000000	1.000000
Maximum	11.36655	30818.44	100.7241	1.000000	1.000000
Minimum	7.607593	14742.53	83.52610	0.000000	0.000000
Observations	56	56	56	56	56

4.2 The Econometric Model

Following the economic model, the econometric model developed is as follows:

$$\begin{aligned}\widehat{PERMIT} = {} & \beta_1 + \beta_2 COAL + \beta_3 OIL + \beta_4 NGAS + \beta_5 BP(-1) + \beta_6 RLHS + \beta_7 SCBR \\ & + \beta_8 HYDRO + \beta_9 EGEN + \beta_{10} ELEC + \beta_{11} IPI + \beta_{12} REG1 + \beta_{13} REG2 \\ & + \beta_{14} JAN + \beta_{15} FEB + \beta_{16} MAR + \beta_{17} APR + \beta_{18} MAY + \beta_{19} JUN + \beta_{20} JUL \\ & + \beta_{21} AUG + \beta_{22} SEP + \beta_{23} OCT + \beta_{24} NOV\end{aligned}$$

A linear multiple regression model was used to determine the effects of the each of the variables on the price of SO_2 permit. Consistent with economic theory the price of permits is a function of the fuel input, supply of permits, the availability of substitutes, cost of using control technology and regulations.

The analysis was conducted using EViews version 6. Banked Permits was included as a lagging variable. This is because permits banked in the current period t_1 will be available for use in the following period. All results were adjusted for heteroskedasticity-constant standard errors and covariance.

CHAPTER 5: RESULTS AND DISCUSSION

5.1 Results

Table 5-1 report the regression results for the significant variables. The significant variables are coal, banked permits, electricity generated from hydrological sources, regulatory uncertainty from the period when CAIR was challenged, and the months of May and June. For each of the significant variables, the signs of the coefficients are as expected.

The coefficient for coal is calculated to be -1.180184. A one cent increase in the price of coal (measured in mmBTU) is estimated to decrease the price of SO_2 permits by approximately $1.18. The decrease in the price of permits is a result fuel switching and blending—a strategy used to comply with SO_2 regulations. As the price of coal increase utilities have the incentive to switch to other fuel source to generate electricity. In addition to the price increase, the costs associated with using coal include operating scrubber technology or require additional permits for SO_2 emissions.

The coefficient for banked permits is calculated to be -0.00016, thus each additional permit banked, the price is expected to decrease by $0.00016. Since banked permits provide additional liquidity to the markets, as the supply of permits increase the price is expected to decrease.

Hydroelectric generation has no associated sulfur dioxide emission and is a substitute for electricity produced from fossil fuel, thus increase in electricity produced hydroelectric sources is expected to have a downward pressure on the price of permits. The coefficient is reported to be -0.003374, where a one thousand megawatt-hour increase in the electricity produced to hydroelectric sources is expected to decrease the price of permits by $0.0033.

Table 5-1: Results of Significant Variables

Variable	**Coefficient**
C	1223.019 (507.3171)**
Coal	-1.1802 (0.6669)*
Banked Permits	-0.00016 (3.98E-5)***
Hydroelectric Generation	-0.0034 (0.0018)*
Regulatory Uncertainty— CAIR overturned	-58.8088 (25.8871)**
May	43.8600 (15.8378)***
June	30.2946 (14.5507)**
R-squared	0.9805
Adjusted R-squared	0.9659
F-statistic	67.6207
Prob(F-statistic)	0.0000
Durbin-Watson stat	1.8244

The Standard Errors are reported in the parenthesis. *, **, *** indicates significance at the 90%, 95%, and 99% level, respectively.

The months of May and June are both expected to increase the price of permits. The upward pressure on permit price is expected due to increasing demand for electricity during the summer months. The month of May is expected to increase the price of permit by approximately $43.86. The month of June is expected to increase the price of permits by approximately $30.30.

The second period of regulatory uncertainty modeled is expected to decrease the price of permits by approximately $58.80. In this model regulatory uncertainty was represented by dummy variables when CAIR SIPs and FIPs were due and when the case was argued and decided by the 9th Circuit court. In this context the dummy variables captured periods when regulations are expected to become more stringent, thus the price of permits are expected to increase. However, after the case was vacated by the courts and the EPA was remanded to develop a new rule in its place the regulatory void created lead to a decrease in the price of permits because it is expected the rule will no longer be valid. Additionally, at the time when the rule was vacated the industry has already banked a considerable amount of permits, allowing greater flexibility for future compliance.

An assumption of the multiple regression model are normally distributed errors. Figure 5-1 demonstrates the histogram of normality. The Jarque-Bera statistic tests the assumption of normality based on kurtosis (peakness) and skewness. Kurtosis is expected to be 3 and skewness is expected to be 0. Eviews calculates the both these values, and test if the test values are significantly different from each other. The null hypothesis for the test assumes normally distributed errors (Hill, et al. 2010). The Jarque-Bera is reported to be 0.2195 and with p-value of 0.8960. Thus based on the Jarque-Bera test statistic, there is insufficient evidence to reject the null hypothesis.

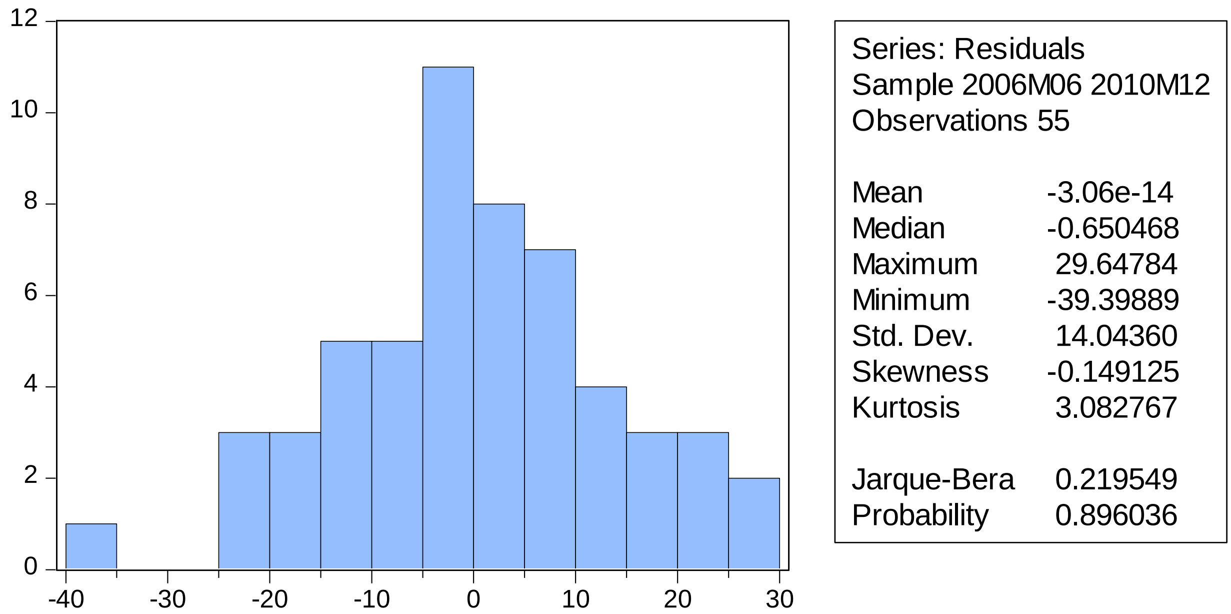

Figure 5-1: Histogram of Normality

5.2 Discussion

Based on the regression results, the period of regulatory uncertainty when the regulation was challenged is expected to decrease the price of permits by approximately $58.80. This is a modest magnitude with maximum prices at $129 and minimum at $3.88. Also notable is the effects of banked permits which also have a very small effect of the price of permits. From the earlier discussion, banked permits were expected to have a large effect on the price since it is an additional source of supply to the industry. Thus during periods of regulatory uncertainty the valuation of banked permits should increase. Given the low market prices for SO_2 emission permits combined with the small effect of regulatory uncertainty and banked permits, it is apparent the industry's demand for SO_2 emission permits has declined.

A possible reason for the declined demand for permits is the adoption of technology by the industry. Installation of control technologies (i.e. scrubbers) would reduce the demand for permits since the industry can comply with the regulatory reductions. This is reflected in the declining price for emission permits and a significant increase in the number of permits banked. Table 5-2 below obtained from the EPA show the number of scrubbers installed by year. With a lead time of approximately two years for scrubber installation (EPA, 2002) the data shows a dramatic increase in the number of newly installed scrubbers in operations starting in 2007.

Table 5-2: Scrubber Installation

Year	Scrubbers (total)	Newly Installed
2000	246	1
2001	260	8
2002	274	6
2003	311	2
2004	321	0
2005	324	7
2006	335	9
2007	363	32
2008	421	46
2009	467	39
2010	511	29

A one-way analysis of variance determined a statistically significant difference between the period before and after the Clean Air Interstate rule was announced. Table 5-3 reports the ANOVA results. Based on the F and P-values there is a statistical difference between the two periods.

The results imply the industry has made plans to comply with the Clean Air Interstate Rule when the rule was promulgated in March of 2005. The historical trend of compliance with

Table 5-3: ANOVA of Scrubber Installation

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	53254.87	1	53254.87	24.58692	0.000782
Within Groups	19493.86	9	2165.984		
Total	72748.73	10			

the Acid Rain Program showed compliance was achieved mostly by the installation of scrubbers because of a more stringent cap on SO_2 emissions. Phase II compliance was dominated by fuel blending and fuel switching. According to Tietenberg (2006) “emissions trading will promote cheaper approaches. When non-technology approaches (such as fuel switching) turned out to be chapter, it is they, and not the new technology, that will be chosen.” The greater stringency of the cap attributed to CAIR have led the industry toward the adoption of scrubber technology.

Five days after the final version of CAIR was announced, the EPA on March 15, 2005 announced the Clean Air Mercury Rule which was designed to reduce mercury emissions. Though a 2000 EPA study concluded it “appropriate or necessary to regulate” coal and petroleum electricity generating utilities, these sources were delisted from the final rule. In response to the delisting, 14 states (listed in table 5-5) implemented regulations to control mercury emission from utilities.

New Jersey v. EPA (2008) challenged the EPA’s decision of delisting coal and petroleum utilities from the Clean Air Mercury Rule, in the U.S. Court of Appeals D.C. Circuit. The court ruled:

“the delisting was unlawful. Section 112 requires EPA to regulate emissions of HPAs.

Table 5-4: States with Mercury Emission Regulations and Year Enacted

State	Year Enacted
New Hampshire	2002
Connecticut	2003
New Jersey	2004
Delaware	2006
Maryland	2006
Illinois	2006
North Carolina	2006
Montana	2006
Minnesota	2006
Massachusetts	2007
New York	2007
Colorado	2007
Georgia	2007
Wisconsin	2008
South Carolina	2008
Michigan	2009
Oregon	2010

> Section 112(n) requires EPA to regulate EUGs under section 112 when it concludes that doing so is 'appropriate and necessary.'"

As a result the Clean Air Mercury Rule was remanded to the EPA for revision in a manner that is consistent with the court's decisions

Additional support for the installation of scrubber technology is the ability to remove mercury in addition to sulfur dioxide. Scrubbers have to ability to remove oxidized mercury with an efficiency rate of 80% - 90% which translates to approximately 70% - 78% of total mercury. (Srivastava, Hutson, Princiotta, & Staudt, 2006) (Senior, Helble, & Sarofim, 2000).

Though CAIR was vacated by the D.C. Circuit in December of 2008, the courts placed a two year deadline for the EPA to develop a replacement rule. Therefore there remained the expectation that the stringency of the replacement rule would comparable to the SO_2 and NO_x reduction mandated by CAIR. Coupled with an additional regulation for mercury emissions, compliance would require the use of control equipment.

CHAPTER 6: CONCLUSION

The use of market based instruments is effective when there is a framework that changes the regulatory environment in which firms and individuals operate. In this case, in an unregulated environment, a profit maximizing firms have little incentive to reduce the level of pollutant emitted in the atmosphere. Regulations such as Title IV of the CAAA of 1990 attached opportunity costs for each unit of pollutant emitted, thus changing the incentive structure of firms. The incentives created by imposing opportunity cost combined with the ability to trade the rights to emit, enabled firms to cost-effectively achieve the target reduction.

The subsequently loss of a regulatory constraint was expected to results in an increase in the level of pollutant emitted in environment due to the decline in the opportunity cost. Such loss of the regulatory constraint occurred in 2008 when the U.S. Court of Appeals D.C. Circuit vacated the Clean Air Interstate Rule which required the industry to further reduce its emission.

Regulatory uncertainty when analyzed in the context of Title IV exerted a significant relatively moderate effect of on the price of SO_2 permits during the final days of CAIR. Though the price volatility was above normal, during this period the market price for SO2 permits sharply declined. The prices remained low even in the face of a temporarily reinstated the rule by the D.C. Circuit, and the expectation of a replacement rule. Additionally, SO_2 emissions continued the downward trend to levels that is beyond the Acid Rain Program cap of 8.9 million tons per year.

It appears the industry has already made provisions to meet the regulatory mandated reductions when the final version of CAIR was announced in 2005. This is evident from the number of scrubbers installed reported by the EPA. As shown in chapter 5, after allowing for an approximate lead time of two years, the number of newly installed scrubbers dramatically increased starting in 2007. As per the court's decision, the rule was remanded back to the EPA to develop a new rule for CAIR's replacement. The rule did not pass judicial review because of the strategies it employed to enforce the standards, thus the expectation for the new rule is an equally stringent emission cap and changes to means by which states and the industry meet the requirements.

Even in the face of uncertainty the program continued to demonstrate dynamic efficiency as illustrated by the lower emission. In addition, the program also continued to demonstrate cost-effectiveness. This is shown by the industry's ability to deploy control technologies when needed to comply with regulatory requirements.

The overruling of CAIR is a loss of a required condition for market based incentive programs to be effective. The program however benefited from other regulations. This included the rules under the Acid Rain Program, and state regulations.

Future research should consider the rate of technology adoption that was demonstrated after 2007. Further research into the effects of regulatory uncertainty would benefit to conduct investigation at the state level.

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APPENDICIES

Appendix A: List of Regulatory and Proposed Regulatory Actions

Date	**Description**
Jan. 1995	Acid Rain Program Phase I begins
Jan. 2000	Acid Rain Program Phase II begins
Jan. 2004	The Clean Air Interstate Rule Proposed
Mar. 2005	Clean Air Interstate Rule Announced – Final version
Mar. 2005	Clean Air Mercury Rule Announced – Final version
Mar. 2007	EPA finalized more stringent rules for Particulate Matter 2.5
Apr. 2007	EPA administrator Steven Johnson met with the Canadian Ministry of Environment to reduce the transport of pollutants across the US-Canada border
Mar. 2008	CAIR (North Carolina v. EPA) argued in the U.S. Courts of Appeals, DC. Circuit
Jul. 2008	North Carolina v. EPA decided. The D.C. Circuit vacated the rule and remanded it back to the EPA for revisions
Sept. 2008	EPA petitioned the Court's ruling on the grounds of protection of human health and environmental integrity
Dec. 2008	D.C. Circuit grants a temporary stay and remand

Appendix B: ANOVA results for the justification of inclusion dummy variables

One-way ANOVA analysis was performed to determine if there is any statistical difference in the price of SO2 permits as a result of regulatory actions.

Tighter PM 2.5 Standards

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	73925.1	1	73925.1	90.85688	2.97E-16	3.922879
Within Groups	94382.64	116	813.6434			
Total	168307.7	117				

CAIR Argued

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	56713.32	1	56713.32	169.2099	1.96E-21	3.960352
Within Groups	26813.24	80	335.1655			
Total	83526.56	81				

D.C. Circuit July 2008 decision

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	109152.2	1	109152.2	267.4855	1.53E-27	3.957388
Within Groups	33461.55	82	408.0677			
Total	142613.7	83				

EPA Petition for a re-hearing

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	21472.01	1	21472.01	43.52061	3.83E-09	3.957388
Within Groups	40456.81	82	493.3757			
Total	61928.82	83				

D.C. Circuit decision on the re-hearing

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3084.49	1	3084.49	13.04982	0.000542	3.96676
Within Groups	17963.56	76	236.3627			
Total	21048.05	77				

VITA

Narendra Paramanand holds a Bachelor Degree in economics from Baruch College, City University of New York. While pursuing his undergraduate degree, he held several jobs and internships in finance field. During his senior year at Baruch College he enrolled in Introduction to Ecology merely to fulfill a requirement for graduation, but found the subject to be fascinating and environmental sustainability a worthwhile life goal to pursue.

With limited experience he worked with Dr. Chester Zarnoch at Baruch College as a Research Assistant to gain experience and deepen his knowledge of the subject. While independently learning about environmental sustainability he recognize the opportunity combine his educational background in economics with environmental science.

In the Fall of 2010 he enrolled as a Graduate Student in the Department of Environmental Science at Louisiana State University where he pursued a Master of Science in Environmental Science with a focus on economics.