Spring 2019

Are firm emissions data likely to be accurate under carbon-dioxide cap & trade programs? An economic analysis

Kyle Beck

Are Firm Emissions Data Likely to be Accurate Under Carbon-dioxide Cap & Trade Programs?

An Economic Analysis

An Honors College Project Presented to

the Faculty of the Undergraduate

College of Economics

James Madison University

April 7th, 2019

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by Kyle Beck

Accepted by the faculty of the Economics Department, James Madison University, in partial fulfillment of the requirements for the Honors College.

FACULTY COMMITTEE:

Project Advisor: Scott R. Milliman, Ph.D.

Reader: Maria Papadakis, Ph.D.

Reader: William C. Wood, Ph.D.

HONORS COLLEGE APPROVAL:

Bradley R. Newcomer, Ph.D., Dean, Honors College

PUBLIC PRESENTATION:

This Work is accepted for presentation, in full, at The Honors Symposium on April 5th, 2019

This Project conforms to the JMU Honor Code:

Student: Kyle C. Beck

Acknowledgements

I would like to thank James Madison University for providing me the tools and knowledge necessary to embark on a project such as this. I would also like to thank Dr. William Wood and Dr. Maria Papadakis for agreeing to be my readers, as well as for the expertise they provided throughout the research process. Finally, I would like to thank Dr. Scott Milliman for advising me throughout this year and a half long journey and introducing me to the world of environmental economics.

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Abstract

Numerous policy makers around the world have implemented carbon dioxide (CO_2) cap and trade programs in an effort to combat global climate change. However, under this policy option emitters face incentives to both overstate prior emission levels and then exaggerate emissions reductions induced by regulation. I first build a simple conceptual model which demonstrates these incentives for fraud, and then outline institutional conditions which could plausibly enhance, or else reduce, firm incentives to disseminate erroneous emissions data under this policy option. Next I analyze real world evidence suggesting that duplicitous emissions data, particularly for the pre-regulatory period, is a serious concern for cap and trade programs. I conclude by suggesting strategies for enhancing the accuracy of firm emission data under this policy option.

I. Introduction

There has never been an issue as complex and intertwined into the very fabric of our society as global climate change. In both advanced and developing countries fossil fuels are one of the key ingredients in economic growth. Many of the advances in industrial manufacturing, energy production, and transportation would not be possible if it were not for the coal and oil that power them. Furthermore the expanded use of fossil fuels is helping lift millions of people in developing countries such as India and China out of poverty. Yet, that same energy source that has launched us into the modern age also threatens to destroy the society it helped build.

Multiple studies published in peer-reviewed scientific journals point to the following conclusion: Warming trends in global temperatures over the last 100 years are likely due in large part to human-induced increases in carbon dioxide (CO_2) emissions, and absent major abatement measures, these trends will probably continue into the future (Scientific Consensus, 2018). Furthermore, most of the leading scientific organizations around the world have given public endorsements of these findings, including the American Association for the Advancement of Science, the American Geophysical Union, The Meteorological Society of America, the Intergovernmental Panel on Climate Change, and many more (Scientific Consensus, 2018).

Although the exact effects of human induced climate change are unknown, a wide range of published evidence concludes that the net costs of damage resulting from climate change are most likely to be significant, and to become greater as time goes on (Global Climate, 2017). The United Nations Intergovernmental Panel on Climate Change warned that in the worst-case scenario, these impacts could be irreversible (Warrick and Mooney, 2014). According to NASA, as temperatures continue to rise, droughts and heat waves are expected to become more intense. Furthermore the intensity, frequency, and duration of North Atlantic hurricanes will increase. In addition sea levels are forecasted to rise by one to four feet by 2100 (Global Climate Change, 2018). If sea levels continue to rise at the rate seen over the last 200 years, destructive erosion, wetland flooding, soil contamination, and increased flood risk are all likely to occur (Nunez, 2019). Not only will global climate change cause destructive physical damage, it will also hurt the world economy. In a study done by the Energy Policy Institute at the University of Chicago, it was predicted that the increase in temperature from global climate change will lower global productivity. Productivity is projected to drop by as much as 4 percent per degree increase in temperature beyond 80 degrees Fahrenheit, and about by about 3 percent (Rising Temperatures, 2018). Therefore, although the exact future effects of climate change on the world are unclear, it is reasonable to assume that the potentially severe and irreversible impacts of climate change associated with the worst-case scenario(s) is enough to justify the world taking action.

This invites the question of what that action should be, as the world is made up of many independent nations with different priorities and political agendas. By definition, adaptation policies are designed to alter both manmade and natural environments to reduce the negative impacts of climate change. Examples of adaptation policies include changing building codes in flood prone areas to be more resistant to floods, limiting the use of air conditioning units to buildings such as hospitals, as well as coastal walls. Preventative polices on the other hand aim to stop such harms from occurring by reducing greenhouse gas emissions. This thesis assumes that if the world takes no preventive steps to reduce CO_2 emissions and puts all efforts into adaptation policies, that the costs of adaptation policies will be clearly higher than preventative polices alone (or some combination of the two). Furthermore, as natural disasters increase in frequency and severity, additional costs of disaster relief will also grow. With this assumption, assessing the ability of various abatement regulations – such as CO_2 cap and trade systems – to reduce the costs of preventive policies becomes highly policy relevant. The world, after all, faces numerous claims for limited resources, just a few examples being inadequate healthcare, the commonplace of hunger in large parts of the developing words, and the increasing needs for infrastructure. Reducing global warming at the lowest possible cost, then, is a worthy goal, since doing so will free up resources to address these vitally important competing needs.

In this thesis I will focus on the particular policy option known as cap and trade. Cap and trade programs are designed to reduce atmospheric pollution. While cap and trade programs can deal with numerous types of emissions and chemicals, the majority of programs use Carbon Dioxide (CO_2) as the unit of sale, or convert non-CO_2 emissions into CO_2-equivelant units (CO_{2-eq}). For simplicities sake this paper will assume all permits represent Carbon Dioxide emissions (Johnson, 2011).

The "cap" of cap and trade is the overall emissions level that the program wants to reduce too, which is lowered overtime. This cap is split up among firms into allowances, which are also known as permits to emit a certain quantity of a greenhouse gas or gasses. The annual allocation of allowances to each firm is presumably lower than their current emission levels, and each firm must buy additional permits if they emit more than their initial number of allowances. The idea is that the trading of these permits provides incentives for firms to cut emissions in order to reduce costs (How cap and trade works, 2019). For example say there are two Firms (A and B), where Firm A has a high cost of reducing emissions, and Firm B has a low cost of reducing emissions. Firm A will choose to reduce emissions until the cost of reducing emissions by one unit becomes greater than the cost of buying an additional equivalent permit. Firm B will reduce emissions below the required reductions set by the program, as their low cost of abatement allows them to make a profit off of selling unused permits. The goal of cap and trade programs is to reach the same emissions reductions as direct controls—government regulation which requires all firms to lower emissions to a certain level—at a lower cost to firms and consumers.

There are quite a few carbon cap and trade systems in existence. In China they have the National Carbon Market—which is the world's largest, covering 1.4 billion people. The coalition of countries in Europe created the European Union's Emissions Trading System (EU ETS). California's cap and trade program is the 4th largest in the world and covers one of the world's largest economies (How cap and trade works, 2019). California's program, the EU-ETS and China's National Carbon Market are all examples of mandatory cap and trade. The Regional Greenhouse gas initiative (RGGI) covers nine states in northeastern United States, and as mentioned previously is also a mandatory system, but most states require each company to buy all of their permits at the beginning of each year. In other words there is no initial allocation of permits (Elements, 2019). Cap and trade systems are popular with politicians and environmentalists, and thus are one of the most discussed options for reducing emissions.

In cap and trade programs firms with high abatement costs may have strong incentives to distort emissions data they provide to regulators. This distortion can hamper the effective implementation of cap and trade programs. There are two forms that these distortions can take: first, firms can overstate their initial or "historical" emissions, and second, firms can attempt to falsify emissions data once the program is in place to show they have reduced emissions while in reality they have not. In the case of the first distortion, regulators would allocate too many emission allowances, allowing emission levels to remain at their initial level, and even rise in some cases. If a firm was large enough, or overstatement was commonplace among firms this distortion could undermine the entire trading program by artificially lowering price of permits and potentially reducing the level of emission abatement. Concerning the second distortion, exaggerated emissions reductions could expand the number of permits available in the program, thus lowering incentives for low abatement cost firms to reduce emissions.

This paper assesses how these distortions effect cap and trade programs. First I will construct a model to show the incentive for firms to misstate initial emission levels or influence the initial cap in cap and trade programs. I will also demonstrate the incentives to falsify emissions data—this being where firms state they are abating, when in reality are not reducing emissions—and explore whether or not this is possible. While I will show incentives for both of these distortions, this paper will only provide institutional data on overstating initial emissions levels. This paper concludes with guidance to policy makers on how to prevent and address these potential abuses of the system.

II. Model

Literature Review

There are multiple approaches to modeling marginal cost of abatement in cap and trade programs, but most are fairly straightforward and similar to the model constructed in this paper. Morris, Paltsev, and Reilly (2011) constructed their model with cost of CO_2 reduction on the y-axis and quantity of CO_2 reduced on the x-axis. This model used the marginal abatement cost (MAC) curve to show how these costs change over the long run of a cap and trade program. Klepper and Peterson (2004) modeled MAC with cost in dollars ($) on the y-axis, and percent reduction in emissions relative to initial benchmark on the x-axis. Finally, Ellerman et al., (1998) modeled MAC with the price of carbon on the y-axis and the quantity of CO_2 abated on the x-axis.

Conceptual Model

I postulate that the extent to which firms distort their emission data is a function of the associated private (firm) benefits and costs, which are described in greater detail below.

Benefits of Emission Information Distortion

I assume that the greater the abatement costs a firm must incur in order to reduce CO_2 emissions, the more likely the firm will distort their prior emissions level (with the hope of evading these costs). Distortion incentives are particularly high when providing pre-intervention emission level data to regulators. If historical emissions are exaggerated, then actual emission reductions are correspondingly lower due to the likelihood that the regulator will mandate smaller pollution cutbacks. In contrast, if a firm can easily reduce CO_2 emissions at a relatively low cost, then the savings generated by evading emission reductions via exaggerating historical emission levels will correspondingly be less.

Cost of Emission Information Distortion

I postulate that the main costs of providing false data are the financial penalties associated with being brought up legal charges of fraud, which in turn are detection. Further, detection odds are greater if firms use similar production easier for both regulators and the firms themselves to infer the reporting of false data. Similar production methods across firms also increases the odds that they are competitors in output markets, which then generates incentives for firm to report on each other (in order to drive up the costs of rivals).

Taxonomy for Predicting the Likelihood of False Emission Data

With benefits and costs defined in this manner, we can then construct a taxonomy of firm duplicity on emission data, as shown in Table 1. High cost abatement firms operating in permit markets with heterogeneous cost structures have the highest odds of submitting erroneous emissions data; low cost polluters operating in permit markets with homogenous costs structures have the lowest odds of falsifying data; while firm facing an intermediate mixture of benefits and costs (low benefits/low costs; high benefits/high costs) lie somewhere between these two extreme with respect to engaging in information distortion.

Table 1	Production technology homogeneity (PT-HOM) (Often many firms in the same industry)	Production technology heterogeneity (PT-HET) (Often few firms in different industries)
Low Cost of Abatement Producers (LC)	• Small benefits of engaging in emissions data distortion • Higher likelihood/cost of getting caught	• Small benefits of engaging in emissions data distortions • Lower likelihood/cost of getting caught
High Cost of Abatement Producers (HC)	• Large benefits of engaging in emissions data distortion • Higher likelihood/cost of getting caught	• **Large benefits of engaging in emissions data distortion** • **Lower likelihood/cost of getting caught**

Low Cost of Abatement Producers with Production Technology Homogeneity

In this case there is a low-cost of abatement producer with many firms in the same industry, resulting in homogeneity among different firms production technologies. As their cost of abatement is already low, there is less incentive for engaging in emissions data distortion. In other words, for this firm the cost of reducing emissions is so low, that it will not only be able to meet the required emission reductions, but also continue to abate emissions past the cap in order to sell excess permits for profit. Additionally, as there is homogeneity with respect to production technologies, there is a greater likelihood that another firm would be able to recognize suspicious emissions estimates and report them for misstatements. These firms are also in direct competition with one another, providing further incentives to scrutinize other firm's practices.

Low Cost of Abatement Producers with Production Technology Heterogeneity

In this case there is a low-cost of abatement producer with few firms in different industries resulting in heterogeneity among different firms production technologies. As their cost of abatement is already low, there is little incentive for engaging in emissions data distortion. Since there is heterogeneity with respect to production technologies, there is a lower likelihood that another firm would be able to recognize suspicious emissions estimates and report a competitor for fraud. These firms are also not in direct competition with one another, further reducing incentives to scrutinize other firm's practices.

High Cost of Abatement Producers with Production Technology Homogeneity

This case involves a high-cost of abatement producer with many firms in the same industry, resulting in homogeneity among different firm's production technologies. As their cost of abatement is high, there is a large incentive for misstating initial emissions. But as there is homogeneity with respect to production technologies, there is a greater likelihood that another firm would be able to observe suspicious emissions estimates and report a competitor for emissions data distortion. These firms are also in direct competition with one another, further incentivizing them to scrutinize other firm's practices.

High Cost of Abatement Producers with Production Technology Heterogeneity

Here there is a high-cost of abatement producer with few firms in different industries, resulting in heterogeneity among different firms production technologies. As their cost of abatement is high, there is a large incentive for misstating initial emissions. Due to heterogeneity among production technologies, there is a lower likelihood that another firm would be able to observe suspicious emissions estimates and report them for emissions data distortion. These firms are also not in direct competition with one another, further reducing incentives to scrutinize other firm's practices. For these reasons the model predicts that this category of firm is the most likely to engage in emissions data distortion, as well as the most likely not to get caught.

Model Parameters

Our model assumes a free permit system in which permits are given to participants without charge. Free permits are often seen as compensating participants for sunk costs associated with the changing business environment (Sterner and Muller, 2007). Although the initial allocation of permits is free, any firm that emits beyond the initial set of allowances distributed by the program must buy addition permits equivalent to the amount emitted in excess. The overall cap and subsequent distribution of allowances is set in part by historical emissions data given by firms. In a real world scenario the use of self-reported historical emissions can be a result of political bargaining, lack of pre-program data on emissions, or budget constraints on the cap and trade program. Cost of abatement per ton of CO_2 in terms of dollars ($\$/CO_2$) is represented on the y-axis, and quantity of CO_2 emitted in millions of metric tons per time period (CO_2) represented on the x-axis.

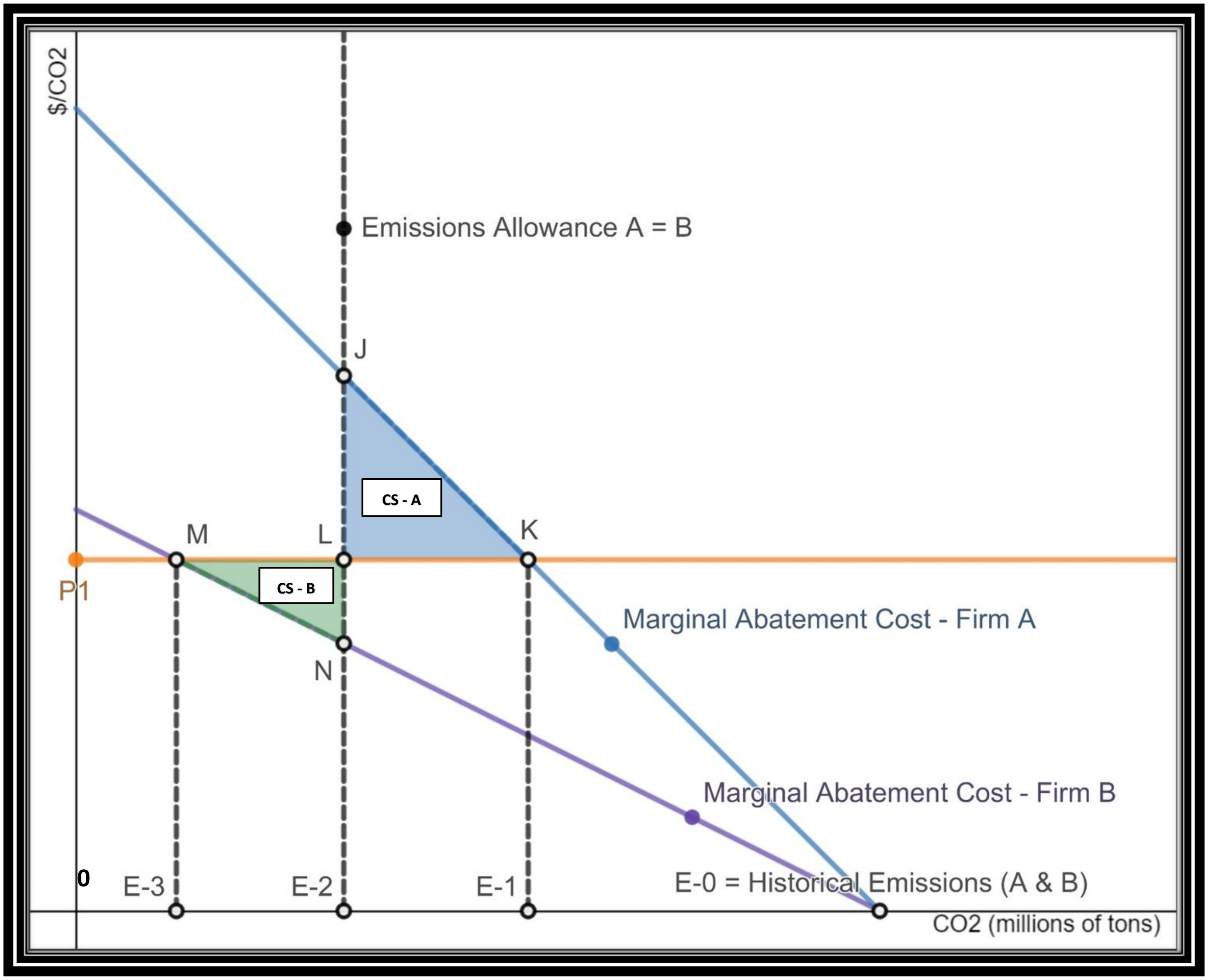
In our simple model, we will have 2 firms illuminating incentives for distortion: Firm A and Firm B. Firm A is a high cost producer with production technology heterogeneity (HC & PT-HET) Firm B is a low-cost producer, with production technology heterogeneity, who operates in a different industry than Firm A. As mentioned previously, if a firm was large enough, overstatement of historical emissions could undermine the entire trading program by artificially lowering price of permits and potentially reducing the level of emission abatement.

For this thesis it is assumed that neither Firm A nor Firm B is large enough to significantly affect the price of permits.

Marginal Abatement Cost (MAC) represents the cost of investing in new production technologies or changing to a different fuel source like natural gas or renewables in order to reduce emissions. Firm A is assumed to have a MAC > than Firm B. In real world cap and trade programs initial allocation of permits is much more complex, but for this model assume that each firm's initial allocation of permits is equivalent to 90 percent of reported historical emissions (i.e. a 10 percent emissions reduction).

Model Analysis

Figure 1



Base Case – Both Firms Report Accurately

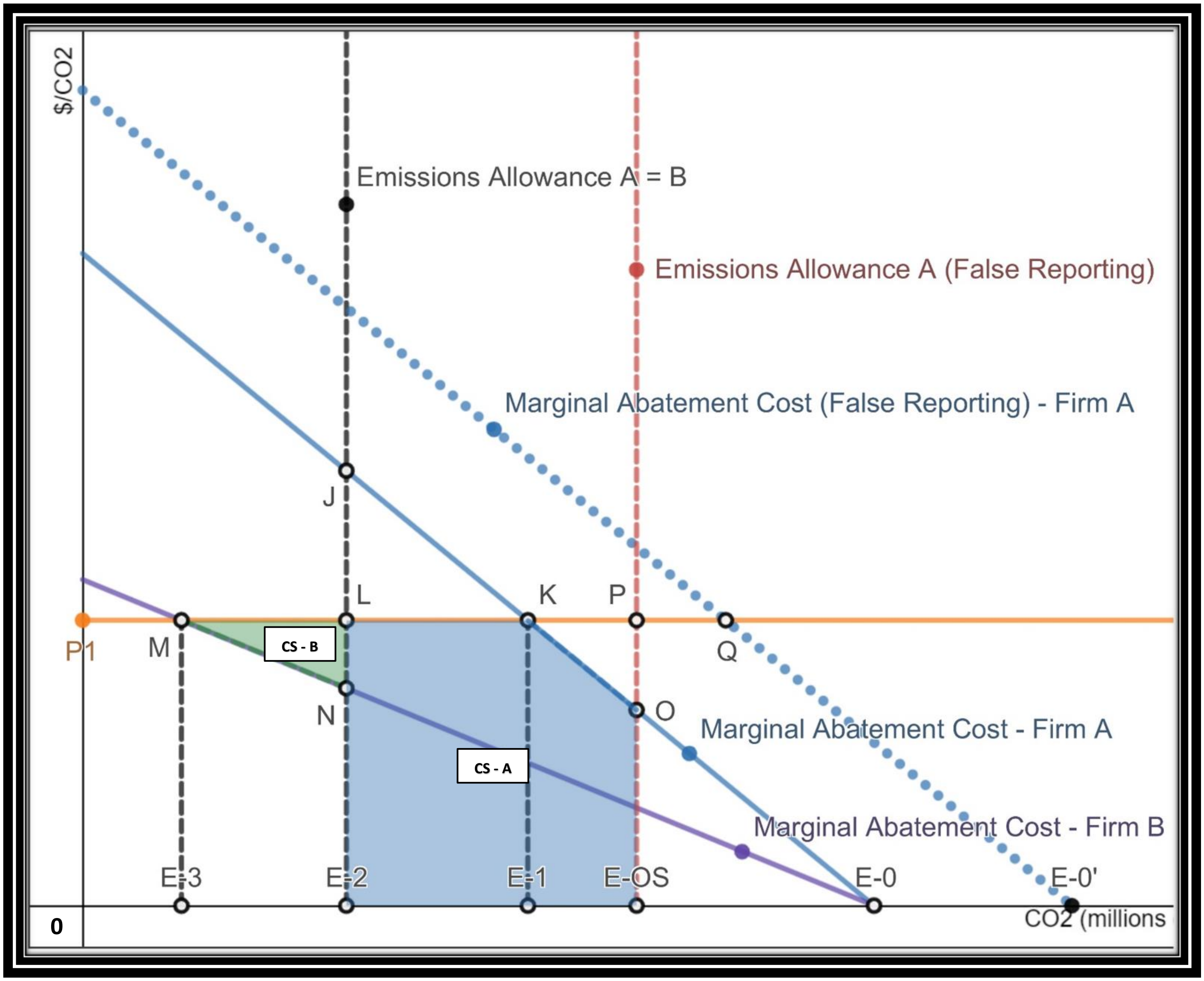
In Figure 1, Firm B has accurately reported their historical emissions level to be E-0. Firm A has also accurately reported their emissions levels to be E-0. Both firms had the same initial emissions level, so the vertical Emissions Allowance A = B line is the same for each firm and represents the maximum each firm is allowed to emit (E-2) before they are required to either reduce emissions or purchase additional permits. The net total abatement cost for Firm B = [area

NE-0E-2] – [area MLN] (the latter area is the profits from selling E-2 to E-3 permits). The total abatement/permit cost for Firm A = [area LKE-0E-2].

The orange horizontal line denoted Permit Price represents the price of a permit to emit 1 metric ton of CO_2. When cap and trade program work as intended, Firm A will reduce emissions until its MAC curve intersects the Permit Price line. At this point the cost of abatement becomes greater than the cost of buying addition permits. Thus Firm A will choose to purchase permits from other firms to cover the remainder of its emissions. Likewise as Firm B's cost of abatement is relatively low, so they will abate emissions below the quantity required by the program, and sell their unused permits to higher cost firms such as Firm A. The blue shaded area denoted CS-A [area JLK] represents the cost savings to Firm A versus direct controls. The green shaded area denoted CS-B [area MLN] represents the costs savings to Firm B versus direct controls. These cost savings come from the profit Firm B makes from selling their excess permits. While both firms experience cost savings as opposed to a direct control policy, they still incur net cost increases as opposed to the pre-regulatory period. Furthermore it is clear that the total abatement cost for Firm A is much higher than the total abatement cost for Firm B, putting Firm A at a distinct disadvantage.

As mentioned in Table 1 and its subsequent discussion, however, this imbalance of marginal abatement cost also creates an incentive for Firm A to engage fraudulent behavior, as they are still incurring costs that absent participation in the program they would not face. In our model's setup, the most likely form this fraud would take is overstating initial emission levels, as seen in Figure 2.

Figure 2



Case 2 – Firm A Overstates Historical Emissions

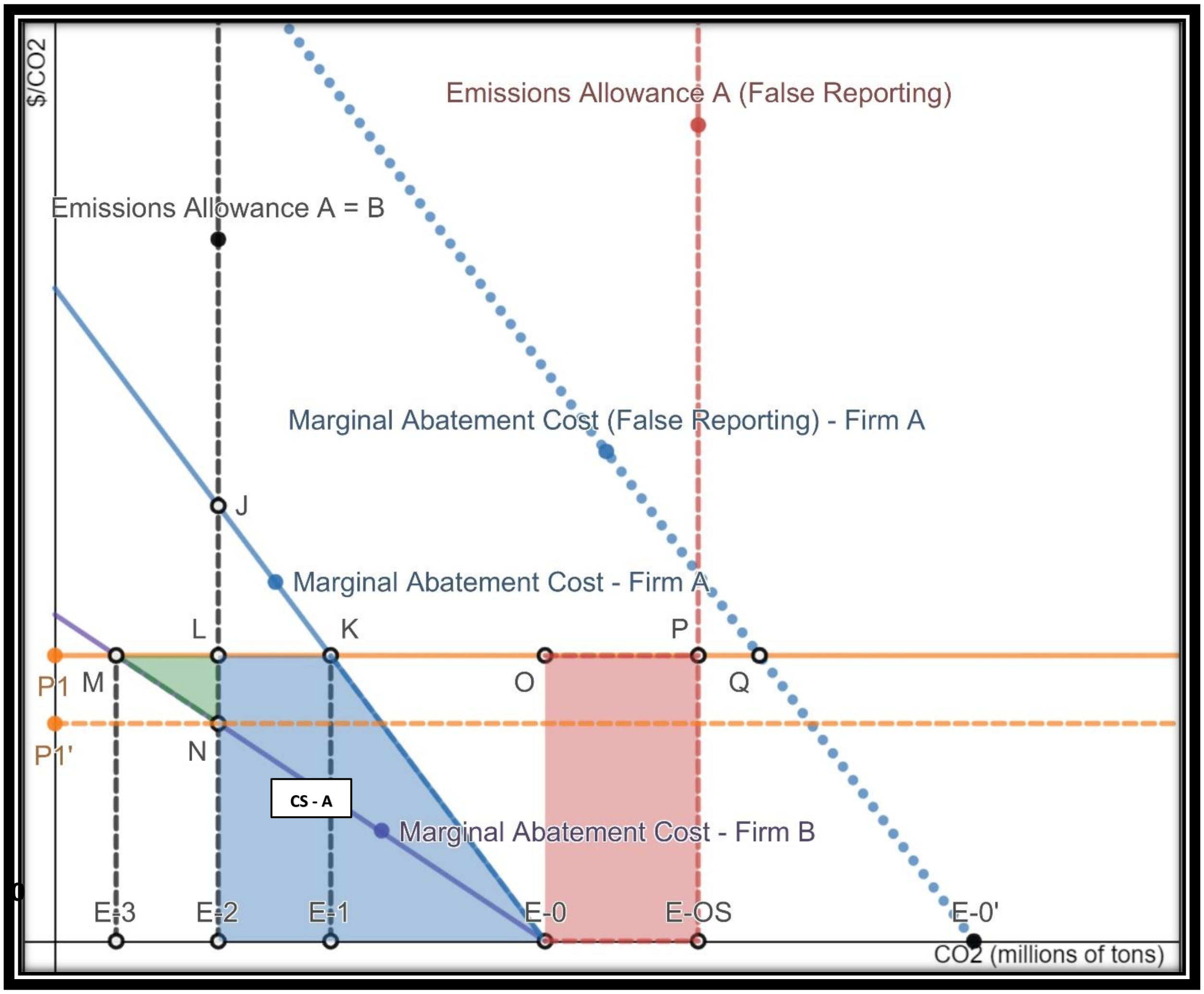
In Figure 2 Firm B has accurately reported their emissions levels to be E-0. Firm A, on the other hand has overstated their emissions levels to be E-0'. The vertical Emissions Allowance A = B line represents the maximum Firm B is allowed to emit (E-2) before they are required to either reduce emissions or purchase additional permits. This is also what the emissions allowance would be for Firm A if they had truthfully reported that their initial emissions levels were E-0. The vertical line labeled Emissions Allowance A (False Reporting) represents the falsely inflated emissions allowance corresponding with Firm A's overstated initial emissions of E-0'.

Area [PQE-0'E-OS] represents the total abatement costs if Firm A were to actually have baseline emissions of E-0' and reduced emissions/purchased additional permits to E-OS. Area [OE-0E-OS] represents the real cost of abatement that Firm A faces by overstating initial emissions and reducing emissions from their true level of E-0 to the artificially high allowance of E-OS. Area [LKE-0E-2] represents the cost of abatement that Firm A would face if they reported their true baseline emissions of E-0, and abated emissions to E-1. Finally, Area [MLN] represents the total abatement cost Firm B faces when reduces emissions from E-0 to E-3.

If Firm A were to accurately report their initial emissions, they would be at a great disadvantage to Firm B. In this scenario, Firm A told the regulating body of the cap and trade program that their baseline emissions were E-0', while in reality their baseline emissions were E-0. This overstatement results in Firm A only being required to reduce emissions from E-0 to E-OS, rather than E-2. Recall that Firm A is a high cost producer with production technology heterogeneity (HC & PT-HET) and Firm B is a low-cost producer, with production technology heterogeneity, who operates in a different industry than Firm A. Firms and regulators in Firm A's industry have a lower chance of spotting their emissions data fraud, as they exhibit production technology heterogeneity. Furthermore Firm B operates in a different industry, which gives them less incentive to report Firm A, as they are not direct competitors.

Not only does this deception prevent the emissions abatement target from being reached, but it also potentially threatens the economic viability of the entire cap and trade program. In this case there are no excess permits introduced into the market by Firm A. Firm B still has excess permits to sell, but Firm A has no need to buy them. However, if Firm A were to have gone even further in their overstatement—as seen in Figure 3—the effects could be devastating.

Figure 3



Case 3 – Firm A Drastically Overstates Historical Emissions

In Figure 3 Firm B has accurately reported their emissions levels to be E-0. Firm A, on the other hand has overstated their emissions levels to be E-0'. The vertical Emissions Allowance A = B line represents the maximum Firm B is allowed to emit (E-2) before they are required to either reduce emissions or purchase additional permits. This is also what the emissions allowance would be for Firm A if they had truthfully reported that their initial emissions levels were E-0. The vertical line labeled Emissions Allowance A (False Reporting) represents the falsely inflated emissions allowance corresponding with Firm A's overstated initial emissions of E-0’. Area [PQE-0’E-OS] represents the total abatement costs if Firm A were to actually have baseline emissions of E-0’ and reduced emissions/purchased additional permits to E-OS.

As mentioned previously, if Firm A were to accurately report their initial emissions, they would be at a great disadvantage to Firm B. In this scenario, Firm A told the regulating body of the cap and trade program that their baseline emissions were E-0’, while in reality their baseline emissions were E-0. However, as opposed to the scenario in Figure 2, Firm A’s overstatement is so drastic that it is allotted more permits than it truly emits, allowing the firm to not reduce emissions at all, and sell excess permits for profit. Hence the total cost savings for Firm A (as opposed to accurately reporting emissions) is equal to the area denoted CS-A [area LKE-0E-2] + [area OPE-OSE-0]; the latter being the profit Firm A makes from selling its excess permits.

In this scenario Firm A’s overstatement of historical emissions level has led to such a large quantity of excess permits being introduced into the market that the price of permits actually falls. The law of supply and demand states that there is an inverse relationship with quantity supplied and quantity demanded, and that demand has a positive relationship with price. So as Firm A artificially increases the supply of permits in the market, the demand for permits falls, which in turn lowers the price. This can be seen in the movement of the line P1 to P1’. This movement will lower the amount of emissions abated in future periods. With the new price of permits P1’, it is no longer cost effective for Firm B to abate emissions to E-3, defeating the entire purpose of cap and trade. However, all of these changes to the market are likely to grab the attention of regulators.

If Firm A is known to be a high cost of abatement firm, it would seem unlikely that they were able to reduce emissions by such a great margin, and were left with excess permits to sell.

Such an unexpected increase in the supply permits in the market, the decrease in demand for Firm B's permits, as well as the drop in price of permits brought about by Firm A's overstatement would most likely cause regulatory inquiry. These interpretations of the model suggest that there may be an upper limit on emissions overstatement, and if such large overstatements occur they could only take place during the infancy of the program. While the implications of overstating initial emissions can seriously derail a cap and trade program, another possible manifestation of fraud is false reporting or biased estimation of emissions after a cap and trade program is already established.

III. Emissions Monitoring – Real World Complications

Emissions Monitoring Methods

Direct Measurement

There are three standard ways for measuring emissions in a cap and trade program, the first of which is direct measurement. Direct measurement is enabled by the use of Continuous Emissions Monitoring Systems (CEMS). CEMS are "electromechanical instruments that sample, analyze, measure and record" emissions data by being installed in the exhaust/smoke stack of an emitting unit (McAllister, 2011, p. 1203). CEMS is very effective at monitoring CO_2 emissions—the focus of this paper. The Acid Rain Program created under the 1990 Clean Air Act (CAA) used CEMS to generate very reliable data on CO_2 emissions in the United States which has greatly helped cap and trade programs that came after it (McAllister, 2011, p. 1203). In addition the CEMS systems required by the Acid Rain Program provision of the CAA:

> "…must be in continuous operation, and must be able to sample, analyze and record emissions data at least every 15 minutes and then to reduce the data to one hour averages … (making) the system capable of providing a nearly continuous and very accurate account of the volume of emissions leaving a facility" (Peeters, 2006, p. 180).

This strict requirement extremely limits opportunities for falsely reporting emissions data. Furthermore the RGGI relies on CEMS data to monitor compliance within the program. Over all the electricity sector in the United States generates 40 percent of its total CO_2 emissions, and 80 percent of these electricity producers already have CEMS monitoring devices in place. (McAllister, 2011, p. 1203). This makes CEMS especially useful/viable for new CO_2 cap and trade programs within the United States.

Emissions Factors

The emissions factors method is used when direct measurement is too costly or not feasible under the programs structure (McAllister, 2011, p. 1205). The general formula for estimating emissions using emissions factors is: “Activity Rate x Emissions Factor = Emissions.” The measure of “Activity Rate” can be a variety of things such as the number of hours a facility is operating, or the amount of fuel used during a day of operation. The measure of “Emissions Factor” is calculated by taking the mass of the pollutant emitted divided by the corresponding unit of activity that causes emissions (McAllister, 2011, p. 1206). The cost savings over direct measurement can be substantial, but there are concerns about emissions factors accuracy, as over half of the emissions factors developed by the EPA are rated “below average” or “poor” quality (EPA Can Improve, 2006). Furthermore, the EPA’s Office of Inspector General released a report in 2006 which found that misuse of emission factors led to uncontrolled emissions and that the EPA’s estimation program needed vast changes to increase accuracy (McAllister, 2011, p. 1205-1206). In this report it was found that for three industry sectors reviewed, “inappropriate use of emissions factors contributed to more than one million tons of pollutants not being controlled (EPA Can Improve, 2006). One example of a greenhouse gas emissions factors can be used for is Carbon Monoxide (CO) that is produced from industrial broilers. Another example is Volatile Organic Compounds (VOCs) which are a byproduct of the production of ethanol that is later mixed with gasoline. In 2002 the EPA accused companies of knowingly using “a faulty emissions factor” for permitting purposes (EPA Can Improve, 2006).

Self-Reporting

Due to limited resources of governments, many cap and trade programs rely on self-monitoring/reporting. Cap and trade programs inherently create incentives for fraud, as no matter how much cost saving occurs as opposed to direct controls, firms are still incurring new costs. While there is little research on the accuracy of self-reporting in cap and trade programs, there have been some studies done on The Toxics Release Inventory (TRI). The TRI is an EPA report on toxic chemicals that industrial and federal facilities report releasing into the environment (Toxics Release Inventory, 2019). Similar to cap and trade programs the TRI requires industries to report emissions on an annual basis. The statute that implemented TRI doesn't allow the EPA to inspect facilities and verify self-reporting, but the few states that have inspected facilities found vast under compliance with the program. One study found that some self-reports were off from true levels by a factor of two (McAllister, 2011, 1209). While this is by no means conclusive evidence that self-reporting fraud is widespread in cap and trade systems, it does suggest that oversight may be beneficial.

Evidence of overstating initial emissions & inflated emission caps

European Union Emissions Trading System (EU ETS)

The European Union Emissions Trading System (EU ETS) covers about half of the European Union's CO_2 emissions and mainly regulates electricity generators and large industrial emitters (Schmalenensee, et al., 2017). When the carbon price was introduced in 2005, European governments negotiated the right to decide how many permits would be allocated to their national industries to cushion the blow of the new regulation (The EU, 2010, p. 4). During the first carbon trading trial phase of the program (2005-2007), it seemed that too many permits were allocated. The 2007 cap ended up being 8.3 percent higher than verified 2005 greenhouse gas emissions. By 2012, 21 out of the 27 members of the EU-ETS requested emission caps higher than 2005 verified emissions (The EU, 2010, p. 4). Another analysis found that allowances' spot and future prices have sharply declined during the initial allocation period due to alleged initial over allocation (Bebbington & Gonzalez, 2008, p. 704). A paper published by the journal of Environmental and Resource Economics found that during the first two years of the EU-ETS, verified carbon emissions were 60 million tons lower than the number of allowances given out during that period. When a cap and trade program has more allowances than verified emissions, it is known as being in a "long" position, which is often interpreted as a sign of over-allocation (Ellerman and Buchner, 2008, p. 1-2).

RECLAIM

The Regional Clear Air Incentives Market (RECLAIM) program is a cap and trade program adopted by southern California, aimed at reducing NO_x and SO_2 emissions (Schmalensee and Stavins, 2017 p. 64). In both academic literature and political debate, many have criticized the program, as initial permit allocations were thought to have been too great, allowing industries to cheat the system through over-estimates and under-estimates of initial emissions (Profeta, 2005, p. 16).

Many of these issues stem from how the program was designed. Instead of matching buyers and sellers of RECLAIM Trading Credits (RTC), the program outsourced this process to private brokerage companies. This outsourcing of a crucial process created information imbalances, which in turn created the perception of the market being manipulated by those who participated in RECLAIM. Multiple stakeholders in the program noted allegations of market manipulation by brokers and industry participants (Egelston and Cohen, 2004, p. 10). When those familiar with the program were interviewed, they suggested that RTCs were intentionally withheld by brokers and insider trading occurred in order to create a false perception of high demand, thus artificially increasing the price of permits. In 2002, an Environmental Protection Agency investigation found vast evidence of wrongdoing by the brokers involved in RECLAIM. Furthermore, the South Coast Air Quality Management District (SCAQMD)—the body responsible for implementing and operating the RECLAIM program—issued violations which resulted in fines against one of the brokerage firms for misreporting trades (Egelston and Cohen, 2004, p. 10).

RGGI

It is thought that the Regional Greenhouse Gas Initiative (RGGI) significantly overestimated emissions from the states in the consortium during its initial compliance period. This led to an initial emissions cap that was above real emissions levels (Flynn, 2018). Allowing participating emitters to bank substantial portions of their permits for the next compliance period, while not actually reducing emissions. After the 2012 program review, RGGI lowered the emissions cap by 45 percent, and after another review in 2016 they lowered the cap by an additional 30 percent to adjust for the initial over-allocation (Flynn, 2018).

This is still a problem today with new members trying to join the consortium. Virginia's proposed initial cap for emissions was criticized in a joint statement by RGGI: "Virginia could realize a measure of climate leadership by adopting a lower starting allowance budget than currently set forth in proposed regulation. Setting Virginia's initial budget at an appropriately ambitious level is particularly important given the nature of the consignment auction to private entities" (Vogel, 2018). Furthermore, many stakeholders posted their criticisms during the public comment period:

Richard H. Ball, Ph.D:

- "The baseline of 33/34 MMT of CO2 is much too high and would lead to a much lesser reduction in emissions than is desirable."
- "Emissions have been on the decline already and the targeted reduction would happen with or without the RGGI"
- "My conclusion from the scenario analyses in the Appendices is that it would be feasible to achieve reductions under a Base Cap of 28 MMT." (Regulation, 2018).

The Institute for Policy Integrity at New York University School of Law:

- "Currently, little information is available about the assumptions underlying the forecasts."
- "The 33-34 MMT cap is most likely too generous."
- "Joint Stakeholder Comments submitted to RGGI (by, among others, Arcadia Center, Natural Resource Defense Council and Sierra Club) suggest that 2020 baseline should be set in the range of 30-32 million short tons." (Regulation, 2018).

Daryl Downing, Va. Conservation Network:

- "The 2020 base year emissions cap should be between 30 and 32 million tons." (Regulation, 2018).

Pamela Goddard, National Parks Conservation Association:

- "The 2020 base year emissions cap should be between 30 and 32 million tons." (Regulation, 2018).

IV. Conclusion

Limitations

The model laid out in this paper and subsequent discussion strongly suggests that there are incentives for firms to overstate initial emissions levels in cap and trade programs. While valuable insights have been gained, there are many limitations to the model and its underlying assumptions. First and foremost our model of cap and trade is much simpler than real world cap and trade programs. There are very complex procedures for creating the initial cap as well as the subsequent allocation of permits. In addition while overstatement of historical emissions can damage cap and trade programs in their infancy, many programs have come up with solutions to mitigate this damage—as will be discussed below. Furthermore our model only focused on CO_2 emission reduction, while any comprehensive cap and trade program will deal with a vast array of greenhouse gasses. This has other implications regarding emissions monitoring. CEMS has been found to be quite accurate in monitoring CO_2 emissions, and its use is widespread in the United States, making it hard for firms to engage in emissions (CO_2) reporting fraud in cap and trade programs once they have been established.

Conclusion & Policy Implications

Climate change is one of the most pressing issues in modern history. The complexity and scale of the problem calls for large collective action in time where it seems laws are almost impossible to pass. Progress has been made in the United States and around the world. For example, cap and trade systems can be found from California to the North Eastern United States, and all the way to China. However in a world with scarcity of resources, many programs and initiatives are all fighting for the same funding as cap and trade programs. Therefore, reducing global warming at the lowest possible cost is a worthy goal, since doing so will free up resources to address these vitally important competing needs.

This goal cannot be achieved, however, if these carbon reduction programs are riddled with fraud and deceit. The model laid out in this paper showed clear economic incentives for overstating initial emissions in cap and trade programs it also showed the cascading effects this type of fraud can have on all aspects of the program. In addition to analyzing overstatement of initial emissions levels, this paper explored how emission levels are measured, estimated and reported. The research shows there are weaknesses and potential for abuse in estimation methods, but there are steps cap and trade programs can take to counter these drawbacks.

While CEMS is very effective for monitoring CO_2 emissions, and a few other greenhouse gases such as NO_x and SO_2, it is not able to measure all relevant emissions in a comprehensive cap and trade program. This is especially true of "non-stationary" emitters, such as automobiles and other modes of transportation (Continuous Emissions Monitoring, 2019). Therefore most programs have to deal with some form of estimation factors and self-reporting. The EPA's Acid Rain Program (ARP) found an effective solution through offering incentives for compliance with the program. The EPA did this by adding provisions to the regulation and statutes, some of which include: reducing the frequency of quality assurance checks on participating firms when a quality assurance test goes well, having universal and comprehensive digital record keeping and reporting requirements, and implementing automatic penalties that costs the firm more than the cost of the permits (Schakenbach, Vollaro, and Forte, 2006, p. 1577). Despite the aforementioned limitations of CEMS, it is still one of the most effective solutions for monitoring CO_2 emissions from some of the largest polluters in the United States. This leads into another successful aspect of the ARP, which was the complete emissions data record requirement. Each emitting firm was required to install a CEMS or equivalent technology, and reported emissions every hour the plant was in operation (Schakenbach, Vollaro, and Forte, 2006, p. 1581).

As mentioned previously, the RGGI had a public comment period on Virginia's proposal to join the consortium. Forums that bring the public and experts into the conversation are also useful tools, as many states already in the consortium strongly suggested Virginia lower the initial cap as current members feared it would flood the market with excess permits.

There have also been well documented cases of cap and trade programs adjusting to and overcoming initial over allocation of permits. One such case is the EU ETS. Much of the over allocation of permits in the initial phase of the program has been attributed to faulty historical data, and as the program has progressed they have created a strong data set to base future caps and allowances on (Schmalenensee, et al., 2017). In recent years the program has shifted away from free allowances to an auction based system, which has helped stabilize prices (Schmalenensee, et al., 2017). The EU ETS also added provisions that retired excess allowances in phase 3 of the program, added discretionary price management mechanisms, and accounted for firms that left and entered the market (Perthuis and Trotignon, 2014).

Another possibility would be to implement a whistleblowing system, similar to the United Kingdom's National Audit Office's whistleblowing policy. Such a policy would provide rewards and protections for agents within and without firms who report abuses. This would be beneficial as those working for competing firms and those working within fraudulent firms know the most about production processes and costs. In addition to a whistleblowing system, having a temporary court appointed oversight agent placed within firms that are caught falsifying emissions data could potentially curb abuses of the system.

Finally, as more emissions reduction programs are implemented around the world the abundancy and accuracy of historical emissions data continues to grow. Cap and trade programs should use historical emissions data if available, and when that data is absent or incomplete, the program should rigorously compare estimates and self-reports of initial emissions levels to similar sized countries or programs that do have historic data. Despite the difficulties surrounding the implementation and maintenance of cap and trade programs, they remain politically viable and economically feasible methods for reducing emissions. Therefore, cap and trade programs should continue to be implemented, but also improved and adjusted for the potential problems that come with them.

References

Auction Results. (2019, March 13). Retrieved March 25, 2019, from https://www.rggi.org/auctions/auction-results

Climate Change Connection. (2019). Retrieved April 5, 2019, from https://climatechangeconnection.org/solutions/carbon-pricing/cap-trade-system/carbon-markets/

Continuous Emissions Monitoring Fact Sheet. (2019, April 9). Retrieved April 8, 2019, from https://web.archive.org/web/20090211082920/http://epa.gov/airmarkets/emissions/continuous-factsheet.html

Egelston, A., & Cohen, M. J. (2004). California RECLAIMs market failure: Lessons for the Kyoto Protocol. *Climate Policy, 4*(4), 427-442. doi:10.1080/14693062.2004.9685535

Elements of RGGI. (2019). Retrieved October 18, 2018, from https://www.rggi.org/program-overview-and-design/elements

Ellerman, A. D., & Buchner, B. K. (2008). Over-Allocation or Abatement? A Preliminary Analysis of the EU ETS Based on the 2005–06 Emissions Data. Environmental and Resource Economics, 41(2), 267-287. doi:10.1007/s10640-008-9191-2

Ellerman, Denny, A., Decaux, & Annelène. (1998, October 01). Analysis of post-Kyoto CO_2 emissions trading using marginal abatement curves. Retrieved January 28, 2019, from https://dspace.mit.edu/handle/1721.1/3608

EPA Can Improve Emissions Factors Development and Management. (2006). Retrieved April 7, 2019, from https://www.epa.gov/sites/production/files/2015-11/documents/20060322-2006-p-00017.pdf

Flynn, J. D. (2018, March 03). Mitigating Greenhouse Gas Emissions in the Northeast and Mid-

Atlantic Transportation Sector: A Cap-and-Invest Approach. Retrieved February 7, 2019, from http://harvardelr.com/2018/02/18/mitigating-greenhouse-gas-emissions-in-the-northeast-and-mid-atlantic-transportation-sector-a-cap-and-invest-approach/

Gillingham, K., & Stock, J. H. (2018). The Cost of Reducing Greenhouse Gas Emissions. *Journal of Economic Perspectives, 32*(4), 53-72. doi:10.1257/jep.32.4.53

Global Climate Change: Effects. (2018, November 28). Retrieved April 10, 2019, from https://climate.nasa.gov/effects/

How cap and trade works. (2019). Retrieved February 3, 2019, from https://www.edf.org/climate/how-cap-and-trade-works

Jan Bebbington & Carlos Larrinaga-González (2008) Carbon Trading: Accounting and Reporting Issues, European Accounting Review, 17:4, 697-717, DOI: 10.1080/09638180802489162

Klepper, G., & Peterson, S. M. (2004). Marginal Abatement Cost Curves in General Equilibrium: The Influence of World Energy Prices. SSRN Electronic Journal, 28(1), 1-23. doi:10.2139/ssrn.615665

McAllister, L. (2011, March). The Enforcement Challenge of Cap-and-Trade Regulation. Retrieved January 25, 2019, from https://www.researchgate.net/publication/228185269_The_Enforcement_Challenge_of_Cap-and-Trade_Regulation

Morris, J., Paltsev, S., & Reilly, J. (2011). Marginal Abatement Costs and Marginal Welfare Costs for Greenhouse Gas Emissions Reductions: Results from the EPPA Model. *Environmental Modeling & Assessment, 17*(4), 325-336. doi:10.1007/s10666-011-9298-7

Nunez, C. (2019, February 27). Sea level rise, explained. Retrieved March 20, 2019, from https://www.nationalgeographic.com/environment/global-warming/sea-level-rise/

Peeters, M. (2006). Inspection and market-based regulation through emissions trading The striking reliance on self-monitoring, self-reporting and verification. *Utrecht Law Review, 2*(1), 177. doi:10.18352/ulr.22

Perthuis, C. D., & Trotignon, R. (2014). Governance of CO2 markets: Lessons from the EU ETS. *Energy Policy, 75*, 100-106. doi:10.1016/j.enpol.2014.05.033

Profeta, T., & Daniels, B. (2005). Design Principles of a Cap and Trade System for Greenhouse Gases. SSRN Electronic Journal, 1-14. doi:10.2139/ssrn.1261011

Regulation for Emissions Trading [9 VAC 5 - 140] Public Comment Forum. (2018, January 08). Retrieved November 1, 2018, from https://townhall.virginia.gov/L/Comments.cfm?StageID=8130

Rising temperatures harm worker productivity, causing global losses. (2018, August 30). Retrieved March 21, 2019, from https://news.uchicago.edu/story/rising-temperatures-harm-worker-productivity-causing-global-losses

Schakenbach, J., Vollaro, R., & Forte, R. (2006). Fundamentals of Successful Monitoring, Reporting, and Verification under a Cap-and-Trade Program. *Journal of the Air & Waste Management Association,56*(11), 1576-1583. doi:10.1080/10473289.2006.10464565

Schmalensee, Richard, Stavins, Robert N., Lessons Learned from Three Decades of Experience with Cap and Trade, *Review of Environmental Economics and Policy*, Volume 11, Issue 1, Winter 2017, Pages 59–79, https://doi.org/10.1093/reep/rew017

Scientific consensus: Earth's climate is warming. (2018, February 12). Retrieved April 09, 2018, from https://climate.nasa.gov/scientific-consensus/

Sterner, T., & Muller, A. (2007). Output and abatement effects of allocation readjustment in permit trade. Climatic Change, 86(1-2), 33-49. doi:10.1007/s10584-007-9281-0

The EU Emissions Trading System: Failing to deliver (pp. 1-16, Rep.). (2010). Friends of the Earth Europe. www.foeeurope.org/climate/download/FoEE_ETS_Oct2010.pdf.

Vogel, N. (2018, September 27). Statement on Re-Proposed Virginia Greenhouse Gas Rule. Retrieved April 9, 2019, from https://www.rggi.org/sites/default/files/Uploads/Press-Releases/2018_09_27_Virginia_Statement.pdf

Warrick, J., & Mooney, C. (2014, November 02). Effects of climate change 'irreversible,' U.N. panel warns in report. Retrieved April 08, 2018, from https://www.washingtonpost.com/national/health-science/effects-of-climate-change-irreversible-un-panel-warns-in-report/2014/11/01/2d49aeec-6142-11e4-8b9e-2ccdac31a031_story.html?amp;utm_term=.e4d18d232a7a&noredirect=on&utm_term=.4c0b30989f28