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A New Approach to Climate Change: A Consideration of Ancillary Benefits in Linking Regional Permit Trading Systems

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Abstract: In this paper, I investigate the economic efficiency of two major approaches to greenhouse gas reduction, and evaluate their respective benefits. First, I trace the path of action and thinking on addressing climate change from a global to a regional level. Second, I consider the major economic benefits of having a globally-integrated greenhouse gas abatement system. Third, I consider the economic benefits of regional approaches to climate change, with a focus on the ancillary benefits from greenhouse gas abatement. I conclude by reviewing the challenges to linking regional abatement systems into a cohesive network, and suggest a potential future approach to an economically-efficient abatement of greenhouse gas emissions.

Keywords: Carbon abatement, ancillary benefits, equimarginal principle, cap-and-trade systems, climate change history

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Section I. Introduction

The potential for climate change to dramatically alter global environmental, political, social, and economic conditions has placed it as one of the most significant challenges of the 21st Century. Current warming of the Earth's climate is at .8 degrees Celsius over pre-industrial levels, and without significant action within the next three decades, warming over 2 degrees Celsius is almost assured (World Bank, 2014: 20-22). Warming of the Earth's atmosphere can include consequences such as changes in marine and terrestrial ecosystems, rising sea levels, extreme heat events, altered rainfall patterns, reduced crop yields, and impact on population patterns (World Bank, 2014: 20-22). The widespread changes possible from climate change have spurred a global effort to limit greenhouse gas emissions in order to put the world on a more sustainable trajectory in limiting the global rise of temperatures.

My paper seeks to look at the reduction of greenhouse gas emissions from an economic efficiency perspective, looking at the most cost-efficient methods of pollution abatement. In Section II, I take a historical perspective on addressing climate change, and trace how views and actions on climate change have evolved since the early 1990's until present. I look at how initial efforts on climate change sought to approach emissions abatement in the context of a global agreement, modeled after successful efforts to reduce ozone depleting gases in the 1987 Montreal Protocol. I then show how the vision on climate change action shifted from a global to a regional/local approach in the mid-2000's, and survey recent regional actions. In Section III, I introduce the economic benefits of a global approach to climate change, focusing on the equimarginal principle and how this approach takes advantage of differing marginal costs of abatement of carbon across countries. In Section IV, I analyze the benefits to approaching climate change from a regional level. I focus on the addition of ancillary benefits when considering the benefits of carbon abatement, and how that increases the marginal benefit of carbon abatement done within the regulating region. Finally, I conclude in Section V on the challenges of linking regional carbon markets into a broader global system, and how the inclusion of ancillary benefits in climate change discussions can re-frame the debate over greenhouse gas reduction.

Section II. A Brief History of Addressing Climate Change: From Rio de Janeiro 1992 to Paris 2015

While the history of action on climate change is relatively short, its short history has seen significant evolution. I will divide the history into two sections: 1992-2005 and 2005-present. The first period, 1992-2005, represents the period of a "global" vision for action on climate change, characterized by the international recognition of climate change as a vital global issue, and the push for international agreements such as the Kyoto Protocol and a search for an appropriate successor. The second period, 2005-present, is the "regional" focus period, where frustration with inaction on an international scale led to a movement for action from a municipal, state, or regional level. This period is started by the adoption of the European Union Emissions Trading Scheme, and potentially bookended by the adoption of a new global agreement at the Paris 2015 Conference. As with the definition of any specific periods, these are meant as broader conceptual outlines, and each period certainly had elements and themes of the other. But the broader movements on climate action seem to follow this general outline, and mark the transition of climate change action to lower levels of government.

A. A Global Vision for Climate Change Action

To better understand present efforts on climate change, it's important to follow the broader historical development of action on climate change, and efforts on addressing other environmental problems, especially those related to air pollution. One of the first global environmental movements to address air pollution issues was the movement to protect the ozone layer. While abating carbon emissions and other greenhouse gases is a much more complex and broader issue than ozone emissions, it can provide a historical model for addressing a transnational air pollution problem. International action on ozone protection began with the Vienna Convention of 1985, which coordinated international action on ozone layer research and monitoring, and facilitated information exchange between countries. The 1987 Montreal Protocol built on the work of the Vienna Convention, and established country-specific targets for the removal of ozone damaging pollutants. These international conferences established momentum for continued work on the reduction of ozone pollution, creating the Multilateral Ozone Fund in 1990, which committed $2.55 billion in U.S. dollars for developing countries pollution control efforts. International ozone protection efforts have generally been seen as a great success, with the removal of most ozone-damaging substances from production by the late 1990's (Falkner and Stephen, 2010: 254). While reducing greenhouse gas emissions is a much more difficult problem than ozone protection, the success of the international approach to a global air pollution problem helped inspire the international approach to action on climate change beginning in the 1990's.

While the Montreal Protocol inspired future international efforts on climate change, it had specific characteristics that led to its success, and were different than future climate change agreements.The Montreal Protocol found most of its success from its strict enforcement of mechanisms to reduce CFC's, and strong penalties for non-participation, including trade sanctions. Developing countries were rewarded for joining the Protocol through outside foreign investment in compliance measures. The strength of enforcement mechanisms in the Montreal Protocol were a key difference with the future Kyoto Protocol climate agreement (Barrett, 216: 1999).

The first period of a vision for action on climate change, the "global" period, can be traced back to the 1992 Rio de Janeiro Conference on Environmental and Development. In Rio, the UN Framework on Convention on Climate Change (UNFCCC) was established. The UNFCCC sought "to achieve…stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with climate system…" (Depledge, 2004: 36). The Convention established the principle of "common but differentiated responsibility," meaning that developed countries were expected to contribute more in emissions reductions efforts than developing countries, recognizing their unequal contributions to greenhouse gas levels (Depledge, 2004: 37). Developed countries that had been responsible for the largest share of global greenhouse gas emissions were labeled Annex I countries, with an overall target to reduce emissions to 1990 levels (Selin and VanDeveer, 2015: 12).The UNFCCC also initiated yearly Conference of Parties meetings (COP) to ensure continued global action on climate change.

After Rio de Janeiro, the most significant global effort on climate change was the adoption of the 1997 Kyoto Protocol. The Protocol established differentiated commitments to greenhouse gas reductions by developed and developing countries, and committed countries to an average emissions reduction of 5.2 percent from 1990 levels by 2008-2012 (Selin and VanDeveer, 2015: 13, Gupta, 2010: 645). The 39 countries with agreements to emissions reductions could make reductions five different ways. Two of those ways focused on purely country-based approaches. These included country-specific emissions reductions proposals and the counting of carbon sinks, such as forests that absorb more carbon than they emit, in emissions targets. The other three ways involved international cooperation. Countries could trade emissions permits with other Annex I countries, reduce carbon emissions in other Annex I countries in the Joint Implementation program, or invest in emissions reductions in developing countries through the Clean Development Mechanism, or CDM (Selin and VanDeveer, 2015: 13). The agreement to a transnational, comprehensive emissions reduction treaty developed on a core of international cooperation led to optimism that global agreements would be the way forward for future actions.

The path of academic work on addressing climate change follows these international movements, and the optimism of the late 1990's and early 2000's in coming to a global agreement on climate change is revealed through this work. Warwick McKibben and Peter Wilcoxen's 2002"The Role of Economics in Climate Change Policy" is an example of an academic piece attempting to refine global emissions trading schemes. The authors dismiss the Kyoto Protocol as deeply flawed in reliance on rigid emissions targets in addressing a problem that has many uncertainties, but argue that a new hybrid approach of emissions permits and carbon taxes could still take advantage of global cooperation. They write, "A good first step would be for the United States, perhaps joined by large emitters, to adopt a modified form of the hybrid policy unilaterally" (McKibben and Wilcoxen, 2002: 128). Scott Barrett and Robert Stavins' 2003 "Increasing Participation and Compliance in International Climate Change Agreements" also seeks to find alternative approaches to a global agreement, in particular the failure of the Kyoto protocol. They explore fourteen different alternative proposals by themselves and other authors from academic literature on climate change. The authors conclude that, "Ultimately, both cost-effectiveness conditional on implementation, and probability of implementation are important. What seems clear at this juncture is that considerably more attention needs to be given…to those aspects of international climate agreements that will affect the degrees of participation and compliance that can reasonably be expected to be forthcoming." (Barret and Stavins, 2003: 371). While both articles acknowledge the failure of the Kyoto Protocol as a functional emissions Treaty, the focus on redesigning policy with an emphasis on flexibility and participation suggest a continued focus on international cooperation, and participation of all countries in any future agreement.

B. The Rise of Regional Climate Change Movements

As the success of the Kyoto Protocol as a truly binding, international agreement began to falter with the refusal of the United States, the world's largest greenhouse gas emitter, to sign the Treaty, elements of a new approach to climate change began to appear. The second period, the "regional" period, is marked by the adoption of the European Union Emissions Trading System in 2005. Regional initiatives began to develop, even in countries like the U.S. who had refused a binding global treaty. The Northeast Regional Greenhouse Gas Initiative (RGGI), conceived of in 2003 and implemented in 2009, brought together nine northeastern U.S. states to reduce emissions in a cap-and-trade system from the region's power plants (Selin and VanDeveer, 2015: 29). California and Quebec have launched systems to reduce carbon emissions through cap-and-trade schemes, and have begun exploring linking their systems with British Columbia, Ontario, and Manitoba under the Western Climate Initiative (Selin and VanDeveer, 2015: 30).

The European Union Emissions Trading Scheme is one of the best examples of a regional trading system, linking 27 European countries into one greenhouse gas emissions reduction program. The EU ETS has been phased in in three stages, each expanding the industries falling under the regulations and gradually harmonizing permit distribution. Originally, nations had discretion over the distribution of credits to different sectors of the economy, but the third and second phases involved harmonizing the sectoral distribution of permits. The ETS also put limits on the number of offset credits that could be purchased through the Clean Development Mechanism. The ETS allows for unlimited banking of permits from year to year, and has a secondary market for future permits (Newell et al, 2013: 127).

The Regional Greenhouse Gas Initiative was formed by a collection of seven Northeast states in 2007 to implement a cap and trade system for large electricity generators. The aim of RGGI is to reduce emissions to 10 percent below 2009 levels by 2018. RGGI uses an auction to sell permits to electricity generators, with revenues going to state governments for investment in renewable energy or efficiency projects. Similar to RGGI, California has begun a cap and trade system for the power sector and a limited amount of heavy industry. Two-thirds of permits are auctioned currently, with a target of 80 percent by 2015. The program will also expand to include transport fuels. California's system also includes a futures contract market (Newell et al, 2013: 131). New Zealand and Australia have also begun cap and trade systems. Australia has started with a carbon tax on top polluters, with the plan to phase into a permit system in 2015. New Zealand launched an emissions trading system in 2008, with caps based on Kyoto protocol commitments. New Zealand's system has been built with the idea of linking to international markets, although international uncertainty regarding climate change programs has hurt this aspect.[1]

While the thinking and action on addressing climate change has gradually shifted towards a regional model, both approaches have advantages to them in reducing emissions in an efficient

[1] This and the previous paragraph are from my paper "Linking Regional Carbon Markets: A bottom-up approach to climate change", written for Prof. Robert Mohr in ECON 798, December 2013.

way. In the next two sections, I will explore the potential economic efficiency considerations of both a global and regional approach to carbon abatement.

Section III. The Economic Benefits of a Global Carbon Market

While recent action on climate change has moved from the global to regional level, the potential for a future global agreement to be reached, either from a top-down international agreement or a bottom-up linkage of existing regional carbon markets, makes it important to consider the economic and environmental benefits of a global agreement. If a global agreement can't be reached, then certain elements of a global carbon market can be accessed through the linkage of carbon markets.

The development of a global agreement on carbon emissions has significant economic and political advantages. One of the primary advantages of an agreement with widespread participation is that it eliminates the problem of free-riding. Free-riding is when one country takes advantage of climate changes characteristic as a global problem by reaping the benefits of other countries carbon abatement work without equal participation in carbon abatement. Since the action of one country often have little impact on global levels of greenhouse gases, their inaction has little negative benefit, but allows the country to gain almost the same benefits as if it had abated emissions (Ostrom, 2009: 30).

A global agreement also minimizes the problem of the leakage of emissions from regulated countries to unregulated countries. When countries commitment to carbon abatement varies, there is the potential for carbon-intensive production to be moved to countries without abatement regulations. Different regulatory approaches can also create market price differences in renewable products between countries, creating potentially negative externalities in unregulated countries country (Ostrom, 2009: 29). A global agreement can force all pollution sources to face similar regulations, creating a disincentive to move carbon intensive production to an unregulated market.

A. The Equimarginal Principle: Cost-efficient reduction of greenhouse gas emissions

From an economic efficiency perspective, the primary benefit of a global market in carbon emissions is the ability to take advantage of varying costs of marginal abatement across countries. Since regulators aim to set pollution levels where marginal benefits equal marginal costs, access to less expensive marginal costs of abatement allows for a lower marginal cost curve for global emissions, allowing for more carbon abatement and a resulting increase in benefits from the additional abatement. This flexibility in emissions abatement helps a global carbon market best meet the equimarginal principle. The equimarginal principle states that when all pollution sources face the same marginal cost of abatement, total pollution abatement cost will be minimized (Berck and Helfand, 2011: 280). The use of a market-based system in carbon abatement, like cap-and-trade, meets these criteria. Firms are allowed to trade with one another, allowing the market to have a set marginal cost of abatement, or marginal cost to pay for a pollution permit. The logic behind the equimarginal principle is that polluters who have low marginal costs of abatement will do the majority of the pollution abatement, and will be compensated by the polluters who have higher marginal costs of abatement and will do a smaller amount of pollution abatement. While cost reduction is only one consideration for a pollution regulator, from an economic efficiency perspective, it’s one of the most important, and is arguably one of the most important measures in designing an emissions control policy (Berck and Helfand, 2011: 280).

Applying the equimarginal principle to a global carbon market, including as many countries as possible in an emissions trading program is the most efficient global carbon abatement approach. The global marketplace allows for a uniform price on carbon emissions across all countries. This is especially important when considering how developed and developing countries often face drastically different marginal costs of abatement, and access to the marginally cheaper abatement options in a developing country has the potential to make emissions abatement more economically feasible (Enqkvist et al, 2011: 9-10). When emissions abatement is uncoordinated between countries, and each country is required to do equivalent amounts of abatement, then emissions abatement will be done in a cost-inefficient way. An inability to split emissions abatement work in a manner that abates carbon at the least-cost fails to meet the equimarginal principle.

Figure 1. Equimarginal Principle in Action: Deadweight loss from an unequal emissions split

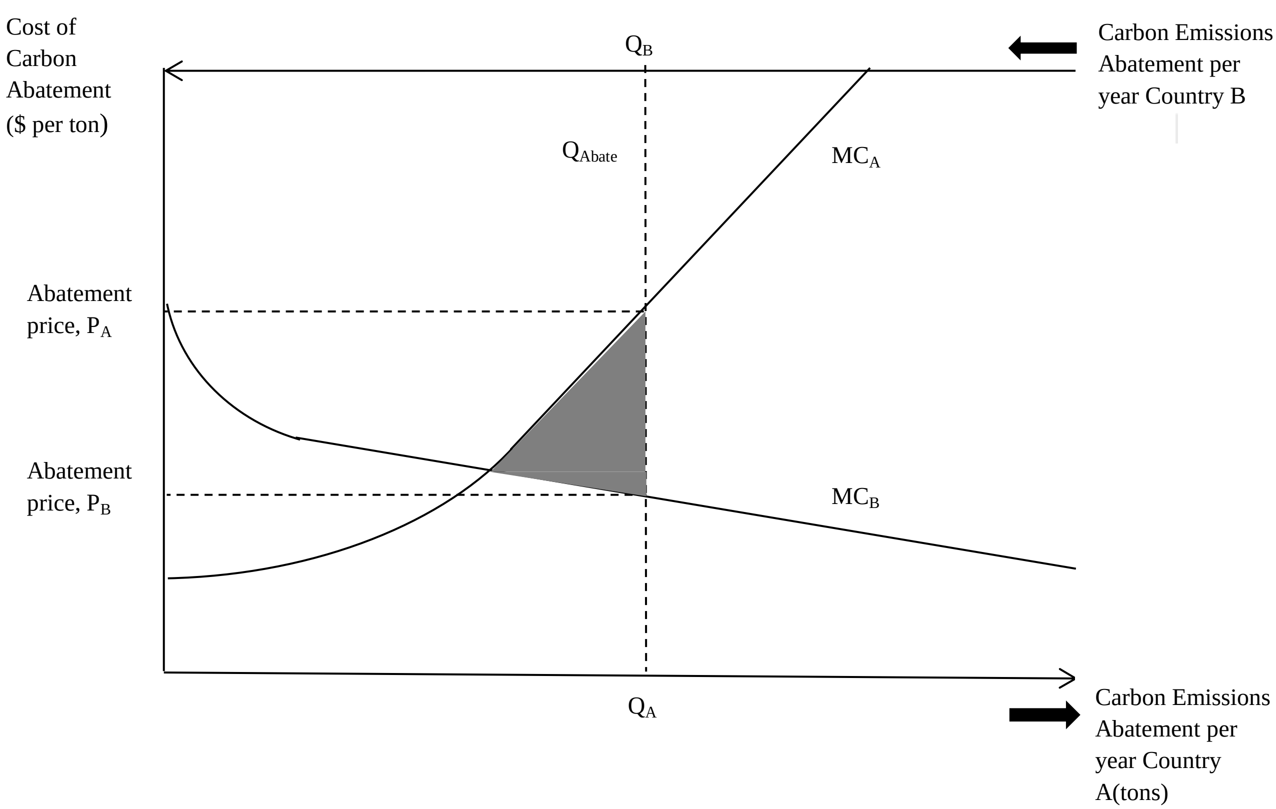
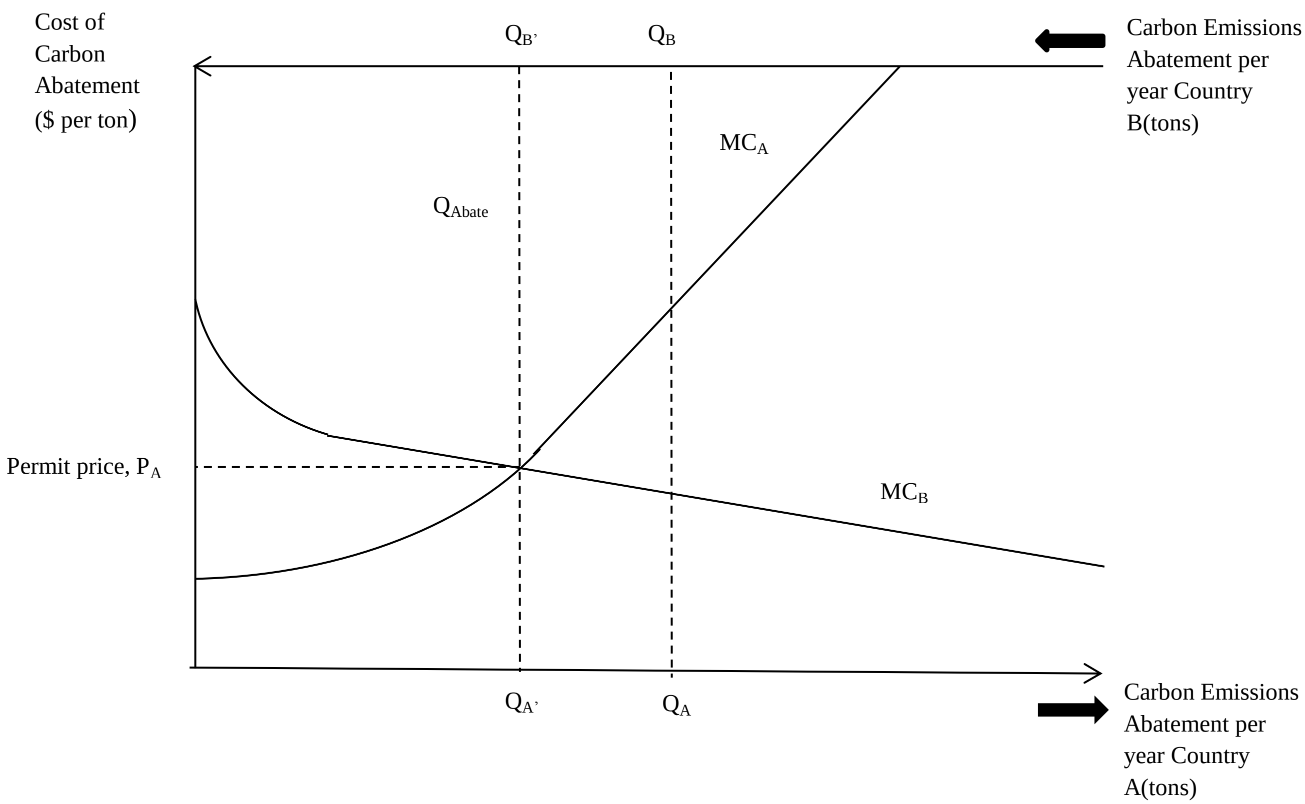


Figure 1 graphically illustrates the cost inefficiencies when countries do not collaborate on emissions reductions. The graph illustrates the marginal costs of abatement of carbon for two countries, Country A and Country B. Country A could be viewed as a developed country, with a relatively steep marginal cost of abatement curve, illustrating the relatively increased difficulty of emissions abatement in a developed country. Country B can be viewed as a developing country, with a shallower marginal cost of abatement curve due to the relatively less costly emissions reductions available. The Y axis represents the cost of a permit to emit one ton of carbon, and each X axis represents the amount of carbon abated by Country A and Country B, respectively. Any point along the X axis results in an equal amount of abatement; the only differences among points on the X axis are the varying allocations of abatement.

If an agreement is reached where both Country A and Country B are required to reduce equal amounts of emissions, but are not allowed to trade emissions permits, then there will be a resulting deadweight loss, shown by the shaded area in Figure 1. The deadweight loss represents the area where Country A should be paying Country B to abate part of its emissions quota due its marginally cheaper costs of emissions abatement. This is the area where transactions should be happening between the two parties, but aren’t. Under this scenario, Country A would pay abatement price P_A for its most expensive ton of carbon abated, while Country B would pay abatement price P_B. The deadweight loss from not having a globally integrated emissions abatement system is one of the strongest economic arguments for taking a global approach to greenhouse gas abatement.

Figure 2 demonstrates how deadweight loss in emissions abatement can be minimized. To reduce emissions in the most cost-efficient way, a global trade between emissions abatement systems is needed. The most cost-efficient point for emissions abatement is where the marginal cost of abatement for Country A, MC_A, crosses the marginal cost of abatement for Country B,

Figure 2. Equimarginal Principle in Action: Varying marginal costs of abatement



MC_B. This point meets the equimarginal principle, with both countries facing the same marginal cost of abatement, price P_A. If emissions reductions are split equally between each country, as seen in Figure 2, Country A will buy permits from Country B up until the country quota, and abate emissions up until the point where Country A's marginal costs of abatement equals Country B's marginal cost of abatement. The emissions abatement done in Country A will now be much less, at point $Q_{A'}$ instead of point Q_A. Country B will take over much of the abatement, abating $Q_{B'}$, instead of Q_B. The benefits of a global market for carbon permits are demonstrated in Figure 2, as trade allows for the most cost-efficient reduction of emissions.

While there are important characteristics of climate change to support a global approach, the primary economic motive is to do emissions abatement in the most cost-effective manner. The problems of "free-riding" on the benefits of abatement work by non-abating countries, and the leakage of pollution from an abating country to a non-abating country are both addressed through a global agreement on climate change. But more importantly, global collaboration can allow for cheaper emissions abatement, allowing for a lower overall marginal cost curve for emissions abatement, leading to a greater total amount of abatement.

Section IV. The Argument for Regional Carbon Markets: Including Ancillary Benefits in Measuring the Benefits of Climate Change Action

While a global carbon trading system can have significant economic advantages in efficiently abating carbon emissions, political inaction on an international scale have limited any comprehensive climate agreements. The growth of regional and national emissions trading schemes over the past decade have emerged as a new path forward on addressing climate change, with action being taken independently on much smaller scales of government. Although the movement towards regional cap-and-trade approaches to climate change certainly has not had the same benefits of a comprehensive global agreement on climate change, regional efforts to address climate change do have significant benefits. From the increased ability to innovate on carbon abatement approaches at a smaller scale, to ancillary benefits from carbon abatement, regional approaches to climate change appear to be a worthy alternative of a global agreement. The potential to combine the benefits from both global and regional approaches through trading system linkages appears to be worth exploring more, although trade restrictions appear necessary to maintain the ancillary gains from regional carbon abatement.

One argument for regional carbon networks is the principle of environmental federalism, as discussed by Wallace Oates. In its most traditional sense, environmental federalism is the principle that environmental protection should be done at the level of pollution. That is, the regulation of an environmental problem should be done by the unit of government who is impacted the most, allowing local regulators to set pollution standards based on their local knowledge of the issue (Oates, 2009: 1). For climate change, this logic suggests that the impact of carbon emissions as a global problem requires it to be dealt at a global level. It's thought that if the impacts of climate change are spread fairly evenly across the globe, then each country should have responsibility in reducing carbon emissions. But the benefits from a federalist system of climate change emissions reduction, from both a theoretical and empirical sense, appear to undermine this logic.

A decentralized system can allow for innovation in climate policy design, allowing different regulators to experiment with the best way to implement carbon reduction programs. This is the idea of laboratory federalism, where regulators can learn from the successes and failures of policies on a smaller scale, hopefully promoting more innovation and creativity in reducing carbon emissions. Oates cites an historical example of this is the 1970's and 1980's emissions trading programs at the state level, whose collective experience spurred the 1990 Clean Air Act system of tradable sulfur allowances (Oates, 2002: 22). Others have argued that climate policy should be done at a local level due to the difficulty in enforcing climate regulations, relying on stronger national and regional institutions. Victor, House, and Joy argue that climate policy should be similar to the system of federalism proposed by James Madison in U.S. Constitutional debates. They argue that this federalist approach will allow governing institutions to build credibility on climate action needed for effective markets (Victor et al, 2005:

1820). Nobel laureate Elinor Ostrom has written that a "polycentric" approach to climate change will be the most comprehensive and effective method to address the issue. The benefits to such an approach are they ability for experimentation on multiple levels, finding out true benefits and costs of different approaches, and building trust and support for actions within smaller governmental units (Ostrom, 2009: 35, 39)

Another potential strength of a regional system is the avoidance of large financial transfers between countries. When countries with similar marginal costs of abatement are allowed to exchange emissions permits with each other, total financial transfers will be relatively low due to the limited gains from trade. The greater the differences in marginal costs curves, the greater the international financial transfers will be between systems (Green et al, 2014: 1066). As marginal cost curve differences increase, the benefits of trade also increase, making the linkage of two very different carbon abatement systems economically efficient but with large associated financial transfers. Such transfers of wealth would most likely be politically unfeasible, but also disrupt international trade balances. Developed countries would be purchasing large amounts of permits from developing countries, potentially leading to large trade deficits between imports and exports, and causing a depreciation of currency exchange value for the developed country (McKibbin and Wilcoxen, 2002: 126). Changes in import/export trade balances could alter the trade dynamics for entire industries. Even under a global agreement, financial transfers between countries would most likely be limited, in turn limiting the potential for cost efficiencies in a linked system.

A. Ancillary Benefits of Regional Carbon Abatement

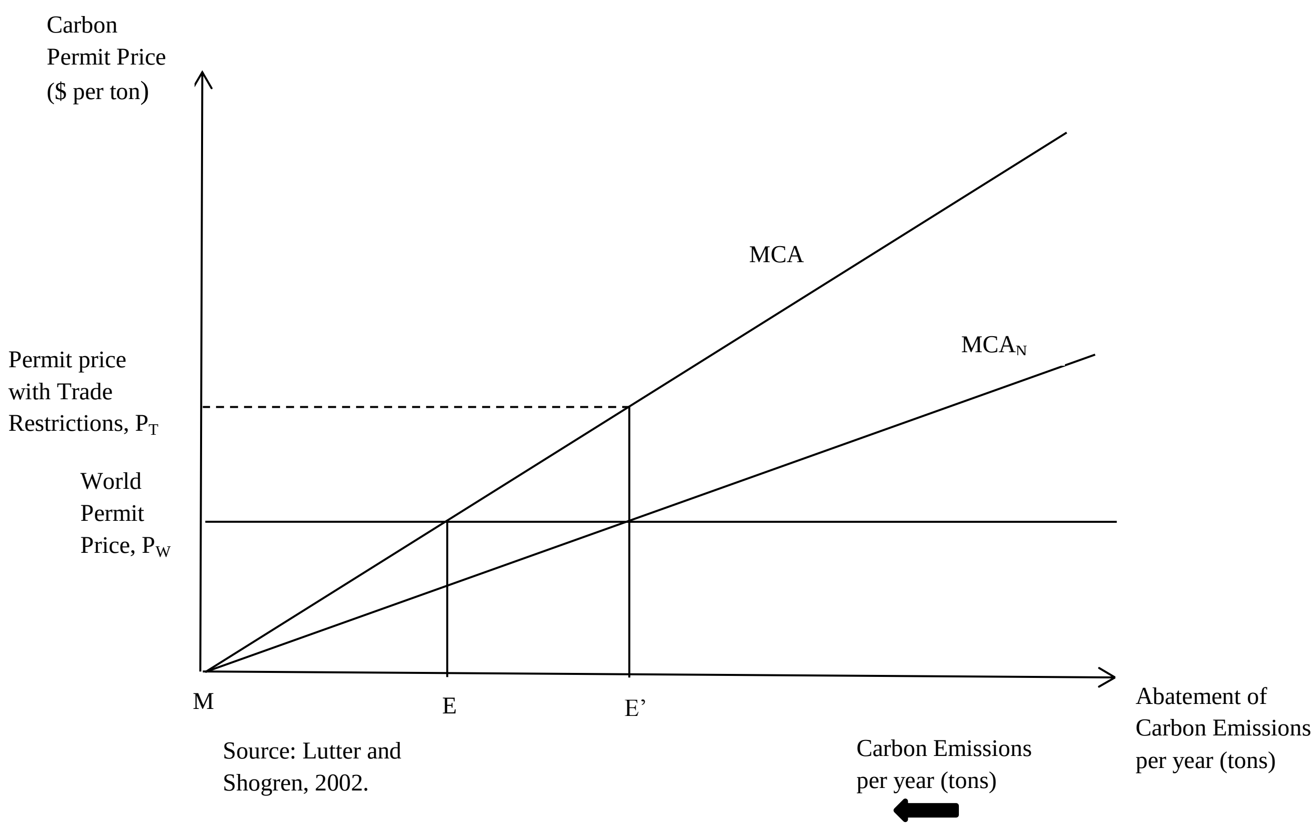
While the lack of significant international wealth transfers, the benefits of increased experimentation and innovation in carbon abatement systems, and the potential to combine smaller-scale approaches into larger systems make regional systems attractive, there are significant local benefits to carbon abatement that are often overlooked. Climate change is primarily thought of as a global problem, and that any benefits from a reduction in carbon emissions would be felt on a global level. But the abatement of carbon emissions often brings local, or ancillary, benefits. Ancillary benefits can range from a reduction in particulate pollution from the limiting of fossil fuel emissions to increased recreation opportunities from reforestation programs (Krupnick et al, 2002: 5).

The primary ancillary benefits arise from the reduction of particulate pollution. There are significant gains from reduced mortality rates and reductions in drivers of chronic morbidity rates such as heart disease and respiratory illness (Krupnick et al, 2002: 17). Other potential ancillary benefits include improved visibility and prevention of damage to ecological resources (Krupnick et al, 2002: 17-18). There are potential negative ancillary benefits, such as a transition from carbon-intensive energy sources to zero-emission nuclear power, bringing additional negative ancillary risks (Krupnick et al, 2002:19).

Different from the long-term benefits of carbon abatement, most ancillary benefits are short-term and are fairly localized (Krupnick et al, 2002: 2). The addition of ancillary benefits when considering an efficient level of carbon abatement can change the calculation of marginal benefits and marginal costs for regulators, and bring another dimension of potential benefits from carbon abatement into consideration. Including ancillary benefits as a consideration in climate policies can help reduce some of the perceived advantages from free-riding. Instead of inertia on climate change action being supported by concerns over free- riding from other countries, ancillary benefits of climate change policies can be captured primarily by the region that takes the abatement action. Ancillary benefits partly move carbon abatement from a purely global to a local-global hybrid problem, possibly providing an impetus for action on climate change on a smaller-scale.

In Figure 3, the ancillary benefits of carbon reduction are modeled in a permit trading system. The Y axis represents the price of a permit to emit one ton of carbon in dollars, which equals the marginal cost of abating one ton of carbon. The X axis represents the abatement of carbon emissions per year in tons. MCA, the marginal cost of abatement for a ton of carbon, represents the marginal cost of abatement for each ton of carbon emitted for all industries within the permit trading program. The MCA curve is upward sloping due to the increasing marginal costs of reducing each additional ton of carbon emitted, representing the

Figure 3. Optimal Demand for Emissions Permits when considering Ancillary Benefits



Source: Lutter and Shogren, 2002.

increased difficulty of reducing emissions the lower the emissions get from the baseline level of emissions. The MCA_N curve, the net marginal cost of abatement, takes the MCA curve and subtracts the ancillary benefits, leaving the net marginal cost of abatement with respect to the ancillary benefits of local abatement of emissions.

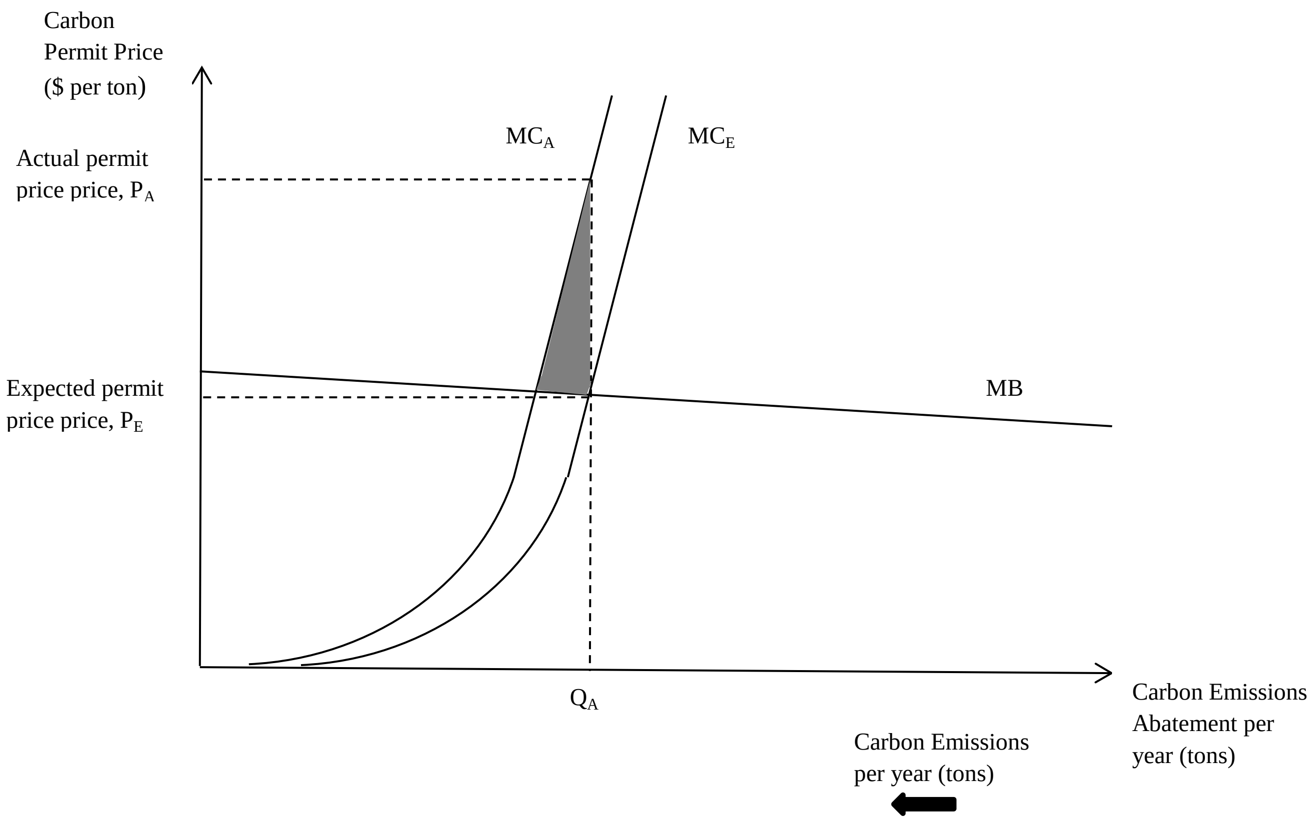
There are two ways to think about the World Permit Price line, P_W. First, P_W represents the cost of permits traded on a global carbon emissions exchange. It is flat in this model to account for the minimal impact that a single regional trading program would have on the price of permits. Second, when considering the World Permit Price, an efficient price would be set by regulators at a level where the global marginal costs of emissions abatement is equal to the global marginal benefits of emissions reductions. This allows the P_W line to be thought of as the global marginal benefits of emissions reductions, a flat line since the properties of carbon as a stock pollutant make it unlikely that any one year of reductions would have a significant impact on overall carbon levels.

In a regional carbon trading system with emissions permits linked to international markets, firms within the trading system would abate carbon emissions up until the point where their marginal costs of abatement equal the global permit price. Instead of abating emissions themselves, they would pay another firm with cheaper marginal costs of abatement to do the abatement by buying an emissions permit. At a global permit price of P_W, this leads to an abatement of E tons of carbon. But when considering the ancillary benefits of carbon abatement, point E is an inefficient level of abatement, and results in a deadweight loss represented by the area between E and E' that is above the MCA_N curve and below the P_W line. The efficient level of abatement when considering ancillary benefits as well is at point E', where the net marginal cost of abatement equals the global permit price, or global marginal benefits of emissions reductions. In order to reach point E', a trade restriction, possible through an import tariff or tax, is needed to increase the price of permits bought on the global market to $P_{T,}$ the permit price with trade restrictions. When the marginal benefits from local emissions reductions is greater than the marginal costs of local emissions abatement, than emissions abatement should be done on a local scale in order to maximize ancillary benefits from climate action.

B. Setting Emissions Caps under Uncertainty

In order to better understand how a regulator may design a regional cap-and-trade system, an explanation of equating marginal costs and benefits to set a pollution quota is needed. Figure 4 illustrates how regulators set permit quotas for cap-and-trade systems, and the resulting impact on permit market prices. The Y axis is the price of the purchase of one carbon permit per ton, and the X axis is the cost of carbon abatement for one year in tons. MC_A and MC_B represent the actual and expected marginal costs of abatement, respectively. Both are upward sloping due to the increasing marginal costs of reducing each additional ton of carbon emitted. The marginal benefit curve is comparatively flat, due to carbon's nature as a stock pollutant, making each additional ton of carbon abated having minimal effect on the total stock of carbon in the atmosphere (McKibben and Wilcoxen, 2002: 118).

Figure 4. Cap-and-trade Systems: Setting permit caps under uncertainty



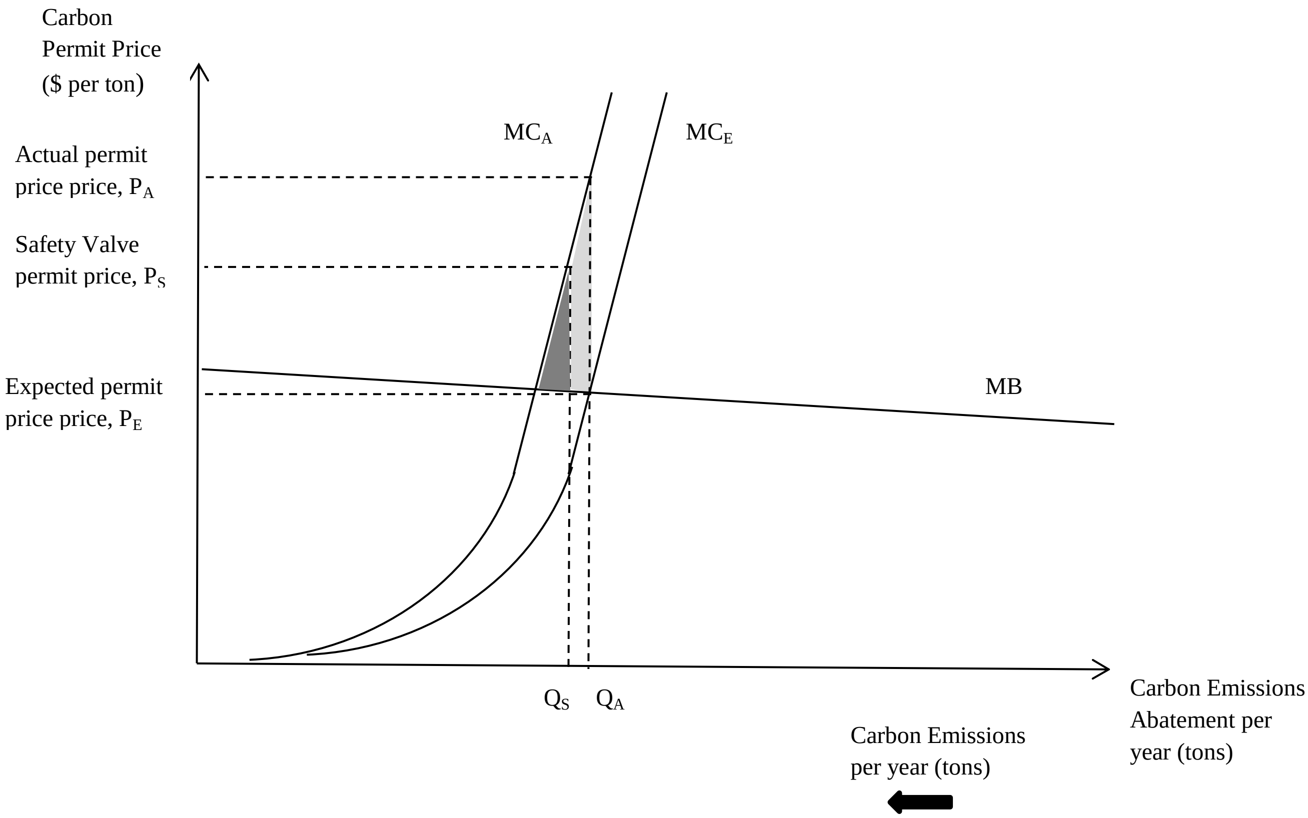
When regulators set carbon emissions quotas, or inversely the amount of carbon that needs to be abated, they estimate both the marginal cost curve of abatement and the marginal benefit curve of abatement. The emissions quota is set at the point where the expected marginal cost of abatement equals the marginal benefits of abatement, seen at Q_A. This is the equilibrium point for the cap-and-trade system; all emissions abatement that has a net positive benefit when compared to the cost have been abated, while no abatement has been done that is marginally more costly than its benefits. Regardless of the actual marginal cost of abatement, once permits have been issued by the regulator, that amount of abatement must be met. Figure 4 illustrates a situation where the actual marginal cost of abatement, MC_A, is higher than the expected marginal cost of abatement, MC_B. This results in a deadweight loss shown by the shaded triangle. This is each ton of abatement done between Q_E, the efficient quantity of abatement given the actual cost curve, and $Q_{A,}$ the actual quantity of abatement decided by regulators. The resulting cost of permits will be significantly higher, with an equilibrium price at P_A instead of P_E. Inversely, if the expected marginal cost of emissions is lower than expected, shifting that MC_A curve to the right of the MC_E curve, than their will be too little abatement of emissions. This would result in deadweight loss from emissions that would have had a higher marginal benefit of abatement than their cost.

When evaluating emissions abatement policies, there are two primary market-based solutions for carbon abatement. One is a cap-and-trade system, as outlined above, and the other a carbon tax. The relatively flat nature of the marginal benefit curve compared to the much steeper marginal cost curve makes a tax more efficient that a permit system, as a set tax on carbon has a slope much closer to the slightly decreasing marginal benefits of carbon abatement (McKibben and Wilcoxen, 2002: 118). If regulators misestimate the marginal cost of abatement when setting a tax, the resulting deadweight loss is much smaller than the same error in a permit policy. So far, market-based carbon abatement has been primarily approached through cap-and-trade rather than a carbon tax, so this paper is primarily focused on cap-and-trade permit systems.

While regulators can design a system that puts a trade restriction on imported emissions permits to capture the ancillary benefits of emissions reductions, there are also two other mechanisms that can be implemented to control permit prices. In Figure 4, the uncertainty of knowing the true marginal cost of emissions reductions are shown, resulting in a significant deadweight loss when regulators underestimate the true marginal cost of emissions reductions and require too much abatement. An inefficient allocation can also result from when regulators overestimate the marginal cost of abatement, requiring too little carbon abatement, resulting in a deadweight loss triangle underneath the marginal benefit curve and above the actual marginal cost curve. The flat nature of the marginal benefits curve can lead to dramatic deadweight loss when regulators misestimate the true marginal costs of emissions reductions in a cap-and-trade system. The importance of controlling permit prices in a regional system is especially important considering the limited number of pollution sources regulated compared to a global market. A misestimating of marginal costs could lead to a significant economic strain on the regulating region, and cause leakage of emissions to other, unregulated markets, negating the impact of the carbon abatement program. In order to combat the potential consequences of misestimating marginal costs, there are two different price mechanisms that can be used to maintain a certain range of permit prices.

The first mechanism is to use a price ceiling, or "safety valve." In Figure 5, regulators have underestimated marginal costs, leading to a deadweight loss equivalent to the darker and lighter triangles combined. These are the excess costs of emissions reductions for which the costs exceed the benefits to society. To hedge against this, regulators can design a system with a price ceiling, set at a predetermined price. This is the price that regulators will begin selling emissions abatement permits at in order to save the firms the additional expense of abating the most expensive emissions. In Figure 5, the price ceiling is set at P_S, the "safety valve" price. Instead of emissions reductions permits costing $P_{A,}$ the actual price, permits will only cost P_S. Since additional permits are sold at P_S, the original deadweight loss from underestimating marginal costs is cut by more than half, leaving only the darker shaded triangle above the P_S line and to the right of the

Figure 5: Cap-and-trade Systems: Designing permit systems with a price control

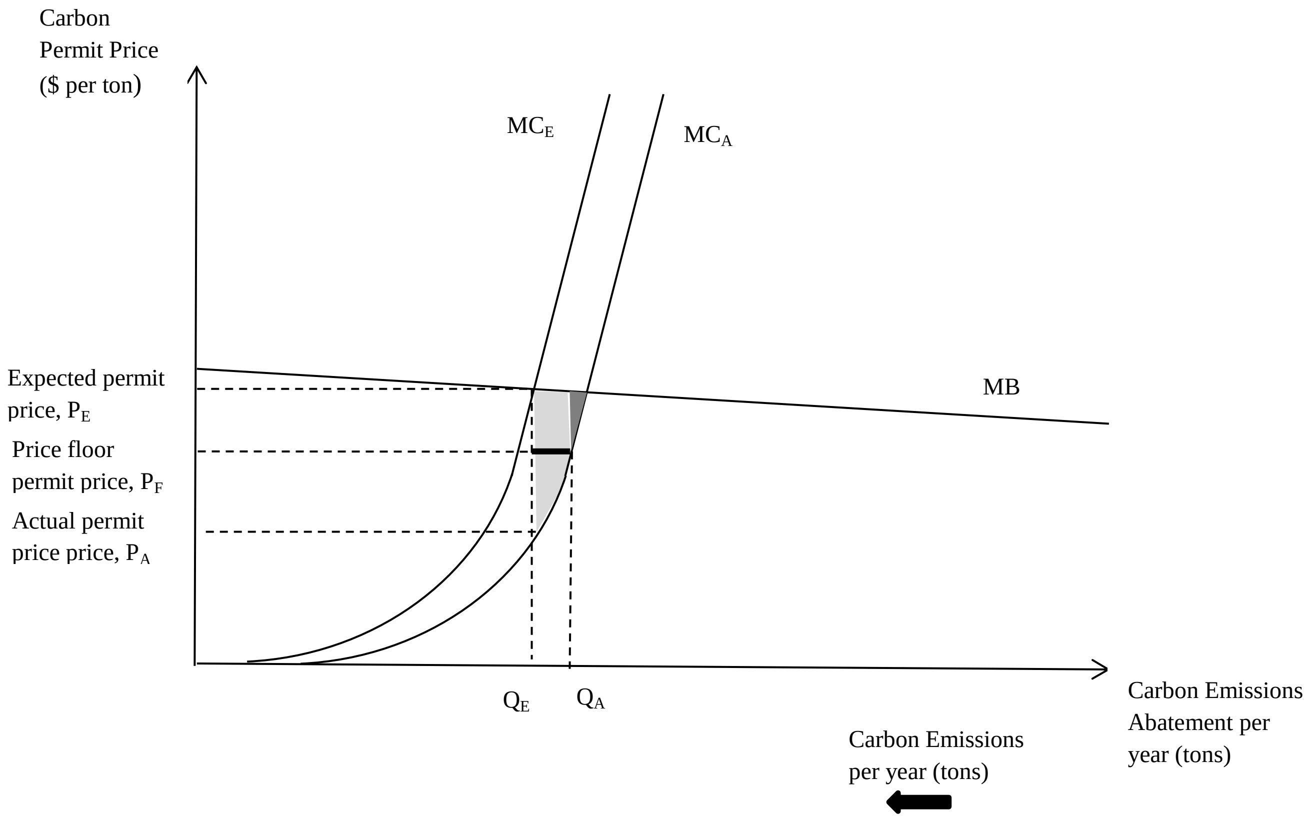


MC_A curve as deadweight loss. The lighter shaded triangle under the P_S line represents the deadweight loss that is avoided by implementing a safety valve price. Through the use of a price ceiling, concerns over high permit costs in a cap-and-trade system can be mitigated.

The price ceiling can be implemented in two ways. The first is during the initial permit auction to firms, where if the firms internally predicted costs of emissions reductions leads them to bid permits up to a price that reaches the predetermined safety valve price. At this point permits would begin being sold at that set price to the auction participants. If firms are acting rationally, than they would abate all emissions up until the point where it's cheaper to buy a permit at the price ceiling than make abatement. Under this scenario, permits should be sold at unlimited quantities at the safety valve price to reduce the deadweight loss the most. The second way to implement a price ceiling is to offer permits at the safety valve price after permits have been allocated and are being traded on a secondary permit market. Operated in a similar fashion to a modern commodity market, the emissions exchange could have a price where the regulator would step in and began selling permits at the safety valve price when permit costs hit that level. Again, assuming that the participating firms are rational, an unlimited quantity of permits could be distributed at that price.

While the greater concern in designing a cap-and-trade system from an economic perspective is permit prices that are too high, causing significant economic loss, there is also a concern that the amount of emissions abatement could be too low from overestimating the marginal costs of abatement. This is shown in Figure 6, where regulators have expected the marginal cost of abatement to be higher than it actually is, resulting in a quantity of abatement that is less than it should be. In Figure 6, an efficient amount of abatement is where the actual marginal cost, MC_A, and the marginal benefits of abatement, MB, meet. But regulators expected a marginal cost curve equal to MC_E, leading to abatement of emissions up to point Q_E. The resulting deadweight loss from this underestimation is equal to the lighter and darker triangles. This is a surplus to firms, as they have to spend less on abatement than they should, but an overall cost to society in that emissions that had a net marginal benefit aren’t being abated. In order to minimize the societal loss from abating too few emissions, a price floor can be integrated into a permit trading system. The implementation of a price floor is different than a price ceiling in that instead of issuing additional emissions permits, the regulator issues less permits than expected. Reading the x axis from right to left, with respect to carbon emissions instead of carbon abatement, the regulator expected to issue emissions permits up until point $Q_{E.}$ But if a price floor is in effect, permits cannot be sold for less than P_A, leading to a quantity of

Figure 6: Cap-and-trade Systems: Designing permit systems with a price floor



permits equal to the distance between Q_E and Q_A not being distributed by the regulator. Firms will not purchase these additional permits due to the marginally cheaper cost for firm to abate emissions rather than buy permits.

Similar to a price ceiling, there are two ways to implement a price floor. A floor can be implemented at the initial auction, with regulators setting a minimum price for permits to be purchased. Or a floor can be implemented after the initial allocation of permits. This involves the regulator buying back permits from the firms at the floor price, with firms being willing to sell until the point where their marginal costs of abatement are higher than the permit price. The idea of paying firms to buy back their emissions permits may be less politically feasible, making a price floor most likely implemented at an initial permit auction.[2]

Using different market design mechanisms, regional markets can capture the ancillary benefits of a carbon abatement program, while mitigating some of the negative externalities associated with regional markets. A well-designed system that requires much of the pollution abatement to be done within region, but also has a safety-valve mechanism to protect against higher than expected marginal costs, can minimize leakages of pollution to other countries and keep the ancillary benefits of climate change action.

Section V. Conclusion

A regional cap-and-trade program with links to other carbon markets would be a way to move from purely regional system to an interconnected global system. Links between carbon markets provide a way to build a broader, globally connected network on climate change, and take advantage of the benefits from global and regional approaches outlined in Section III and IV.

There are different ways to establish direct and indirect links between cap-and-trade systems. Links between markets can be one-way, where permits are only accepted by Market A from Market B, or two-way, where permits can be sold and used in both Market A and B. Markets can also be indirectly linked through a third-party market. In this scenario, Market A and B can buy permits from Market C, indirectly linking prices between the markets (Green et al, 2014: 1064-1065). The basic premise of links between markets is relatively simple, but the difficulties arise in the integration of different systems.

[2] There is also the potential for the regulator to change the value of each emissions permit. For example, one permit could only be worth .75 tons of carbon emitted, rather than 1 ton. I have chosen to focus on only two possibilities for implementing a price floor.

Although direct or indirect linkages between markets certainly are promising for combining efforts, there are significant issues to consider. One issue is the loss of regulatory control over cap-and-trade programs. For example, one system could have a price ceiling, while another system purposely avoids any price control mechanisms, but it's linkage with the market with a price ceiling effectively transfers that characteristic to the non-controlled market. The problem of large financial flows between countries, a problem in any global cap-and-trade program, arises in linking markets. There is also the consideration of different levels of ambition in reducing emissions between countries. An aggressive abatement policy in one country could be a poor match for a more lax abatement market (Green et al, 2014:1064-1066). These are a few of the issues with linkages between markets.

While climate change has long been portrayed as a problem that requires a purely global solution, there appears to be an important local dimension to emissions abatement. Instead of a purely transnational approach, emphasizing the ancillary benefits of carbon abatement programs could encourage action on climate change. The addition of ancillary benefits to the climate change calculus re-frames the problem of addressing carbon pollution. The environmental changes associated with the projected warming of the Earth's atmosphere with inaction on greenhouse gas emissions are drastic, ranging from extreme heat waves to significant losses in agricultural production (World Bank, 2014: 20-22). Although these impacts will have significant societal effects, climate change is often seen as a problem that appears to have little local impact, and whose effects are felt on a long-term time horizon, stretching over centuries, helping diminish the perceived benefits of a pollution abatement plan. But ancillary benefits are felt on a primarily local or regional scale, and have short-term time horizons, making those benefits easily realized.[3] Looking at action on climate change as providing two unique benefits, one local and gained in the short-term, and one global and realized over the long-run, changes the debate over carbon pollution abatement programs, and the economic calculation of the benefits of carbon abatement. From an economic perspective, including ancillary benefits in the valuation of carbon abatement increases the marginal benefits of abatement, increasing the amount of carbon pollution abated.

A potential preview of this framing of climate change as a local-global hybrid problem can be seen in a new Washington state carbon pollution plan. A proposed cap-and-trade program in by Governor Jay Inslee emphasizes the local benefits of carbon abatement. A *NewYork Times* article covered this new approach. "'It is primarily and foremost an issue of health for our children and our grandchildren,' said Inslee…Supporters hailed the plan as historic and bold, saying it will protect human health and the environment." (Associated Press, 2014: 1) While the plan has strong critics, this is an example of a hybrid local-global approach to the benefits from carbon abatement.

There certainly are significant challenges in linking regional carbon abatement efforts into a broader framework, but the regional effort on climate change appears to be a viable solution to addressing global warming on a broad scale. Realizing the separate benefits of carbon abatement on both a local and global scale has the potential to offer a new cost-efficient and politically viable solution to climate change.

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[3] This concept refers to time-discounting future benefits. That is, one "unit" of benefit is worth more today than in the future. The problem of time-discounting the effects of climate change has been widely debated among economists, with Nicholas Stern's 2006 "Stern Review on the Economics of Climate Change" being one of the seminal papers on this issue. Stern's work argues for a very low discount rate on climate change benefits. A critique of Stern's work, and an argument for a higher discount rate, is found in William Nordhaus's 2007 "A Review of the *Stern Review on the Economics of Climate Change*."

Works Cited

Associated Press. "Washington Governor Proposes Carbon Pollution Cap." *New York Times*. (17 December 2014)

Barrett, Scott and Robert Stavins. "Increasing Participation and Compliance in International Climate Change Agreements." *International Environmental Agreements: Politics, Law, and Economics*. 349-376. (2003).

Barret, Scott. "Montreal versus Kyoto." Inge Kawl et al. *Global Public Goods*. Oxford, NY. (1999).

Berck, Peter and Gloria Helfand. *The Economics of the Environment.* Addison-Wesley. (2011)

Depledge, J. "From negotiation to implementation: The UN framework convention on climate change and its Kyoto Protocol." In A.D. Owen and N. Hanley (Eds.), *The economics of climate change* (pp. 35-56). New York, NY: Routledge. (2004).

Enqvist, Per-Anders, Jens Dinkel and Charles Lin. "Impact of the financial crisis on carbon economics: Version 2.1 of the global greenhouse gas abatement cost curve." *McKinsey and Company*. 2010.

Falkner, R., Stephan, H. & Vogler, J. "International climate policy after Copenhagen: Towards a 'building blocks' approach." *Glob. Policy*, 252-262 (2010).

Green, Jessica F, Thomas Sterner, and Gernot Wagner. "A balance of bottom-up and top-down in linking climate policies." *Nature Climate Change.* (26 November 2014).

Gupta, Joyeeta. "A history of international climate change policy." *Wiley Interdisciplinary Reviews: Climate Change* 1.5 (2010): 636-653

Krupnick, Alan, Burtraw, Dallas, and Markandya, Anil. "The Ancillary Benefits and Costs of Climate Change Mitigation: A Conceptual Framework." *OECD*. (2002)

Lutter, Randall, and Jason F. Shogren. “Tradable Permit Tariffs: How Local Air Pollution Affects Carbon Emissions Permit Trading.” *Land Economics*. Vol. 78, No. 2 (May 2002), Pp.159-170.

McKibbin, Warwick, and Peter J. Wilcoxen. “The Role of Economics in Climate Change Policy.” *The Journal of Economic Perspectives,* Vol. 16, No. 2. (Spring 2002) Pp. 107-129.

Newell, Richard, Pizer, William, and Daniel Raimi. “Carbon Markets 15 Years after Kyoto: Lessons Learned, New Challenges.” *The Journal of Economic Perspectives,* Vol. 27, No.1 (Winter 2013): 123-146. Print.

Ostrom, Elinor. “A Polycentric Approach for Coping with Climate Change.” World Bank Policy Research Working Paper No. 5095. (1 October 2009)

Oates, Wallace E. “A Reconsideration of Environmental Federalism.” In Recent Advances in Environmental Economics, edited by J. List and A. De Zeeuw. 2002. Cheltenham, U.K.: Edward Elgar, 1–32.

Oates, Wallace E. “Environmental Federalism.” Weekly Policy Commentary. *Resources For the Future*. (21 September 2009).

Selin, Henrik and Stacy VanDeveer. “Global Climate Change Governance: The Road to Paris”, Environmental Policy, 9th edition, Norman Vig and Michael Kraft, eds. (forthcoming, CQ Press, 2015).

Victor, D.G., House, J.C. & Joy, S. “A Madisonian approach to climate policy.” *Science* 309, 1820-1821 (2005).

World Bank Group. “Turn Down the Heat: Confronting the New Climate Normal.” Washington, D.C.: World Bank. 2014.