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Linking Policies When Tastes Differ: Global Climate Policy in a Heterogeneous World

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The goal of the Harvard Project on International Climate Agreements is to help identify key design elements of a scientifically sound, economically rational, and politically pragmatic post-2012 international policy architecture for global climate change. It draws upon leading thinkers from academia, private industry, government, and non-governmental organizations from around the world to construct a small set of promising policy frameworks and then disseminate and discuss the design elements and frameworks with decision-makers. The Project is directed by Robert N. Stavins, Albert Pratt Professor of Business and Government, John F. Kennedy School of Government, Harvard University. For more information, see the Project's website: http://belfercenter.ksg.harvard.edu/climate

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Abstract

In this paper we discuss the mechanics of linking different types of systems and point out areas where linkage will be difficult. Our goal is to identify opportunities for constructive linkage and policy choices that may limit or hinder linkage. We argue that the basic approach underlying emission reduction credit systems like the Kyoto Clean Development Mechanism (CDM) and Joint Implementation (JI) can be extended to create linkage opportunities in diverse emission control systems in ways that don't necessarily suffer from the shortfalls of the current CDM. Moreover, while emission reduction credit systems are designed to work with market-based systems like cap and trade, we describe ways in which it can interact with tax systems as well as certain regulatory systems.

I. Introduction

Global climate policy faces a tension between the efficiency benefits of uniform global policy and national and regional variation in tastes for differing policies.[1] Although climate negotiations, going back to the Framework Convention, have had a coordinated global policy as their goal, it has become increasingly clear that we are heading towards a less coordinated system of local, national, or regional policies. Different countries will undertake different policies ranging from market-based approaches like greenhouse gas charges or cap and trade systems to quasi-market based systems like renewable portfolio standards to strictly regulatory approaches.

Variations in policies, although catering to local tastes and preferences, can lead to substantial inefficiencies. If the shadow price of carbon is different in different parts of the world, high-cost mitigation strategies may be used where the shadow price is high notwithstanding lower-cost opportunities elsewhere. Moreover, in a phenomenon known as carbon leakage, carbon-intensive industry may move to locations with low shadow prices for carbon. A central question in a world of regional policies, therefore, is how best to coordinate or link different types of systems to minimize these inefficiencies.

In this paper we discuss the mechanics of linking different types of systems and point out areas where linkage will be difficult. We do not suggest an optimal degree of policy homogenization. Rather our goal is to identify opportunities for constructive linkage and policy choices that may limit linkage. We argue that the basic approach underlying emission reduction credit systems like the Kyoto Clean Development Mechanism (CDM) and Joint Implementation (JI) can be extended to create linkage opportunities in diverse emission control systems in ways that do not necessarily suffer from the shortfalls of the current CDM. Moreover, while emission reduction credit systems are designed to work with market-based systems like cap and trade, we describe ways in which it can interact with tax systems as well as certain regulatory systems.

There is a large literature on linking carbon policies. Most of the literature focuses on linking cap and trade systems, either directly or indirectly through a credit system.[2] We summarize and add to that literature, but in addition, we focus here on linking disparate systems, such as linking cap and trade to tax systems or linking market-based systems to command and control regulations.

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[1] See Hahn and Stavins (1999) for discussion in the context of the Kyoto Agreement.

[2] Papers include Ellis and Tirpak (2006), Jaffe and Stavins (2008), Jaffe, Ranson, and Stavins (2009), Flachsland et al. (2008), Flachsland, Marschinski, and Edenhofer (2009), Helm (2003), Carbone, Helm, and Rutherford (2009), Anger (2008), and the papers included in special issues of *Climate Policy*, volume 9, August 2009 and *Mitigation and Adaptation Strategies for Global Change*, volume 14, No. 5 (June 2009).

In Section II we discuss how and why the likely course of climate policies has moved toward local and regional systems. In section III we consider the basic theory of linking. Section IV reviews methods of controlling carbon emissions. Section V then considers how these various systems can be linked and the problems that might arise. Section VI concludes with some discussion of policy implications.

II. The Evolution of Thinking on Global Climate Architecture Since Kyoto

The vision of a climate regime developed in the Framework Convention was of a global, top-down, architecture in which nations, starting with the developed world but then moving to the developing world, would agree to emissions reductions commitments. Although neither the Framework Convention nor its major achievement, the Kyoto Protocol, specified a single global system, such as a global tax or global cap and trade regime, basic obligations on nations would be imposed through an international agreement which would allow coordination, verification, and planning.

It is increasingly likely, however, that the global architecture for climate change will percolate up from national and regional decisions to reduce greenhouse gas emissions rather than from a global agreement. The results of the negotiations in Copenhagen illustrate.

From December 7 through the 18, 2009, delegates from 193 nations met in Copenhagen with the hope of extending the Kyoto Protocol and providing a global agreement on emissions cuts. The conference turned out to be acrimonious and disorganized. At the last minute a small group of nations produced the Copenhagen Accord, which is a non-binding statement of principles. Other conference participants refused to sign the Accord but instead "took note" of it.

Measured against a goal of a global climate agreement, the Copenhagen conference was a debacle. No treaty emerged. No binding commitments were made. Even soft targets were rejected, as was any monitoring of emissions by such major emitters as China. The European countries, the countries that have taken the lead in reducing emissions and advocating for a global climate agreement, were entirely sidelined during the final negotiations. Demands by low-lying nations – those with the most to lose from climate change – were largely ignored.

If we measure the results of the Copenhagen conference not against a goal of a uniform, world-wide policy but instead as working toward a system of regionalized commitments, the results look more positive. A group of major emitting countries that included major developing countries (China and India) agreed to undertake emission reductions of some form. While not a large step forward, it potentially establishes a precedent for more global participation in greenhouse gas emission reductions.

What is clear, however, is that the form of the controls undertaken may differ significantly from country to country. Although the Framework Convention process will continue, after Copenhagen it seems increasingly unlikely that it will produce the type of agreement envisioned at its founding. This result, perhaps, should not be surprising. Analysts studying international agreements essentially predicted it.

For example, Carraro (2007) distills the large game theoretic literature on the design of global environmental agreements into three points. First, a global agreement which all countries ratify is unlikely to be an equilibrium. Second, global self-enforcing agreements are unlikely to emerge as an equilibrium. Third, a global equilibrium coalition structure is likely to emerge with multiple coalitions of different sizes. An implication of these observations is that any global agreement may simply ratify a de facto architecture established by smaller clusters of countries.

Victor (2007) similarly challenges the assumptions that any agreement must include universal participation with integrated international emission trading. Victor notes that the demand for universal participation follows from a need for legitimacy and to address leakage (the shifting of production to regions that do not regulate carbon emissions). He dismisses the first concept as "wooly" and disputes the importance of leakage. On the first point, Victor notes that many legitimate global institutions do not operate on the principle of universal participation. He cites the GATT, the IMF, the UN Security Council and the G8 as examples.[3]

The economic importance of leakage continues to be debated[4] but its political importance cannot be overstated. The Byrd-Hagel Resolution (S. Res. 98) stated that the United States should not be a signatory to the Kyoto Protocol in the absence of any legally binding commitment to emission reductions by developing countries. This resolution passed the Senate in July, 1997 by a vote of 95 to zero. The resolution stated that "the disparity of treatment between Annex I Parties and Developing Countries and the level of required emission reductions, could result in serious harm to the United States economy, including significant job loss, trade disadvantages, increased energy and consumer costs, or any combination thereof[.]"

If Congressional supporters of the Byrd-Hagel Resolution are fundamentally concerned with establishing a global system, then we are at an international impasse unless the mood of Congress changes. If, on the other hand, supporters are primarily focused on harmonizing carbon prices across control systems, then the failure to adopt a global top-down architecture does not necessarily stand in the way of a decentralized and heterogeneous system. It shifts the focus away from the need for a global agreement to the goal of price harmonization among major emitting nations. We believe that this is a more appropriate focus.

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[3] Discontent with these institutions certainly exists, especially among non-participating nations but their fundamental legitimacy has not been called into question.

[4] See, for example, Babiker (2005), Felder and Rutherford (1993), Palstev (2001), Babiker (2001), Kuik and Gerlagh (2003), Bruvoll and Foehn (2006), Di Maria and van der Weft (2008).

Victor also challenges the conventional wisdom that binding targets and timetables are required because governments take binding commitments more seriously. He cites a number of international agreements that have been successful despite not including binding commitments (e.g. ministerial agreements to reduce North Sea pollution, nonbinding commitments to reduce NO_x emissions by a small set of countries alongside countries making binding commitments). For our linkage discussion below, Victor's observation on the lack of need for binding targets as well as universal participation supports the view of heterogeneous policy responses requiring a more flexible linkage approach than would be needed if all countries used the same control scheme.

Jacoby (2007) summarizes the view that we are likely to have national or regional regimes for some time:

> Nations in and out of the Kyoto system are beginning to take action on mitigation and adaptation. Almost all have imposed voluntary schemes; regulations and technology standards are widely applied; subsidies to low CO_2 technologies appear in almost all countries; carbon prices are applied in various forms through taxes or cap-and-trade; and most of the richer parties are spending on R&D, commercial demonstration, and programs of technology transfer. . . . An ultimate comprehensive architecture, if ever reached, will be some integration of the favela of approaches developed in this period . . . In short, domestic actions will not follow international agreement but the other way around.

Jacoby (2007), p. 274

III. The Basic Theory of Linking

Having regional carbon regimes rather than a unified global carbon regime does not matter if the price of carbon is the same across regions. For example, one region might have a tax and another a cap and trade system; as long as the permit price is roughly in parity with the tax rate, the results will be similar to a global regime in that only the most efficient mitigation options will be pursued. The same holds even if one nation or region uses command and control regulation and others use market-based mechanisms so long as the shadow price of the regulations is close to the price elsewhere.

If nations pursue uncoordinated and heterogeneous goals, however, it is unlikely that this condition will be met. If the shadow price of carbon varies across regions, there will be efficiency losses and possibly distributional effects. Efficiency losses arise in the first instance because polluters in regions with a high carbon price will pursue abatement opportunities that cost more than opportunities available in regions with a lower price. These efficiency losses can be large if there are large differences in the marginal abatement cost of emission reductions in different regions.[5]

Carbon leakage is a second source of efficiency losses. Carbon leakage arises when emissions in low price or non-regulating regions go up because of higher carbon prices elsewhere. For example, if one region has a carbon price and the rest of the world does not, industry might relocate to non-pricing areas. Similarly, if regions with stringent carbon pricing use less fossil fuel, the lower demand for fossil fuel may lower the equilibrium price of fossil fuel thereby leading to increased demand elsewhere.[6] Carbon leakage may also result in distributional effects because low price or non-pricing regions can attract industry. There are a number of studies on carbon leakage with results ranging from near zero leakage to more than one hundred percent leakage (because of increasing returns to scale).[7]

A third inefficiency from regional systems is that carbon markets, to the extent that they are used, will be thinner than otherwise, possibly increasing trading costs and reducing price discovery. Smaller and thinner markets also raise the risk that certain participants may be able to exercise market power.

Linking systems can reduce all of these inefficiencies. By linkage, we mean policies that allow for regional carbon regulations to interact to narrow or eliminate differences in the marginal cost of abatement between different regions or countries. The simplest form of linkage is where two countries with cap and trade regimes agree to accept permits from the other country, but there are other forms as well, which we discuss below. We will not treat mere policy coordination – trying to keep shadow prices roughly similar – without an interaction between the regimes as linkage though we do note that this is a possible co-ordination mechanism that could be attempted.

To illustrate the effects of linkage, consider two countries, A and B, that have agreed to reduce emissions of a global pollutant by an amount Q^{Total}. Each country can reduce emissions according to a marginal abatement cost curve. This curve measures the incremental cost of reducing emissions by one more unit. In the absence of fixed costs the area under a country's marginal abatement cost curve measures its total costs of abatement.

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[5] For example, Markandya and Halsnaes (2004) consider the benefits of allowing trading across regions to meet Kyoto obligations. Without trading, cots range from about $200/ton in the United States to $400/ton in Japan, with the EU at $305. When trading is allowed within the developed countries, the costs drop to $77/ton and if trading is allowed globally, the average drops to $36/ton.

[6] Whether demand reductions lower the price of oil depends in large part on how oil producing countries adjust production. Efforts by major oil producing nations to maintain high oil prices undercuts the leakage problem. On the issue of oil producing countries and their response to demand reducing policies, see Sinn (2008).

[7] See sources cited in note 4.

In figure 1 we have drawn a box with width equal to Q^{Total}, the amount of emissions to be reduced. We measure emissions reductions by country A starting at the lower left corner of the box with increasing abatement occurring as we move to the right. The upward sloping line denoted MAC_A is the marginal abatement curve for country A. It is upward sloping to reflect the fact that reducing emissions is increasingly costly as abatement rises. Emission reductions by country B are measured from the bottom right corner with increasing abatement as we move to the left. Country B's marginal abatement curve starts at the lower right corner of the box and increases as we move to the left.

Figure 1a indicates a policy agreement where each country agrees to reduce emissions by the same amount. The marginal abatement cost for country A is higher than the marginal abatement cost for country B at the point where Q_A equals Q_B. If abatement activity were to shift by one unit from country B to country A, the savings in aggregate abatement costs would equal the vertical distance between the two marginal abatement curves. If abatement were shifted from country A to country B until the marginal abatement costs were equalized across the two countries, we would achieve reductions in aggregate abatement costs equal to the area of the shaded triangle in Figure 1a, labeled C_2. Once marginal abatement costs are equalized, no opportunities exist for further reductions in abatement costs by reallocating abatement activity between the two countries.

Figure 1b illustrates a situation where the two countries have agreed to total emission reductions of Q^{Total} and country A is responsible for all abatement. If it carries out abatement only in country A total abatement costs are quite high. By shifting some abatement to country B costs can be reduced with the total cost savings again represented by the shaded triangle, C_2.

In both figures the reduction in abatement costs for country A are given by the areas C_1 plus C_2 while the incremental abatement costs in country B are given by the area C_1. Thus some transfer from country A to country B in the range $C_1 \leq \pi \leq C_1 + C_2$ generates a Pareto improvement, a situation where at least one country is better off and neither country is worse off.

The discussion so far has abstracted from specific greenhouse gas emission control policies. If both countries have cap and trade systems, linking their systems by allowing permits from either country to be used in either country brings about the transfer from country A to country B naturally. In figure 1a, firms in country A would purchase permits at the new equilibrium price *p* from firms in country B. The transfer of resources from country B to country A occurs through the purchase of permits. No explicit transfers are needed.

Both countries are better off because of linkage. The size of the gains is based on the differences in marginal abatement costs in the two countries: the greater the difference, the greater the gains from trade. If after full linkage, the price of permits equilibrates where the MAC's intersect, the relative gains will depend on the steepness of the MAC's: the country with a steeper MAC will gain relatively more (at least if MACs are linear or approximately linear in the relevant region). In Figure 1, country B gains by an amount equal to darker, low triangle in

C_2 while country A gains by the lighter upper triangle. We should, therefore, expect to see a higher demand for linkages by countries with high marginal abatement costs.

Figures 1a and 1b illustrate the important point that the magnitude of payments made by country A to country B depend critically on each country's responsibility for emission reductions under the agreement. For a given level of emissions reduction, country B is better off the greater the share that country A agrees to undertake, even in the absence of linkage. With linkage, country B gains even more because it enjoys the same level of emissions reduction but is now paid an amount equal to darker, lower triangle in C_2.

There may be winners and losers within each country. Full linkage lowers the marginal price of abatement in country A (from p_A to p) and raises the marginal price in country B (from p_B to p). If the holders of permits in country A were not the same as the eventual users of the permits, the holders would have been able to sell the permits at p_A but now can only sell them at p. Similarly, holders of permits in country B now enjoy a windfall but users of the permits must pay a higher price. The uncertain possibility of future linkages also creates price risk for permit holders, who might gain or lose depending on whether linkage is with a country with higher or lower marginal abatement costs.

Linkage can be a challenge to national autonomy. Cost shocks to a single country in fully linked systems transmit throughout the entire system. Consider Figure 2 where some shock in country B rotates its marginal abatement cost curve up. This could occur, for example, if an accident at a domestic nuclear power plant led to a decline in political support for nuclear power and a closing off of this non-greenhouse gas emitting source of electricity. The cost of abating emissions in country B rises leading to a greater desire for emission reducing activities in country A. With a fully linked system, marginal abatement costs would rise in country A by the same amount as in country B (p_A rises to p'_A and p_B rises to p'_B).

This is particularly relevant if a reduction in marginal abatement costs comes about because one country has weak monitoring and verification procedures in place so that reported abatement activity falls short of actual abatement. This transmits lower prices through a fully linked system and weakens overall abatement activities.[8] For example, suppose that country A desires a given level of abatement and enforces a cap and trade regime consistent with that desire but country B, does not care about abatement as much as A, and does not enforce its cap and trade regime. If country A were to link with country B, firms in country A could avoid the necessary emissions reductions by buying the (fraudulent) permits issued by country B. It is as if country B simply issued a slug more permits to firms in country A and pocketed the proceeds.

There will also be game-theoretic concerns created by linkage. The possibility of linkage may affect how countries set up their systems in the first place. Helm (2003). For example, the

[8] This point is discussed in some detail by Nordhaus (2007).

possibility of linkage may give a country an incentive to set a low reduction target in the hopes of selling permits to other countries.

IV. Systems for controlling emissions

Before considering approaches to linking systems for reducing emissions, we should briefly set out the major alternatives from which nations will choose plus describe existing linkages. There are four broad classes of systems, with many variations of each: cap and trade systems, tax systems, subsidies, and command and control regulatory systems.

Cap and trade systems. In a cap and trade system, a nation or region sets an overall target for emissions, typically on an annual basis or for some other relatively short period.[9] The nation then issues, either through an auction, free allocation, or some combination, a number of permits equal to the target. Permits trade freely in the market at a market determined price. To emit a ton of carbon dioxide (or other greenhouse gas in appropriate units, if covered), covered polluters must own and surrender to the government a permit. The result will be an equilibrium price such that each polluter's marginal abatement cost equals the price of permits and, therefore, marginal abatement costs are equalized across all covered entities.

There are a large number of different parameters a nation may choose from in designing a cap and trade system. It must decide which types of emissions are covered and where in the production chain permits will be required. For example, a nation could cover all fossil fuels by imposing a permit requirement upstream on extraction or refining. Or it could impose a permit requirement only on large industrial polluters by requiring these polluters to hold permits. Similarly, it may try to limit price changes by imposing a price floor and/or a price ceiling on permits. It must decide on a monitoring and audit system as well as penalties for noncompliance. Finally, a nation may allow offsets, in which a covered entity can obtain additional permits by reducing emissions outside of the permit base. For example, if only emissions from fossil fuels are covered, entities may be able to obtain additional permits by reducing deforestation or reforesting. Because of the large number of design choices, even nations that choose cap and trade regimes are unlikely to have systems that operate in the same way.

Cap and trade regimes have so far been the favored mechanism for reducing emissions. By far the largest cap and trade regime is the EU ETS. Ellerman and Joskow (2008). It covers about 2 gigatons of CO_2 emissions at more than 11,000 installations in the EU, which accounts for about 45 percent of the EU's CO_2 emissions. After a trial phase beginning in 2005, it has now begun full operations in Phase II which runs from 2008 to 2012. In addition to the EU nations, Liechtenstein, Iceland, and Norway joined the EU ETS in 2008.

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[9] It may set a longer-term target that is to be met by shorter-term objectives. Moreover, through banking and borrowing provisions, it may tie the short term objectives together.

There are a number of smaller cap and trade systems. Japan has a voluntary emissions trading system. Australia is considering a cap and trade system. Various Canadian provinces are considering systems. Norway had a separate regime until it joined the EU ETS. In the United States, a group of states in the northeast have formed the Regional Greenhouse Gas Initiative, which began operations in 2009. A number of western states and Canadian provinces have been working toward a system as part of the Western Climate Initiative.

Taxes. In a tax system, a nation simply sets a price for emitting a ton of carbon dioxide. Covered emitters will reduce emissions until the marginal abatement cost is equal to the tax. Thus, just like with a cap and trade regime, a tax equalizes marginal abatement costs across all covered entities. Similar design issues arise in a tax as in a cap and trade regime, including which entities to cover, where in the production process, and monitoring and enforcement mechanisms.

So far, few nations or regions have adopted carbon taxes. British Columbia has a carbon tax as do Norway and other Scandinavian countries.[10] The British Columbia carbon tax is set at a rate of CAN $20 per ton CO_2 equivalent (as of July 1, 2010) and is levied on fossil fuels.[11] The tax is specifically designed to be revenue neutral with the proceeds used to lower other provincial taxes. After months of debate, France backed away from a new carbon tax that President Nicholas Sarkozy had championed according to Saltmarsh (2010).

Subsidies and credits. A nation or region can set the marginal benefit of abatement to be a desired amount by offering a subsidy for abatement. If a polluter decides to pollute rather than abate, the polluter loses the subsidy, creating a marginal price for pollution equal to the subsidy rate. In a sense, a subsidy works just like a tax except that instead of paying a tax for emissions, a polluter loses a potential subsidy when it emits.

There are two major differences between subsidies and taxes. The first is that a tax increases the overall price of carbon-intensive activities, such as using fossil fuels. A subsidy does not. Second, subsidies are significantly harder to administer because to give a subsidy for failing to pollute, we have to know that the emissions would otherwise have occurred. That is, to give a subsidy, we have to determine behavior in the alternative world without a subsidy and we can only guess at this. This problem is known as additionality and is a significant problem for any subsidy system.

Subsidies often come in the form of emission reductions credit systems or ERCS. ERCS provide credits to firms in uncovered sectors that can be sold to firms in covered sectors who can use these credits in lieu of allowances to meet their obligations under a cap and trade

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[10] Brannlund and Gren (1999) describe the implementation of carbon taxes in Scandinavia. Bruvoll and Larsen (2004) describe and assess the Norwegian carbon tax. Wide-scale exemptions have limited its effectiveness at reducing emissions.

[11] For a current update on the tax, see Ministry of Finance (2010).

system. The Kyoto Protocol's CDM is the most important emission reduction credit system. The CDM works by paying developing countries to reduce emissions when they otherwise would not. The developing country firm receives a Certified Emissions Reduction (CER) equal to the emissions reduction and it sells the CER to a Kyoto Annex B firm to use to meet obligations under the protocol. As Wara (2007) details, additionality has been a serious problem with the CDM, particularly for non-CO_2 greenhouse gases, such as HFC-23. The CDM mechanism illustrates a problem that is common to all subsidy systems: to be successful as a major source of credible and real emission reductions it must be able to scale up and approve, monitor, and verify many projects. But the very pressure to generate large reductions will make it difficult to ensure that the reductions are real.

Command and control regulations. A variety of command and control approaches are possible to reduce greenhouse gas emissions. Regulatory approaches run the gamut from technology-based mandates to quasi-market based approaches. An example of the former would be the mandate that all new coal-fired power plants include technology for carbon capture and sequestration. Another example would be the prohibition of any new coal-fired power plants.

Corporate average fuel economy (CAFE) standards are another form of command and control. CAFE standards mandate minimum average fuel efficiency levels for fleets of vehicles by manufacturer. In April, 2010 the Obama Administration promulgated more stringent fuel efficiency standards for cars and light trucks with a 35.5 mile per gallon goal for cars to be achieved by 2016. In May 2010, Obama announced a further tightening in mileage standards for cars and light trucks for cars produced in 2017 and beyond and in medium and heavy trucks manufactured in 2014 through 2018 (Baker (2010)). While the U.S. CAFE standards focus on fuel efficiency, the European Union has set fleet average CO_2 emission standards for light-duty vehicles (Regulation (EC) No 443/2009). The standard, 130 grams per kilometer, is phased in beginning in 2102 with full phase-in by 2015. The emission target is reduced to 95 grams per kilogram by 2020. See full regulation at European Parliament (2009).

Renewable portfolio standards are popular in the United States (less so in Europe) as a way to support carbon free electricity generation. As of April 2010, DSIRE (2010) reports that twenty-nine states have renewable portfolio standards and another six have renewable portfolio goals. In general these programs require electricity distributors to produce renewable electricity credits (RECs) for some minimum percentage of their electricity sales. RECs are purchased from approved renewable generators who obtain RECs based on their generation of renewable electricity. Sale of RECs is a source of revenue for renewable generators to make their electricity competitive with that of fossil fuel generators.

Feed-in tariffs provide a similar benefit as do renewable portfolio standards. More popular in Europe than the United States, feed-in tariffs require utilities to purchase electricity from renewable sources at minimum prices (or minimum price premiums). Metcalf (2008) describes and contrasts RPS programs, feed-in tariffs and production tax credits in Europe and the United States.

Perhaps the most significant regulatory approach taken to address greenhouse gas emissions in the United States is the U.S. Environmental Protection Agency's decision to regulate greenhouse gas emissions under the Clean Air Act. On Dec. 9, 2009, the EPA Administrator signed an endangerment finding that greenhouse gases in the atmosphere "threaten the public health and welfare of current and future generations" U.S. Environmental Protection Agency (2009). The EPA is moving forward on writing rules to regulate industrial sources of greenhouse gas emissions. The recently released Kerry Lieberman American Power Act of 2010 would remove greenhouse gas emissions from the list of criteria pollutants regulated under the Clean Air Act as part of a comprehensive legislative package to enact a national cap and trade system.[12]

Existing links. Linkages across existing emissions control systems are currently quite limited in large part because there are only a limited number of systems in place. We can view the EU ETS as a linked system because there is no system-wide cap. Instead, individual member states have caps and the systems are harmonized through a central authority. In addition, through its Linking Directive, the ETS links to developing countries through the CDM mechanism.[13]

The Regional Greenhouse Gas Initiative has several linking mechanisms. Offsets elsewhere in the United States are allowed, subject to some limits. In addition, once the allowance price meets specified thresholds, regulated entities can use emissions credits from other cap and trade regimes including the EU ETS and ERC's issued under the United Nations Framework Convention on Climate Change.[14] In the language we will use below, this is both a one-way direct link (RGGI accepting EU ETS permits but not vice versa) as well as an indirect link (both RGGI and the EU ETS accepting emissions reductions credits).

V. Linkage Approaches

As we noted, a considerable literature exists on issues involved in linking cap and trade systems. Much less has been written on linkage opportunities and issues between cap and trade and other policy approaches. The one exception is Hahn and Stavins (1999). Our paper builds on Hahn and Stavins's analysis updating it to consider linkages in a post-Kyoto world.

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[12] sec. 2301 of discussion draft available at http://kerry.senate.gov/americanpoweract/pdf/APAbill.pdf

[13] Council Directive 2004/101/EC, art. 5, 2004 O.J. (L 338) 18.

[14] See Regional Greenhouse Gas Initiative Model Rule 92 (2008), available at http://rggi.org/docs/Model%20Rule%20Revised%2012.31.08.pdf

A. Linking Cap and Trade Systems

As noted above, much as been written on linking different cap and trade systems. We summarize the current state of thinking based on the taxonomy and analysis of Jaffe, Ranson, and Stavins (2009) (hereafter JRS). As noted by JRS, linkages can be direct or indirect. Directly linked systems can be one-way or two-way. Two countries can directly link their cap and trade systems by allowing the use of permits issued by one system to satisfy permit surrender requirements in the other system. A one-way linked system occurs when only one of the countries recognizes the other country's permits while a two-way system occurs when both countries recognize each other's permits. An indirect linkage involves two countries linking through a third.

1. Two-way directly linked systems.

A two-way directly linked cap and trade system between two (or more) countries is perhaps the most easily understood system. As depicted in Figure 1a, permits will flow from the low-priced system to the high-price system until we have equalization of prices (or harmonization) between the two countries. Limits on permit flows could lead to incomplete harmonization of prices. Similarly, allowance system rules may permit the use of foreign system permits but at a less than one-for-one rate. In that case, the permit prices would harmonize up to the exchange rate between the two countries.

Countries can also be linked through a chain of bilateral linkages. For example, if country A is linked directly with country B and country B (but not country A) is linked directly with country C, countries A and C are in effect linked. A common permit price will tend to emerge across the three countries.

There are a number of important issues that can arise when directly linking cap and trade systems. We review the most salient below. The key issue is the extent to which decisions in one country propagate to the other country in ways that might be contrary to local preferences or decisions. While discussed in the context of linking cap and trade systems, most of these issues will arise in other linkage configurations as we note below.

Permit base. It is unlikely that two independently-designed systems will cover the same sectors and greenhouse gases. For example, country A may include the transportation sector in the group of covered sectors while country B does not. Similarly, country A may include a number of greenhouse gases while country B limits its system to carbon dioxide.

If permit bases vary, countries can still link their systems. The country with the narrower base, however, has to accept the broader base in the other country. For example, if country A's permit base is industry and transport while country B's base is only industry, the linked-system's base would be industry in both countries and transport in country A. Country B could not easily link to country A and exclude A's transport sector. The reason is that country A permits trade in a common pool at a single price, so linking to any portion of that pool automatically ends up linking (indirectly) to the entire pool of permits.

If country B's reasons for excluding its domestic transport sector apply to country A's transport sector as well, country B may not want to link systems. It is not clear, however, the extent to which this would be the case. A sector may be excluded from a cap and trade regime for any number of reasons and some may and some may not extend to the same sector in a foreign country. For example, if a sector is excluded domestically because the costs of compliance are excessive, inclusion of that sector by another country would not likely be a barrier to linkage. On the other hand, if a sector is excluded because of problems with monitoring and ensuring compliance, linking to a country that includes that sector may be problematic.

A country with a broad base, on the other hand, may not be willing to link to a country with a narrow base because of distributional considerations. Countries with narrow bases will tend, all else held equal, to have a higher marginal abatement cost. As we noted above, the country with the higher marginal abatement costs tend to gain more than the other country when linking systems. Although both countries gain, the relative size of the gains may make negotiations difficult, particularly when the relative size is determined by a policy decision to have a narrow base.

Similar considerations apply for allowances issued for gases covered by country A but not covered by country B. If country A's allowance system uses a single type of allowance denominated in units of CO_2 and publishes exchange rates for covered greenhouse gases, then it would not be possible for country B to refuse permits sold by country A firms emitting gases not covered by country B to country B firms. If, on the other hand, country A issues separate permits for different gases then country B might choose not to accept permits for gases covered in country A but not in country B.[15]

Offsets. A similar issue arises with non-covered gases in both countries that are allowed as offsets in one country but not the other. Methane emissions in the agricultural sector are an example of a gas commonly not covered by cap and trade systems but which may be allowed in an offset program by some countries. If country A allows agricultural methane offset projects while country B does not, the latter country will have to decide whether offsets can be applied to count against emissions in country B. For all practical purposes, country B will not be able to prevent their use. If country B declares that offsets may not be applied against country B emissions, firm B1 in country B can purchase permits from firm A1 in country A which in turn replaces its permits with offsets purchased from firm A2.

Upstream v. downstream coverage. Nations implementing a cap and trade system have to determine whether to impose it upstream, on the production of fossil fuels, midstream, on industrial users, or downstream, on consumers. In general, the further upstream, the simpler

[15] The American Clean Energy and Security Act (H.R. 2454) proposes separate allowance systems for HFCs with a more rapid phase out of these gases than other covered greenhouse gases. See Sec. 332 of bill passed by the House of Representatives on June 26, 2009.

the system is and the broader the likely coverage but within this limitation, there are a number of choices a nation can make. Transportation can be included in a system either upstream on the production of motor fuel or midstream, on wholesalers or retailers.

Linking systems imposed at different places in the production of emissions should not be a problem. For example, suppose that country A imposes its system upstream while country B imposes its system mid-stream. Midstream businesses in country B could purchase permits from upstream businesses in country A and vice versa.[16]

Auctioned v. freely allocated permits. Regions implementing a cap and trade regime have to choose whether to auction all or a portion of the permits or freely allocate them. It is likely that nations or regions will make different choices and may vary their choices over time. These choices should not pose a barrier to linking systems. Whether firms purchased allowances or received them for free has no bearing on their market price or opportunity cost of use.[17]

Cost containment measures. Nations may take a number of measures designed to avoid unexpectedly sharp increases (and possibly decreases) in permit prices.[18] Cost containment mechanisms include safety valves, price collars, borrowing and banking, and managed reserve systems. If country A's cap and trade system has some form of cost containment while country B does not, cost containment may be transmitted through both systems. To illustrate, assume country A has a cap and trade system with a price collar limiting the price to range between L_A (floor) and H_A (ceiling). In the absence of any limits on trading, permit prices in country B will range between L_A and H_A. Assume a very stringent system in country B leading to high permit prices in the absence of linkage. Firms in country B will choose to purchase permits of firms in country A to cover their emissions.

This situation can also lead to cross-country transfers. If country A has a cap on its permit price and country B does not, when the cap is hit, covered emitters in B will effectively be able to purchase permits from the government of country A to avoid further emissions reductions. If country A's collar is equally spread around the expected permit price, this may

[16] Note that there is a serious problem with countries imposing a cap and trade system or tax in different places in the production cycle because traded products can be double-taxed or not taxed at all. For example, if country A imposes a tax upstream and country B imposes a tax midstream, a product partially produced in country A and country B might face taxes in both or neither. This coordination problem, however, is not related to linking – it exists equally for linked and non-linked systems.

[17] This is true to a first order approximation. Permits can be allocated in ways that distort markets. The American Clean Energy and Security Act (Waxman-Markey) as well as the American Power Act of 2010 (Kerry-Lieberman) allow for output based allowance allocations in trade-affected industries. This amounts to a production subsidy and so reduces the opportunity cost of their use.

[18] Newell, Pizer, and Zhang (2005) provide an analysis of a number of cost containment mechanisms.

not be a problem, at least ex ante, but if the cap is expected to be hit, such a cap may reduce the incentive for country B to link with country A because of the expected transfers.

One mechanism to limit this problem is to adjust the exchange rate for new permits issued pursuant to a cap or permits purchased pursuant to a floor. For example, if both countries have an equal number of permits that are exchanged on a one-to-one basis, and country A issues 20% more under its price cap, the exchange ratio can be adjusted to 1.2 to 1.

Countries would also have to decide how to handle borrowed permits in a banking and borrowing system or a managed reserve system.[19] Assume country A has a managed reserve system in which firms wish to borrow permits to reduce the current permit price. Country B does not. This situation only occurs if country B's permit price in the absence of linking is higher than country A's price in the absence of borrowing.[20] In the absence of any limits, country A's managed reserve becomes available to country B leading to complete price harmonization across the two countries. As with a safety valve system, harmonization would be incomplete if limits are placed on the number of country A permits that could be used in country B.

Enforcement mechanisms. Regions implementing cap and trade regimes will likely have different enforcement regimes, including monitoring, reporting, and verification systems as well as penalty systems. If a country has a weak enforcement system, this can affect the price of permits in a linked system and can potentially be a serious barrier to linking.

To illustrate, suppose that country A has a weaker enforcement system than country B, and the two countries decide to link. The weak enforcement system in country A will lower the permit price in that country and when the two systems link, this lower permit price is propagated to country B. If in the extreme, country A has a very lax enforcement system so that emissions sources in country A can cheat at will, country A would in effect simply be selling permits to firms in country B with no offsetting benefits to country A. If country A has a fixed number of permits, this just adds those permits to the pool of permits for sources in country B.

For this reason, enforcement is likely to be a central concern in linking systems. Countries will have to be convinced that potential linkage partners have comparable enforcement regimes.

Compliance periods. Emission control programs may differ in terms of compliance. Country A, for example, may issue permits that must be used within a three year window while country B issues permits that may be used in a ten year window. Given the stock nature of the pollutant, differences in compliance periods will have no impact on damages from emissions. Fully linked systems with different compliance periods would effectively lead to a uniform

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[19] Murray, Newell, and Pizer (2009) describe how a managed reserve system might work.

[20] If this were not true, it would be cheaper for firms in country A to purchase permits from country B than to borrow against future allocations (which in most programs would have to be repaid with interest).

compliance period based on the longer of the two. If firms in country A wished to bank permits more than three years out, they could sell their own-country permits to firms in country B and purchase country B permits with a longer compliance period. When the firm wished to use the permits it could exchange them with a firm in country B for permits that were released within the three year window recognized by country A.[21]

It is not clear why countries would wish to set short compliance periods such that this becomes an issue. To the extent that there is heterogeneity on this dimension, linkage would effectively lead to homogenization of compliance periods tilted towards the longer period. This facilitates firm planning and would likely contribute to the smooth operation of carbon markets.

2. One-way linkage.

The discussion above assumes two-way linkage. If only one of the two countries allows the use of permits from the other country's system, then we have a one-way linked system. Assume only country A allows the use of permits from country B. Linkage only leads to harmonization if country A has a more stringent cap than country B (in the sense that permit prices are higher in country A in the absence of linking). A safety valve or some other cost containment feature in country A's cap and trade system has no impact in this situation.

B. Linking Cap and Trade and Tax Systems

While cap and trade systems have found favor in Europe and the United States, some countries or regions may choose to implement carbon taxes.[22] Consider country A with a cap and trade system and country B with a carbon tax. The two systems can be linked by allowing cap and trade permits to be remitted as payment for the tax and payment of taxes in excess of emissions in country B to satisfy the requirement to own a permit. Specifically a firm in country B could purchase country A permits and remit them in lieu of tax payments at the country B tax rate. Conversely a firm in country B could remit carbon tax payments to its government in excess of its emissions and receive emission tax payment credits (ETPC) for the tax payment in excess of emissions that could be sold to firms in country A. Those firms could use the ETPC's in place of permits for covered emissions.

In essence, we can think a carbon tax as simply a permit system with a fixed price or very narrow collar on its price. Linkage of a tax and a cap and trade system then is the same as linking a cap and trade system with another cap and trade system that has a price ceiling and floor. Firms could use country A permits used in country B's tax/permit system and conversely,

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[21] This assumes that country A would not accept permits from other systems that were released outside the compliance period.

[22] A number of academics have argued in support of carbon taxes including Cooper (2006), Nordhaus (2007), Nordhaus (2008), Metcalf (2007), Metcalf (2009), and Metcalf and Weisbach (2009) among others.

firms could purchase permits from the government of country B (at the tax rate) and use those permits to satisfy their country A obligations.[23]

It is hard to imagine that an unrestricted linking of these two systems would be politically acceptable. In effect, unrestricted linking turns a cap and trade system into a tax. If permit prices in country A deviated from the tax rate, there would be an incentive to buy or sell permits to push them back into parity. Consider the case where permit prices in country A are higher than the tax rate in country B. Demand for ETPC's in country B to be used to satisfy emissions in country A would be high and would drive permit prices down to the tax rate. Tax revenue, however, would flow to country B. If permit prices in country A are lower than the tax rate in country B, firms in country A would have incentives to undertake additional abatement activities to free up permits to sell to firms in country B. This would drive up permit prices to the tax rate and in effect create a floor in country A's cap and trade system. It would also reduce revenue in the taxing country, a factor that limit's the attractiveness of linking in country B.

The upshot is that if country A has chosen to have a cap and trade regime instead of a tax, linking to a country with a tax system would alter that choice. For example, if country A wants an absolute limit on emissions, linking to a tax system would defeat that goal as domestic industry could always increase emissions by buying permits from country B.

One way to limit this problem would be to restrict linkage to a set number of permits in a given period. For example, firms might be able to satisfy only a fixed percent of their cap and trade obligations with ETPCs purchased from the other country.[24] Similarly, a country with a tax may not be willing to accept an unlimited number of permits as payment of the tax (because doing so reduces tax revenues).

Finally, note that all of the issues with linking cap and trade systems discussed above, such as the permit base and enforcement rules, apply to linking a tax and a cap and trade system.

C. Linkage Through ERCS

ERCS create a method of linking a country with a carbon price to a country without a price. As noted, the CDM mechanism links developing countries to the a cap and trade system, the EU ETS. The use of ERCS with tax systems is also possible. Firms in countries with carbon tax systems could submit emission reduction credits as a credit against carbon tax liability with a credit value equal to the tax rate times the number of tons of emission reductions represented

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[23] Credits in excess of carbon tax liability could be made refundable but more likely would be carried forward or backward as is the practice with other tax credits in the U.S. income tax.

[24] More generally, country A could have a sliding scale whereby a certain percentage of their permit liability could be satisfied with ETPCs at par, an incremental percentage at a given discount, and higher increments at higher discounts up to some limit.

by the credits. All of the concerns about CDMs discussed above (e.g. additionality) apply whether the credit system is linked with a cap and trade or a permit based system. An additional concern is that emission reduction credits used to reduce carbon tax payments have a direct impact on a country's fiscal budget whereas the fiscal impact is less direct in a cap and trade system (and may in fact be immaterial if permits are freely allocated rather than auctioned).

ERCS can create opportunities and possibly problems for linking by two countries that have a carbon price.

Direct linkage. Countries can link to countries with ERCS. This effectively incorporates the ERCS of one country with the cap and trade system of the other. For example, country A may have a cap and trade system that includes an ERCS with a third country. Country B may have a cap and trade system without a similar ERCS. If countries A and B link, country A's ERCS becomes incorporated into country B's system. The concerns about the effectiveness of the ERCS might limit the ability to link to a country with an ERCS. That is, a country that chooses not to have an ERCS, say, because of concerns about additionality, might be equally unwilling to link to a country that has an ERCS.

Indirect linkage. Countries may choose not to link their tax or cap and trade systems directly but could indirectly be linked through engagement with countries with emission reduction credit schemes.[25] Consider two countries with cap and trade systems which are not linked but each of which have ERCS with the same third country. Emission reduction credits would presumably flow to the country with the higher permit price and over time permit prices would equilibrate unless there were limitations on the amount of credit offsets allowed by the higher priced country.

Indirect linkage may, but need not, lead to price harmonization in two indirectly-linked countries, one of which uses a cap and trade system (country A) and the other a tax (country B). If the permit price in country A exceeds the tax rate in country B, emission reduction credits would flow to country A and put downward pressure on permit prices in that country. Assuming no limit on the use of emission reduction credits, permit prices would fall to the level of tax rate in country B. At that point, firms in a country with an ERCS would be indifferent between selling emission reduction credits to firms in country A or B.

If the tax rate in country B exceeds the price of permits in country A, price harmonization is less likely to occur. Emission reduction credits would flow to country B but would have no effect on the tax rate. Upward pressure on permit prices in country A would only occur if current permit prices were being set in the expectation of emission reduction credit use in the future and the expected use falls as those credits are diverted from country A to

[25] This has been noted by Jaffe and Stavins (2008) and Olmstead and Stavins (2009) among others.

country B. This would be possible if country A's cap and trade system allowed banking and borrowing.

D. Linking with Regulatory Regimes

Linking market-based systems with regulatory-based systems may be possible depending on the form of regulation under consideration. Hahn and Stavins (1999) consider linkage between cap and trade systems and a fixed quantity standard. We consider three possible regulatory approaches: quantity standards, intensity standards, and technology mandates.

1. Quantity Standards

Quantity standards could take the form of firm-specific caps on emissions with no provision for trading among covered firms. Caps might take a "bubble" form building on the use of bubbles for air quality management implemented by the U.S. Environmental Protection Agency in the late 1970s where a manufacturer might be required to cut emissions by a given amount at all of its plants within the country.[26] The standard might take the form of a requirement of a uniform percentage reduction in emissions across all firms (or plants). Either way, the marginal cost of abatement is unlikely to be equalized across emitters.

It is possible to link quantity standards to a cap and trade or tax system. Assume country A imposes a quantity standard in the form of a fixed emission cap at the firm level while country B relies on a cap and trade system or tax. Furthermore, let the tax rate or permit price equal p in country B. Firms subject to the quantity restriction in country A with marginal abatement cost at their cap greater than p would prefer to undertake emission reduction activities in country B if those activities could count towards their quantity cap. Imagine that a firm with historic emissions of 100 tons of CO_2 per year now faces a firm-specific annual cap of 60 tons. A linked system would allow the firm to continue to release 100 tons of CO_2 if it submitted permits (or emission reduction credits) purchased from a firm in country B subject to a cap and trade system (or ETPC's from a country with a carbon tax) representing 40 tons of emission reductions in country B.[27] A similar scheme could be allowed to link country A's quantity standard with a country that has an emissions reduction credit system.

Two-way linkage is possible if firms in country A subject to a quantity restriction can receive emission reduction credits for emission reductions in excess of their required reduction. Similar to ETPC's in a carbon tax system, firms would receive emission reduction credits for the difference in emissions between their allowed and actual emissions. Those credits could then be sold to firms in country B subject to a cap and trade system or carbon tax. Trade in this

[26] See http://www.epa.gov/history/topics/bubble/02.htm accessed on May 6, 2010.

[27] This system is easily extendible to a country applying a percentage reduction regulation.

direction would be desirable if the marginal cost of emission reductions for the firm in country A are below the permit price (or tax rate) in country B.

While it is inefficient to create a regulatory approach that caps emissions but does not allow within-country trading to equalize the marginal costs of abatement, countries may choose to do this because institutions to support emissions trading may not be sufficiently robust to effect competitive trading. Political opposition to trading may also shut off this efficiency enhancing policy instrument. A benefit of allowing two-way linking with trading systems in another country (or countries) is that the trading will serve to reduce the dispersion in marginal abatement costs among firms in country A. The cost, however, is the need to monitor and verify emission reductions in a foreign country. A country with a quantity standard would have to rely on the monitoring and enforcement in the linked country with a carbon price.

Conversely, a country with a carbon price linking to a country with a quantity standard would have to ensure that the emissions reductions claimed by low marginal abatement cost firms would not have happened anyway. This raises the possibility of gaming that may make two-way linking with a country setting quantity caps problematic. Imagine country A sets firm-specific quantity caps that are a reduction from a baseline that assumes future economic growth. The caps might allow emissions in excess of current emissions. The country has an incentive to set the cap as high as possible knowing that emission reductions in excess of those mandated by the cap can be sold in other country carbon markets with which Country A is linked. One-way linking in which permits may only be used to help reach quantity targets eliminates this issue.

2. Intensity Standards

Intensity targets are targets specified as emissions per dollar of GDP (or some other measure of economic activity). Intensity targets have been studied by Ellerman and Wing (2003), Pizer (2005), Jotzo and Pezzy (2007), and Newell and Pizer (2008) among others. An appeal of intensity targets is that it sets restrictions on emissions while allowing countries to experience economic growth. Intensity targets may be an attractive option for developing countries which historically have put growth before emission reductions. Like uniform percentage reduction regulations, intensity standards can be translated into specific caps on emissions (given GDP).

If a country sets an intensity standard at the national level it will have to set quantity regulations or some other form of regulation to ensure that national emissions relative to GDP do not exceed the target. Alternatively, a country may set an intensity target in terms of emissions per unit of output or dollar of sales for individual firms. Either way, the firm-specific standard can be translated into a quantity regulation, and the mechanisms described in the previous sub-section can then be applied to link to other countries' trading or tax systems.

3. Technology Mandates

Some countries may mandate specific technologies to reduce greenhouse gas emissions. A country might, for example, prohibit the siting of new coal-fired electric generating plants in the absence of carbon capture and sequestration. They may mandate that power in a given region be produced by a specified portfolio of sources. Or they may require trucks and automobiles to have a specified efficiency. This type of regulatory policy is more difficult to link to greenhouse gas programs in other countries because of the problem of additionality (i.e., identifying the counterfactual). Consider a firm in a country with such a policy that builds a natural gas power plant. Would it have built the plant in the absence of this technology mandate or would it have built a coal-fired power plant in the absence of the technology mandate?

Let us assume for the moment that we can solve the additionality problem (a non-trivial assumption) and the firm can reasonably argue that it would have built a coal plant in the absence of this technology mandate. For linkage to be possible, we have to determine the amount of CO_2 that has been saved by the substitution of the gas-fired for coal-fired power plant. This could be done on a plant-by-plant basis or determination can be made at the national (or international) level as to the emission savings from this mandate per megawatt of capacity. With that determination, one-way linkage is possible. A country with a technology mandate might allow the construction of the coal-fired power plant if the builder submits sufficient allowances (or emission reduction credits) from another country to cover the additional emissions resulting from the construction of the coal-fired facility.

One-way linkage of this form seems unrealistic for a number of reasons. First, we might expect regulatory approaches of the technology mandate form to be more prevalent in developing countries. The linkage described above is a reverse-CDM project that leads to money flowing *out* of the developing country. Second, countries implementing technology mandates may impose the mandates for multiple reasons. A decision by China, for example, to ban coal-fired power plants might arise more from a concern about local air quality than from climate change considerations.

Linkage in the other direction is possible for some technology mandates. Consider a CAFE type mandate on motor vehicle fleet efficiency. Assume, for example, that the Shanghai Automotive Industry Corporation (SAIC), China's largest auto manufacturer, achieves a fleet efficiency that exceeds the mandated efficiency by 2 miles per gallon.[28] Based on agreed-upon assumptions about vehicle miles traveled over the life of the car, the higher fuel efficiency could generate emission reduction credits for SAIC that it could sell to firms in other countries.[29]

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[28] Chinese experts estimate that new cars in China get nearly 36 mpg and that new regulations will increase fuel efficiency to over 42 mpg by 2015 according to Bradsher (2009).

[29] This essentially describes how higher fuel efficiency might be the basis of a CDM project under Kyoto.

Similarly, manufacturing decisions to produce appliances that exceed mandated appliance standards might generate marketable emission reduction credits. A similar gaming issue arises here with lax mandates as described above in the sub-section on quantity standards.

Full harmonization in linked programs occurs when the marginal cost of abatement for greenhouse gases is equalized across countries. While it is unlikely that full harmonization would occur when countries relying on regulation to reduce greenhouse gases link to countries using market based approaches, the difference in marginal abatement costs will likely narrow. Linkage of regulatory systems raises many of the additionality and measurement difficulties of the current CDM structure. Focusing on opportunities such as the one described above with SAIC is in the spirit of a recommendation by Victor (2007) to focus on bi-lateral agreements on emission reductions at a sectoral level that have more bang for the administrative buck than the current CDM approach.

E. Linking With Countries That Take No Action

The only linkage opportunity that arises for countries that implement no measures to reduce greenhouse gas emissions is through an emission reduction credit system like the Kyoto CDM mechanism. As time progresses, we speculate that few major emitting countries will fall into this category. Major emitting countries in the developing world either have or are likely to have some form of regulation in place. The regulations may be aimed at other goals (reducing local pollution or gasoline consumption) but they will have an ancillary benefit of reducing greenhouse gas emissions. Whether the measures taken are sufficiently stringent to effect a substantial reduction in emissions is unclear.[30] But the measures form the basis for linkage as described in the previous section.

VI. Conclusion

If a post-Kyoto architecture develops with multiple approaches to controlling greenhouse gas emissions, linkage structures can contribute to lower overall costs of emission reductions, reduced price volatility in cap and trade systems, greater market liquidity and reduced market power potential. Linking heterogeneous systems, however, will be difficult as has been noted above. And some systems may be impossible to link directly.

Linkage problems are reduced to the extent that different control systems harmonize ex ante on a desired price for greenhouse gas emissions. One possibility is for countries to agree to a price band on emissions. For market based systems, this would mean setting tax rates within a

[30] Senior politicians in China, for example, indicated that a carbon tax is both "obviously necessary" and "feasible" according to a news report from the Xinhau news agency (Xinhua News Agency (2010)). Estimates of the initial tax rate are in the range of 10 RMB per ton of carbon according to Finamore (2010). This works out to a tax rate of roughly $1.50 per ton of CO_2 (if the Chinese rate is actually in terms of carbon dioxide rather than carbon).

band (that would grow over time at some agreed upon rate or schedule) or creating allowance allocations that lead to allowance prices trading within the specified band.[31] For countries taking a non-market oriented regulatory approach, there is no observable price but a shadow price of the regulations would be the appropriate analogue.

If countries do not agree at some broad level on an appropriate price path (or band) for emissions, then linkage would bring about partial or full convergence. But it does so at increasing political cost as financial transfers across borders strain the international emissions control architecture.

In the absence of formal linkage systems, trade flows and movements in carbon intensive activities from high to low price countries – leakage – create a de facto linkage system. Prices will converge to an extent towards the lowest price among significant carbon emitting countries. That price is unlikely to be zero. Enough co-benefits arise with reductions in greenhouse gas emissions in the form of reduced air and water pollution that the shadow price on emissions is positive. But the price is unlikely to be high enough to bring about a sufficient reduction in emissions to ensure we avoid unacceptable build-ups in atmospheric greenhouse gas concentrations by the end of this century.

[31] This could be done explicitly with a price collar. It could also be done through a periodic review of allowance allocation schedules. In addition the price band could be defined in a probabilistic manner: ex post, emission prices would be within a band with some probability. One might define multiple bands with different probability levels.

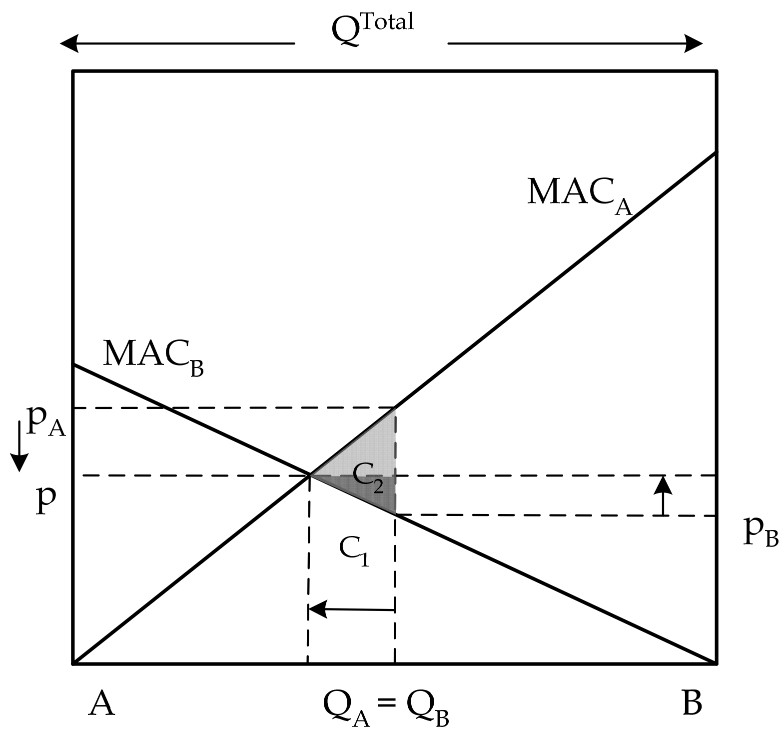

Figure 1a

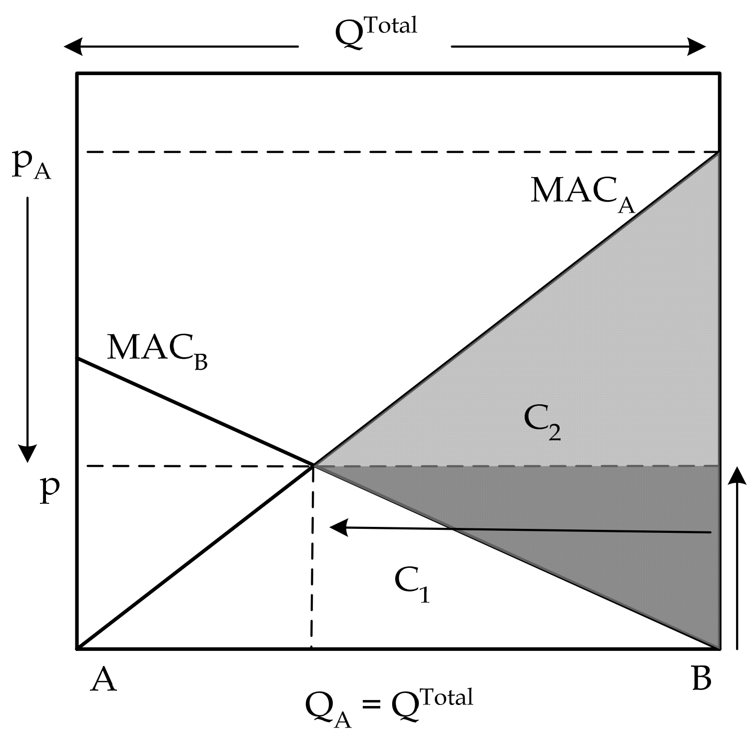

Figure 1b

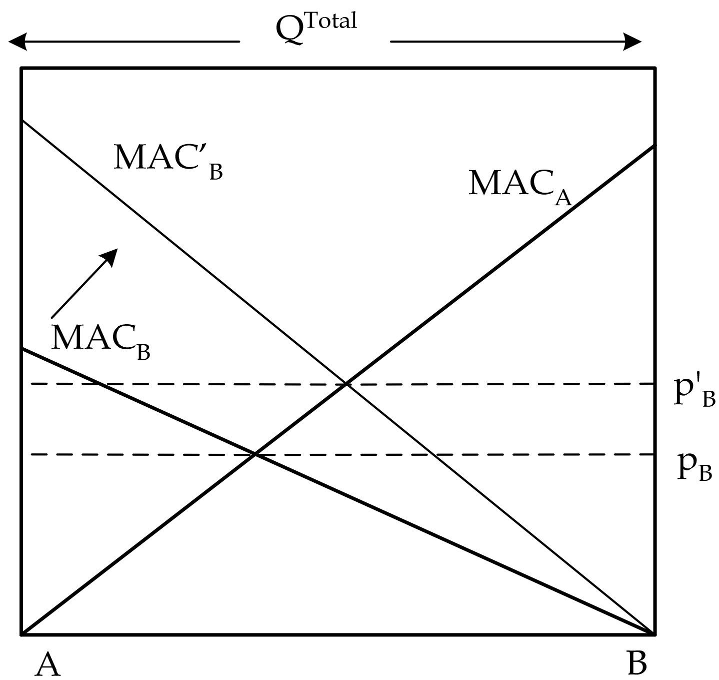

Figure 2

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