What Can an Economist Possibly Have to Say about Climate Change?

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Some time ago, I boarded an airplane for a flight out of Boston's Logan Airport. As I sat down in my seat, it quickly became apparent that the person seated next to me wished to engage in a conversation. Perhaps you have noticed what I have, namely that there tend to be two kinds of people who fly — those who like to have conversations with perfect strangers, and the rest of us.

I am very much in that second category, and so as I sat down in my seat, I had work and a newspaper in front of me, anything to ward off an unwanted conversation. But the gentleman seated next to me persevered, and sought to start a conversation in what is typical fashion for Americans. He asked me, "What business are you in?" I did something foolish — I told the truth. I said, "I'm an environmental economist."

He looked at me, but did not say anything. I looked at him. This went on for what seemed to me to be a very long time. Here is this fellow who wanted to have a conversation, but he did not follow-up with another comment or question. Finally, it dawned upon me, and I understood why he was not saying anything further. I realized that he had concluded that he had just met a living, breathing oxymoron — an internal contradiction. After all, it is either the economy *or* the environment. So what could this phrase — environmental economics — even mean?

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Is Environmental Economics an Internal Contradiction?

I would like to begin by explaining — and I hope demonstrating — that environmental economics is not oxymoronic. The reason I make this claim is, first, because the causes of environmental problems in a market economy (as exists in this country and in nearly all countries of the world) are economic. Environmental problems are the unintended side effects of market activity. When fundamentally desirable market activities are carried out, such as by producers manufacturing the goods that we as consumers wish to purchase and use, environmental pollutants are sometimes emitted in the process. Firms do not explicitly decide to emit those pollutants. Rather, those pollutant emissions are external to the decision-making frameworks of producers (and consumers), and for this reason, economists label these as externalities. So, the causes of environmental problems are economic.

The second reason I claim that environmental economics is not oxymoronic is that the consequences of environmental problems have important economic dimensions, as I will illustrate. So, if the causes of environmental problems are economic, and the consequences of environmental problems have important economic dimensions, then surely an economic perspective is important. Indeed, I will assert that it is essential for a full understanding of environmental problems, and therefore can be exceptionally helpful for the design of solutions — public policies — that are effective, economically sensible, and politically pragmatic. Such economic thinking is particularly important for the formulation of effective, sensible, and politically feasible climate policies (Stavins 2011a).

Thinking about Climate Change: Science, Economics, and Geopolitics

As is often the case in the realm of environmental economics, we must begin with the natural science, which takes us to the economics, and that takes us to the politics, in this case the geopolitics of global climate change.

Basic Science of Climate Change

The ever growing concentrations of greenhouse gases in our atmosphere, caused by the burning of fossil fuels, appear likely to change our earth's climate in ways that many will come to regret. As reports from the Intergovernmental Panel on Climate Change (IPCC) make clear, decades of political inaction have increased the wisdom of intensive efforts over coming decades to avoid the worst consequences of global climate change (IPCC 2014c).

Scientists predict that severe consequences are likely to occur when global average temperatures increase by more than 2 degrees Centigrade (IPCC 2014a). Such a degree of warming would be caused by concentrations of greenhouse gases of about 450 parts per million (ppm) in CO_2-equivalent (CO_2eq) terms (IPCC 2013). But we are now on a path to more than double greenhouse-gas concentrations, to about 1,000 ppm CO_2eq by the end of this century. This would result in average global temperature increases of 3 to 8 degrees Centigrade relative to pre-industrial levels.

Increased temperatures — which may be welcome in some places — are only part of the story. The most important consequences of climate change will be changes in rainfall patterns, disappearance of glaciers, droughts in mid to low-low lying areas, decreased productivity of cereal crops, rise in sea levels, loss of islands and coastal wetlands, increased flooding, more frequent and intense storms, risk of species loss, and spread of infectious disease (IPCC 2014a).

From Science to Economics

The anticipated damages of climate change may be grave, but avoiding them by cutting greenhouse-gas emissions will be neither cheap nor easy. Since the industrial revolution, 300 years of economic growth have been fueled by the combustion of fossil fuels — first coal, then petroleum, and most recently, natural gas. As a result, in the industrialized world, transport, energy, and other infrastructure is highly dependent upon energy generated from fossil fuels. And the large emerging economies — China, India, Brazil, South Korea, Mexico, and South Africa — are rapidly putting in place new infrastructure that is likewise linked with the consumption of fossil fuels, and hence the emissions of more and more CO_2.

The IPCC found that the 450 ppm target can be achieved at an apparently low cost, namely a slowdown in consumption growth of only 0.06 percent a year from now through 2100 (IPCC 2014b). Those numbers are accurately reported, but potentially misleading. A small difference in the interest rate on my savings account can make a big difference in my bank balance after a couple of decades. Likewise, a very small difference in the average growth rate is very significant indeed when it occurs over a 100-year period, which is the case here. The widely-reported 0.06 percent difference in annual growth amounts to an estimated 5 percent loss of global consumption.

What is more, this cost estimate is based on a scenario with "optimal conditions." The assumption is that all countries immediately reduce their emissions to the necessary degree in a cost-effective manner, such as in reaction to a single global carbon price and with the help of various new technologies. Such optimal conditions are highly unlikely to be met. For example, if technologies for capturing the carbon emitted from burning fossil fuels (so-called carbon-capture-and-storage) are unavailable, then the costs of cutting emissions to the necessary levels more than double (IPCC 2014b).

So, from a purely economic perspective, the costs of achieving the 450 ppm target will be significant, but not necessarily unwarranted. A reasonable economic assessment of the target might be "very difficult, but not impossible." Things become more challenging when we move from economics to politics.

From Economics to Politics

Greenhouse gases mix in the atmosphere, and so the location of emissions has no effect on impacts. It does not matter whether greenhouse gases, such as carbon dioxide (CO_2), are emitted in Beloit, Wisconsin, Los Angeles, California, or Beijing, China. Their impacts are independent of the location of the emissions. Because of this, climate change is a global commons problem. Any jurisdiction taking action — a country, a province, or city — incurs the costs of its actions, but the direct climate benefits (averted climate change) are distributed globally. Therefore, for virtually any jurisdiction, the direct climate benefits it reaps from its actions will be less than the direct costs it incurs, despite the fact that the global benefits may be greater — possibly much greater — than the global costs (Stavins 2001).

This presents a classic free-rider problem, which is why international, if not global, cooperation is essential. And it is also why the highest levels of effective governance need to be engaged, that is, national governments.

The Importance of Carbon Pricing

Most policy analysts favor a national carbon pricing policy, that is, a carbon tax or cap-and-trade system (Aldy and Stavins 2012b). Why. The first reason is that no other feasible approach can provide meaningful emissions reductions, for example, the U.S. target of an 83 percent cut in carbon dioxide emissions by 2050, relative to the 2005 level. Secondly, carbon pricing is the least costly approach in the short term, because abatement costs are highly heterogeneous. Carbon pricing has the effect of controlling all sources until their abatement costs on the margin are identical, which means that any aggregate amount of control is achieved at minimum cost. Thirdly, carbon pricing is the least costly approach in the long term, because it provides incentives for carbon-friendly technological change (Jaffe, Newell, and Stavins 2002).

Most policies have favored cap-and-trade over carbon taxes, largely for political reasons, which are related to experience (Schmalensee and Stavins 2013). In the 1980s, the U.S. Environmental Protection Agency (EPA) used cap-and-trade in its leaded gasoline phasedown to remove leaded gasoline from the market and replace it by unleaded gasoline during the period 1982–1987. The result was that leaded gasoline was removed from the market faster than had been anticipated and at an annual cost savings of approximately $250 million (Stavins 2003).

In the 1990s and during the first decade of the current century, emissions leading to acid rain were cut by half under the sulfur dioxide (SO_2) allowance trading program, enacted as part of the Clean Air Act Amendments of 1990. Emissions were brought down faster than had been thought possible, and at a savings of approximately $1 billion per year, compared with what the cost would have been with any politically feasible alternative (Stavins 1998).

Turning next to cap-and-trade systems that have been used to address CO_2 and other greenhouse-gas emissions, the European Union Emissions Trading System (EU ETS), launched in 2008, is by far the world's largest cap-and-trade system, and the world's most important climate-change policy (Ellerman and Buchner 2007). In the United States, the Regional Greenhouse Gas Initiative (RGGI) was launched in 2009 and is scheduled to continue at least through 2019. This cap-and-trade system focuses exclusively on the electricity-generating sector.

Most recently, in California, a cap-and-trade system was launched in 2013, under the Global Warming Solutions Act of 2006. This policy is not only important in its magnitude, but also in its design, and for that reason merits more attention.

Lessons Learned from California's Cap-and-Trade System

California's Global Warming Solutions Act of 2006 is a broad and ambitious policy to cut greenhouse-gas emissions in the state to their 1990 level by the year 2020 (California Legislative Counsel 2006). This policy package, typically known by its legislative designation as Assembly Bill 32 (AB 32), is more ambitious in percentage terms than the Federal climate legislation — the Waxman-Markey bill — that passed the U.S. House of Representatives in 2009, but failed to make it through the U.S. Senate. The California policy includes: energy efficiency standards for vehicles, building, and appliances; renewable portfolio standards for electricity generation that increase from 20 percent to 33 percent; a low carbon fuel standard; and a cap-and-trade system (California Environmental Protection Agency, Air Resources Board 2014).

The AB 32 cap-and-trade system covers 85 percent of the California economy (as of January 2015), with the cap declining through 2020 in order to bring about emissions reductions. The system includes increasing uses of auctions over time, a price collar that essentially creates a hybrid of cap-and-trade and tax, and provisions for the protection of trade-sensitive industries.

The design, enactment, and implementation of the cap-and-trade system provide some valuable lessons. First of all, carbon pricing is necessary, but not sufficient, due to the presence of other market failures, such as the principal-agent problem associated with renter-occupied properties. This is an example of how specific non-pricing policies can be complementary to a carbon-pricing regime.

But some "complementary policies" conflict rather than complement (Goulder and Stavins 2011). In California, this is the case with the Low Carbon Fuel Standard (LCFS) policy and with the renewable-electricity standards. In the presence of a cap-and-trade regime, such additional policies reduce emissions in the targeted sector, but those emissions reductions are undone by increasing emissions in other sectors, as a result of allowance sales. Hence, the consequences of such "complementary policies" targeting sources already covered by a cap of a cap-and-trade system are: (1) no incremental CO_2 emissions reductions are achieved — instead, emissions are simply relocated; (2) abatement costs in aggregate are driven up, because marginal costs are no longer equated; and (3) allowance prices are suppressed, because overall demand for allowances is reduced. So, many so-called "complementary policies" are nothing of the kind. This is not only a problem in California. It is also a major problem in Europe (Stavins 2012).

Other lessons include the fact that the initial free allocation of allowances fostered political support. Although there are sound economic arguments for auctioning allowances, and then using the auction revenue to cut distortionary taxes, and thereby reducing the overall social cost of the program (Goulder 1995), the initial free allocation was essentially good politics.

Also, the system's performance has demonstrated that an economy — wide system is feasible, as well as more effective and much more cost-effective than a sectoral system. And the price collar, which essentially rendered the cap-and-trade system a hybrid of cap-and-trade and a carbon tax, has been effective.

There is one final lesson from California's experience with its cap-and-trade system, which is important because it is linked with a central political concern about any climate policy: the effects of the policy on economic competitiveness. This is a reasonable concern, because a policy that drives up the cost of producing goods and services within one jurisdiction (in proportion to their carbon intensity) would naturally render those goods and services less competitive compared with products that are produced in jurisdictions without such policies in place.

It turns out that although this is a common political concern, it is of less importance economically, partly because it applies only to a limited set of sectors with highly carbon-intensive production. However, because it is a key political concern, policies have frequently been put in place to address these competitiveness concerns as part of cap-and-trade (as well as other climate policies). In the cap-and-trade context, the approach to addressing competitiveness concerns has typically been to allocate the allowances for free, rather than selling them.

What is the effect of such free allocation of allowances on competitiveness. The answer is that it accomplishes nothing. It does make the firms that receive the free allowances quite happy, of course, because the allowances are as good as cash. They are worth thousands or even millions of dollars on the market. But because the free allocation is inframarginal, it has no effect on competitiveness. A firm's marginal cost of production is not affected. It receives the free allowances, puts the money in the bank, but the incentive to relocate its production or to locate future investments in other jurisdictions remains unchanged.

On the other hand, by making the allowance allocation contingent on production it can be made marginal, rather than inframarginal, and thereby can reduce competitiveness effects. This is, in fact, what is done in the California system with its "output—based updating allocation" system, which makes the allocations marginal. So, in the California system, competitiveness risks and related leakage risks are reduced for trade-sensitive sectors. However, significant leakage risks remain for the electricity sector, due to contract reshuffling (Bushnell, Peterman, and Wolfram 2008). Ultimately, the only way to eliminate competitiveness risks altogether is through broader national and international coalitions of action.

The National Context

Carbon pricing is a very sensitive political issue, particularly in the United States. Why. For one thing, it makes costs transparent, unlike conventional policy instruments, which tend to hide their costs. From an economic perspective, it is highly desirable to make the costs of policies and products transparent, but from a political perspective, this is a great disadvantage. Conservative opponents of climate policy in the U.S. Congress found it easy to associate cap-and-trade with the T-word. Indeed, cap-and-trade was successfully demonized as "cap-and-tax" (Schmalensee and Stavins 2013).

Antipathy by conservatives to cap-and-trade systems is ironic, given past experience with the development and implementation of these policies. President Ronald Reagan developed and implemented through his EPA, the leaded gasoline phasedown using cap-and-trade. President George H. W. Bush developed and implemented the sulfur dioxide allowance trading program to cut acid rain by half, as part of the Clean Air Act Amendments of 1990. And President George W. Bush proposed the Clean Air Interstate Rule, which used a cap-and-trade system to cut sulfur dioxide emissions by an additional 70 percent.[2] In congressional debates about climate policy, cap-and-trade was collateral damage in the battle against climate action, which itself was a consequence of the severe political polarization that has increasingly characterized the U.S. Congress (Stavins 2011b).

Does this mean there will be no U.S. climate policy. No, because, in fact, there already is U.S. climate policy in place, and much more has been proposed.

The U.S. Supreme Court, EPA, and the Clean Air Act

There has been a cascade of policy, beginning with a 2007 U.S. Supreme Court decision in *Massachusetts v. EPA*, which required EPA to consider regulating mobile sources of CO_2. This led to EPA's Endangerment Finding in 2009, which affirmed that CO_2 endangers public health and welfare. This, in turn, required EPA to regulate mobile sources of CO_2 emissions, a requirement that the Obama administration met through more stringent Corporate Average Fuel Economy (CAFE) standards. That action defined carbon dioxide as a pollutant under the Clean Air Act, and thereby led to EPA's subsequent proposals of regulation of CO_2 emissions from the electricity sector, both for new and existing sources.

The rule affecting new power plants was proposed on September 20, 2013, and will, when finalized, have the effect of essentially ruling out the construction of new coal-fired power plants, unless they capture and store their CO_2 emissions, using so-called carbon capture and storage (CCS) technology. But the rule will have virtually no impact, because even without the rule, no new coal-fired power plants were planned or even contemplated, as a result of the low price of natural gas (from unconventional sources) relative to the price of coal.

Much more important is the rule for existing electricity power plants, the Clean Power Plan, which was proposed on June 2, 2014, and which would reduce CO_2 emissions from the electricity sector by 30 percent below their 2005 level by the year 2030 (Fowlie, *et al*. 2014). If the final rule (expected in June 2015) survives legal challenge, it will facilitate cost-effectiveness through its provisions for flexibility, but will the rule be efficient. That is, will it maximize welfare. Welfare maximization is a difficult criterion to meet, and so we can ask a more modest question: is the rule likely to enhance welfare, that is, will its benefits exceeded its costs?

2 That rule was subsequently invalidated by the courts, for reasons not associated with the cap-and-trade mechanism *per se* (Schmalensee and Stavins 2013).

An Economic Analysis of the Clean Power Plan

This is a good point at which to remind ourselves that greenhouse gases mix globally in the atmosphere, and so damages are spread around the world and are unaffected by the location of emissions. This means that any jurisdiction taking action — a region, a country, a state, or a city — will incur the direct costs of its actions, but the direct climate benefits (avoided damages of climate change) will be distributed globally. Hence, the direct climate benefits a jurisdiction reaps from its actions will inevitably be *less* than the costs it incurs, despite the fact that global climate benefits may be *greater* — possibly *much* greater — than global costs.

EPA released its 376-page Regulatory Impact Analysis (RIA) of the proposed Clean Power Plan rule the same day it released the 645-page proposed rule itself (U.S. Environmental Protection Agency 2014). An RIA is essentially a benefit-cost analysis, required for significant new Federal rules by a series of Executive Orders going back to the presidency of Jimmy Carter, and reaffirmed by every president since, including most recently President Obama.

Given the fundamental economic arithmetic of a global commons problem, it would be surprising — to say the least — if EPA were to find that the expected benefits of the proposed rule would exceed its expected costs, but this is precisely what EPA found. Indeed, its central estimate is of positive net benefits (benefits minus costs) of $67 billion annually in the year 2030 (employing a mid-range 3 percent discount rate). How can this be?

First, EPA does not limit its estimate of climate benefits to those received by the United States (or its citizens), but uses an estimate of global climate benefits. Second, in addition to quantifying the benefits of climate-change impacts associated with CO_2 emissions reductions, EPA quantifies and includes (the much larger) benefits of human-health impacts associated with reductions in other (correlated) air pollutants.

U.S. versus Global Damages

There are surely ethical arguments (and possibly legal arguments) for employing a global damage estimate — as opposed to a U.S. damage estimate — in a benefit-cost analysis of a U.S. climate policy (Gayer and Viscusi 2014), but until recently all Regulatory Impact Analyses (RIAs) had focused exclusively on U.S. impacts.

In the context of a conventional RIA, it does seem strange — at least at first blush — to use a global measure of the benefits of a U.S. regulation. If this practice were applied in a consistent manner —

that is, uniformly in all RIAs — it could result in some quite bizarre findings. For example, a federal labor policy that increases U.S. employment while cutting employment in competitor economies might be judged to have zero benefits. As another example, under global accounting, if a domestic climate policy had the unintended consequence of causing emissions and economic leakage (through relocation of some manufacturing to other countries), that would not be considered a cost of the regulation (and with diminishing marginal utility of income, it might be counted as a benefit).

However, a counter-argument to this line of thinking is that the usual, narrow U.S.-only geographic scope of an RIA is simply inappropriate for a global commons problem. Otherwise, we would simply restate in economic terms the free-rider consequences of a global commons challenge. In other words, a domestic-only RIA of a climate policy could have the effect of "institutionalizing free riding."[3]

I leave it to legal scholars and lawyers to debate the law, and I defer to the philosophers to debate the ethics. Instead, we can ask what the consequences would be for EPA's analysis if a U.S. climate benefits number were used, rather than a global number. For this purpose, we can start with EPA's estimates (from its RIA of the proposed rule[4]) of 2030 benefits and costs, using a mid-range 3 percent real discount rate. The estimated (global) climate benefits of the rule are $31 billion.

In order to think about what the domestic climate benefits might be, we can turn to the Obama administration's original calculation of the "social cost of carbon" in 2010 (Interagency Working Group on Social Cost of Carbon 2010), where the Interagency Working Group estimated a central global value for 2010 of $19 per ton of CO_2, and noted that U.S. benefits from reducing greenhouse gas emissions would be, on average, about 7–10 percent of global benefits across the scenarios analyzed with the one model that permitted such geographic disaggregation.[5]

Taking the midpoint of the Obama Working Group's 7–10 percent range, U.S. damages (benefits) may be estimated to be 8.5 percent of global damages, which would reduce the $31 billion reported in the RIA to about $2.6 billion, which is considerably **less** than the RIA's estimated total annual compliance costs of $8.8 billion (assuming all states facilitate cost-effective actions). This validates

3 Of course, if global benefits are to be included in a regulatory assessment, it can be argued that global costs (such as leakage) should also be considered.

4 See Table ES-7 on page ES-19 and Table ES-10 on page ES-23 of U.S. Environmental Protection Agency 2014.

5 The Interagency Working Group also suggested that if climate damages are simply proportional to GDP, then the U.S. share would be about 23 percent. However, given the reality of highly unequal geographic distribution of climate-change effects worldwide (IPCC 2013), combined with the exceptionally heterogeneous nature of climate sensitivity among the world's economies, which vary from those with trivial reliance on agriculture to those dominated by their agricultural sectors (IPCC 2014a), the justification for the second approach is not compeling.

the intuition that for virtually any jurisdiction, the direct climate benefits it reaps from its actions will be less than the costs it incurs (again, despite the fact that global climate benefits may be much greater than global costs).

There are abundant caveats on both sides of this simple analysis. One of the most important is that if the proposed U.S. policy were to increase the probability of other countries taking climate-policy actions (which is likely the case), then the impacts on U.S. territory of such foreign policy actions would merit inclusion even in a traditional U.S.-only benefit-cost analysis. More broadly, although it has been traditional to use a U.S.-only benefits measure in RIAs, the current guidelines for carrying out these analyses from the Office of Information and Regulatory Affairs of the U.S. Office of Management and Budget (Circular A-4) requires that geographic U.S. benefit and cost estimates be provided, but also allows for the optional inclusion of global estimates (U.S. Office of Management and Budget 2003).

Pending resolution (or more likely, discussion and debate) from lawyers and philosophers regarding the legal and ethical issue of employing domestic benefits versus global benefits in a climate-regulation RIA, it is very important to recognize that there is an even more important factor that explains how EPA came up with estimates of significant positive net benefits (benefits exceeding costs) for the proposed rule (and would even if a domestic climate benefits number were employed), namely, the inclusion of (domestic) health impacts of other air pollutants, the emissions of which are correlated with those of CO_2.

Correlated Pollutants and Co-Benefits

The proposed regulation to reduce CO_2 emissions from the electric power sector is intended to achieve its objectives through a combination of less electricity generated (compared with a business-as-usual trajectory), greater dispatch of electricity from less CO_2-intensive sources (natural gas, nuclear, and renewable sources, instead of coal), and more investment in low CO_2-intensive sources. Hence, it is anticipated that less coal will be burned than in the absence of the regulation (and more use of natural gas, nuclear, and renewable sources of electricity). This means not only less CO_2 being emitted into the atmosphere, but also decreased emissions of correlated local air pollutants that have direct impacts on human health, including SO_2, nitrogen oxides (NOx), particulate matter (PM), and mercury (Hg).

It is well known that higher concentrations of these pollutants in the ambient air we breathe — particularly smaller particles of particulate matter (PM2.5) — have very significant human health impacts in terms of increased risk of both morbidity and mortality (Driscoll, *et al*. 2014). The numbers dwarf the climate impacts themselves. Whereas the U.S. climate change impacts of CO_2 reductions due to the proposed rule in 2030 are probably less than $3 billion per year (see above), the health impacts (co-benefits) of reduced concentrations of correlated (non-CO_2) air pollutants were estimated by EPA to be some $45 billion/year (central estimate).[6]

The Bottom Line

The combined U.S.-only estimates of annual climate impacts of CO_2 ($3 billion) and health impacts of correlated pollutants ($45 billion) greatly exceed the estimated regulatory compliance costs of $9 billion per year, for positive net benefits amounting to $39 billion per year in 2030. This is the key argument related to the economic efficiency of the proposed rule from the perspective of U.S. welfare. If EPA's global estimate of climate benefits ($31 billion per year) is employed instead, then the rule looks even better, with total annual benefits of $76 billion, leading to EPA's bottom-line estimate of positive net benefits of $67 billion per year. See the summary in Table 1.

Thus, the Obama administration's proposed regulation of existing power-sector sources of CO_2 has the potential to be cost-effective, and it can also be welfare-enhancing, if not welfare-maximizing. Proponents of the administration's proposed rule are likely to take this assessment of EPA's Regulatory Impact Analysis as evidence of the sensibility of the rule, and opponents of the administration's proposed actions are likely to claim that my assessment of the RIA provides evidence of the foolishness of EPA's proposal. So it is in our pluralistic system.

A View of the International Domain: Placing Climate Negotiations in Perspective

The frequently-heard cliché about the baseball season applies even more to international climate-change policy: it is a marathon, not a sprint. Here are four reasons why.

First, scientifically, what matters is the stock of carbon in the atmosphere, not how much we emit at any given point in time. The damages from climate change are linked with concentrations, not with emissions *per se* (IPCC 2013). The stock of CO_2 in the atmosphere is like a bathtub that fills up as water continues to flow from the spout. But this atmospheric bathtub has a very slow drain, as it takes decades to centuries for greenhouse gases to precipitate out of the atmosphere (mainly as oceans slowly absorb CO_2).

6 This assumes that the co-benefits estimated by EPA are based upon a comparison with a business-as-usual baseline that includes the effects of all existing EPA and state regulations for these same local air pollutants.

Second, economically, virtually all sound analyses have found that the cost-effective path of climate action will involve a gradual tightening of emissions target globally so as not to unnecessarily render (fossil-fuel burning) infrastructure prematurely obsolete (IPCC 2014b). In other words, an affordable climate policy will not outlaw the use of current carbon-intensive technologies, but will provide incentives (or possibly requirements) for the adoption of more carbon-friendly technologies as we renew our infrastructure and machinery. It would be absurdly costly to confiscate and destroy our gasoline-powered cars today and force individuals to purchase zero-emission vehicles. Rather, it makes economic sense to put in place policies that increase the likelihood that our next car will be significantly more fuel-efficient, if not carbon-neutral.

Third, technological change (innovation) will be key to bringing down the costs of fighting climate change in the long term, both for economic rationality and political feasibility. Companies will only develop and adopt low-carbon technologies in response to long-term price signals (Jaffe, Newell, and Stavins 2002).

Fourth, administratively, the creation of durable international institutions will be essential. The climate challenges the world faces today are at least as great as the challenges faced by world leaders when they gathered in Bretton Woods, New Hampshire, in 1944 to establish international monetary and financial order after World War II. Five decades were required to develop and solidify the World Bank, the International Monetary Fund, and the World Trade Organization. A new international climate regime will not be effective overnight.

For all of these reasons, international climate negotiations will be an ongoing process — not a single task with a clear end-point. Climate negotiations should aim at progress towards the foundation for meaningful long-term action, rather than focusing on an unattainable immediate “solution.”

The challenge presented by the long-term character of the climate problem is immense. Politicians in representative democracies have strong incentives to appeal to today’s voters by giving them benefits which will be financed by future generations. The climate challenge calls for precisely the opposite — today’s citizens agreeing to costly actions that will protect future generations.

Searching for the Path Forward

For the past seven years, I have directed the Harvard Project on Climate Agreements, the mission of which is to help identify the key design elements of a scientifically sound, economically rational, and politically pragmatic international policy architecture for global climate change. The Project draws upon ideas from leading thinkers around the world from academia (economics, political science, law, and international relations), private industry, governments, and nongovernmental organizations (NGOs). This has included more than fifty research initiatives in Argentina, Australia, China, Europe, India, Japan, and the United States.

Four major lessons have emerged from the three books and more than seventy-five discussion papers, *Viewpoints*, and policy briefs that the Project has published. First, market-based approaches to public policies will be essential.

Second, getting carbon prices right will be necessary, but not sufficient. This is because of other market failures that exist, such as the public-good nature of research and development (R&D). It is well known that because of the spillovers of information that results from innovative activity, the private sector tends to systematically underinvest in basic R&D activity. This raises the need for effective, direct technology policies, such as government funding of private-sector R&D.

Third, "developing country" participation will be essential. It will be impossible to address climate change without meaningful participation by the key emerging economies. Even if all countries in the "industrialized world" — the countries belonging to the Organization for Economic Cooperation and Development (OECD) — were to reduce their emissions to zero, global emissions would still increase, because increases in emissions are coming from the large emerging economies of China, India, Brazil, South Korea, Mexico, South Africa, and Indonesia. Therefore, a central task in international negotiations is developing the means to bring these key emerging economies on board.

Fourth and finally the *de facto* post-2020 international policy architecture may already be emerging, namely, the direct and indirect linkage of regional, national, and sub-national cap-and-trade and other policy instruments (Ranson and Stavins 2013; Bodansky, Hoedl, Metcalf, and Stavins 2014).[7]

Thinking about the International Climate Negotiations

Two fundamental realities — the global commons nature of the problem plus its long-term character — present fundamental geopolitical challenges. Twenty years ago, when 172 governments met in Rio de Janeiro, Brazil, for the original "Earth Summit," they agreed on a legally binding framework for climate policies, the United Nations Framework Convention on Climate Change (UNFCCC) (United Nations 1992), and established two key principles. One was the goal of "stabilization of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic [manmade] interference

7 For a comprehensive, up-to-date survey of the scholarly literature from economics, political science, international relations, and law, see: Stavins, *et al*. 2014.

with the climate system." The other defined how this goal should be pursued: "The Parties [to the UNFCCC] should protect the climate system … on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities" (United Nations 1992).

This second principle signaled the conviction that although the climate problem is a global commons issue, with all countries contributing, some countries had contributed more to the stock of emissions in the atmosphere than others — and those countries were the wealthier countries of the world. Hence, a specific set of industrialized countries (listed in Annex I of the Convention) were committed to take actions "with the aim of returning [their greenhouse gas emissions] individually or jointly to their 1990 levels" (United Nations 1992).

When the members of the UNFCCC met for the first follow-up meeting in 1995 in Berlin, they agreed that "common but differentiated responsibilities" meant that only the industrialized countries listed in Annex I would commit to emission reductions. The developing countries not listed in Annex I would take on no such commitments. This so-called Berlin Mandate was then codified with numerical national targets and timetables in the 1997 Kyoto Protocol (United Nations 1997). It opened up a dramatic gap between rhetoric and reality (Aldy and Stavins 2012a).

By the time of the Berlin Mandate, the developing countries already emitted more greenhouse gases every year than the well-to-do countries listed in Annex I (World Resources Institute 2012). See Figure 1. Even in terms of emissions per capita, they were not far behind. By 2005, when the Kyoto Protocol entered into force, almost fifty of the non–Annex I countries had per capita fossil fuel CO_2 emissions that were higher than those of the lowest-emitting Annex I country (U.S. Energy Information Administration 2012).

In the end, the Kyoto Protocol failed to constrain the world's six largest greenhouse-gas emitters; either because they were still classified as developing countries and therefore did not take on commitments (China, India, Brazil, and Indonesia), or because they failed to ratify the Protocol (United States), or because they ratified it but adopted only a non-binding emissions target (Russia).

Since 1990, the base year of the Kyoto Protocol, emissions have grown by approximately 5 percent annually in the non–Annex I countries, while remaining about flat in the Annex I countries (U.S. Energy Information Administration 2012). Furthermore, the split into countries with commitments and those without has made fighting climate change much more expensive: it has effectively quadrupled the global cost of emission cuts that are necessary to stabilize atmospheric concentrations of greenhouse gases, relative to a cost-minimizing scenario (Nordhaus 2008).

But prospects for change began to emerge in 2009, when the UNFCCC members met in Copenhagen, Denmark, and a year later in Cancun, Mexico. The agreements they reached began to blur the distinction between Annex I and non–Annex I.

They departed even further from the distinction between developed and developing countries at their meeting in Durban, South Africa, in 2011. Here they agreed on a structure that would entail the participation of all parties in the effort to mitigate greenhouse gas emissions (United Nations 2011). Under the "Durban Platform for Enhanced Action," delegates agreed to craft a future legal regime that would be "applicable to all Parties ... under the Convention." This promised the potential to essentially eliminate the Annex I/non–Annex I distinction, and thereby be an important step toward breaking the logjam that has prevented progress. All eyes are now on the Paris climate conference scheduled for the end of 2015.

International cooperation is necessary for fighting climate change, but fully global action is not. The reality is that sixteen countries and regions (counting the European Union as one) account for approximately 80 percent of global emissions. And two countries stand out as the greatest current — and historical — contributors: China, estimated to account for 29 percent of global CO_2 emissions in 2012; and the United States, with 15 percent of the estimated global total in that year. Next in line are the twenty-seven countries of the European Union (12 percent), India (6 percent), Russia (5 percent), and Japan (4 percent). With the top two contributors accounting for nearly half of all emissions, attention has understandably focused on China and the United States.

Chinese Developments

The prognosis for meaningful, economy-wide climate policy in China is similar to the U.S. case. There are positive developments in China on several fronts. China may achieve its goal of reducing the carbon intensity of its economy 45 percent below the 2005 level by 2020, but China's coal consumption and total CO_2 emissions are expected to continue to increase (International Energy Agency 2014).

Much has been written in the Western press about the Chinese government's concern about worsening local air pollution — the mix of particulates, ozone, sulfur, and nitrogen oxides that hang over Beijing and other cities (*Economist* 2014). Pollution has been growing gradually, but daily and hourly peak levels — particularly of particulates — have been increasing more rapidly, with hourly concentrations in Beijing now having exceeded the worst experienced in Los Angeles in the 1960s by more than ten times (Zhang, Wong, and Lee 2015).

China's burgeoning middle-class has begun to demand action to improve air quality, partly facilitated by the spread of social media, and government statements have begun to respond to this pressure. Prime Minister Li Keqiang opened the 2014 session of the National People's Congress with a resounding declaration of war on environmental pollution, warning about the downside of the rapid and unconstrained economic development China had enjoyed (*Economist* 2014).

Emissions of many of the local air pollutants — including from coal-fired power plants, industrial facilities, and motor vehicles — are correlated with emissions of CO_2 from the same sources. Hence, actions aimed at improving air quality will also likely curb CO_2 emissions (although in some cases, CO_2 and local air pollutants are substitutes, not complements, as in the case of using coal gasification to produce clean-burning methane).

Convergence of U.S. and Chinese Perspectives

China and the United States have engaged in debates on climate change regarding the fundamental question of who should do what. They and their respective allies in the developing and developed worlds have clashed over the call under the Durban Platform for a global climate deal that is "applicable to all Parties … under the Convention." The United States and other industrialized countries insist that this calls for an agreement that brings about emissions reduction pledges by all countries. In particular, they understand it to include industrialized countries plus the large emerging economies.

But China, India, and most countries in the developing world, have pointed out that the Durban Platform was adopted under the auspices of the UNFCCC, with its key principle of "common but differentiated responsibilities" — the idea that rich countries should bear a greater share of the burden of tackling climate change — as well as the subsequent mandate calling for emissions reductions only by developed (Annex 1) countries. Therefore, they have said, the Durban Platform calls only for emission reduction commitments from the industrialized nations.

In the midst of this frustrating finger-pointing, there are reason for cautious optimism — namely bilateral discussions on climate-change policy between China and the United States. Such bilateral negotiations between China and the U.S. — possibly outside of the UNFCCC — may be where real progress is made. When this happens, it will largely be because of an emerging convergence of interests.

First, the annual CO_2 and greenhouse-gas emissions of these two countries have converged. While U.S. CO_2 emissions in 1990 were almost twice the level of Chinese emissions, by 2006 China had overtaken the United States (Figure 2). These are the world's two largest emitters (World Bank 2014).

Second, cumulative emissions are particularly important, because it is the accumulated stock of greenhouse gases in the atmosphere that cause climate change. Any discussion of distributional equity in the climate realm therefore inevitably turns to considerations of "historic responsibility." Looking at the period 1850–2010, the United States led the pack, accounting for nearly 19 percent of cumulative global emissions of greenhouse gases, with the European Union in second place at 17 percent, and China third, accounting for about 12 percent of global cumulative emissions (World Bank 2014). But that picture is rapidly changing. Emissions are flat to declining throughout the industrialized world, while increasing rapidly in the large emerging economies, in particular China. Depending on relative rates of economic growth, China may top all countries in cumulative emissions within ten to twenty years.

Third, China and the United States both have historically relied mostly on coal for generating electricity — and both are trying to do something about it. At a time when U.S. dependence on coal is decreasing (largely due to increased supplies of natural gas and hence lower gas prices), China continues to rely on this dirty fuel (International Energy Agency 2014). But China's concern about the health impacts of local air pollution may lead it to wean itself away from coal. Importantly, both countries have very large shale gas reserves. U.S. output (and use for electricity generation) has been increasing rapidly, bringing down CO_2 emissions. Chinese exploitation has been constrained by available infrastructure — it lacks pipelines — but that will change.

Fourth, both countries have been moving forward with policies that explicitly address greenhouse-gas emissions, and in both countries these have featured sub-national market-based policy instruments — in particular, cap-and-trade systems. In China, the government has launched local and regional CO_2 cap-and-trade systems in Shenzhen, Shanghai, Guandong, Beijing, Tianjin, Hubei, and Chongqing (Liu 2014). In the United States, California's ambitious AB-32 cap-and-trade system continues to make progress, while in the northeast, the Regional Greenhouse Gas Initiative (RGGI) is witnessing higher allowance prices due to more severe targets recently adopted by the nine participating states (RGGI 2014).

Fifth, CO_2 policy action is also immanent at the national level in both countries. In China, the government has stated its intention to link its local and regional CO_2 cap-and-trade systems together in a nationwide system. In the United States, the failure in 2009 of meaningful carbon-pricing policy in the Congress has led the Obama administration to turn to regulatory action, including its June 2014 announcement of proposed CO_2 regulations for existing power plants. It is striking that just as CO_2 emissions reductions in China are most likely to be achieved as by-products of policies targeting particulates and other local air pollutants, the Obama administration's economic analysis of its proposed CO_2 limits on power plants justifies the costs of those limits by appeal to the health benefits of reductions in correlated local air pollutants.

Sixth and finally, there is the reality of global geopolitics. If the twentieth century was the American Century, then many observers, including leaders in China, anticipate (or at least hope) that the twenty-first century will be the Chinese Century, one of global leadership, not obstruction (Jolly and Buckley 2013).

For all these reasons, there should be no surprise that on November 12, 2014, Chinese President Xi Jinping and U.S. President Barak Obama issued a joint announcement of expanded cooperation on climate-change mitigation, including new U.S. emission-reduction targets for 2025, and — for the first time — a commitment from China to cap its emissions by 2030 or earlier, after which they would decline.[8]

The Path Ahead

The political climate in the United States presents its own challenges to progress. Indeed, it will take a great deal of dedicated effort — and profound luck — to find political openings that can bridge the wide partisan divide that exists on climate-change policy and environmental issues more broadly.

Think about the following. Nearly all major U.S. environmental laws were passed in the wake of highly publicized environmental events or "disasters," such as the spontaneous combustion of the Cuyahoga River in Cleveland, Ohio, in 1969, and the discovery of toxic substances at Love Canal in Niagara Falls, New York, in the mid-1970s. But the day after the Cuyahoga River caught fire; no press reports commented that the cause was uncertain, that rivers periodically catch on fire from natural causes. On the contrary, it was immediately apparent that the cause was waste dumped into the river by local industry. A direct consequence of the observed "disaster" was, of course, the Clean Water Act of 1972.

But climate change is distinctly different. Unlike the environmental threats addressed successfully in past U.S. legislation, climate change is essentially unobservable to the general population. We observe the weather, not the climate. Until there is an obvious, sudden, and perhaps cataclysmic event — such as a loss of part of the Antarctic ice sheet leading to a dramatic sea-level rise — it is unlikely that U.S. public opinion will provide the tremendous bottom-up demand that inspired previous national action on the environment.

That need not mean that there can be no truly meaningful, economy-wide climate policy until disaster has struck. But it does mean that bottom-up popular demand may not come in time, and

8 All of the text above regarding China-U.S. convergence on climate change (with the exception of the single paragraph describing the November 2014 announcement by Presidents Xi and Obama) was written prior to the joint announcement.

that instead what will be required is inspired leadership at the highest level that can somehow begin to bridge the debilitating partisan political divide.

Parting Words

As I hope I have illustrated, environmental economics is not an oxymoron — an internal contradiction. Far from it, an economic perspective is absolutely essential for a full understanding of environmental problems. Therefore, economic analysis is nothing less than key for the design of solutions that will be environmentally effective, economically sensible, and politically pragmatic. That has been the common theme of all of the sessions in which I participated at Beloit College as the 2014 Upton Scholar, a week that I will not forget.

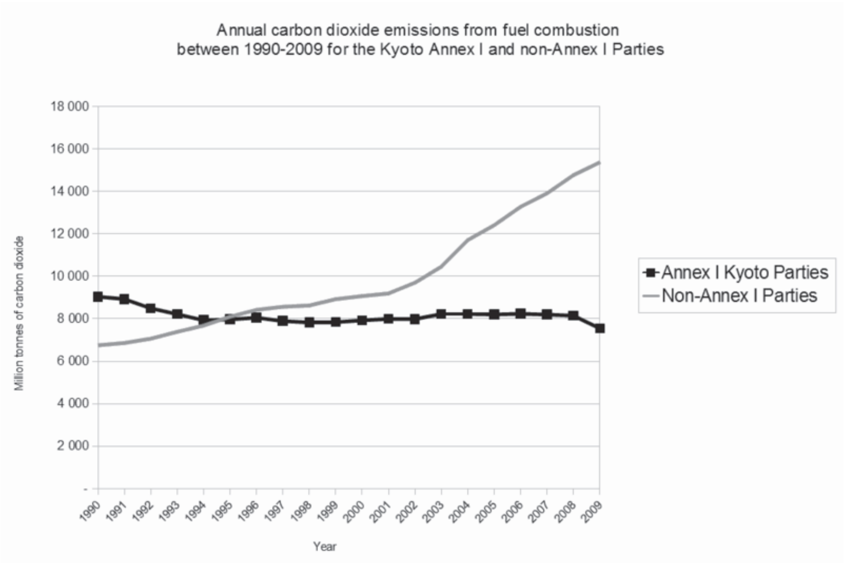
Table 1: Estimated Benefits and Costs of EPA's Proposed Clean Power Plan Rule in 2030

(Mid-Point Estimates, Billions of Dollars)

	Climate Change Impacts		Health Impacts (Co-Benefits) of Correlated Pollutants plus …	
	Domestic	Global	Domestic Climate Impacts	Global Climate Impacts
Benefits				
Climate Change	$ 3	$ 31	$3	$31
Health Co-Benefits			$45	$45
Total Benefits	$ 3	$ 31	$48	$76
Total Compliance Costs	$ 9	$ 9	$ 9	$ 9
Net Benefits *(Benefits − Costs)*	**– $ 6**	**$ 22**	**$ 39**	**$ 67**

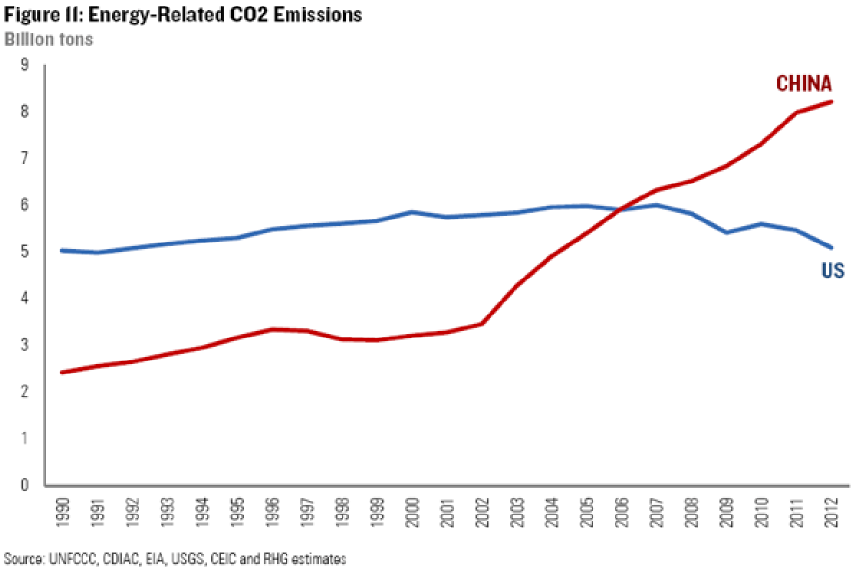
SOURCE: Interagency Working Group on Social Cost of Carbon 2010; IPCC 2013; IPCC 2014a; U.S. Environmental Protection Agency 2014. Reproduced from Stavins 2014.

Figure 1



SOURCE: Wikimedia Commons 2014.

Figure 2



SOURCE: Rhodium Group, 2013.

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The goal of the Harvard Project on Climate Agreements is to help identify and advance scientifically sound, economically rational, and politically pragmatic public policy options for addressing global climate change. Drawing upon leading thinkers in Argentina, Australia, China, Europe, India, Japan, and the United States, the Project conducts research on policy architecture, key design elements, and institutional dimensions of international and domestic climate policy. The Project is directed by Robert N. Stavins, Albert Pratt Professor of Business and Government at the Harvard Kennedy School.

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