Example 8.1
The Kyoto Protocol

The scientific community has reached a consensus that emissions of greenhouse gases – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) – are an important contributor to global warming and need to be sharply reduced. Reducing emissions of CO_2 is the primary need, simply because CO_2 emissions dwarf the emissions of the other gases. The question, though, is how to do this.

There are three main difficulties in controlling greenhouse gas (GHG) emissions. The first is that greenhouse gases mix completely into the atmosphere no matter where they are emitted. Therefore, the warming that results is truly a global and nonexclusive external diseconomy: emissions by anyone affect everyone. All countries, at least all the important GHG emitters, have to agree to limit their emissions. The second is that each country has a powerful incentive to free ride on the emissions reductions of every other country precisely because the effects of the GHG emissions on global warming are nonexclusive. A country receives the same advantage from a given reduction in emissions no matter whether it reduces the emissions or some other country does. The final difficulty is the principle established by the Treaty of Westphalia in 1648, that no country is obligated to do anything asked of it by the international community without its consent. This only enhances the incentive to free ride on the emissions reductions of other countries.

Forging international agreements of any kind is difficult under the best of circumstances, but controlling GHG emissions in the face of these difficulties is an especially daunting task. Nonetheless, in 1992 the United Nations Framework Convention on Climate Change (UNFCCC) resolved to work towards an agreement that would stabilize GHG concentrations in the atmosphere at a level that would prevent them from interfering with the climate system. An agreement to reduce GHG emissions was realized on December 11, 1997 with the signing of the Kyoto Protocol.

The Protocol placed the initial burden of limiting GHG emissions on the developed countries, referred to as Annex 1 countries in the Protocol. They comprise the industrialized countries within the Organization for Economic Cooperation and Development (OECD), and the countries of Eastern Europe and the former Soviet Union. The goal was to reduce annual GHG emissions in the Annex 1 countries by 2008 to 2012 to a level approximately 5% below their emissions in 1990. To achieve this, 39 developed countries, referred to as the Annex B countries in the Protocol, were given specific emission quotas that ranged from 8% below their own 1990 emissions (23 countries, the most common target) to 110% above their 1990 emissions (Iceland). [1] The target for the United States was a 7% reduction. In addition, the Protocol recommended that the countries establish a system of marketable permits to emit greenhouse gases that would be distributed without charge in proportion to their 1990 emissions. But it did not establish such a system nor provide a set of rules under which it would operate. The final details of the Kyoto Protocol were worked out in meetings of the UNFCCC in Bonn and Marrakech in July and October–November of 2001. Principal among them was an agreement on the penalty for countries that exceeded their emissions quotas.

The Kyoto Protocol took effect when two conditions were met:

1. The Protocol was ratified by 55 countries
2. The Protocol was ratified by a subset of the Annex 1 countries that accounted for at least 55% of the aggregate Annex 1 emissions in 1990.

The first condition was satisfied in May 2002 when Iceland ratified the Protocol, and the second in November 2004 when Russia ratified the Protocol. Following the Russian ratification, the UNFCCC declared the Protocol to be in force on February 16, 2005. As of October 2007, 175 countries had ratified the Protocol.[2]

The Kyoto Protocol is, unfortunately, a testament to the problems that can arise in tackling global issues. It did not have much of an impact on GHG emissions.

The Protocol suffered a huge blow at the outset with the defection of the United States. In March 2001, President Bush declared that the U.S. would not abide by the Protocol because the costs were simply too high to bear. This was a death knell to the

[1] The Annex B countries differ slightly from the Annex 1 countries, because the UN exempted a few of the developed countries from the Protocol, so the different names are used to distinguish the two sets. The Annex B countries include three countries that are not Annex 1 countries—Croatia, Lichtenstein, and Monaco—and exclude two Annex 1 countries—Belarus and Turkey. There are 38 Annex 1 countries and 39 Annex B countries. Source: R.Guesnerie, "A Future for Kyoto?", *Working Paper No. 2006–98*, Paris-Jourdan Sciences Economiques, Appendix 1. Appendix 1 also lists the emissions targets for each Annex B country. The countries that were allowed to equal or exceed their 1990 emissions were: Australia (108%—which withdrew from the Protocol), Iceland (110%), New Zealand (100%), Norway (101%), the Russian Federation (100%) and the Ukraine (100%).

[2] Details of the Protocol can be found on the UNFCCC's website: http://unfccc.int/kyoto_protocol/items/2830.php

goal of reducing GHG emissions 5.3% below their 1990 level. The U.S. accounted for 32% of worldwide CO_2 emissions in 1990.[3] If it did not meet its Protocol allocation of a 7% reduction in its emissions below its 1990 levels, the other countries could not possibly make up the difference.

The United States defection was understandable, and pointed to one of the design flaws of the Protocol. Global warming depends on the accumulated amount of greenhouse gases that have mixed in the atmosphere, to which the annual emissions add only a small percentage. Economists refer to global warming as a stock externality for this reason, in contrast to most externalities, which are flow externalities. By allowing GHG emissions of the Annex 1 countries to remain at about 95% of their 1990 levels, the Protocol would not have much effect on the stock of accumulated gases in the atmosphere until far into the future. Therefore, the benefits in terms of slowing the rate of global warming were small, whereas the costs of reducing annual emissions by 5% or more were potentially quite large. In addition, the flows were defined relative to a date, 1990, that was fifteen years before the Protocol took effect and approximately twenty years from the 2008–12 period when the Annex B countries' targets were to be met. This penalized countries that already had relatively low emissions in 1990, such as Norway, and countries that had grown rapidly since 1990, such as the United States. Conversely, it benefited countries that had experienced slow growth since 1990, such as Russia and the other former Soviet and Eastern European countries, all of which suffered deep recessions in the 1990s as they were trying to transform themselves from centrally planned economies to decentralized market economies. Russia's measured GDP fell by nearly 60% before it began to recover in the late 1990s.

Consequently, had a marketable permit scheme evolved as envisioned by the Protocol, the U.S. would have been the main buyer of permits and would still have had to achieve deep cuts in production to meet its 7% target by 2012. Given that it had done nothing to reduce greenhouse gases by 2001, the required production cuts would have been so large as to be almost unattainable. At the very least, the costs would be enormous with very little offsetting benefit. William Nordhaus has developed a macroeconomic model of the world economy that includes the effects of greenhouse gas emissions on global warming.[4] He estimated that the cumulative benefits to the U.S. over time would be in the order of $0.25 trillion, against costs of $5.75 trillion – i.e., a net cost of $5.5 trillion. Moreover, the countries of the former Soviet Union and Eastern Europe would be the major sellers of permits and because of this would receive net benefits, estimated by

[3] B. Buchner, C. Carraro, I. Cersosimo, and C. Marchiori, "Back to Kyoto? US Participation and the Linkage Between R&D and Climate Cooperation," *Discussion Paper No. 3299*, Centre for Economic Policy Research, April 2002.

[4] The model is called the Regional Integrated Model of Climate and the Economy, referred to as RICE. For a description of the model, see the Appendix of W. Nordhaus, "Life After Kyoto: Alternative Approaches to Global Warming Policies," Yale University and the NBER, December 7, 2005. The example draws heavily from the analysis of the Kyoto Protocol presented in this paper.

Nordhaus to be $2.33 trillion, with Russia capturing most of the gains. The U.S. was simply unwilling to bear net costs of this magnitude and transfer such large amounts of purchasing power to Russia. [5]

Another design flaw in the Protocol was the unwillingness to set emissions quotas for developing countries. This meant that China, the second largest emitter of greenhouse gases, was not required to reduce its emissions. With both China and the U.S. freed from reducing their emissions, and with both economies having grown rapidly since 1990, the Protocol will cover only 30% of worldwide GHG emissions by 2010. Among the remaining Annex B countries, only the European Union had established a marketable permit trading system by 2007, and the EU emissions account for just 8% of worldwide emissions. [6] One study estimates that GHG emissions in 2010 will be 25% higher than their 1990 levels.[7]

A related difficulty is that there are no provisions or even recommendations for adding new countries (the majority of which would be developing countries) to the envisioned permit trading system. Most of the developing countries will require transfers of some kind from the developed countries as a condition for joining the permit trading system, and all countries will have to reach an agreement on both the form of the transfer mechanism and the size and distribution of the transfers. This is not likely to be easily accomplished.

Finally, the Protocol's recommendation of a permit trading system as a means of achieving the overall emissions reductions at the lowest possible cost may not have been the best choice. A permit trading system with each permit allowing a certain amount of carbon to be emitted would be fine in a world of perfect certainty and perfect information. (The carbon content varies among the greenhouse gases and the accumulated carbon in the atmosphere is the cause of global warming, so the amount of carbon emitted is the proper unit of account for the permits.) Since global warming is an aggregate externality, a worldwide trading scheme that establishes a single permit price for firms in all countries is the correct approach in principle. Moreover it would be equivalent in its effectiveness to a single worldwide tax rate on carbon emissions levied on all firms.

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[5] These cost and benefit estimates are the cumulative costs and benefits over time expressed in 2005 dollars, and are relative to a no-control baseline. Chapter 20 of the textbook describes how to convert future dollars into their current or present value. The estimates appear in Figure 2 of Nordhaus, *op. cit.*, p. 24. Because of the small benefits to the proposed annual emissions reductions, Nordhaus estimates that the Protocol would have a worldwide net cost of $4.5 trillion (with the U.S. included). The non-annex B countries of the world would receive net benefits of $.6 trillion, achieved mostly by free-riding on the reductions of the annex B countries.

[6] *Ibid.*, Figure 1, p. 23.

[7] B. Buchner, *et. al*., *op. cit*., p. 9. The study referred to is by J. Eyckmans, *et. al*., "Is Kyoto Fatally Flawed? An Analysis with MacGEM," *mimeo*, KULeuven. Other studies with similar estimates are also cited. Early forecasts of what global emissions would be by 2010 did not foresee the reduction in economic activity during the Great Recession that started in 2007, which had the effect of temporarily reducing CO_2 emissions.

The marketable permit and tax solutions are not equivalent, however, in the real world with its uncertainties and asymmetric information. The carbon tax would appear to be the better choice as a practical matter, for a number of reasons.

The first relates to the pattern of the marginal benefits and marginal costs of reducing global warming. Since global warming depends on the accumulated stock of GHG emissions, the marginal benefits of reducing the flow of emissions in any one year are likely to be fairly constant over a wide range of emissions reductions. In contrast, the marginal costs are likely to rise sharply the more the emissions are reduced. Therefore, given the inevitable uncertainties associated with measuring the marginal benefits and costs of emissions reductions, the goal should be to keep tighter control over the marginal costs. As described in Chapter 7 of the textbook, taxes are better for controlling marginal costs, permits for controlling marginal benefits, so the carbon tax is the preferred option on this score.

Second, the carbon tax provides better incentives to countries should they attempt to exploit their information advantage regarding the behavior of their own firms under an emissions reduction program. Marketable permits would be allocated to and bought and sold by countries, which would then distribute the permits to their firms. Suppose the firms in some country falsely claim that they have reduced their emissions below the targeted amount and the government discovers they are lying. The government's incentive under the permit system is to claim that its firms have reduced their emissions, so that it can sell permits to other countries. If the price of permits is high, the government can transfer a substantial amount of revenue to itself by selling the permits. Therefore, the interests of the firms and their governments to lie are the same. Under a tax regime, in contrast, false claims of emissions reduction by a country's firms rob the government of tax revenue, so that the benefits of lying become a zero-sum game between the firms and the government rather than a positive sum game. This advantage would become especially important if the developing countries were eventually given emissions quotas, since many of them have far less open and accountable societies than do the developed countries. It would be very difficult to monitor emissions reductions in these countries.

Third, many economists are worried that the price of carbon would be highly variable under a marketable permit scheme, which would lead to very different incentives to reduce emissions over time. They point to the experiences of the U.S. marketable permit scheme to reduce the sulfur dioxide (SO_2) emissions of the electric utilities and the EU's Emissions Trading Scheme. The price of the US-SO_2 permits was highly volatile, ranging from $70 per ton in 1996 to $1,550 per ton in 2005. The permit prices for a ton of carbon emissions in the EU have ranged from $23 to $104.[8] In contrast, a single carbon tax rate would be constant in the face of changing economic conditions, and could be

[8] Nordhaus, *op. cit*. The U.S.-SO_2 prices are reported on p. 14, the EU-ETS carbon prices on p. 8.

varied in measured amounts over time as needed to maintain an average amount of aggregate emissions reductions over, say, a five year period.

Fourth, the appropriate allocations of permits each year across countries is difficult to determine in the face of technical change and uneven economic growth rates within the countries.

Finally, many countries already have carbon taxes on the use of fossil fuels, so that a single harmonized carbon tax established for all countries would not be all that much different from a tax that is already widely used.

The main difficulty for the tax regime is that countries have all kinds of taxes and subsidies in place that affect greenhouse gas emitting firms. Therefore, the UNFCCC would ideally have to set variable tax rates across countries that equalize the effective net carbon tax on their greenhouse gas emissions firms. This is undoubtedly too much to ask; the tax scheme would necessarily be imperfect. But it would not suffer from the other problems that beset a marketable permit scheme.

In conclusion, the Kyoto Protocol was a noble attempt to halt the increase in global warming, but good intentions do not necessarily produce good results in the arena of international politics. The design flaws of the Protocol, coupled with the defection of the United States, rendered it at best a 'good start' in securing international cooperation for the battle against global warming.

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With the Kyoto Protocol scheduled to end in 2012, over 120 countries met in Copenhagen in December of 2009 to forge a new GHG emissions agreement. The meeting was not a success, to say the least. A number of countries left the meeting early. Those that remained to the end hastily drafted a document on planned emissions reductions that amounted to little more than a set of empty promises.

A breakthrough finally occurred at the Paris Climate Conference in December of 2012. 195 nations forged an agreement on climate control under which each country would submit a plan for reducing GHG emissions. The plans, called Intended Nationally Determined Contributions (INDCs), constituted the first universal and legally binding agreement on climate control. The U.S. INDC set a target of reducing its GHG emissions by 26-28% below its 2005 pre-Great Recession level by 2025.

Although the Paris agreement was undeniably an important first step for international cooperation on climate control, the question remains whether the INDCs are

enforceable. Also, the overall reduction in GHG emissions agreed to by the 195 nations was not enough to keep the increase in global warming below the UN's target of 2°C.

There is good reason to be hopeful, however, because the Unites States and China took the lead in generating the Paris agreement. They reached a joint agreement in November of 2014 to control GHG emissions and promote clean energy. These two countries are estimated to emit between one-third to forty percent of all GHG emissions. They clearly have to be the two major players in attempts to reduce worldwide GHG emissions.

Under their joint agreement, the U.S. pledged its commitment of a 26-28% reduction in GHG emissions below its 2005 level by 2025. China agreed that its CO2 emissions would reach a peak around 2030, and also that it would increase the share of non-fossil fuels for generating energy to about twenty percent by 2030. The latter is a fairly ambitious goal, because to reach it, China will have to increase its zero-emissions capacity—e.g., nuclear, wind, solar—by an amount greater than the combined current capacity of all its coal fired plants. China had never before made any commitments with respect to GHG emissions or energy production. On March 31, 2016, Presidents Obama and Xi Jinping announced that they would sign the Paris agreement on April 22[9].

[9] See www.whitehouse.gov/the-press-office/2016/03/31/us-china-joint-presidential-statement-climate-change and https://www.whitehouse.gov/the-press-office/2014/11/11/fact-sheet-us-china-joint-announcement-climate-change-and-clean-energy-c