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Comment V. Kerry Smith

If we could rely on technological innovation to dramatically reduce the costs of mitigating greenhouse gases, then climate policy would be easy. All the analyses of the design and impacts of climate policy can agree with this point. Nordhaus (2008), for example, finds the present value of abatement costs would be about one-fourth that of his optimal approach if we could assume a low-cost backstop technology was available to replace fossil fuels when carbon's price reached five dollar a ton (in 2005 dollars). The Stern (2006) report makes exceptionally optimistic assumptions about technological advance, assuming abatement costs will decline by sixfold by 2050. Thus, the focus of Charles Kolstad's chapter is especially important. He notes that serious theoretical analysis to understand the effects of different climate policies on technical change needs to "unpack" the internal structure of the innovation process. He examines the interactions between three parties—the regulator, the firm facing environmental regulation and needing to control its emissions, and the firm offering new abatement technologies to reduce incremental abatement costs. In a stylized model that abstracts from uncertainty and the effects of regulatory policy in output markets, he finds that price and quantity instruments for regulating pollution can be made equivalent in terms of realizing the first-best (efficient) amount of abatement and innovation. However, the total return to innovation is not the same for these two instruments and the distribution of returns between the polluting firm and the innovating firm is also different. Innovators appropriate all the

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gains from innovation with a quantity standard and share the gains with a price instrument.

Kolstad's recognition of the importance of the internal process of innovative activities is to be applauded. As with all good research, it helps to answer some questions and frames new ones. I consider three questions here: Does past experience with other pollution control policy suggest we should be optimistic about technical change reducing abatement costs? Is Kolstad's single pollutant focus limiting? and What lessons from other analyses of innovation are relevant for climate policy?

Past Experience

The signature example of an incentive-based environmental policy is the SO_2 permit trading program. Glowing accounts of its success can be found in the middle and late nineties.[1] It is difficult to disentangle all factors contributing to abatement costs and assess how much new innovations reduced control costs. Nonetheless, a simple comparison suggests that modest, not dramatic, unanticipated cost savings seems to be the most plausible conclusion that can be drawn from experience with this program. To arrive at this conclusion I extracted estimates of the long-run incremental costs of controlling SO_2 that were expected for 2010 from Burtraw's (1998) summary of what was known before the program was implemented. He suggested that the ICF (1990) study probably offered the best picture of expectations prior to the implementation of the SO_2 trading program because it included a detailed characterization of the ultimate design for the rule. This study estimated long-run marginal costs of controlling SO_2 in 2010 would be \$579 to \$760 per ton (in 1995 dollars). Using the consumer price index to convert these estimates to 2009 dollars, they are between \$820 and \$1,077 per ton.

The best estimates for the incremental control costs today would seem to be the spot price of SO_2 permits. Figure 4C.1, panel A reproduces a chart from Cantor Fitzgerald's trading records for the period 2003 to 2009, the last full year before the permits stopped trading in May 2010 (see figure

1. It is easy to get carried away with promises that technology will eliminate costs of pollution abatement. For example, Carol Browner noted when she was EPA administrator and was discussing the SO_2 program as EPA administrator that, "During the 1990 debate on the acid rain program, industry initially projected the cost of gas emission allowance to be \$1,500 per ton of sulfur dioxide...Today these are selling for less than \$100" (March 10, 1997). Unfortunately, today the story is very different. The US market for SO_2 emissions to control acid rain, for example, has had no trades since the Spring of 2010. One explanation is the uncertainty caused by court rulings and the development of recently finalized regulations to address SO_2 emissions that affect downwind ambient air quality. What is at issue is uncertainty over exactly how an SO_2 permit can be used. Recorded permit prices are effectively zero. Reestablishing the SO_2 permit market using new permits will require resolution of these sources of uncertainty. The recently finalized regulations attempt to do so by establishing a new, tighter, cap on SO_2 emissions from most, but not all, of the facilities subject to the acid rain SO_2 program. The prices of the new SO_2 permits under this program are expected to be positive, but those facilities not subject to the new program may now choose to emit more SO_2 given that the acid rain cap is no longer binding.

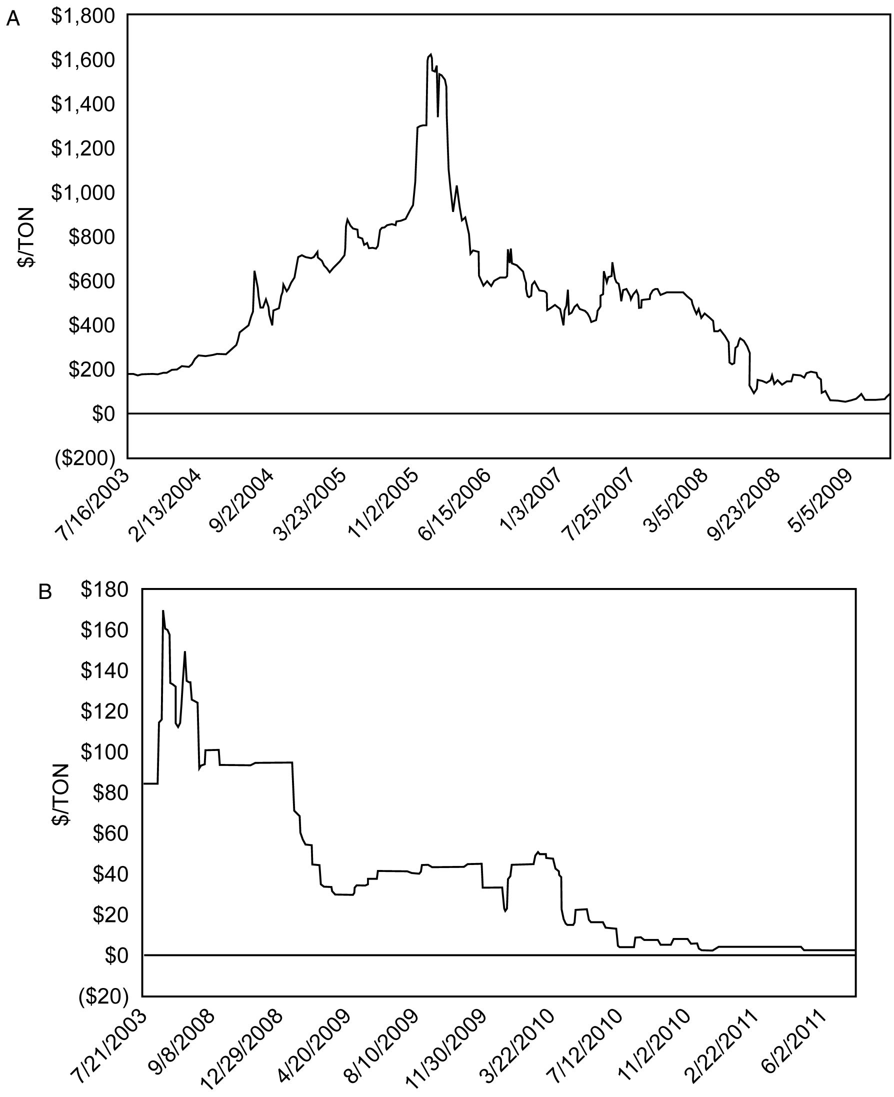

Fig. 4C.1 Spot prices for SO_2 permits: *A*, To May 2009; *B*, A year later to May 2010
Source: Cantor Fitzgerald website (accessed 5/21/2010).

4C.1, panel B). These results are in the dollars of the year of the exchange. There is not a smooth pattern. Spot prices for sulfur permits are, like other prices, influenced by a number of factors including expectations for what is to happen with other environmental policies.

Using a midrange of spot prices in the two years prior to the economic downturn and converting them to 2009 dollars yields about $635 a ton or a 23 percent decline from the low end of the expectations for incremental costs estimated in 1990. This would be about a 1.3 percent decline each year over these twenty years, certainly not negligible gains from unrecognized technologies, but also far short of the pace needed for a sixfold decline in costs in forty-five years, as assumed in the Stern report.

Pollutants Do Not Go Away

One of the earliest papers arguing that environmental externalities were pervasive, by Ayres and Kneese (1969), also emphasized the importance of an explicit recognition of materials and energy balances in modeling production and consumption. They argued we can change the form of pollution and where it is dispersed but the materials and heat comprising residuals do not go away. In the end we must decide where they are to go. Kolstad's model focuses on reducing abatement costs without dealing with the disposition of what is abated. This issue never comes up in his model and I believe in further refinements it should. Innovation may create a new problem. For example, suppose we are able to reduce the costs of controlling airborne emissions by passing them through a water mist instead of using a mechanical device. This innovation would create a watery sludge that captures the particles that would otherwise have been captured mechanically and removed as solid waste.

This point is important for several reasons. Changes in the regulations on a different pollutant—NO_x—could influence the costs of controlling CO_2. As Burtraw and Szambelan (2009) suggest, the interconnections between pollutants, reflecting Ayres and Kneese's warning to be sure economic analysis recognized the "physical realities" of production (and consumption), can be responsible for links between the markets for different tradeable pollution permits. A tangible example of such links, in the context of expectations about regulations, can be found in figure 4C.1, panel A. Court decisions about the implementation process for the Environmental Protection Agency (EPA)'s Clean Air Act Interstate Rule (CAIR) to control particulate matter and NO_x caused dramatic moves in the SO_2 allowance price (the spike in December 2005 in figure 4C.1, panel A) and ultimately the drop of prices to zero in 2010 (see figure 4C.1, panel B). In the United States, as of this writing (September 2011) macroeconomic policy is likely to be the major short-term source of uncertainty that can affect other environmental policies. In the future with economic recovery it will be climate policy. Such regulatory uncertainty has implications not only for controlling greenhouse gases but potentially for the consistency of the signals that permit prices provide for innovations in the abatement of all pollutants.

Lessons

At least two lessons from recent literature should be noted. First, Vernon Ruttan's (2006) last book argued that revolutionary departures from existing technological trajectories require new institutions. He was not optimistic that civil institutions could assemble the resources and create incentives that would lead to dramatic breakthroughs. Part of the reason for his relative pessimism was the inability of free societies to structure institutions that make these sustained commitments. In Kolstad's model commitments are given in the first stage of his regulatory game and remain consistent in his model. In the real world they change and may not be sufficiently consistent.

A more recent overview of innovation in different sectors reported in the Henderson and Newell (2011) volume suggests competition and not government is a more useful guide for innovation policy. This conclusion may well be right for private goods and services—but what about nonmarket services? Markets do not provide signals for them. The prices from permits are a start but we have seen how they can be undone by a court ruling and regulatory "fixes"—thus we must conclude that there are few areas where such markets are well established and reliable as a source of long-term signals. How do we avoid serious mistakes—creating with technological "cures" a set of problems that are worse than where we started? It is only by unpacking the details of the innovation process, as Kolstad has started, that we can hope to answer these questions.

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