A Pricing Mechanism for CO_2 Emissions that Incorporates Future Revisions of Estimates of the Cost of Today's Emissions

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Abstract:

The efficiency of mechanisms to control CO_2 emissions is limited by disagreement about the harm from these emissions. Thus existing emission control mechanisms require negotiated compromise regarding either the efficient price or the level of emissions to be tolerated. As an alternative to conventional mechanisms, we offer a mechanism in which today's price of emissions is determined by a market-based estimate of future beliefs about the cost of emissions. This reduces the uncertainty about the right price for emissions and makes it likely that emitters will base their emission decisions on more accurate estimates of the harm they cause.

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1. Introduction

With adequate information, CO_2 emissions can be controlled efficiently by either tradable allowances or emission prices. Current attempts to control CO_2 emissions favor tradable allowances that emitters receive free of charge,[1] although some have argued that controlling greenhouse gases through either prices or a combination of price and quantity controls would yield greater social benefits (see, for example, Pezzey, 1992, and Pizer, 2002).

The efficiency of any control mechanism is limited by the fact that current estimates of the magnitude of the harm from CO_2 emissions vary widely, partly because of uncertainty about the impact of emissions of CO_2 on climate and partly because of uncertainty about the economic costs of climate change. However, future scientific research is likely to reduce both of these uncertainties, making the best estimates of the harm from today's CO_2 emissions much more precise and accurate, say, 30 years from now than they are today. Thus it is sensible to seek a control mechanism for CO_2 emissions that takes account of prospective improvements in our understanding of the harm from today's CO_2 emissions. Ideally, such a mechanism should be neither more difficult nor more costly to implement than existing tradable allowance programs. This paper describes a simple pricing mechanism that meets both requirements.

Because of uncertainty regarding costs of CO_2 emissions, one cannot require that emissions stop at the quantity where marginal cost equals marginal benefit. What one can ask a pricing mechanism to do is to induce today's emitters of CO_2 to emit only if the benefits of emissions are at least as great as the best estimate of the harm that their emissions cause, including the expected harm caused by the fact that the harm is uncertain. A good pricing

[1] For example, the European Union Emissions Trading Scheme or the Chicago Climate Exchange.

mechanism will also permit emitters to hire others who are better bearers of uncertainty to bear the cost of the uncertainty. We achieve these two goals with a combination of government bonds that emitters are required to purchase and whose redemption price is a function of the future estimate of the cost of today's CO_2 emissions, and a prediction market in which these bonds can be traded. We describe our pricing mechanism in Section 2, and we compare our mechanism with conventional emission taxes and tradable allowances in Section 3. Section 4 concludes.

2. The Pricing Mechanism

Our pricing mechanism consists of two parts. Part one is a requirement that every emitter of CO_2 whose emissions can be measured with sufficient accuracy at a non-prohibitive cost buy, for each ton of CO_2 emitted in 2007, a special 30-year zero-coupon government bond with a face value equal to the estimated upper limit of the total harm of one ton of CO_2 emitted in 2007. Denote this estimate by $H^U_{2007}(2007)$, where the subscript indicates the year when the estimate is made and the parentheses show the year to which the estimate applies. When the bond matures in 2037, a prescribed process (see below) will be used to identify the 2037 estimate of the present value, discounted to 2007, of the harm of one ton of CO_2 emissions in 2007, $H^E_{2037}(2007)$. The bond's redemption value in 2037, R_{2037}, will be

$$R_{2037} = \max\left[\left(H^U_{2007}(2007) - H^E_{2037}(2007)\right)(1 + r_{2007})^{30},\, 0\right] \tag{1}$$

where r_{2007} is the interest rate for 30-year bonds that prevailed in 2007. If the redemption value is positive, then an emitter who buys the bond in 2007 and holds it for 30 years has paid the 2037 estimate of the costs that he caused 30 years earlier by emitting one ton of CO_2. If the

2037 estimate of harm exceeds the 2007 estimate of the upper limit, then the bond's redemption value is zero. It seems appropriate for society to bear the burden of any harm that was not foreseen in 2007.

The bond's face value must be set above today's estimate of the most likely cost of a ton of CO_2 emissions, to ensure that emitters pay for the harm from their emissions if this harm turns out to exceed the harm that was considered most likely in 2007. If $R_{2037} > 0$, then emitters receive a refund for the amount they overpaid in 2007 plus accrued interest. However, the requirement that emitters buy bonds of an amount that almost certainly (by today's expectations) exceeds the future estimate of today's harm leads to three concerns. First, such a requirement may reduce emissions below their optimal level if liquidity constraints force emitters to reduce emissions solely because they cannot afford the required bonds. Second, even emitters who do not face liquidity constraints may prefer not to invest in 30-year bonds. Third, uncertainty about the size of the refund makes it more difficult to assess the liabilities of emitters and thereby to determine the market value of emitting companies.

We address these concerns by introducing a prediction market in emission bonds as the second part of our pricing mechanism. This prediction market is simply a secondary market for the bonds that ensures that at any point in time, *t*, the bond's price reflects the present value of the bond's expected redemption value at *t*. Let *x* denote the beliefs in year 2007 + *t* about the 2037 estimate of the damage of a ton of CO_2 emitted in 2007, and let *f*(*x*) be the density function of these beliefs in 2007 + *t*. The bond's price in 2007 + *t* is then

$$P_{2007+t} = \int_0^\infty \max[H_{2007}^U(2007) - x, 0]\, f(x) dx \, \frac{(1 + r_{2007})^{30}}{(r_{2007+t})^{(30-t)}} \qquad (2)$$

where r_{2007+t} denotes the interest rate for a zero-coupon (30 – *t*)-year bond in year 2007 + *t*. Equation (2) makes no allowance for the possibility that uncertainty in the bond's expected redemption value is costly. This is appropriate if the uncertainty in the redemption value is uncorrelated with the overall uncertainty in financial markets, in which case the cost of the uncertainty can be diversified away. If there is a positive correlation, then the uncertainty in the bond's redemption value will be costly, and markets will subtract the present value of this cost from the price in equation (2).

As long as $P_{2007+t} > 0$, the market predicts the 2037 estimate of the harm of one ton of CO_2 emissions in 2007. The market fails to predict this future estimate if $P_{2007+t} = 0$. But because emitters will not be held responsible for harm above the upper limit of today's estimates, the bond's price nevertheless permits straightforward assessment of the liabilities of emitters. The prediction market also provides emitters with liquidity, because emitters who do not wish to hold bonds can sell their bonds and thereby recover the present value of the current estimate of their overpayment.

For the prediction market to operate as intended, the rules according to which the bond's redemption value will be determined in 2037 must be specified in 2007. Determining the bond's redemption value requires the joint effort of scientists who are trained to assess the physical consequences of CO_2 emissions and economists who are trained to assess the monetary value of these physical consequences. It is unlikely that our understanding of the harm of CO_2 emissions will improve sufficiently over the next 30 years to permit the development of an uncontested formula that translates emissions into monetary harm. Thus, in case the members of either group are unable to reach agreement, it is necessary to have specific rules about how to combine their different assessments. One possible set of rules is that adopted by the Intergovernmental Panel on Climate Change (IPCC). The IPCC does not undertake own research, but bases its conclusions regarding climate change on the assessment of peer-reviewed and published analyses (see IPCC, 2004). This increases the probability that the bond's redemption price will be determined by scientific consensus. The same set of rules can also be used to determine the 2007 estimate of the upper limit of harm per ton of 2007 CO_2 emissions.

While it would be straightforward to devise more precise rules to determine the bond's redemption value, this would reduce the possibility of incorporating improvements in the process of assessing the harm of CO_2 emissions. On the other hand, the more scope there is for revision of the rules, the greater is the risk of insider trading on the basis of prospective changes in the rules. Fairness to traders requires that whatever process may be used to revise the rules in the future be delimited in the initial contracts.

Because those who assess the harm from CO2 emissions may be tempted to base their assessment on political considerations, it is important to ensure that the assessment criteria are as objective as possible. In addition, the prediction market will be able to predict the harm from 2007 CO_2 emissions only if market participants have access to the information on which this assessment will be based. The procedure adopted by the IPCC fits these requirements reasonably well—those in charge of determining the harm do not make any assessments on their own but use only freely accessible results of peer-reviewed and published research. A multi-stage approval process that is open to all emitters serves as control mechanism. The fact that the IPCC is able to regularly issue reports that are not summarily rejected by the public suggests that this combination of open sources and multi-stage control is operational.

As long as the assessment of the harm requires human decisions, it is impossible to ensure that the redemption value is determined without any political considerations. But this caveat applies to any public process for determining cost-based prices and therefore should not count against our mechanism. Below we argue that our mechanism provides better protection against political abuse than conventional emission taxes and tradable allowances.

For the mechanism to be efficient, the total cost of administering the bonds, implementing the prediction market, and measuring CO_2 emissions must not exceed the expected value of the harm from CO_2 emissions. The IPCC already compiles and weighs most of the information necessary to determine the bonds' initial prices and their redemption values, so the marginal cost of setting the bonds' prices would be fairly low. Because the sole purpose of the bonds is to generate a certain rate of return for overpaid funds, it is possible to use zero-coupon versions of existing 30-Year US Treasury bonds and add a contract clause that specifies the rules that determine the share of the bond's value that the bond holder will receive. Experience with the Iowa Electronic Markets (http://www.biz.uiowa.edu/iem/) and other prediction markets suggests that such markets can be implemented at low cost. Finally, experience with tradable allowances suggests that it is possible to obtain measurements of CO_2 emissions from large emitters at fairly low cost. Thus our pricing mechanism is likely to be no more expensive and no more difficult to implement than existing tradable allowances. Assuming that the administration of the bonds is about as expensive as the collection of corrective taxes, our mechanism is also no more expensive than conventional pricing mechanisms.

3. Comparison with Conventional Emission Taxes and Tradable Allowances

We argue that our pricing mechanism is likely to be more efficient than conventional emission taxes and tradable allowances, and that our mechanism makes it more difficult to pursue CO_2 regulations that further purposes other than efficient CO_2 emissions.

First, conventional emission tax mechanisms require consensus or compromise regarding the tax rate, and tradable allowances require consensus or compromise regarding the level of emissions. In contrast, our mechanism employs a market to estimate what the consensus or compromise will be at a time when it is reasonable to expect much less disagreement. The long experience with prediction markets suggest that such markets tend to provide more accurate information about uncertain events than alternative prediction mechanisms.[2] Thus our mechanism is likely to achieve a more efficient reduction in CO_2 emissions than conventional emission tax mechanisms and current emission trading markets. Note the difference between our prediction market and existing futures markets for emission allowances (for example, the European Climate Exchange). Such futures markets permit emitters to hedge their risk with respect to increases in the price of *future* emissions. In contrast, our prediction market permits emitters to hedge their risk with respect to their eventual liability for *current and past* emissions.

[2] See, for example, Rhode and Strumpf (2004) and Wolfers and Zitzewitz (2004).

Second, a major problem of all regulatory mechanisms that do not employ prediction markets is that it is too easy for regulations to come to be based on political goals rather than on the best estimate of what control parameters are optimal. In contrast, the fact that the redemption value of the bonds in our mechanism will be determined in 2037 makes it harder to implement environmental regulation in 2007 that deviates from today's best understanding of the harm from CO_2 emissions. If $H^U_{2007}(2007)$ is set too low, then the bond's price will quickly fall to zero, thereby making the official underassessment of the harm visible. This will make it more difficult to defend underassessing the harm again in the following year when setting $H^U_{2008}(2008)$. Conversely, if $H^U_{2007}(2007)$ is set higher than necessary, then the bond's price in the prediction market will be correspondingly higher, permitting emitters to escape the overly strict regulation by selling their bonds in the market.

Note the difference between our mechanism and existing tradable allowances. While it is true that the price of tradable allowances also varies with the number of allowances, markets for emission allowances lack a mechanism that indicates when the number of allowances is set too low, and therefore do not provide a guard against overly strict regulation. Our mechanism possesses such protection, and thus makes it more difficult to use environmental regulation for a purpose other than optimal reduction in CO_2 emissions.

Finally, while it would in principle be straightforward to require emitters to pay for their initial allowances, emission trading mechanisms often provide emitters with free allowances. Pricing mechanisms make it more difficult to obscure the fact that every ton of emissions can be regarded as the "marginal ton" that ought to bear the cost of the harm that it causes. However, it may be inappropriate for emitters to bear the entire burden of purchasing our mandatory bonds, because this would assume that emitters should have anticipated the regulatory policy. Pezzey (2003) has argued that proposed price control mechanisms should exempt some level of emissions because it is politically infeasible to require emitters to pay taxes (which are equivalent to our mandatory bonds) for all of their emissions. This can be accomplished by giving each emitter bonds for some specified level of emissions for a specified length of time. Because emitters receive the bonds regardless of their level of emission, such lump-sum compensation would preserve incentives for efficient emissions.

4. Conclusion

Our main motivation for developing the pricing mechanism described here arises from a belief that scientific research over the next 30 years is likely reduce the uncertainty about the physical consequences of today's emissions of CO_2 on climate and about the economic costs of climate change. If this belief turns out to be overly optimistic and the assessment in 2037 is as uncertain as today's assessment, then our mechanism will have mainly introduced an additional layer of uncertainty about the price of emissions. If emitters immediately sell their bonds in the secondary market, then their 2007 payments for their emissions will not differ from those that they would have to pay under conventional emission taxes with appropriate rates. However, global awareness of the likelihood of human induced climate change has increased considerably over the past 10 years, and the confidence intervals of the IPCC's predictions of the effect of climate change have decreased. Thus it seems appropriate to expect that our understanding of the effect of CO_2 emissions on climate change will continue to improve over the next 30 years. Our mechanism assures that some person or combination of persons will voluntarily pay the 2037 estimate of the cost of 2007 CO_2 emissions, at least as long as this estimate does not exceed today's maximum estimate of the harm. In the latter case, our mechanism ensures that someone will pay for at least this maximum estimate.

For our pricing mechanism to be attractive, the bonds' 2037 redemption price must be determined primarily by scientific rather than political considerations. The open-source procedure adopted by the IPCC provides some control against political pressure, but it is impossible to ensure that political influence will be completely eliminated. As long as the participants in the prediction market believe that the bond's redemption price will be more closely based on scientific considerations than a price today would be, our mechanism provides better protection than conventional regulatory taxes and allowances against political influence in 2007. There can be no guarantee that the total payment for 2007 emissions will be based exclusively on the best future estimate of the emissions' harm. But if citizens find it impossible to put minimal trust in the regulators who value and administer the bonds, then it is unlikely that they will find any regulatory environmental policy agreeable.

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