BOOK REVIEW

A. S. Manne and R. G. Richels, *Buying Greenhouse Insurance: The Economic Costs of CO_2 Emission Limits*, The MIT Press, Cambridge, Mass., 182 pp., 1992, ISBN 0-262-13280-X, $27.50.*

Buying Greenhouse Insurance uses the Global 2100 model to analyze the economic costs of varying degrees of global CO_2 emission reduction for a wide range of assumptions concerning the prospect for future improvements in the efficiency with which energy is used, the cost and availability of natural gas, and the long term cost and timing of renewable energy resources. The stated objectives are not to provide definitive forecasts – an admittedly impossible task – but rather, to identify the impact of alternative assumptions on the projected cost of CO_2 emission constraints, to clarify specific areas of disagreement, and to provide a logical framework for thinking about the trade-offs between costs and emission reductions.

The book opens with an overview chapter which acknowledges that the impacts associated with unrestrained emissions of greenhouse gases could be large, that there are major disagreements concerning the cost of reducing emissions, and that there are cost-effective opportunities for improving energy efficiency and reducing CO_2 emissions. Unlike some of their colleagues, Manne and Richels do not assume that energy markets are behaving perfectly and that every option is already being adopted for costless improvements of energy efficiency. They allow for a continuous, non-priced induced improvement in energy efficiency through the autonomous energy efficiency improvement parameter, or AEEI, and accommodate the spectrum of opinion concerning how large this efficiency potential is and how fast it can be delivered by altering the value of AEEI.

Buying Greenhouse Insurance is divided into two sections, the first of which presents the main results of the authors' modelling exercise and policy implications, the second of which delves into the details of the model structure. Those not interested in technical details might be tempted to skip the second part. However, an understanding of the model structure is essential if one is to make an informed judgement concerning the robustness of the results, and thus the validity of the policy implications presented in the first part.

The Global 2100 model divides the world into five major geopolitical groups. Within each region, total economic output is computed based on a simple function

* Editor's Note: The Editor received two copies of this book and inadvertently asked for two reviews, one by W. R. Cline (*Climatic Change* **23: 2**, February 1993), and this one. But due to the importance of the topic felt both should be published.

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of the capital stock, labour supply, and electric and non-electric energy *demand*. The total output is allocated among current consumption, investment, and payment of energy costs. The change in capital stock over a given 10 year time step depends on the rate of depreciation of the pre-existing stock and the amount of new investment. The allocation of output between savings and investment is determined through maximization of discounted utility (which is equated with consumption). Energy demand is determined based on the prescribed value of the AEEI parameter, energy supply costs, an elasticity of substitution between energy and other productive inputs, and overall economic activity potential. Included among the energy sources are low and high cost carbon-free electricity (which could be new nuclear or a number of possible renewable energy sources) and a non-electric, carbon-free backstop (which could be hydrogen made using renewable energy) available in unlimited quantities but at high cost.

According to Manne and Richels, the discounted cost of reducing U.S. emissions to 80% of the 1990 level by 2010, and holding emissions constant thereafter, ranges from close to zero to \$3.5 trillion as the assumed AEEI varies from 1.5% yr^{-1} to 0.5% yr^{-1}, the availability of non-electric renewable energy supplies increases from 0 to 20 EJ (exajoules, or 10^{18} Joules) yr^{-1}, and the eventual cost of low-cost, carbon-free electricity ranges from 5 to 7.5 cents/kWh. The required peak carbon tax (if taxation were the sole policy tool used to induce emission reduction) ranges from about \$100/tonne for the optimistic case to \$600/tonne for the pessimistic case. Future costs in their analysis are largely determined by the assumed value for AEEI as well as the assumed timing and cost of carbon-free energy sources. The possibility that reducing U.S. CO_2 emissions by 20% could entail close to zero net cost is an unusual conclusion coming from economists, although engineering-oriented analysts have come to this conclusion for many years. Nevertheless, Manne and Richel's base-case scenario assumes a U.S. GDP loss which asymptotes at about 2.5% by the middle of the next century. In some cases, larger losses are indicated for other countries.

Manne and Richel's economic analysis is followed by a discussion of decision making under uncertainty and an assessment of optimal hedging strategies, given various probabilities concerning the degree of CO_2 emission constraint that will be required in the future and when uncertainty in the magnitude of the eventual constraint can be resolved. Two key conclusions that emerge from this analysis are, first, that some degree of constraint now is optimal, even before uncertainties are resolved, and second, that "the less faith we have in the possibility of near-term research accuracy, the greater is the need for precautionary actions" (page 86). I would add that, the greater the magnitude of constraint that can be achieved at zero economic cost and the greater the non-climatic benefits associated with initial constraints, the greater the constraint that is justified now.

Buying Greenhouse Insurance stands out among recent assessments of the cost of CO_2 emission reduction by economists in forcefully stating that the estimated costs are very sensitive to highly uncertain input assumptions. Manne and Richels deserve much credit for attempting to incorporate the full range of opinion on this subject and, in so doing, to demonstrate the extent of uncertainty in future costs.

In spite of their open-mindedness, I nevertheless feel that Manne and Richels have formulated their model, and chosen input assumptions, such that the costs of carbon constraints under optimal policies are significantly over-estimated. In the spirit of provoking further debate about costs and the appropriate framework for assessing costs – one of the stated objectives of Manne and Richels – I would like to enumerate the following criticisms of their analysis:

- Global 2100 does not include *feedbacks* between policy (as represented by the magnitude of the CO_2 emission constraint) and the value of key parameters such as the timing and cost of carbon-free energy sources or the value of AEEI. Both the timing and cost of advanced, carbon-free energy sources should be a function of the CO_2 emission constraint since, with intelligent policy formulation, a tighter emission constraint would be accompanied by greater support for research, development, and demonstration of carbon-free energy sources. It is also likely that the AEEI is itself subject to manipulation through appropriate government policies. Examples of how this could be achieved include programmes designed to reduce transaction costs in energy efficiency retrofits of existing buildings; reducing the gap between building codes and other standards on the one hand, and state-of-the-art, cost-effective practice on the other hand; sponsoring design competitions to accelerate improvement in the state-of-the-art; or assisting in up-front financing of energy efficiency improvements. Many of these programmes are best carried out at the municipal level, such as the community-based building retrofit programme being developed for the City of Toronto (see Harvey, 1993). Perhaps it is because Manne and Richels do not include these feedbacks that they conclude that a 50% CO_2 emission reduction would be more costly than a 20% emission reduction, in contrast to the conclusion of the American Council for an Energy Efficient Economy and others (Alliance *et al.*, 1991).
- In spite of the authors' acknowledgement that energy markets are not perfect and that there are opportunities, of uncertain magnitude, for costless CO_2 emission reduction, the Global 2100 model is formulated such that the possibility that carbon limits could *improve* the performance of the economy is automatically ruled out, a feature the authors openly acknowledge. However, to the extent that policies to reduce CO_2 emissions focus greater attention on capturing the existing cost-effective potential to reduce energy use, economic performance could very well be improved.
- The use of a single, average cost for advanced carbon-free electricity and for each competing, fossil fuel-based electricity results in an all-or-nothing situation in the sense that use of carbon-free sources will impose economic costs until the cost of carbon-free electricity drops to the average cost of the cheapest available fossil-fuel based electricity. In reality, advanced carbon-free electricity can be cost-effective even when more costly than the average

fossil fuel cost if it is available at times when it is costly to supply electricity from fossil fuel sources. This is already the situation today in many regions for photovoltaic and solar thermal electricity generation, which are generally available in greatest quantity during times of peak, air conditioning-based electricity demand.

– Global 2100 does not allow for premature retirement of capital investments when the marginal cost of continued operation of an existing facility, including obsolete fossil fuel electricity supply, exceeds the cost of building a new facility, nor does it allow for mid-life retrofitting of existing buildings. Rather, "energy consumers are locked in by their past acquisitions of capital goods and by the rate of depreciation. There is flexibility only in the case of new investment" (page 119). By formulating the model this way, significant cost-effective opportunities to reduce CO_2 emissions, which exist today, are ruled out. A striking example involves the case of coal-based electricity power plants located outside major urban demand centers. Mid-life refurbishing of conventional coal-based facilities has, in the case of plants outside Toronto, cost around \$600/kW, which is comparable to the cost of *new*, gas-fired combined cycle power plants! Furthermore, by locating 300–600 MW of gas-fired electricity generation downtown (at a cost of \$250–450 million), \$100 million or more in future transmission corridor upgrade costs can be avoided in the case of Toronto.
– Different energy forms are treated as perfect caloric substitutes in computing total energy demand and economic competitiveness. Thus, a gigajoule of coal is equivalent to a gigajoule of natural gas, in spite of the fact that natural gas can be used to generate electricity almost three times more efficiently than coal if, unlike coal in most jurisdictions, the power plant can be located in urban centres and combined with a district heating system.* Another example involves the computation of the carbon tax required to make the non-electric, carbon-free backstop (likely to be hydrogen) competitive with gasoline. For hydrogen at \$16.67/GJ (a reasonable long term price), gasoline at \$8.33/GJ, and a carbon differential of 0.4 tonne/GJ, Manne and Richels compute a carbon tax of \$208/tonne required to make the carbon-free backstop competitive. However, if fuel cells become commercially available for automotive applications, hydrogen could be used at least 3 times more efficiently than gasoline, so that the effective price would be less than that of gasoline. Depending on the difference in the purchase cost of hydrogen- and gasoline-fueled vehicles, it is possible that *no* carbon tax would be needed to make hydrogen competitive with gasoline on a life-cycle basis, given the fuel costs cited above.
– The economic production function used by Manne and Richels appears to be formulated in such a way that it would not accurately capture the effect

* Although only 25–50% of the input fuel in a gas cogeneration system is converted to electricity, the efficiency on the margin – that is, the electricity generated divided by the incremental gas use – is typically 80–90%, compared to 30–35% for conventional, coal-based electricity.

of radical tax reform. Suppose, for example, that the tax burden were to be shifted from labour and income to resource inputs (including energy) as part of a broader effort to foster environmentally sustainable development, as advocated by Herman Daly ('Farewell Lecture to the World Bank', 14 January 1994, unpublished). Revenue neutral tax reform would alter the economically optimal mix of capital, labour, and energy inputs without necessarily reducing GDP. In contrast, any increase in energy prices in the Global 2100 model, whatever the cause, tends to reduce GDP.

– The costs attributed to CO_2 emission constraints by Global 2100 do not allow for sharing of the costs of CO_2 emission reduction when CO_2 emission reduction addresses other societal objectives, such as reduction of urban and regional air pollution through reduced use of fossil fuels.

Apart from these technical concerns, *Buying Greenhouse Insurance*, like every other cost analysis this reviewer has read, does not consider population policy as a policy tool in restraining greenhouse gas emissions. Clearly, there are many potentially important feedbacks between the rate and form of economic growth in developing countries, population growth, and future CO_2 emissions which needed to be analyzed. If a future global warming regime involves a system of tradeable permits in which permits are allocated based on population in a fixed year, then countries with high population growth rates will have an economic incentive to stabilize their population as quickly as possible. This in turn requires directing development toward the provision of basic human needs, education, and key social services, all of which would have significant beneficial long term economic impacts. These criticisms are equally applicable to recent so-called 'integrated assessments' of greenhouse gas emission policies, none of which include feedbacks between CO_2 policy, population growth, and economic development.

Finally, *Buying Greenhouse Insurance* raises the question of what 'business-as usual' (BAU) means. Manne and Richels, like other economists, present a number of fixed BAU CO_2 emission scenarios, against which various emission constraint scenarios are compared. Since these scenarios involve CO_2 emissions increasing over time, the gap between BAU and fixed emissions increases over time (in less sophisticated economic analyses than undertaken by Manne and Richels, this alone causes the cost of CO_2 limitation to increase over time). However, once an initial emissions constraint is imposed, even if subsequently rescinded, the future BAU trajectory would itself almost certainly have been changed forever. This is because implementation of a CO_2 emission constraint would stimulate new discoveries and technological developments that either would not have occurred at all or would have occurred much later. If the BAU trajectory itself changes continuously as a CO_2 constraint is maintained, then the increasing gap between the CO_2 constraint case and the initial BAU trajectory is not particularly meaningful. This being the case, the benefits of an early hedging policy to limit CO_2 emissions are increased.

In summary, *Buying Greenhouse Insurance* has stimulated this reviewer to think about the costs of controlling CO_2 emissions, and in this sense, achieves one of its stated objectives. The authors have gone a long way toward bridging the differences between earlier macro-economic based analyses, which generally concluded that constraints on CO_2 emissions would entail enormous costs, and bottom-up or engineering based analyses, which conclude that very large reductions are possible at little to no cost. However, there are a number of features in the analyses by Manne and Richels which lead the present viewer to conclude that the estimated costs of constraining CO_2 emissions, given carefully designed policies, are still too high. For those wishing to follow the main developments in economic thinking on global warming, *Buying Greenhouse Insurance* is essential reading. However, as the authors themselves would undoubtably agree, much more work remains to be done before any firm conclusions can be drawn.

References

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