Constraints on Alternative Energy-Producing Technologies and End Points in the Amelioration of Global Warming

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May, 2017

Extended Abstract

The mitigation of global warming produced by emissions from burning fossil fuels, has become a significant issue in many parts of the world. The potential for disaster is well understood. Indeed, scientists have indicated that to reduce the risk of large-scale loss of human life, current emissions of these greenhouse gasses need to be reduced by 80% by the year 2050 and lowered to zero sometime after that.[1] Responding to this situation, countries attending the UN Climate Change Conference held in Paris in December of 2015 pledged to reduce emission to zero sometime during the second half of the 21st century.

The problem of how these reductions should be achieved, or whether they can be achieved at all,[2] has generated an enormous literature. The discussion in economics has partly focused on the timing, the rate of adjustment, and costs of emission reduction. In this context, Nordhaus [7] and Tol and Yohe [11] draw attention to the discount factor and the expected value of future damage in present terms. Others, such as Weitzman [15] have argued that structural uncertainties about climate and the potential damage of emissions are more important. Another line of argument has been pursued by Nordhaus [8] in the development of the DICE model and the use of it to evaluate policies, such as carbon taxation, that would reduce emissions through the operation of market forces. The DICE model has been extended by Popp [9], [10] to permit

[1] See, for example, Intergovernmental Panel on Climate Change [5].
[2] Trainer [12] has suggested that the 80% emission goal cannot be achieved by supply-side action.

technological change and include the development of carbon-free sources of energy. Optimal control models examining the effects of knowledge accumulated by either R&D or learning-by-doing that trace out optimal emission paths based on cost-effectiveness and cost-benefit criteria have been developed by Goulder and Mathi [4]. And Acemoglu *et al* [2] consider the prevention of environmental "disaster" from emissions in a model that produces output with combinations of machines that degrade the environment and those that do not.

In public policy and energy studies attention has centered on the properties of energy sources and the mix of those sources required to reduce emissions (e.g., Abbott [1], Lenzen [6], and Weissbac *et al* [14]). Much of that discussion has concentrated on whether it is possible to achieve sufficient reductions by devoting available resources to renewables such as wind and solar, or whether it is necessary also to include nuclear power. Frank [3] and the US Energy Information Administration [13] have considered the costs of alternative energy sources.

It is implicitly, if not explicitly recognized in this literature that society or its policy makers have to make choices in any attempt to ameliorate global warming. Emission goals have to be set. The time period during which these goals are to be achieved needs to be determined. And the mix of alternative energy sources that will replace emission-producing productive capacity has to be worked out. But the literature typically approaches these choices, if it does so at all, in a fragmented way and the issues are often clouded by the unnecessary introduction of complicating elements such as pricing structures, discount rates, and the specification of particular production functions. When these elements are removed, the amelioration of global warming is reduced to a straightforward end-state problem.

Perhaps due to the presence of the complicating elements noted here, there are a number of general questions to which fully satisfying answers have not yet been given: How can the 'best' time-path for achieving lower-emission goals be characterized and described in a simple, direct manner? What role do the goals and the mix of alternative energy sources play in the tracing out of that time-path? Are there any limits to the goals that can be set and the mix that can be chosen that are imposed by the circumstances in which the global warming problem is set? And what are the implications for the time-path of choosing a future time at which emission goals are to be reached? Answers to these questions are likely to play an important role in devising policies to meet the pledges of emission reductions agreed to at the UN Paris conference of December 2015.

This paper provides a stripped down dynamic model that helps answer these questions by determining the best path to a specified emissions goal in an explicit time frame and with different mixes of alternative energy sources. The model is abstract, highly simplified, illustrated by a specific example, and not intended to provide a workable solution to an actual global warming problem. Nevertheless there are a number of unexpected conclusions that will likely carry over in a complex way to more general and realistic circumstances faced by policy makers. The findings relate, in part, to the constraints imposed on the setting of emission goals, and the constraints imposed on the mix of zero-emissions energy-generating sources by the capacity of the economy to produce enough of those sources to reach the goals selected.

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