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How much will it cost to reduce carbon emissions? Answers to this crucial question frequently involve simulations performed with complex economic models. More than a dozen different models have been used, leading to widely divergent forecasts. There are hundreds of variables and numerous, intricate relationships in the leading models, making it appear all but impossible to explain why forests differ. However, this analysis finds that eight key assumptions largely determine the predicted economic impacts of reaching CO_2 abatement targets. Using reasonable choices about these assumptions, the predicted costs of substantial reduction in carbon emissions are quite low or even negative – that is, carbon reduction may even stimulate economic growth.

Models, Assumptions, and Conclusions

An economic model is just a set of assumptions about the structure and functioning of the economy. It inevitably simplifies reality in order to make the model easier to analyze. Economic modelers try, with mixed results, to develop simplified yet still realistic representations of economic relationships.

Just as atmospheric models of climate change have improved through debate among practitioners, so have economic models. So-called "top-down" models, based on aggregate representations of the economy as a whole, provide a focus on overall balances and constraints, often drawing heavily on economic theory; these models often, though not always, lead to pessimistic conclusions about the costs of energy savings and carbon reduction. "Bottom-up" models begin with a disaggregated examination of the potential for energy savings and emission reduction in individual sectors of the economy, often leading to more optimistic conclusions about the potential for low-cost or no-cost savings. Debate between the advocates of these two approaches has led to some models adopting features of the other approach; as the assumptions converge, so do the forecasts.

In either style of model, two kinds of assumptions are critical: those that determine the predicted costs of abating carbon emissions, and those that estimate the value of the environmental benefits from reducing fossil fuel combustion. Abatement costs depend in part on assumptions about possible substitutions among fuels and technologies, the expected future rate of technical change, and the availability of non-fossil fuel alternatives. Abatement costs also depend on assumptions about markets and institutions, such as the extent of market distortions and low-cost savings opportunities that exist at present, the potential for international trading in emission reduction credits, and the use that will be made of carbon tax revenues.

Most models are not constructed in ways that can take account of the environmental benefits of reduced fossil fuel consumption. However, a few models do factor in these benefits, including both the avoidance of climate change damages, and the reduction in other air pollution damages such as acid rain and human health hazards. These factors, along with the abatement cost assumptions, large explain why models predict such different economic costs of stipulated emission reductions. “Under a reasonable standardized set of assumptions, most economic models would predict that the macroeconomic impacts of a carbon tax designed to stabilize carbon emissions would be small and potentially favorable.” [8]

How the Assumptions Determine the Predictions

To clarify how the key assumptions shape a model’s economic predictions, the authors analyzed 162 different predictions from 16 of the leading models. Each of the models has been used repeatedly, with differing input assumptions leading to differing forecasts. Each forecast includes a predicted percentage change in GDP in some future year (relative to the expected baseline GDP if there were no new climate change policies), and a corresponding percentage change in CO_2 emissions in the same year. Forecasts involving a 35% reduction in CO_2 emissions relative to baseline, for example, ranged from a 1.5% increase in GDP above the projected baseline to a 3% decrease.

A statistical analysis of the 162 predictions shows that just eight assumptions, plus the level of reduction in emissions, account for 80% of the variation in predicted economic impacts. (Emission reduction alone accounted for only 35% of the variation.) Four of the eight assumptions stand out as having the greatest effects:

1. *Does the model assume that the economy always adapts efficiently to changed conditions, at least in the long run, or does it assume that there can be persistent inefficiencies?* Efficient adaptation leads to lower predicted costs of emission reduction.

2. *Will international “joint implementation” of emission reduction, such as trading emission rights between countries, be achieved?* Predicted costs are lower with joint implementation.

3. *Will government revenues from a carbon tax or from auctioning emission permits be “recycled” in the form of reductions in distorting other taxes?* Costs are lower with revenue recycling.

4. *Does the model include non-climate economic benefits from air pollution abatement?* According to the models, the non-climate benefits of reduced air pollution are much more valuable, in the near term, than the climate benefits.

The other four assumptions have a smaller but still noticeable impact on predictions of the GDP change associated with a given level of emission reduction.

5. *How much scope for inter-fuel and product substitution does the model assume?* The more substitution is possible, the lower the predicted costs of emission reduction.

6. *Does the model assume that "backstop" non-fossil energy sources are available at a constant cost?* The availability of a backstop energy source (such as solar power) limits future energy price increases, thereby lowering the costs of emission reduction.

7. *Does the model include economic benefits from avoiding or reducing climate change?* Inclusion of climate change benefits makes the net cost of emission reduction lower.

8. *How many years does the model assume it will take to reach a CO_2 reduction target?* Slower reduction is less costly.

With best-case assumptions in all or even most of the eight areas, economic models predict that reduction of carbon emissions will actually increase GDP in 2020 relative to baseline. Conversely, with worst-case assumptions in each of these areas, economic models predict that substantial reduction in carbon emissions will impose a loss in GDP relative to the business-as-usual case. For example, consider the target of reduction of carbon emissions to 1990 levels by 2010 and stabilization at that level thereafter. Under the least favorable assumptions in the eight key areas, meeting this target would reduce U.S. GDP by 2.4%, relative to baseline. Under the most favorable assumptions, meeting the same target would increase U.S. GDP by 2.4%. Either way, the impact on U.S. economic growth over the next two decades would be negligible.

Further Modeling Issues

Many additional issues have been raised (and are discussed in the original essay) concerning long-run economic modeling of energy use, carbon emissions, and climate change. Top-down models typically assume that all cost-effective improvements in energy efficiency have already been made, an assumption that is repeatedly contradicted by actual experience. On the other hand, bottom-up models have sometimes identified vast inefficiencies in current energy use, perhaps understating the costs of converting to new technologies.

International joint implementation, the subject of one of the key assumptions, has been tried only in experimental pilot programs to date. Many details remain to be ironed out before this is a workable policy; still, the modeling results highlight its importance. Similarly, the models emphasize the significance of recycling of carbon tax or emission permit revenues via cuts in other taxes. A lively theoretical debate among economists has addressed the exact nature and magnitude of the benefits from recycling environmental tax revenues, but revenue recycling clearly should be part of a climate change mitigation strategy.

Predictions that a carbon tax or a cap-and-trade policy to reduce CO_2 emissions would seriously harm the economy are unrealistic. They stem from worst-case modeling assumptions. Under more reasonable assumptions and preferable policy approaches, a carbon tax is a cost-effective way of reducing the risks of climate change and would do no damage to the economy. More likely, taking the environmental effects into account, it would bring long-term benefits. [36]