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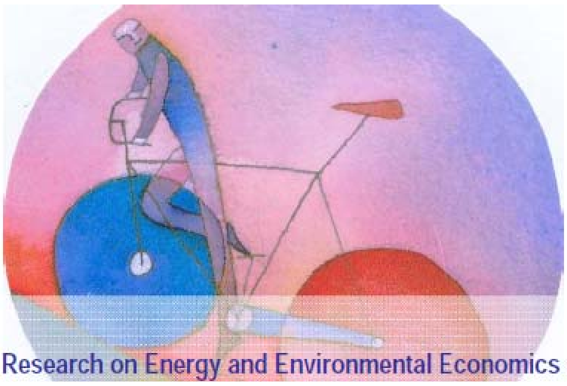

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# Modeling Climate Change Mitigation Options: A Review of Tol's Contribution to Copenhagen Consensus

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# Modeling Climate Change Mitigation Options: a Review of Tol's Contribution to Copenhagen Consensus

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ABSTRACT

*Copenhagen Consensus Center organized an initiative, in which an Expert Panel of outstanding economists convened in Washington DC in September 2009 to compile a prioritized list of specific solutions in the fight against Climate Change. The basis for the discussions and the ranking were Assessment Papers prepared for five different categories of solutions to Climate Change. Richard S.J. Tol was in charge of writing the Assessment Paper on Traditional Mitigation policies, by reviewing the existing frontier academic literature and presenting the economic costs and benefits of relevant solutions together with the strengths and weaknesses in the applied methodology. To ensure complete information on each category of solutions, all Assessment Papers were balanced by alternative views by one or two economists, preparing a critical Perspective Paper. This is one critical review of Tol's contribution.*

*Keywords*: Climate Change, Integrated Assessment Models, Mitigation, International Environmental Agreements.

*JEL classification*: C68, F18, Q52, Q54, Q56

**Introduction**

The purpose of this paper is to critically review Richard Tol's Assessment Paper on Traditional Mitigation, prepared for the Copenhagen Consensus Centre.
This Perspective Paper should therefore provide a counterbalance to the Assessment Paper, thus ensuring the Expert Panel a comprehensive presentation of Climate Change and its viable solution.

The Assessment Paper includes three parts. The first part is a general survey on economic modelling of climate change impacts, whose content is basically the same of a recently published paper (Tol, 2009). This is a very useful overview, which is, however, only indirectly related to mitigation policy. The second part provides some information about the structure and characteristics of the FUND model, which is used to simulate a number of alternative mitigation policies, all based on carbon taxation or emissions trading. Much of the material here is drawn from the technical documentation of the model, available at www.fnu.zmaw.de/FUND.5679.0.html.
The third part illustrates the simulation exercises and comments the results. The working hypothesis here is the availability of a budget of $250 billions per year for a period of ten years, to be spent on climate change mitigation. The FUND model is used to explore a number of policy options, ranking them in order of benefit/cost ratio.

Since the FUND model is central to this analysis, it is importanto to understand its structure, potential and limitations. I will address this issue in the second section of this Perspective Paper. Only after knowing something more about the model capabilities, we shall understand how much we should trust the results, and how they could possibly be interpreted.

In a third section I shall focus on the numerical exercise and output of the model. Finally, a concluding section provides some overall evaluation of the Assesment Paper, proposing also some general thoughts about climate change mitigation policies.

**The FUND Model**

In the FUND web page, one can read:

> *It is the developer's firm belief that most researchers should be locked away in an ivory tower. Models are often quite useless in unexperienced hands, and sometimes misleading. No one is smart enough to master in a short period what took someone else years to develop. Not-understood models are irrelevant, half-understood models treacherous, and mis-understood models dangerous.*

This is true. However, I would add that results cannot be trusted, especially for policy guidance, without a certain degree of understanding of model characteristics. Models should never be black boxes. Furthermore, models are based on a number of assumptions and simplifications, which must be recognized when assessing the output of numerical simulations. This is precisely why I am starting this Perspective Paper by looking at the structure and features of the FUND model.

The most recent technical description of the model is Anthoff and Tol (2008). Unfortunately, this document does not completely describe the model structure, but deals primarily with the climatic and impacts modules. That is, how emissions translate into temperature changes and how a number of climate change impacts are valued. Nothing is said about the number of sectors considered, substitution possibilities, trade, income and capital flows.

Still, one can understand a number of key features of the model. Perhaps the most relevant one is: population and per capita income follow exogenous scenarios. This should mean that there is no fully-fledged (dynamic) economic model inside. Also, neither climate change impacts nor policy (mitigation or adaptation) affect (potential) economic growth. Actual growth is influenced by a number of impacts, modelled by specific equations, in which one impact (often, but not always, valued in monetary terms) is a function of temperature (level and change). The ad-hoc equations appear to be reduced-form relationships derived from sectoral micro-studies. The reliability of these selationships therefore depends on the quality of the underlying studies, which seems to be variable. For example, the most recent version of FUND includes an extreme weather module, expressing the economic damage due to an increase in the intensity of tropical storms. I was quite surprised to find such a function in the model, as I know there is no consensus among climatogists about how and whether climate change affects the number, location and intensity of storms.

Another rather obscure point is the link between impacts and national income, on one hand, and between costs and GDP, on the other hand. National income is a flow variable, accounting for market transactions, but impacts relate also to stock variables (e.g, water resources) and non-marketed goods and services (e.g., ecosystems).

Mitigation and adaptation costs are not always macroeconomic costs, because what is cost for one individual may be income for another individual. For example, suppose that dikes are built to protect the seacoast, or expenditure on health services prevents the spreading of diseases, related to climate change. These are monetary transactions between agents within the same economic system. There is no loss of primary resources; therefore only second order effects (whose sign is a priori ambiguous) affect GDP and income.

How these costs are considered in the FUND framework, and how income is influenced? Do these costs enter in the cost/benefit ratios? We do not really know.

Carbon dioxide emissions are calculated on the basis of the Kaya identity, therefore depend on economic growth, as well as on energy and carbon efficiency. Energy and carbon efficiency may be affected by policy intervention, but it is not clear how. Methane and nitrous oxide emissions are exogenous. SF6 emissions are linear in GDP and GDP per capita (exougenously given). Sulphur dioxide emissions follow grow with population (elasticity 0.33), fall with per capita income (elasticity 0.45), and fall with the sum of energy efficiency improvements and decarbonisation (elasticity 1.02). There is no option to reduce SO emissions.

The FUND model does not (explicitly) account for technological progress (except through trends in efficiency improvements, and other ad-hoc formulations of abatement costs). It is not possible to simulate policies aimed at fostering climate-friendly technologies. There are no backstop technologies. All these characteristics suggest that mitigation and adaptation costs may be overestimated.

What policy instruments are available in FUND and what policies can be simulated? Again, this is not well explained in the technical documentation, but the simulation exercise illustrated in the Assessment Paper relies on a pure carbon tax which, ideally, would be equivalent to a perfect emissions trading regime (with no exemptions, no transaction costs, no uncertainty and - I think - no banking). Still, even if we are sure that carbon taxation can be simulated, it is not clear how this brings about a reduction of emissions in the model and how tax revenue is redistributed (or, equivalently, how emissions rights are allocated). What is known from other papers and models is that the way rights are allocated does make a huge difference in the results. Property rights or redistribution schemes can be cleverly desigend to realize a system of incentives which could dramatically lower the costs of mitigation and adaptation policies, especially when these are linked to technological improvements, knowledge and research.

**Simulation Scenarios**

Copenhagen Consensus 2009 hypothetically dispenses $250 billion per year on climate policy for a period of 10 years. Five scenarios are considered in the Assessment Paper.

In the first scenario, the countries of the OECD implement a uniform carbon tax such that the net present value of the abatement cost equals $2 trillion, the net present value of $250 billion per year for ten years. The discount rate is 5% per year (which is a lot!). Costs are discounted to 2009. This is achieved by a carbon tax of $700/tC, starting in 2010 and rising with the discount rate. The carbon tax is zero from 2020 onwards.

In the second scenario, all countries implement a carbon tax of $250/tC in 2010, rising with the discount rate, but returning to zero in 2020. This also leads to an abatement cost of $2 trillion.

In the third scenario, it is assumed that climate policy after 2020 will continue as before. That is, the carbon tax keeps rising with the discount rate between 2020 and 2100.

In the fourth scenario, for ten years, $250 billion is invested in a trust fund. This trust fund finances a century-long programme of emission abatement such that the net present value of the abatement cost over the century equals $2 trillion. This is achieved by a uniform carbon tax for all countries, which starts at $12/tC in 2010 and rises with the discount rate.

In the fifth scenario, only a part of the $250 billion is invested. The carbon tax in 2010 is set equal to the Pigou tax ($2/tC), also known as the marginal damage costs of carbon dioxide emissions and the social cost of carbon. The carbon tax is applied world wide, and equal for all countries.

Before looking at the results, let me comment the characteristics of the five scenarios, and what we should expect. Using Tol's own words (Tol, 2009):

> *Climate change is the mother of all externalities: larger, more complex, and more uncertain than any other environmental problem. The sources of greenhouse gas emissions are more diffuse than any other environmental problem. Every company, every farm, every household emits some greenhouse gases. The effects are similarly pervasive. (...) Climate change is also a long-term problem. Some greenhouse gases have an atmospheric lifetime measured in tens of thousands of years.*

Therefore, if the climate change externality is "so much global" (in terms of space and time) we can expect that policies, which affect a limited number of regions for a limited number of years, should be quite ineffective, whereas policies involving all countries for long time should be preferred. We do not need a model to understand this.

Second, in which sense is a carbon tax "a cost"? From basic public and welfare economics we know that any tax generates revenue, and revenue should be accounted for in the total welfare, as well as in the Gross Domestic Product. Costs associated with taxation are only due to price distortions (e.g., deadweight losses) and dynamic inefficiency (if one can prove that the economy grows less because of taxation). We do not know if and how the carbon tax revenue has been redistributed in the model. As mentioned above, this little detail makes a lot of difference in the real world.

A similar kind of reasoning applies to the third and fourth scenarios, where money goes to emissions abatement. Let me first say that forcing the economy to spend the money in emissions abatement is like adding a constraint, so results cannot be better than the case where a price for carbon is introduced, but consumers and firms are free to choose whether to reduce emissions, or to abate, etc. Anyway, who gets the money spent on carbon abatement? This is left unexplained.

The last scenario departs from the CCC prescriptions, and simply applies a Pigouvian tax. Surprisingly, the author assumes, as something obvious, that the marginal damage cost of carbon emissions is known and equal to only $2/tC. But this is not at all obvious. There is no consensus on this and many alternative estimates are available in the literature. Furthermore, I think that the same model used for the simulation exercises (FUND) has also been used to estimate the marginal damage cost! Now, in a perfect world with perfectly competitive markets, the introduction of a perfect Pigouvian tax is first-best policy, which must bring about a total welfare improvement, unless the tax is paid to the Mars economy.

Having said all this, now let us look at the results and see whether we can find any surprise.

The two policy scenarios that concentrate effort in the first decade are less effective than the scenario that spends the same amount of money over the century. This does not come as a surprise. Even the \$2/tC century-long policy is about as effective in the long run as the \$250/tC decade-long policy, and at a fraction of the cost. If the \$250/tC initial carbon tax is maintained over the century, carbon dioxide emissions fall by more than 90% in 2050 and by almost 100% in 2100 compared to the baseline; 2050 emissions are some 20% of 2000 emissions in this scenario. No surprise.

Emissions respond only slowly to policy, and concentrations respond even more tardily. A \$12/tC initial carbon tax would almost stabilise the CO2 concentration at around 680 ppm. An initial carbon tax of \$250/tC would keep the concentration below 450 ppm; as other greenhouse gas are uncontrolled, the temperature continues to rise to 2.4ºC above pre-industrial in 2100.

Table 3 in the Assessment Paper shows the net present costs and benefits as well as the benefit-cost ratios of the five alternative policy scenarios. The five scenarios are ordered in the intensity of climate policy in the OECD in the coming decade. Starting at the bottom, spending a lot of money on carbon dioxide emission reduction in the near term in the OECD does not pay off, as expected. A much greater benefit can be achieved if the same money is used to finance worldwide abatement – essentially because emission reduction is cheaper in poorer countries – but the benefit-cost ratio is about 1 to 100. If the same programme is repeated decade after decade, abatement costs go up considerably but benefits rise even faster. Still, the benefit-cost ratio is only 1 to 50. The benefit-cost ratio improves considerably if the \$250 billion is spend over the century rather than over the decade, of course. A benefit-cost ratio is of 1 to 4 is the result. If the initial carbon tax is set equal to the estimated marginal damage cost, the benefit-cost ratio unsurprisingly exceeds unity: 3 to 2. Over the century, this policy spends only 1/20th of the funds (hypothetically) available to the Copenhagen

Consensus.

**Conclusion**

FUND is an interesting model whose main advantage is the integration, often in the form of reduced-form relationships, of many sectoral micro models, coming from different scientific areas. This is very important in a field like climate change science, which is intrinsically multi-disciplinary. This advantage, however, becomes a disadvantage to the extent that heterogeneity in the model components creates internal inconsistency. How severe a problem like this can be in the FUND model is difficult to say, as its technical documentation is not very informative.

Richard Tol's Assessment Paper on Climate Change Traditional Mitigation, prepared for the Copenhagen Consensus Centre, is largely based on the FUND model and the results of a set of simulation exercises, where a number of policy options are explored and assessed. In this Perspective Paper, I pointed out a series of limitations of the FUND model, as well as some other points, which remain quite obscure and limit the interpretation of the results. However, when considering the simulation scenarios, I also made some general remarks, which are confirmed by the model results and bring me to think that we could have got about the same findings with a different model (or possibly without any model at all!). In other words, we can trust the results even if we do not trust the model.

Furthermore, the considerations above bring me to think about the usefulness of assessing mitigation policy through numerical simulation, in which hypothetical but simple carbon taxation or emissions trading scheme is implemented. Mitigation policy in the real world is much more complicated. Think about the European Trading System (ETS), as an example. There are industries exempted, there are relevant transaction costs, informational asymmetries, uncertainty. In short, there are many implementation details that cannot be easily captured by a stylized model, but ultimately may make a difference between a successful and an unsuccessful scheme. In this sense, I think the keyword should be “incentives”. Successful mitigation policies should aim at creating systems of incentives (often implying positive externalities), especially in the presence of technological and organizational innovation.

I am a modeller myself and I am naturally sympathetic to all efforts aimed at using quatitative tools for policy assessment. There is no perfect model and all models imply simplifications of some kind. The important thing is not to hide them under the carpet, which, in this context, would take the form of complicated set of equations, unexplained assumptions, etc. This kind of danger is much more present in a multi-disciplinary Integrated Assessment Model, like FUND, because, for example, it would be very difficult for an economist like me to notice that an equation in the climatic sub-model is inconsistent with another one, say about impacts on water resources.

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