Fondazione Eni Enrico Mattei

The White House and the Kyoto Protocol: Double Standards on Uncertainties and Their Consequences

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NOTA DI LAVORO 89.2006

JUNE 2006

CCMP – Climate Change Modelling and Policy

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Summary

This paper compares the level of uncertainty widely reported in climate change scientific publications with the level of uncertainty of the costs estimates of implementing the Kyoto Protocol in the United States. It argues that these two categories of uncertainties were used and ignored, respectively, in the policy making process in the US so as to challenge the scientific basis on the one hand and on the other hand to assert that reducing emissions would hurt the economy by an amount stated without any qualification. The paper reviews the range of costs estimates published since 1998 on implementing the Kyoto Protocol in the US. It comments on the significance of these cost estimates and identifies a decreasing trend in the successive estimates. This implies that initially some of the most influential economic model-based assessments seem to have overestimated the costs, an overestimation that may have played a significant role in the US decision to withdraw from the Protocol. The paper concludes with advocating that future economic estimates always include uncertainty ranges, so as to be in line with a basic transparency practice prevailing in climate science.

Keywords: United States, Kyoto Protocol, Cost Estimates, Uncertainties

JEL Classification: Q5, Q54, Q58, C82

This paper is also circulated as Environmental Economics and Management Memorandum # 47, Chaire Lhoist Berghmans, CORE, Université catholique de Louvain, Belgium.

The authors thank Vincent van Steenberghe and Thierry Bréchet for valuable comments on an early draft of this paper and Stephen J. DeCanio and Saon Ray for relevant references.

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"The Kyoto treaty would have wrecked our economy, if I can be blunt."
George W. Bush, President of the United States,
interview to *ITV*, July 4, 2005

"Many people have falsely assumed that you have to choose between protecting the environment and protecting the economy. Nothing could be farther from the truth. In California, we will do both. (…) Pollution reduction has long been a money saver for businesses. It lowers operating costs, raises profits and creates new and expanded markets for environmental technology."
Arnold Schwarzenegger, Governor of California,
The Independent, July 3, 2005

1. Introduction and Plan of the Paper

On the eve of the 2005 G-8 Summit in Gleneagles, the President G.W Bush seems to have admitted - 13 years after his father, who signed and got ratified the United Nations Framework Convention on Climate change (UNFCCC) - that the scientific basis of climate change was sound and that it is time for some action. Besides downplaying scientific assessments during five years on grounds of remaining large uncertainties, the US federal administration hampered the political process towards the Kyoto Protocol ratification on grounds of economic analysis results. The rationale behind the US stance can be summarized as follows:

1) Developing countries are not assigned targets in the Kyoto Protocol; this puts the US economy at a disadvantage as compared to competitors from developing countries, especially China, India and Brazil.
2) The domestic economic impact of implementing, by 2012, the 7% reduction of emissions relative to 1990 emission level required by the Kyoto Protocol is too costly for the US economy.

Notwithstanding the rationale for the exemption given to developing countries at this stage of the process[2], it is surprising that those who argued for years that uncertainties about the science of climate change were a good reason for delaying action did not refer to any uncertainties that might conceivably affect the *economic* assessment underlying the above mentioned positions.

[2] Explicit in the UNFCCC. See the principle of "common but differentiated responsibilities" in the Convention and the principles of Art. 3.1 on leadership from developed countries.

This paper compares, in Sections 2 and 3, the orders of magnitude of these two kinds of uncertainties: those dealt with in the scientific assessment of projected global temperature change and those associated with the cost assessments of implementing the Kyoto Protocol in the US. While such comparison deals with variables of totally different nature (global temperature *vs* emissions reduction costs) and relating to different time scales (100 years vs 10 years, respectively) the comparison is nevertheless logically feasible, as we shall show. It is also instructive if only to reiterate the importance of rendering explicit, in the policy making process, the levels of uncertainty associated with model-based projections in *both* climate physics and economics.

In Section 4, we discuss various aspects of the cost estimates of greenhouse gas emission reductions, and offer some suggestions as to how the estimates should be communicated. In Section 5, the paper reviews the published range, since 1998, of costs estimates of implementing the Kyoto Protocol in the US. It identifies a trend showing that initially, the economic model-based assessments have overestimated these costs and that such overestimation played a significant role in the US decision to withdraw from the Protocol. In section 6 we conclude with further suggesting that the cost of implementing the Kyoto Protocol in the US be reassessed on the basis of updated models and data, and that the associated uncertainties be made public.

2. The range of scientific uncertainties

The IPCC Third Assessment Report (IPCC, 2001a) indicates that for an emission path consistent with a stabilisation level of 550 parts per million (ppm) of carbon dioxide in the atmosphere (B1 family of emission scenarios), the Earth global temperature rise in 2100 would be ranging from about 1.4°C to 2.6°C[3] relative to 1961-1990 mean observations. For emissions scenarios with larger emissions (A1FI family of scenario), the Report indicates results that range from 3.3°C to 5.6°C[4] (cfr. **Figure 1** and **Table 1**). These estimates of uncertainties on global temperature change illustrate differences in results obtained with alternative climate models for given GHG concentrations.

3 IPCC-SYR, Figure SPM-10b, p.34. The figures given in IPCC, 2001, WG I Report, p. 70. figure 22 are slightly different (1.5°C to 3°C) because the set of model used is not identical.

44 IPCC-SYR, Figure SPM-10b, p.34. The figures given in IPCC, 2001, WG I Report, p. 70. figure 22 are slightly different (3.5°C to 6.1°C) because the set of model used is not identical.

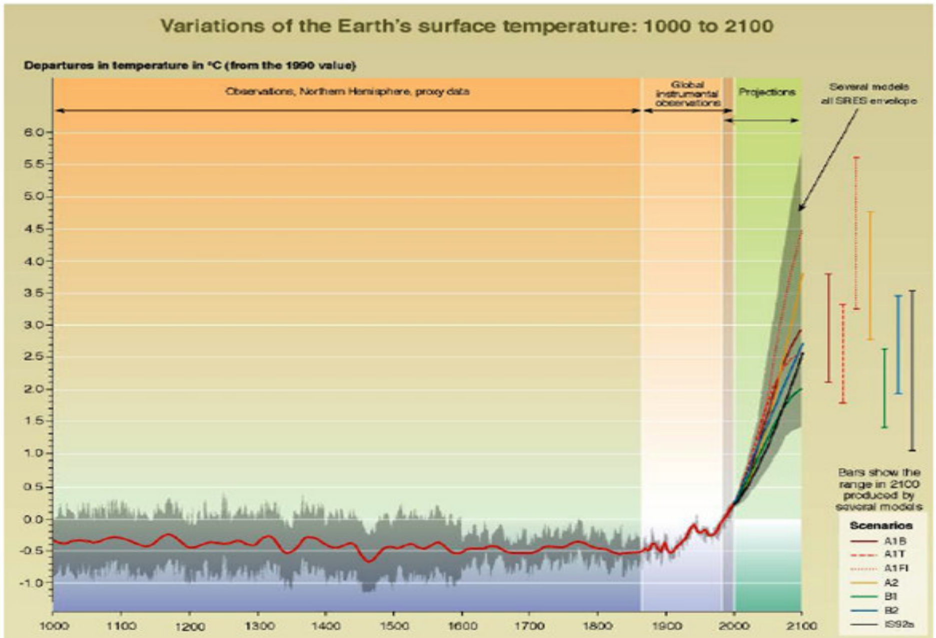

Figure 1: Simple climate model results. Global mean temperature projections for the six illustrative SRES scenarios (IPCC, 2000) using a simple climate model tuned to a number of complex models with a range of climate sensitivities. IS92a results are taken from previous IPCC estimates (IPCC, 1995). The darker shading represents the envelope of the full set of thirty five SRES scenarios using the average model results. Source : IPCC, 2001a. IPCC-SYR, Figure SPM-10b, p.34.

When these model-based uncertainties are combined with the uncertainties on emission scenarios, the range of simulated global temperature changes for all IPCC-SRES (2000) scenarios is estimated to be from 1.5°C to 5.8°C[5] for the year 2100. The IPCC (2001a) report did not specify any likelihood considerations on these estimates. This range turned out to revise the top-range value which was previously 3.5°C in IPCC Second Assessment Report. Schneider (2001) and Reilly et al. (2001) argued that the absence of any probability assignment would lead to confusion, as users select arbitrary scenarios or assume equiprobability. As a remedy, Reilly et al. estimated that the 90% confidence limits were 1.1 to 4.5°C. Using different methods, Wigley and Raper (2001) found 1.7 to 4.9°C for this 1990 to 2100 warming.

5 IPCC, 2001, WG I Report, p. 527.

	Min (°C)	Max (°C)	Mean (°C)	Standard deviation (°C)	Coefficient of variation
Temperature change: scenarios compatible with 550 ppm CO_2 stabilisation level	1.4	2.6	2.0	0.85	42
Temperature change: scenarios compatible CO_2 stabilisation level above 1000 ppm	3.3	5.6	4.45	1.63	37
Temperature change: All scenarios SRES scenarios	1.5	5.8	3.65	3.04	83
Range estimated in Reilly et al. (2001) with 90% confidence	1.1	4.5	2.8	2.40	86
Range estimated in Wigley and Raper (2001)	1.7	4.9	3.3	2.26	69
All scenarios	1.1	5.8	3.45	3.32	96

Table 1: IPCC projected global average temperature change in 2100 relative to 1961-1990 observations and simple uncertainty estimation. The mean and standard deviations are computed from the extreme Min and Max values mentioned. Therefore, they are somewhat overestimated in comparison with uncertainty estimates that would be based on the full set of model outputs. Sources: IPCC (2001), Reilly et al. (2001) and Wigley and Raper (2001).

In previous IPCC assessment reports, projections for global average temperature by 2100, have been estimated from 1°C to 5°C[6] in the First Assessment Report (IPCC, 1990) and from 1 to 3.5°C in the Second Assessment Report (IPCC, 1995). The publication of IPCC Fourth Assessment report is due in 2007. On the basis of published model projections since 2001, the range of projected global temperature change should not differ much from the estimates published in the Third Assessment Report.

3. The range of cost uncertainties

Assessments of the total annual cost of implementing the Kyoto Protocol in the US range from US$ -63 billion to 508 billion in 2010[7]. **Figure 2** shows the total abatement cost estimates of the Kyoto Protocol implementation in the USA. The extreme scenarios are displayed with respect to trading flexibility and all scenarios meet the US Kyoto target. All models show that emissions trading substantially reduces the overall cost of meeting the Kyoto target. Cost estimates in scenarios without trading range from 41 to 508 billions US$, whereas scenarios with trade estimates range from -63 to 241 billion US$. In terms of Gross Domestic Product (GDP) loss relative to a business as usual projection, figures range from -

6The "business as usual" estimate projected is 3°C increase but the extreme BAU scenario reaches up to 5°C.

7 In this paper, costs estimates have been converted into US$ 2004 using GDP deflator from Williamson (2005).

0.4% to 4.2% for the year 2010 (**Figure 3**). The price versus GDP impact of the Kyoto target is shown in **Figure 4**. It reveals the dispersion of model based marginal abatement costs and shows that for most models the estimate of the overall cost is below 2% of GDP. The US President claimed in February 2002 that implementing the Protocol would cost US$ 400 billion (US$1992) and 4.9 millions jobs to the US economy by 2012 (Bush, 2002). However, no indication was provided neither on the model and the relevant scenario that generated these figures nor on the uncertainties attached to them.

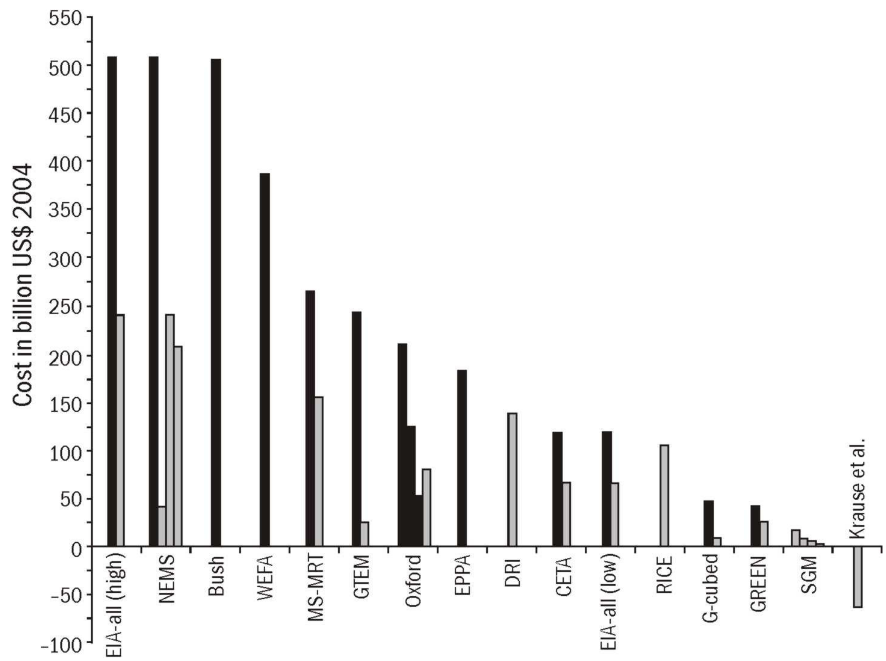

Figure 2: Total abatement cost estimates of the Kyoto Protocol implementation in the USA (billions of US $ 2004). For each model (listed on the abscissa), black bars show cost estimates in scenarios without emission trading while grey bars show estimates from scenarios with the widest trading accounted for in the scenarios' description. For some models, published estimates vary by the source (as reported when several bars appear on the figure - details are given in the source spreadsheet mentioned below) in spite of identical trading conditions. All models show that emission trading substantially reduces the overall cost of meeting the Kyoto target. Cost estimates in scenarios without trading range from -63 to 508 billions US$, whereas scenarios with trading range from 1 to 241 billion US$. Sources: Data collected from Weyant and Hill (1999), IPCC (2001b), EIA (1998), CEA (1998), Bush (2002), Lasky (2003), Krause et al (2002) and authors' calculations, as reported on a spreadsheet downloadable from http://homepage.mac.com/ph.tulkens/Work/FileSharing20.html.

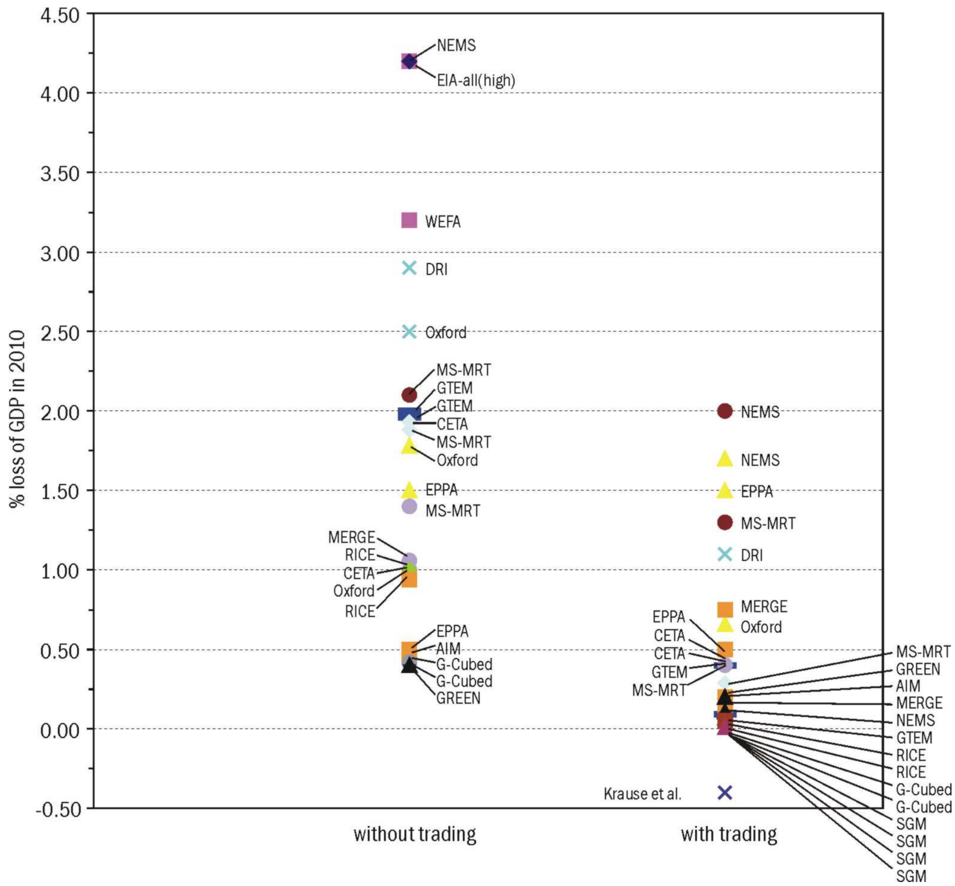

Figure 3: Total abatement cost estimates of the Kyoto Protocol implementation in the USA expressed in terms of GDP loss. As in the previous figure, the scenarios are displayed in two categories: those with no trading and those with extreme trading flexibility. All models show that emission trading substantially reduces the overall cost of meeting the Kyoto target. Cost estimates in scenarios without trading range from 0.4 to 4.2% of US GDP in 2010 whereas scenarios with trade estimates range from - 0.4 to 2.0 % of US GDP in 2010. Sources: same as Figure 2

The uncertainties that are associated with these cost estimates for the year 2012 are of course of a quite different nature from those affecting the projections of global temperatures at the end of the 21st century. Therefore a comparison of these uncertainties formulated directly in terms of the above figures would not be appropriate. However, the *orders of magnitude of the uncertainties* (expressed in a relevant statistical form) in both types of assessments can validly be compared. The aim is not to show that uncertainties on climate variables are lower than on economic variables. The magnitude of the uncertainties depends very much on which variables are chosen in the climate and in the economic models.

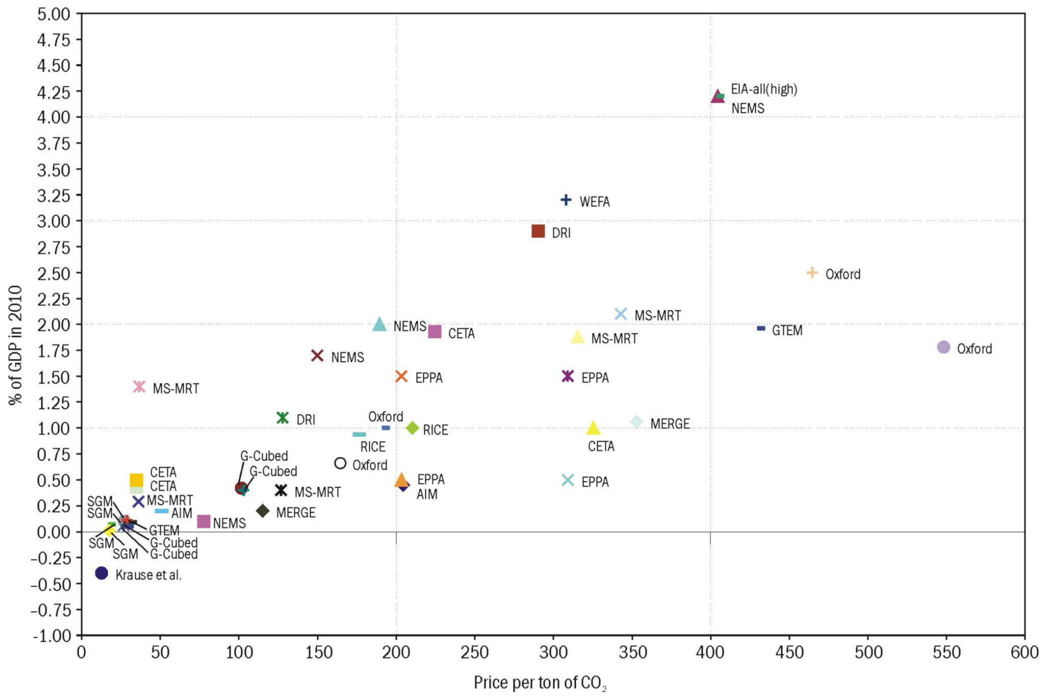

Figure 4: Model estimates of permit price and percent loss of GDP in 2010 resulting from implementing the Kyoto Protocol in the USA. Estimates from scenarios with trading and without trading are shown. The figure shows that most of the model-based estimates indicate an overall cost below 2% of GDP. Sources: same as for Figure 2

The uncertainty estimates are given in **Tables 2** and **3** in terms of total cost and of percentage of GDP loss respectively[9]**.** Accounting for the full set of projections available, uncertainties on cost estimates of Kyoto emission reductions diverge by a factor of about 500 (and not all estimates show an economic loss) whereas trends in global temperature diverge by a factor of about 4 (but all indicate a warming trend). Statistically speaking, the standard deviation and the coefficient of variation[10] indicate, in a normalised form, how large the uncertainties are for each set of scenarios and for all scenarios taken together. Such results showing very large uncertainties on costs estimates should encourage inquiry into and communication on economic uncertainties in at least as much as is done for scientific uncertainties.

9 The cost estimates for the USA depend on several factors explained in details in EIA (1998) and also commented in Lasky (2003), Barker and Ekins (2004) and Fisher and Mogernstern (2005). The point here is not to describe the reason for uncertainties but just to evaluate the level of uncertainty.

10 That is, the standard deviation divided by the mean and multiplied by 100.

Table 2: Range and uncertainty of cost estimates for the year 2010 in billions of US dollars of the Kyoto Protocol implementation in the USA

Total cost (billions US$ 2004)	**Min**	**Max**	**Mean**	**Standard deviation**	**Coefficient of variation**
Scenarios without trade	41	508	231	167	72
Scenarios with trade	-63	241	76	88	116
All scenarios	-63	508	146	153	105

Sources: see bottom of Figure 2

Lasky (2003) summarises the uncertainties on the cost of Kyoto in the USA to be in the range of 0.5 to 1.2% of GDP in 2010. Based on the same set of model studies from the Energy Modelling Forum (EMF-16), Fisher and Morgenstern (2005) estimate the uncertainties to be of a factor of five or more. But our review of the literature gathering scenarios with and scenarios without emission trading indicates a significantly wider range of uncertainty (from -0.4 to 4.2% of GDP in 2012). Among the high cost estimates, it is a figure in line with the highest estimate from the Energy Information Administration (EIA, 1998) that has been used by the US President in his address. There is no reason to leave it out of the set of estimates accounted for in an uncertainty analysis, just as estimates showing a *negative* cost should not be excluded either.

Table 3: Range and uncertainty of GDP percent loss in 2010 for the Kyoto Protocol implementation in the USA.

Total cost (% of GDP loss in 2010)	**Min**	**Max**	**Mean**	**Standard deviation**	**Coefficient of variation**
Scenarios without trade	0.4	4.2	1.75	1,14	65
Scenarios with trade	-0.4	2.0	0.46	0.57	124
All scenarios	-0.4	4.2	1.04	1,07	103

Sources: see bottom of Figure 2.

The $400 billion figure[11] is significantly higher than the highest estimate on total cost found in the peer-reviewed literature published in Weyant et al. (1999). Supposedly, the figure derived from a particular scenario that did not take into account the substantial cost lowering arising from emission trading and the implementation of the other flexibility mechanisms agreed upon in the Kyoto Protocol. However, the Marrakech Accords had been finalised since December 2001, in which extensive cost minimizing measures from global

[11] This figure was taken from estimates in US$1992. It corresponds to 508 billion US$2004 using a GDP deflator.

trading had been adopted. All economic models available at the time showed significant cost reduction (about 50%) in scenarios where emission trading had been accounted for. The White House estimate of 2002, if made on the assumption that no trading would take place in the Kyoto agreement, was derived from a basis that was no longer relevant[12].

Theses misleading facts and figures show that a balanced approach in dealing with the two uncertainties on the science and on the economics of the issue was not followed in the White House communication about the Kyoto Protocol and the existence of anthropogenic climate change. Costs estimates higher than estimates from academic studies and based on a biased selection of scenarios were given to the public and the media, without any form of qualification. This has likely contributed to the opinion-building favouring the rejection of the Kyoto Protocol by the US.

4. Ambiguities in the presentation the cost estimates of greenhouse gas mitigation.

The President's address does not specify whether the 400 billion US$ correspond to an annual cost during the Kyoto first commitment period (2008-2012) or to the cumulative costs to reach the target of minus 6% emissions relative to 1990 levels. Considering that the US GDP increases currently by about 300 billion US$ per year, Kyoto looks indeed as a potential threat to the economy that would even bring the US to a negative growth! Recently however, in their detailed look at the Energy Information Administration report (EIA, 1998), Barker and Ekins (2004) just quoted also reveal that in the scenario computed by the EIA, the emissions cut to reach the Kyoto target is assumed to be implemented over the four years 2005-2008 only, without emission trading and with a high baseline growth of CO_2 emissions from 1990 to 2005. Under these conditions, which are far from corresponding to the final Kyoto agreement, it is not surprising that a high cost estimate was produced.

But is this the right way to interpret the figures? The same Energy Information Administration (EIA, 1998 p. xii, table ES5) reports that implementing Kyoto in the US

[12] According to Baker and Ekins (2004), "the highest costs in the EIA study [that inspired the President speech in 2002] come from the worst-case assumption of a 6% cut in CO_2 emissions below 1990 levels by 2010". Moreover, the same authors note that "this result was not intended by the authors of the EIA report to be seen as the outcome of the proposed legal commitment of the Kyoto Protocol, which allows for multiple gases and flexible mechanisms, including international permit trading. It was intended to be a standardized scenario to be compared with the results of other modeling exercises, such as those by the EMF-16."

would entail a GDP loss of 4.2% in 2010[13]. In other words, in 2010, the projected GDP would be 4.2% lower than in the reference case. In terms of *annual* economic growth over the period 2005-2010, the rate under Kyoto is 1.2% whereas the projected reference growth rate is 2.0% Thus, in the scenario that contains the highest cost estimate of all economic models reviewed in this study and where benefits from emission trading are not taken into account, Kyoto would cost the US 0.8% of annual growth rate over the period 2005-2010. And the GDP in 2010 would be indeed about 400 billion US$1992 below its level in the reference case.

It is however misleading to say that it would cost 400 billion US$ in 2010 to the US economy because the way the cost impacts the economy is in fact much more complex than a direct cost immediately imputed to the GDP of the year considered. The net economic cost does indeed depend to a large extent on how the revenue of the emissions reduction policy is being recycled into the national economy. The EIA (1998) report includes a scenario where some type of revenue recycling is being considered and under that scenario, the overall cost drops to from 4.2% to 1.9% of GDP in 2010; the annual growth loss is then estimated as 0.4% instead of 0.8% in the Kyoto scenario without revenue recycling. It is very unfortunate that the results of this last scenario, although issued in the same study and with identical emission reductions targets, were not mentioned in the President's address.

Beyond this discussion of cost evaluation, in all cases the estimates of growth loss need to be interpreted in the right context. In the EIA 1998 growth scenario, the US economy would grow by 36% between 1996 and 2010. Would a growth of 31.8% instead, under the most pessimistic of the EIA scenarios, have wrecked the US economy? Current data and projections (EIA, 2006) show that over the period 1998-2012 the US GDP is likely to grow by 51 %. This means that over the same period, a scenario where in 2010 the GDP would be 4.2% lower would have implied an average annual growth rate of 2.67% instead of 3.03% in the reference case. Put this way, even the misleading high cost estimate given for the cost of Kyoto would not have done much harm to the US economy.

Few papers in the economic literature specify how cost estimates are being distributed over time. Most papers give an annual cost but fail to specify over which period the cost is

[13] The total cost of implementing the Kyoto objective in the Unites States is in most publications given in US$ (with reference to a particular year) or in percentage of US GDP in 2010. The latter metric avoids the discount rate problem and allows easier comparison of costs across years (Barker and Ekins, 2004)

being felt. However, time distribution of this cost matters. If the total cost of meeting the Kyoto Protocol target is imputed to the five year commitment period, it is very likely to be higher than if that cost were distributed over a longer period with early mitigation action taken. This is simply because of the well known differences between short run and long run costs. Allowing for time allows for cost saving adjustments that are hardly negligible. Evidence of cost savings associated with early action are reported in the literature Barker and Ekins (2004) and Kallbekken and Rive (2005). Again, providing precise information on how costs would be distributed over time would have improved the understanding of the nature of the issues involved.

In his lucid book, DeCanio (2003) raises criticisms and caution on the interpretation of economic model results used for cost assessments of GHG emissions reduction. His detailed analysis argues that all current modelling frameworks are biased towards overestimating the costs of ameliorating climate change. His conclusion is not that model projections are not useful for cost assessment. Rather, it calls the attention to the low confidence level that can be attached to point wise estimates and the ensuing necessity of presenting ranges.

The above facts on lack of explicit information on costs assessments and on their meaning have left room for the misleading interpretation referred to above. This is a strong reason for recommending that *cost estimates be communicated with uncertainty ranges and in the relevant context* to ensure proper interpretation of the models' output. Recent evidence that the Kyoto agreement is still presumed costly (witness, *The Economist* 2005[14]) shows that experts in the field did not communicate sufficiently or effectively over the proper interpretation of their claimed results. These have therefore been susceptible of political manipulation — a situation that everyone in science would like to see prevented in the future[15].

[14] "The Kyoto protocol, which is the subject of a big international meeting in Montreal this week and next, is costly and unlikely to achieve its stated aims." December 3, 2005.
[15] The thoughtful explanations given in Baker and Ekins (2004) on cost assessments and their interpretation are an example that should inspire future studies of greenhouse gas emission reduction costs assessments.

5. Actual and potential gains from model updates

5.1. Economic model-based studies

Beyond the issue of the political use in the US of costs assessments related to the Kyoto Protocol, some lessons emerge from this much debated story for economic modelling in the context of international negotiations on a possible future climate policy regime beyond Kyoto. Some but only very few publications post US Kyoto rejection looked at uncertainty estimates. Moreover, among the models involved in EMF-16 (Weyant, 1999), only Manne and Richels (2001) have included the provisions adopted in the Marrakech Accords in a modelling exercise to reassess the costs estimates for the US post US withdrawal from the agreement. Their cost estimate was of 0.75% of GDP in 2010. More recently Krause et al. (2002) found that an integrated least-cost strategy for mitigating US greenhouse gas emissions would produce an annual net output *gain* of roughly 0.4% of GDP in 2010 instead of a GDP loss. This result further extends the uncertainty of costs estimates to the basic question whether reducing greenhouse gas emissions hurt of benefits the economy.

Lasky (2003), reviewed cost assessments published from 1998 to 2000 and thoughtfully presented the figures in a consistent manner. Fisher and Morgenstern (2005) used meta-analysis on the EMF-16 model outputs to examine the importance of structural modelling choices in explaining differences in cost estimates. More recently, the US Senate (EIA, 2005) examined the cost of different proposed GHG policy programmes and compared the cost of those new proposals to the cost of implementing Kyoto. The Kyoto scenario was no longer an option in the process but merely a baseline for assessing the relative cost of other proposals. Interestingly, for the Kyoto scenario and without using the relevant model to re-compute the costs, (the estimate given is based on a scenario computed in EIA, 1998) the figure given amounts to 41 billion which corresponds to a factor of 10 lower than the cost estimated in 1998 and communicated in 2002.

The evolution of cost estimates expressed in percentage of GDP loss as published since 1999 is summarized in **Table 4**. Because complying with the Kyoto Protocol is, policywise, an outdated issue in the US, modelling projections on the cost of the Kyoto Protocol in the US has, to our best knowledge, no longer been undertaken since the study of Manne and Richels (2001) and Krause et al. (2002). This is unfortunate because, should this reassessment be made today, with the Protocol finalised as in the Marrakech Accords of 2001 and the subsequent Climate Conference of the Parties decisions (that is, accounting with multi-gas emission reduction programmes, carbon uptake in forests, updated knowledge on marginal abatement costs and trading benefits), it is very likely that the overall cost estimate projected, with the same set of models as used in the late nineties, would be much lower than previously foreseen. And, equally likely, the uncertainty margins of the estimates would be significantly reduced — if they had been stated.

Table 4: Summary of the range of GDP loss estimates of the Kyoto Protocol implementation in the USA for the year 2010, according to various sources.

Total cost (% of GDP loss in 2010)	**EIA, 1998**	**EMF-16, 1999**	**Manne and Richels, 2001**	**Krause et al., 2002**	**EIA, 2005**
Maximum	4,2	3.2	0.75	-0.4	0,004
Minimum	0,01	0,1			

5. 2. Climate model-based studies

A few years ago, when climate modellers noticed that their models tended to overestimate global warming because the aerosols representation was missing in their models (Mitchell and Johns, 1997), climate models were modified to take that phenomenon into account. New simulations results were compared to the most recent data sets available to assess the quality of the new sets of simulations. Climate modellers repeatedly compute climate projections for this century and beyond, with different versions of their models. In doing so, they not only use up-dated GHG concentration projections as input, they also reassess earlier climate change estimates with new model versions and compare their findings with their former results and with those of other modelling teams in organised model inter-comparison frameworks. Over the last decade, extensive climate model inter-comparison projects have been realised such as CMIP, AMIP, OCMIP and PMIP (cfr. relevant web sites references). Practice in model validation and verification in climatology has significantly improved, inspired directly by practices in weather forecasting. The concept of "ensemble simulation" has become a standard method to account for model sensitivity to initial conditions and key parameters. Some of these practices are transposable to modelling exercises in other fields.

In economic modelling, simulation protocols and inter-comparison projects such as done in the Energy Modelling Forum are an appropriate framework for model comparisons studies. However, our review leaves us with the impression that most economic papers published until now on the cost of Kyoto for the USA, with the exception of Lasky (2003), do not provide the full set of information necessary for in depth understanding of the results. In addition, by working systematically on different sets of scenarios, the current practice of economic modelling makes it difficult to compare results rigorously between models and between models and data sets. The adoption of experimental setups such as those in place for climate model inter-comparison projects would bring a significant improvement in economic modelling practice. In this spirit an obviously interesting exercise would be to repeat, today, an inter-comparison on the cost of implementing the Kyoto Protocol in the USA. The outcome of such exercise would give indications on the progress made in the discipline.

5.3. New data

With the implementation of emission reduction programmes (voluntary or mandatory) in various part of the world, including the US, large sets of data on observed costs are made available and could be used for a better validation of the results of the economic models.

The information so obtained is sometimes surprising. Thus, from the industry sector, - the one whose representatives have asserted for years that emission limitation would hurt business and create unemployment - some programmes recently implemented have revealed that observed costs were much lower than what had been estimated. For instance, British Petroleum saved money in its emission reduction programme within its plants. Witness John Brown, Chief executive of BP, who writes: "*Counter intuitively, BP found that it was able to reach its initial target of reducing emissions by 10% below its 1990 levels without cost. Indeed, the company added around $650 million of shareholder value, because the bulk of the reductions came from the elimination of leaks and waste. Other firms -- such as electricity generator Entergy, car manufacturer Toyota, and mining giant Rio Tinto -- are having similar experiences. The overwhelming message from these experiments is that efficiency can both pay dividends and reduce emissions* (Brown, 2004)

In Europe, the factual data that emerge from the recently implemented carbon market are as follows. On the carbon credit market, credits are exchanged between 10 and 33 $/ton

CO_2 (Point Carbon, 2006a). Project-based credits from the Clean Development Mechanism (CDM) (from developing countries) are negotiated around 6 to 27 \$/t$C0_2$ (Point Carbon, 2006b). Those data are not yet representative of the real cost of reducing emissions, however. The size of the market (in terms of the amount of credits traded) as well as its liquidity are insufficient for the recorded prices to reflect marginal abatement costs accurately. Moreover, the link between the European carbon credit market and the world market for Kyoto-based projects is also not yet in place (Lecocq and Capoor, 2005). When a sufficiently large and liquid market will operate, the current EU carbon credit market prices might change significantly. It is thus premature to conclude that the higher figures will keep prevailing.

The emerging data showing real costs should help in assessing the affordability of emission policies even in the Kyoto context. They should also assist economic modellers in better validating their forecasting tools. **Figure 4** illustrates the carbon prices in the US and the GDP impact of implementing Kyoto as projected in the studies referred to in this review. Although no direct comparison of the carbon price with observed carbon prices can be made, the orders of magnitude are indicative of the range of uncertainties, among projections and between model outputs and observations.

There are precedents of overestimation of the cost of emission reduction programmes by economic models, the most conspicuous one being the case of SO_2 emission reductions in the US. In the case of SO_2, the overestimation was considerable, as evidenced by Joskow et al., 2000. Smith et al. (1998) warn on how cautious one should be when comparing costs estimates with allowance prices and on the limits of such comparisons.

Another example seems to be the implementation of the Montreal Protocol on ozone depleting substances. No systematic assessment of the overall cost of the Montreal Protocol implementation has been done, to the best of our knowledge. However, evidence in the direction of costs overestimation is provided by DeCanio (2003, p. 146-147) and DeCanio and Norman (2005). Harrington et al. (2000) compared *ex ante* and *ex post* cost estimates for regulatory policies and found that the 28 studies taken into account had a predominant tendency to overestimate the cost *ex ante*.

Of course, the case of GHG is different and the causes for a potential overestimation of abatement costs programmes are likely not to be the same. However, because of the precedents just mentioned, the hypothesis of an overestimation of GHG emission reduction costs deserves close scrutiny.

6. Summary and Conclusion

The two quotations given at the beginning of this paper illustrate interpretations by politicians can differ on economic assessments, even when they belong to the same party. Such opposite views are, at best, a qualitative indicator of the uncertainties associated with the cost assessment of GHG emission reductions.

In the case of the Kyoto Protocol, the message conveyed by the White House was only that implementing the Protocol would cost 400 billion US$ per year by 2012 and that such cost would be harmful to the economy. We show that these figures of costs estimates were based on outdated scenarios, higher than the highest estimate available in the literature, and that the figures were not accompanied by appropriate information for a proper interpretation. One may therefore plausibly think that such biased messages conveyed to the media and the public have played a role in gaining popular support for the US rejection of the Protocol in 2001.

This review also shows that scientific evidence from economic modelling exercises performed to date does not show that the implementation of the Kyoto Protocol would have “wrecked” the US economy. Data and studies recently made available show that some of the published estimates have entailed large overestimations of the costs.

Since communicating deliberately high cost estimates obviously has political effects, researchers in this context should insist upon systematically communicating the uncertainty ranges on projected estimates and on explaining how the results should be interpreted. Economic modelling researchers in this field should take advantage of the experience acquired by climate science modellers. Systematic backcasting exercises (Schwartz et al., 2002) and *ensemble* simulations (Murphy et al, 2004) instead of a few model runs are current practice in climate modelling that may be relevant to assessing uncertainties in economic modelling. The use of similar tools for uncertainty analysis in climate and economic modelling would not only contribute to knowledge gains, it would also greatly facilitate the communication of uncertainties to decision makers[16].

Preparing and publishing revised assessments of the cost to the US of implementing the Kyoto Protocol is not only a matter of good scientific practice: it would also have an important impact on developing countries who also fear the burden of costs and tend to use the same argument as the US to postpone discussions on action from their side.

Politically, a major shift in US international policy on climate change under this presidency remains unlikely. Scientifically however, a better acknowledgment of the uncertainties associated with cost estimates of GHG emission reductions would give the economic estimates an increased credibility. Such improvement would be helpful to the worldwide policy process currently under way.

Aknowledgments

The authors thank Vincent van Steenberghe and Thierry Bréchet for valuable comments on an early draft of this paper and Stephen J. DeCanio and Saon Ray for relevant references.

[16] Some further recommendations to economic modellers are given in Peterson (2006).

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(lxxviii) This paper was presented at the Second International Conference on "Tourism and Sustainable Economic Development - Macro and Micro Economic Issues" jointly organised by CRENoS (Università di Cagliari and Sassari, Italy) and Fondazione Eni Enrico Mattei, Italy, and supported by the World Bank, Chia, Italy, 16-17 September 2005.
(lxxix) This paper was presented at the International Workshop on "Economic Theory and Experimental Economics" jointly organised by SET (Center for advanced Studies in Economic Theory, University of Milano-Bicocca) and Fondazione Eni Enrico Mattei, Italy, Milan, 20-23 November 2005. The Workshop was co-sponsored by CISEPS (Center for Interdisciplinary Studies in Economics and Social Sciences, University of Milan-Bicocca).
(lxxx) This paper was presented at the First EURODIV Conference "Understanding diversity: Mapping and measuring", held in Milan on 26-27 January 2006 and supported by the Marie Curie Series of Conferences "Cultural Diversity in Europe: a Series of Conferences.

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