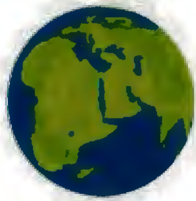

4th International Workshop
on Uncertainty in Atmospheric Emissions

7-9 October 2015, Krakow, Poland

PROCEEDINGS

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About the Workshop

The assessment of greenhouse gases and air pollutants (indirect GHGs) emitted to and removed from the atmosphere is high on the political and scientific agendas. Building on the UN climate process, the international community strives to address the long-term challenge of climate change collectively and comprehensively, and to take concrete and timely action that proves sustainable and robust in the future. Under the umbrella of the UN Framework Convention on Climate Change, mainly developed country parties to the Convention have, since the mid-1990s, published annual or periodic inventories of emissions and removals, and continued to do so after the Kyoto Protocol to the Convention ceased in 2012. Policymakers use these inventories to develop strategies and policies for emission reductions and to track the progress of those strategies and policies. Where formal commitments to limit emissions exist, regulatory agencies and corporations rely on emission inventories to establish compliance records.

However, as increasing international concern and cooperation aim at policy-oriented solutions to the climate change problem, a number of issues circulating around uncertainty have come to the fore, which were undervalued or left unmentioned at the time of the Kyoto Protocol but require adequate recognition under a workable and legislated successor agreement. Accounting and verification of emissions in space and time, compliance with emission reduction commitments, risk of exceeding future temperature targets, evaluating effects of mitigation versus adaptation versus intensity of induced impacts at home and elsewhere, and accounting of traded emission permits are to name but a few.

The *4th International Workshop on Uncertainty in Atmospheric Emissions* is jointly organized by the *Systems Research Institute of the Polish Academy of Sciences*, the Austrian-based *International Institute for Applied Systems Analysis*, and the *Lviv Polytechnic National University*. The 4th Uncertainty Workshop follows up and expands on the scope of the earlier Uncertainty Workshops – the *1st Workshop* in 2004 in Warsaw, Poland; the *2nd Workshop* in 2007 in Laxenburg, Austria; and the *3rd Workshop* in 2010 in Lviv, Ukraine.

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Sensitivity of marginal abatement cost curves to variation of G4M parameters

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Abstract

Because of the G4M model non-linearity marginal abatement cost curves (MACCs) are sensitive to variation of the model parameters, irrespective of the fact that the same parameter variations are applied in both zero-CO_2 price and non-zero-CO_2 price runs. Since integrated assessment models in general are complex computer models with non-linearity one may expect all MACCs constructed using such models are sensitive to variation of the model parameters. The MACCs constructed using G4M are much more sensitive to parameter variation at a certain range of CO_2 prices, usually low CO_2 prices. The MACCs for total biomass CO_2 emissions constructed using G4M are most sensitive to variation of corruption coefficient (measuring efficiency of use of abatement costs) and, on the second place, to agriculture land price. Experts applying MACCs for policy analysis must be aware of uncertainty features of the MACCs as the uncertainty can influence the outcome of the analysis.

Keywords: G4M, marginal abatement cost curve, sensitivity, model parameters

1. Introduction

Marginal Abatement Cost Curve (MACC) relates potential of greenhouse gas (GHG) emissions reduction over a baseline and costs of the reduction. It is often used by research institutions and governments in a number of countries for analysis of mitigation policies. MACCs are constructed, in particular using integrated assessment models. MACCs provide information for analysis of such policy instruments as implementation of a CO_2 tax or a cap-and-trade system [1].

Experts employing MACCs for policy analysis must be aware of uncertainty in the MACCs as the uncertainty can influence the outcome of the analysis. For example, in case of a CO_2 tax implementation an uncertain MACC may give wrong information on possible reduction of CO_2 emissions resulting from the implemented tax; in case of introduction of a cap-and-trade system an uncertain MACC may misinform on carbon price that could result from a certain volume of carbon allowances.

Global Forest Model (G4M) simulates afforestation, deforestation, forest management directed at sustainable wood production, response of the mentioned processes to CO_2 price incentives and respective CO_2 emissions. G4M is applied for development of MACCs including such mitigation options as enhanced afforestation, avoiding deforestation and forest management directed to both wood production and carbon sequestration [2].

This study is aimed at answering the questions: what is sensitivity of the MACCs to selected model parameters and how the parameter uncertainties can impact GHG abatement policies related to forest sector?

2. Method

We study sensitivity of MACCs to variation of three G4M parameters selected in the consultations among the project[3] partners: corruption coefficient (*cr*), wood price (*w*) [USD/m3] and agriculture land price (*l*) [USD/ha]. The corruption coefficient measures the efficiency of incurred costs for abatement: *cr*=1 (highest efficiency) means that no abatement costs are consumed by corruption and *cr*=0 (lowest efficiency) means that all costs are consumed by corruption.

We run the G4M model for a number of CO_2 price scenarios: initial prices starting in 2020 (0, 1, 3, 5, 10, 15, 20, 25, 30, 40, 50, 60, 80, 100, 120 USD/tCO_2) and rising 5% per year (that results in CO_2 price range of 4-520 USD/ton CO_2 in 2050) using standard parameter values as in [2]. For the purposes of sensitivity analysis we vary the values *cr*, *w*, and *l* mentioned above: we decrease/increase them by 1, 2.5, 5, 10, 50 and 90% (only single parameter was changed during a run). For a year within the range 2020-2050 a MACC is defined as a difference of biomass CO_2 emissions at zero CO_2 price and a non-zero CO_2 price. The emissions include afforestation, deforestation and forest management components. The parameter deviation was applied to all CO_2 price runs thus serving as a bias for MACC. For the run we used population and GDP following SSP2 scenario (https://secure.iiasa.ac.at/web-apps/ene/SspDb/dsd?Action=htmlpage&page=about), wood demand, regional agriculture land prices and wood prices were estimated by GLOBIOM model (http://www.globiom.org/) under assumption of bioenergy demand of 50PJ/year.

We calculated 12 MACC variations for each parameter. The results get the following notations: *crpV*, *crmV*, *wpV*, *wmV*, *lpV* and *lmV*, where *p* means an increase of a parameter, *m* means a decrease of a parameter and *V* means 1, 2.5, 5, 10, 50 or 90% change of the parameter. Because of limited space of the paper we present detailed analysis of MACC sensitivities to 10, 50 and 90% variation of the parameters globally as well as summary information for Brazil, Indonesia and Mexico for the year 2030.

3. Results

At 1-5% variation of the parameters deviation of the global MACC curve follows the shape of respective deviations at 10% variation of the parameters but the amplitude is smaller. At 10% variation of the parameters the global MACC curve is most sensitive when CO_2 price is 5 USD/tCO_2 (Figure 1-3). At this CO_2 price a decrease of the corruption coefficient (means more abatement costs are consumed by corruption) makes the highest impact on the MACC – the efficiency of abatement costs decreases by 230 MtCO_2/year. Increase of the corruption coefficient (means less abatement costs are consumed by corruption) has a slightly smaller effect on the MACC – the abatement increases by 229 MtCO_2/year. Agriculture land price variation influences the MACC considerably – decrease of the land price yields 172 MtCO_2/year higher abatement while increase of the land price decreases the abatement by 122 MtCO_2/year. Global MACC's deviation from a baseline (all parameters *cr*, *w*, *l* unchanged) diminishes with the increasing CO_2 price slower than the countries' MACCs considered in the study. The variation of corruption coefficient makes the maximum impact on the global MACC across the 3 parameters at CO_2 prices 1-30 and 80 USD/tCO_2. The variation of wood price makes the maximum impact on MACC across the 3 parameters at 40-60

[3] "Options Market and Risk-Reduction Tools for REDD+" funded by the Norwegian Agency for Development Cooperation under agreement number QZA-0464 QZA-13/0074.

and 100-120 USD/tCO_2. Wood price reaches its maximum impact on MACC at 15 USD/tCO_2.

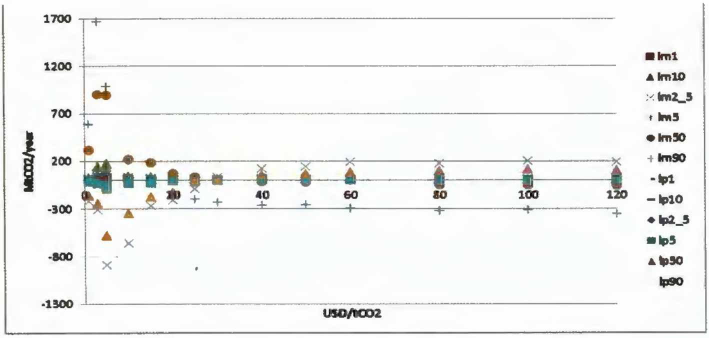

Figure 1. Sensitivity of MACC for total biomass CO_2 emissions to deviations of agriculture land price globally in 2030.

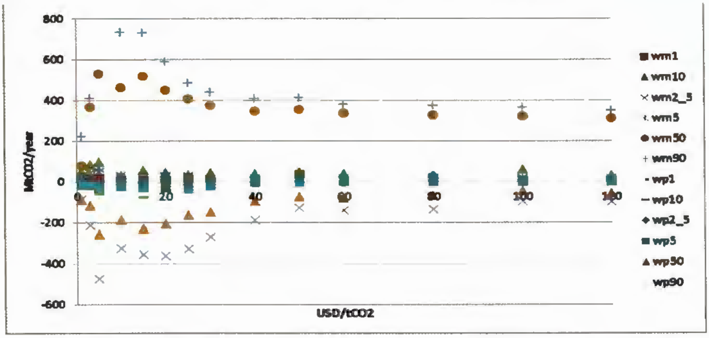

Figure 2. Sensitivity of MACC for total biomass CO_2 emissions to deviations of wood price globally in 2030.

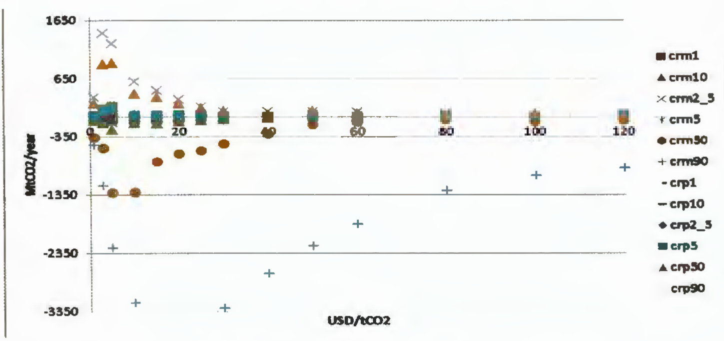

Figure 3. Sensitivity of MACC for total biomass CO_2 emissions to deviations of corruption coefficient globally in 2030.

At 50% variation of the parameters the global MACC curve is most sensitive when CO_2 price is 5 USD/tCO_2 (Figure 1-3). At this CO_2 price decrease of the corruption coefficient (means more abatement costs are consumed by corruption) causes deviation of the MACC by -1,310 MtCO_2/year. The effect of the corruption coefficient variation diminishes by 15 times to -75 MtCO_2/year at 120 USD/tCO_2. The corruption coefficient has the largest impact on MACC across the parameters at 1 and 5-30 USD/tCO_2. Wood price has a considerable effect on MACC at all CO_2 prices with maximal value of 531 MtCO_2/year at 5 USD/tCO_2 and has the largest effect across the parameters at 40-120 USD/tCO_2. Agriculture land price makes maximum impact on MACC (903 MtCO_2/year) at 3 USD/tCO_2 when it overcomes the effect of the other parameters.

At 90% variation of the parameters the MACC curve is most sensitive at 20 USD/tCO_2 (Figure 1-3). At this CO_2 price decrease of the corruption coefficient (means more abatement costs are consumed by corruption) causes deviation of the MACC by -3,477 MtCO_2/year. The effect of the corruption coefficient variation diminishes slowly and has the highest impact on MACC across the parameters at 5-120 USD/tCO_2. Agriculture land price has lower impact with maximum at 5 USD/tCO_2 (1,699 MtCO_2/year), it exceeds the impact of the other parameters at 1 and 3 USD/tCO_2. Wood price reaches its maximum impact on MACC (733 MtCO_2/year) at 10 USD/tCO_2.

The corruption coefficient has the largest impact on the MACC at all levels of the parameter changes. With increasing the amplitude of the parameter variation the maximum impact shifts from 5 USD/tCO_2 (at 10 and 50% variation) to 20 USD/tCO_2 (at 90% variation). Wood price has relatively even impact at all CO_2 prices, while agriculture land price has two picks – higher at low CO_2 prices and lower at high CO_2 prices. Increase of the parameter variation amplitude to 90% defuses the CO_2 price at which individual parameters cause maximum deviation of MACC.

For Brazil and Mexico similarly as in the global case considered above the corruption coefficient has the largest impact on the MACC at all levels of parameter variations. With increasing the amplitude of the parameter variation the maximum impact shifts from lower CO_2 prices to higher: in Brazil – from 5 USD/tCO_2 (57 MtCO_2/year) at 10% corruption coefficient increase to 10 USD/tCO_2 (-443 MtCO_2/year) at 50% corruption coefficient decrease and to 15 USD/tCO_2 (-644 MtCO_2/year) at 90% corruption coefficient decrease; in Mexico – from 10 USD/tCO_2 (-9 MtCO_2/year) at 10% corruption coefficient decrease to 15 USD/tCO_2 (-51 MtCO_2/year) at 50% corruption coefficient decrease and to 25 USD/tCO_2 (-70 MtCO_2/year) at 90% corruption coefficient decrease.

In Indonesia the corruption coefficient does not make the overall maximum impact on the MACC, nevertheless the impact is considerable especially for CO_2 prices over 5 USD/tCO_2 and large variation of the parameter. With larger decrease of the corruption coefficient the maximum of its impact on MACC shifts to higher CO_2 prices. The corruption coefficient has the largest impact on MACC across the parameters at CO_2 prices greater than 5 USD/tCO_2 for 50 and 90% variation of the parameters. Agriculture land price decrease has the largest impact on MACC at all levels of the parameter changes. With increasing the amplitude of the parameter variation the maximum impact shifts from 5 USD/tCO_2 (-28 MtCO_2/year) at 10% increase of the agriculture land price to 3 USD/tCO_2 (177 MtCO_2/year) at 50% and to 1 USD/tCO_2 (306 MtCO_2/year) at 90% decrease of agriculture land price.

4. Discussion

The parameter deviation was applied to all CO_2 price runs thus serving a bias for MACC. In this case MACC deviation is caused by the model non-linearity across CO_2 prices, i.e. different sensitivity of the emissions to the same deviation of a parameter at zero and non-zero CO_2 prices. For the studied countries and globally the emission response to alteration of agriculture land price is very high at CO_2 prices 3-10 USD/tCO_2 symmetrically to negative and positive deviations of the parameter (see Figure 4 for the global case).

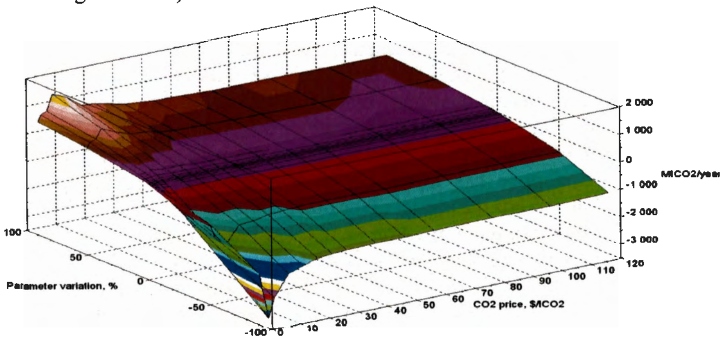

Figure 4. Sensitivity of total biomass CO_2 emissions to agriculture land price globally in 2030.

The emission response to wood price alteration has different shapes in the studied countries while the global case incorporates features of all countries. In Brazil the sensitivity is high at all CO_2 prices but at the prices 1-5 USD/tCO_2 the sensitivity changes its sign (with a maximum at 10 USD/tCO_2). The "anomaly " is explained by the fact that at some CO_2 prices increase of wood price causes increase of deforestation rate because a part of deforested wood is sold that pushes switching from forestry to agriculture. This is the effect of an interplay between agricultural land price, CO_2 price, and wood price. The effect comes from the decision-making algorithm of G4M: conversion from forest to agriculture is based on the highest level of net present value (NPV) that can be achieved by one of these land use alternatives. In this case a higher wood price is not enough for economically sustainable forestry and (as a one-time profit from selling the wood) adds an incentive for moving to agriculture (deforestation) [2]. In Indonesia the emission response to wood price is variable over the CO_2 prices with maximum deviations around 3 and 60 USD/tCO_2. In Mexico the emission response to wood price is symmetrical by the sign of the parameter variation with maximum at 10-15 USD/tCO_2. For Mexico we see the same effect of increasing deforestation with increasing wood price at 5-10 USD/tCO_2. The global picture communicates similar message: for the carbon price about 10 USD/tCO_2 an increase of wood price increases deforestation as compared to a baseline corresponding to that carbon price (10 USD/tCO_2).

The emission response to variation of the corruption coefficient has a similar shape – with a sharp maximum deflection of the emissions at CO_2 prices 3-10 USD/tCO_2 when the corruption coefficient increases (see Figure 5 for the global case). When the corruption coefficient decreases the sensitivity is high at a wide range of CO_2 prices up to the whole range if the corruption coefficient decreases by 90%.

The G4M model is non-linear on and sensitive to the variation of the *cr*, *w*, and *l* model parameters. Existence of a range of CO_2 prices under which the MACCs are very much sensitive to the variation of model parameters, is, probably, model specific and connected with simulation of decision making and values of NPVs of the alternative land uses.

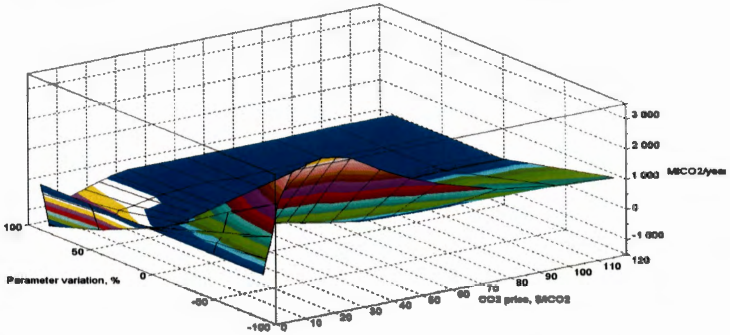

Figure 5. Sensitivity of total biomass CO_2 emissions to corruption coefficient globally in 2030 (greater coefficient means higher efficiency and less corruption).

4. Final remarks

Because of the G4M model non-linearity MACCs are sensitive to variation of the model parameters, irrespective of the fact that the same parameter variations are applied in both zero-CO_2 price and non-zero-CO_2 price runs. Since integrated assessment models in general are complex computer models with non-linearity one may expect all MACCs constructed using such models are sensitive to variation of the model parameters.

The MACCs constructed using G4M are much more sensitive to parameter variation at a certain range of CO_2 prices, usually low CO_2 prices.

The MACCs for total biomass CO_2 emissions constructed using G4M are most sensitive to variation of corruption coefficient (measuring efficiency of use of abatement costs) and, on the second place, to agriculture land price.

Experts applying MACCs for policy analysis must be aware of uncertainty features of the MACCs as the uncertainty can influence the outcome of the analysis, e.g. misinform on possible reduction of CO_2 emissions resulting from the implemented CO_2 tax or misinform on carbon price that could result from certain total carbon allowances in case of introduction of a cap-and-trade system.

Acknowledgements

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