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The problem of ranking CO_2 abatement measures: A methodological proposal

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ABSTRACT

Marginal Abatement Cost curves are considered a standard tool for analysing the impacts of mitigation measures and are one of the most used methodologies for evaluating abatement options by comparing their cost-effectiveness. Nevertheless some discrepancies regarding their construction and interpretation arose in the last few years. In this paper, we analyse the methods found in the literature for evaluating and ranking abatement measures, identify unsolved issues and propose three alternative methods. The first method, Gain Maximizing (GM), supports an environmentalist attitude and performs a direct comparison of measures with both negative and positive costs. The second, Extended MAC method (EMAC), considers an economically driven point of view, weighting the negative cost options according to its economic savings over its reduction potential. The third is a Balanced Ordering Method (BOM), consisting in a linear weighted combination of two discretional seed methods, which allows decision makers to create new rankings adjustable to a specific greenhouse gases policy, whether it is fully or partially driven by economical or environmental positions. Finally, the authors propose a methodology for comparing methods based on their Kendal tau distance to the benchmarks considered relevant in the decision making process (economical profit and environmental benefit).

1. Introduction

Decision makers face several difficulties in finding appropriate solutions to greenhouse gas (GHG) mitigation without imposing heavy economic burdens on society in the context of limited budgets and divergent interests of environmentalists or economically driven actors. Policy makers in developed and developing countries around the world are substantially committed to the reduction of carbon emissions over the coming years, since the global energy use and its corresponding emissions will grow.

Policy makers, together with governments, make use of models and tools such as Marginal Abatement Cost curves (MACC or MAC curves) to negotiate with emitting sectors and environmentalists the developing of route maps for emissions reductions with limited budgets (Moran et al., 2008). These help them to identify policies and appropriate instruments to justify investment decisions (Kesicki, 2013) and to demonstrate how much abatement an economy can afford and the area to focus on in order to achieve target emission reductions (Vogt-Schilb & Hallegatte, 2014).

MAC curves can be defined as a graphical ordered representation of energy measures, which can be used to rank these measures in terms of their specific marginal cost of reducing GHG emissions (one tonne of equivalent CO_2), or the extra cost added to the total cost for a unit of output (Paulson, 1948). More recently, Kesicki and Strachan (2011) defined a MAC curve as a "*graph that indicates the cost, usually in \$ or another currency per tonne of CO_2, associated with the last unit of emission abated for varying amounts of emission reductions (generally in million tonnes of CO_2)*".

In the challenge of designing decarbonizing policies economically efficient, policy makers rank and prioritise the available abatement measures with regard the costs and mitigation potentials by applying MAC curves. MACCs show the economic and technological feasibility of climate change mitigation, relating the marginal cost of emission abatement for varied technologic options. In other words, MACCs shows the economic and technological feasibility of climate change mitigation, by relating the marginal cost of emission abatement for varying amounts of emission reduction,

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Notations

The following concepts, symbols and acronyms are used in this article:

ΔB_m	Economic benefit generated by the energy savings for a measure m
ΔC_m	Associated net present value associated to a measure m
ΔE_m	GHG abatement potential associated to a measure m
$BOM^{\alpha}(\mu_1, \mu_2)(m)$	Balanced Ordering Method for methods $\mu1$ and $\mu2$, and a balanceα
$Cost_m$	Total cost of the measure m ($Cost_m = \Delta C_m - \Delta B_m$)
ENV	Environmentalist benchmark
GHG	Greenhouse gases
$GM(\varepsilon)$	Gain maximizing method being ε a very small value
$GM(1)$	Gain maximizing method being ε=1.
GM_m	Gain value for a measure m
GRE	Greedy benchmark
EMAC	Extended MAC method
$EMAC_m$	Extended MAC value for a measure m
MACC	Marginal Abatement Costs Curve
MAC_m	Marginal cost of abating a tonne of CO_2 for a measure m
m	Measure
NPV	Net present value
$sign(x)$	Sign of x
τ_{MAC}	Set of ordered measures applying method MAC
τ_{Ward}	Set of ordered measures applying method Ward
τ_{Taylor}	Set of ordered measures applying method Taylor
$\tau_{GM(\varepsilon)}$	Set of ordered measures applying method GM(ε) being ε a very small value
$\tau_{GM(1)}$	Set of ordered measures applying method GM(ε) being $\varepsilon = 1$
τ_{EMAC}	Set of ordered measures applying method Emac
$K\left(\tau_{\mu_1}, \tau_{\mu_2}\right)$	Kendall tau distance between methods μ_1 and μ_2

becoming a standard tool to illustrate the economics of climate change mitigation as a tool for policy analysis (Kesicki & Ekins, 2012; Kesicki, 2012).

MAC curves are considered a standard tool, especially for analysing the impacts of the Kyoto Protocol (Contreras, 2016; Ellerman, Jacoby, & Decaux, 1998; Klepper & Peterson, 2006). Several applications are found in agriculture (Bockel, Sutter, Touchemoulin, & Jönsson, 2012; MacLeod et al., 2010; Moran et al., 2008; Moran et al., 2010), shipping (Magnus, Tore, Peter, Øyvind, & Stig, 2011), building (Mortimer, Ashley, Moody, Rix, & Moss, 1998; Ibn-Mohammed, Greenough, Taylor, Ozawa-Meida, & Acquaye, 2013; Kuusk, Kalamees, & Maivel, 2014), the cement industry (Szabó, Hidalgo, Císcar, Soria, & Russ, 2003), watercycle (van Odijk, Mol, Harmsen, Struker, & Jacobs,, 2012), transport (Kok & Annema, 2010), non-CO_2 greenhouse gases (Gallaher, Petrusa, & Delhotal, 2005) and policy making (Kesicki, 2010; Morthorst, 1994; Toke & Taylor, 2007).

Although MAC curves are proven to be extremely efficient in communicating results regarding the economic implications of climate mitigation by reporting the cost and potential of a list of mitigation measures (Vogt-Schilb & Hallegatte, 2014), some discrepancies arose relating to the construction and interpretation of MAC curves in recent years (Ackerman & Bueno, 2011; Kesicki & Ekins, 2012; Kesicki & Strachan, 2011; Kok & Annema, 2010). Kesicki and Strachan (2011) and Kesicki and Ekins (2012) uphold that MAC curves are a useful tool but its simplistic approach is misleading, possibly causing biased decision-making. Kesicki and Ekins (2012) categorise these shortcomings into those that are general faults of MAC curves and those that are specific to the MACC approach. The general shortcomings consider the inability to capture the intersectoral, intertemporal and macroeconomic interactions, as well as the wider social implications related to climate change mitigation. The MACC specific weaknesses include the lack of full disclosure behind the calculations that can lead to problems when defining an emission baseline as MAC curves cannot display those interactions.

Ackerman and Bueno (2011) stated that abatements with negative net costs are controversial among economists and problematic for modelling purposes and avoided this issue by assuming a near-zero but positive cost on all negative-cost abatements. In a similar way, Kesicki and Ekins (2012) disputed the existence of negative abatement costs, which produce a return on investment (with the so-called win-win measures). These authors argue that those results could be explained by an insufficiently extensive cost definition, non-financial barriers to implementation or inconsistent discount rates and consequently these costs are not compatible with an efficient market.

Taylor (2012) and Ward (2014) dealt with the flaw in the cost-effectiveness calculation that generates the MAC curves relating to negative costs. Taylor (2012) did not take into account the arguments of Ackerman and Bueno (2011) and Kesicki and Ekins (2012) but instead focused on the mathematical treatment and accuracy of the ranking of options that generate income (negative cost). The problem is that MAC curves use the same criteria for ranking abatement measures with positive and negative costs. The resulting rank applying traditional MACC for the negative side favours measures that produce low emission reductions over options with the same negative cost but greater CO_2 reduction potential (Taylor, 2012; Ward, 2014), even when assuming properly calculated costs resulting in negative results. This rank is therefore unreliable.

Taylor (2012) was the first author to propose a solution for this issue. He devised an alternative partial ranking method using a Pareto front for measures with negative costs and uses MACC to measure the positive ones. Taylorís model ranks measures with positive and negative costs using different approaches, which could provide discontinuous results and often ranking draws that are ambiguous and open for subjective selection. Ward (2014) proposed to plot a function that is more directly related to the benefit (in terms of avoided CO_2), taking a range of values or simply plotting the net benefit of each measure. This procedure consists of adopting measures of financial benefit, added to the emissions avoided and multiplied by an assumed value of avoided emissions.

All previous ranking methods do not take into account the interests of decision makers, regardless of whether they are fully or partially driven by economical or environmental positions. In order to partially fill this gap, we discuss three novel methods for evaluating and raking abatement measures. These are plotted in a graphical representation similar to the MAC curve, which produces continuous results for positive and negative costs.

In Section 2 we describe the fundamentals of the MACC method and its anomalies. Section 3 briefly presents the alternative ranking methods for negative cost available in the literature. In the Section 4, the authors propose two new methods: the first called The Gain Maximizing method, designed with an environmental focus, and the second called the Extended MACC method, designed with a greedy driven point of view. The Section 5 shows a comparison and discussion of the analysed ranking methods. The Section 6 presents the Balanced Ordering Method that gathers the goodness of the exposed approaches as a weighted combination of any of the exposed methods (that will work as seed methods), enabling decision makers to represent their specific interests in the ranking of GHG abatement measures. A case study for Colombia is presented