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Prior to Economic Treatment of Emissions and Their Uncertainties Under the Kyoto Protocol: Scientific Uncertainties That Must Be Kept in Mind

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Abstract In a step-by-step exercise – beginning at full greenhouse gas accounting (FGA) and ending with the temporal detection of emission changes – we specify the relevant physical scientific constraints on carrying out temporal signal detection under the Kyoto Protocol and identify a number of scientific uncertainties that economic experts must consider before dealing with the economic aspects of emissions and their uncertainties under the Protocol. In addition, we answer one of the crucial questions that economic experts might pose: how credible in scientific terms are tradable emissions permits? Our exercise is meant to provide a preliminary basis for economic experts to carry out useful emissions trading assessments and specify the validity of their assessments from the scientific point of view, that is, in the general context of a FGA-uncertainty-verification framework. Such a basis is currently missing.

Keywords Kyoto protocol · full greenhouse gas accounting · uncertainty · verification · emissions · emission changes · signal detection · emission limitation or reduction commitments · risk of not meeting commitments

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1 Introduction

Full carbon accounting (FCA) or full greenhouse gas accounting (FGA),[1] uncertainty, and verification, in connection with the detection of greenhouse gas (GHG) net flux changes (also termed net flux signals), are crucial issues for the functioning of the Kyoto Protocol (Grassl et al., 2003; Nilsson et al., 2000; Nilsson, Jonas, Obersteiner, & Victor, 2001; Nilsson, Jonas, & Obersteiner, 2002; Nilsson et al., 2007; Schulze, Valentini, & Sanz, 2002; Steffen et al., 1998; Valentini et al., 2000). However, we must observe that these issues are not being concomitantly and rigorously discussed in a holistic context among or between physical scientists and experts from other disciplines (e.g., economics). Physical scientists do not

[1]FCA refers to a full carbon budget that encompasses and integrates all carbon-related components of all terrestrial ecosystems and is applied continuously in time. The components are typically described by adopting the concept of pools and fluxes to capture their functioning. The reservoirs can be natural or human-impacted and internally or externally linked by the exchange of carbon as well as other matter and energy. Net biome production (NBP) is the critical parameter to consider for long-term (decadal) carbon storage. NBP is only a small fraction of the initial uptake of CO_2 from the atmosphere and can be positive or negative; at equilibrium it is zero (Steffen et al., 1998, p. 1393; Jonas et al., 1999, p. 9; Nilsson et al., 2000, pp. 2, 6–7; Shvidenko & Nilsson, 2003, Section 2). FGA simply extends the definition of FCA to include other relevant GHGs (Nilsson et al., 2007, Section 1). However, a clear agreement on which gases are included is still outstanding.

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scrutinize, in a holistic context, the basis that has been set by the political negotiators of the Protocol, nor do they specify the scientific constraints under which the Protocol will operate. There are many consequences of this. To safeguard their carbon trading assessments from an uncertainty-risk point of view, experts from financial institutions might, for example, ask questions that physical scientists cannot answer, such as: how credible in scientific terms are tradable emissions permits? Economics experts typically carry out assessments that are not integrated within a proper physical scientific FGA framework (i.e., they cannot properly specify the validity of their assessments from a physical scientific [verification-related] point of view). Moreover, scientists, for their part, fail to assemble crucial knowledge that will prove useful in improving the Protocol prior to and for its follow-up commitment periods. In this context, we refer to recently completed collaborative work on the preparatory detection of uncertain GHG emission signals under the Kyoto Protocol (Jonas et al., 2004a) that should have been applied before/during negotiation of the Kyoto Protocol and that addresses the question: how well do we need to know what net emissions are if we want to detect a specified emissions signal at a given point in time?

This work advances the emission reporting of Annex I countries under the Protocol, as it takes uncertainty and its consequences into consideration, that is, 1) the risk that a country's true emissions in the commitment year/period are above its true emissions limitation or reduction commitment (i.e., the risk that the country will not meet its commitment); and 2) the detectability of the country's target. The authors' approach can be applied to any net emitter, and in our follow-up work, (Jonas et al. 2004b and 2004c), we demonstrate how evaluation, in terms of risk and detectability, of GHG emission signals can become standard practice. These two qualifiers can be determined and could indeed be accounted for in pricing GHG emissions permits.

We use our preparatory signal detection work as an example in an exercise that identifies step by step beginning at FGA and ending with signal detection the relevant physical scientific constraints and choices that are involved in applying signal detection within an FGA-uncertainty-verification framework. In other words, our signal-detection results can be properly evaluated against a solid physical scientific background. Our primary intention in this exercise is not to undermine the Protocol, which is not placed within such a framework and has also not been subject to preparatory signal detection, but to compensate for the lack of lucidity in the thinking behind the Kyoto Protocol and the conditions under which it will operate, including the consequences that it will have.

Moreover, our signal-detection results are of practical use. Emission signals that are assessable in terms of detectability or statistical significance have a direct bearing on how carbon permits are evaluated economically. Thus, our second intention is to use our work to build a bridge from the physical sciences to economics, that is, to offer properly specified, physical–scientific uncertainty and risk-related information that can be used by economic experts when they are working out the details of emissions trading.

Our paper is structured as follows: in Section 2 we set the stage for working within a consistent FGA-uncertainty-verification framework. In Section 3 we expose the reader to the verification of emissions in the context of bottom–up and top–down accounting. In Section 4 we explain how we merge bottom–up/top–down verification of emissions and temporal signal detection. In Section 5 we present the quantitative results of two fundamentally different preparatory signal-detection techniques and illustrate the far-reaching consequences of dealing with uncertain emission signals. Finally, in Section 6, we summarize the lessons drawn from our step-by-step analysis and establish the background against which we evaluate our signal-detection results.

Our paper is strongly guided by science–theoretical considerations and attempts to present a number of issues in a holistic context, something that has not, to our knowledge, been done elsewhere. While longer discussions of each of the issues is required, we have chosen to keep Sections 2 to 5 short to facilitate reading. However, we insert cross-references, which direct the reader to additional background information where the issues are discussed in greater depth.

2 Setting the Stage for Working within a Consistent FGA-Uncertainty-Verification Framework

In this section we develop an understanding of plausibility, validation, and verification based on our favorite way of categorizing uncertainty (Section 2.1);