Energy Policy 51 (2012) 957–972

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Estimating the social cost of non-CO_2 GHG emissions: Methane and nitrous oxide ☆

Alex L. Marten *, Stephen C. Newbold

National Center for Environmental Economics, U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue, Washington, DC 20460, USA

HIGHLIGHTS

- ► We compute the social cost of CO_2, CH_4, and N_2O emissions.
- ► We compare the social costs of non-CO_2 GHGs to the value from the $SCCO_2$ and GWP.
- ► Using the $SCCO_2$ to value abatement of GWP based CO_2-e may result in large errors.
- ► Valuing non-CO_2 abatement with the GWP and $SCCO_2$ will usually be an underestimate.

ARTICLE INFO

Article history:
Received 18 June 2012
Accepted 28 September 2012
Available online 12 October 2012

Keywords:
Social cost of carbon
Global warming potential
Integrated assessment

ABSTRACT

Many estimates of the social cost of CO_2 emissions ($SCCO_2$) can be found in the climate economics literature. However, to date few estimates of the social costs of other greenhouse gases have been published, and most are not comparable to current estimates of the $SCCO_2$. We construct an integrated assessment model that combines MAGICC and economic components from DICE to estimate the social costs of CO_2, CH_4, and N_2O for the years 2010–2050, using assumptions similar to the recent U.S. government interagency SCC working group. We compare our estimates of the social costs for non-CO_2 gases to those produced using the $SCCO_2$ to value "CO_2-equivalent" emissions, calculated using global warming potentials (GWPs). We examine the estimation error associated with using GWPs for single- and multi-gas abatement policies. In both cases the error can be large, so estimates of the social costs of these gases should be used whenever possible. However, if direct estimates are not available the value of reductions estimated using GWPs will typically have lower absolute errors than default estimates of zero, and provide lower bounds of the abatement benefits.

1. Introduction

The social cost of carbon dioxide ($SCCO_2$) has become a common metric in estimating the benefits associated with incremental reductions of carbon dioxide emissions.[1] The $SCCO_2$ has been widely studied (see Pearce, 2003 for a review) and researchers have produced a large set of varied estimates (Tol, 2007, 2011). Newly developed estimates of the $SCCO_2$ are now being used to assess the benefits of CO_2 emission reductions associated with U.S. government regulations.[2] However, recent climate policy analyses, particularly those conducted by the U.S. government, have been unable to quantify the benefits of reductions in non-CO_2 greenhouse gas (GHG) emissions due to a lack of comparable social cost estimates for these gases. This paper begins to fill this gap by calculating an internally consistent set of estimates of the social costs of CO_2, CH_4, and N_2O, based on assumptions similar to those used by the United States Government Interagency Working Group on the Social Cost of Carbon (USG, 2010, hereafter, the "SCC working group"). We also compare the use of direct estimates of the social costs of non-CO_2 GHGs to alternative estimates suggested by some analysts (e.g., Price et al., 2007) based on global warming potentials (GWPs), which measure the contribution of non-CO_2 GHG emissions to a long run measure of atmospheric radiative forcing relative to that of CO_2. In both cases we consider

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* Corresponding author. Tel.: +1 202 566 2301; fax: +1 202 566 2338.
E-mail address: marten.alex@epa.gov (A.L. Marten).

[1] Much of the previous literature has used the term "SCC" to refer to the social cost of carbon dioxide whether reported in tons of C or CO_2. In this paper we must be more specific since we are discussing the social cost of other greenhouse gases, including another carbon-based molecule, methane.

[2] For a list of recent rules using the $SCCO_2$ in analysis we refer the reader to Table 1 of Kopp and Mignone (2012).

0301-4215/$ - see front matter Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.enpol.2012.09.073

the sensitivity of our results to the adoption of the SCC working group assumption regarding constant discount rates, which has been noted as a departure from standard practice in climate economics (Kopp and Mignone, 2012).

The paper is structured as follows. In Section 2 we review the literature on the "social cost of carbon [dioxide]," including a brief recap of the recent SCC working group. We also review the much smaller literature on the social costs of other greenhouse gases, including CH_4 and N_2O, and discuss the small set of previous studies that have examined the implications of using GWPs to translate non-CO_2 GHGs into "CO_2-equivalents" for use in economic analysis. Section 3 describes the integrated assessment framework that we use to produce estimates of the social costs of CO_2, CH_4, and N_2O, which combines a climate model (MAGICC v5.3, Wigley and Raper, 1992; Wigley, 2005) with elements of a prominent climate economics integrated assessment model. (DICE, Nordhaus and Boyer, 2000; Nordhaus, 2008). In Section 4 we present our main results, starting with our direct estimates of the social costs of all three GHGs. We then use these estimates to calculate what Fankhauser (1994) denoted as the "global damage potentials" (GDPs) for CH_4 and N_2O, for comparison to their respective GWPs. The degree to which the GDPs of these gases diverge from their GWPs, combined with the shares of the overall GHG emission reductions attributable to each gas under a particular policy, will determine the error in GWP-based benefit estimates. We calculate the magnitude of this error over a wide range of hypothetical mixed-GHG emission reduction policies, and we compare these results to the error induced by excluding non-CO_2 GHGs from the analysis altogether. We conclude in Section 5 with a brief summary and discussion of the potential policy implications of our results.

2. Background

The social cost of carbon dioxide, $SCCO_2$, is intended to be a measure of society's willingness to pay to prevent the future damages that would arise from an incremental unit of CO_2 (typically one metric ton) being emitted in a given year.[3] In principle, the $SCCO_2$ summarizes the impacts of climate change on all relevant market and non-market sectors, including agriculture, energy production, water availability, human health, coastal communities, biodiversity, and so on. As such, estimates of the $SCCO_2$ play an important role in assessing the benefits of policies that result in marginal reductions of CO_2 emissions. $SCCO_2$ estimates are typically calculated using integrated assessment models (IAMs), which combine simplified models of the climate system and the economy, including the key feedbacks between the two. Small and not-so-small differences in the structural assumptions and the underlying studies used for parameter calibrations among IAMs have led to a wide range of published $SCCO_2$ estimates, from roughly \$0 to \$100 per metric ton of CO_2 (NAS, 2009).

In 2009 the U.S. government undertook an interagency process to establish consistency across federal agencies when valuing incremental CO_2 emission changes in regulatory impact analyses (RIAs). Towards this end, the SCC working group used three widely known IAMs and imposed consistency across several key inputs, including the socio-economic-emission scenarios, discount rate, and climate sensitivity probability distribution. To represent some of the uncertain model inputs, the SCC working group considered five socio-economic-emission scenarios and three discount rates. In the end, the SCC working group selected four estimates of the $SCCO_2$ for use in upcoming RIAs: \$5, \$21, \$35, and \$65. These values are reported in 2007 dollars, apply to emission reductions in 2010, and grow over time at 1–4% per year (USG, 2010, Table 4). The first three values are the average estimates across all IAMs and scenarios using discount rates of 5%, 3%, and 2.5% per year, respectively. The last estimate is the 95th percentile across all models and scenarios using a discount rate of 3% per year. These estimates are intended to be used in RIAs for all U.S. federal agency regulations that result in marginal changes in CO_2 emissions.[4] The SCC working group did not provide estimates of the social costs of non-CO_2 GHGs, though they noted that such values will be important for future policy analyses.

The few estimates of the marginal social costs of other GHGs that are available in the climate economics literature rely on outdated modeling assumptions or are otherwise incompatible with recent $SCCO_2$ estimates. For example, some previous studies primarily focused on marginal emission reductions during the mid 1990s and sometimes the early 2000s (Kandlikar, 1995; Tol et al., 2003; Hope, 2005). With the exception of Fankhauser (1994), no estimates were provided for the years currently of concern to policy makers, and in most cases only a single time period was considered. Extrapolating these estimates to current and future years is not possible without additional assumptions. Furthermore, many of the previous estimates (Kandlikar, 1995; Hammitt et al., 1996; Tol et al., 2003) were based on reference scenarios that are nearly 20 years old and have now been superseded by newer studies (Houghton et al., 1992; Nakicenovic et al., 2000). The most recently published estimates of the social cost of non-CO_2 GHGs are values for CH_4 produced by Hope (2005) using the integrated assessment model PAGE95.[5] However, PAGE95 is substantially different than the current version of the PAGE model (Plambeck and Hope, 1996; Plambeck et al., 1997; Hope, 2006). In recent years much attention has been paid to the social costs of CO_2, both in terms of updating the integrated assessment models to reflect progress in our understanding of the physical impacts and economic damages from climate change, and exploring the sensitivity of $SCCO_2$ estimates to important modeling assumptions (Nordhaus, 2010; Narita et al., 2010; Hope, 2009). Similar attention to non-CO_2 greenhouse gases would be of great benefit to policy analysts who are currently working to assess the impacts of regulations that affect more than just CO_2 emissions.

In the interim it may seem that an easy solution would be to simply convert non-CO_2 GHG emissions to "CO_2-equivalents" (CO_2-eq) using their respective global warming potentials (GWPs) and then value these with the $SCCO_2$.[6] This approach has been suggested by the U.K. Department for the Environment, Food, and Rural Affairs (Price et al., 2007). While a number of previous studies have shown that this simple solution may be inaccurate (Reilly and Richards, 1993; Schmalensee, 1993; Fankhauser, 1994), other studies have shown that in cost-effectiveness analyses, where the aim is to minimize the cost of reaching a concentration or temperature stabilization target in some future year, the increased cost required to reach the target due to using proxy trading ratios

[3] In general terms the $SCCO_2$ represents the ratio of the partial derivative of the social welfare function with respect to CO_2 emissions and the partial derivative of the social welfare function with respect to consumption.

[4] The $SCCO_2$ may not give an accurate estimate of total benefits if applied to large, or "non-marginal," emission reductions (relative to total global emissions), so analyzing large policies may require tailored applications of the IAMs to each policy scenario.

[5] It is worth noting that two new working papers by Waldhoff et al. (2011) and Thureson and Hope (2012) seek to offer updated estimates for the social cost of non-CO_2 GHGs.

[6] Unless noted otherwise, the use of the term GWP in this paper refers to the estimates developed by the IPCC for AR4 using a 100 year time horizon. In this case the GWP is the ratio of the integrated radiative forcing from a 1 kg pulse of given gas over the time horizon and the same measure for an equivalent pulse of CO_2. The IPCC estimates are based upon the assumption of baseline concentration remaining at current levels and lifetimes of 12 years for CH_4 and 114 years for N_2O. For more information we refer the reader to Section 2.10 of Solomon et al. (2007).