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Multiple-pollutant cost-effectiveness of greenhouse gas mitigation measures in the UK agriculture

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ABSTRACT

This paper develops multiple-pollutant marginal abatement cost curve analysis to identify an optimal set of greenhouse gas (GHG) mitigation measures considering the trade-offs and synergies with other environmental pollutants. The analysis is applied to UK agriculture, a sector expected to make a contribution to the national GHG mitigation effort. Previous analyses using marginal abatement cost curves (MACCs) have determined the sector's GHG abatement potential based on the cost-effectiveness of a variety of technically feasible mitigation measures. Most of these measures have external effects on other pollution loads arising from agricultural activities. Here the monetary values of four of the most important impacts to water and air (specifically ammonia, nitrate, phosphorous and sediment) are included in the cost-effectiveness analysis. The resulting multiple-pollutant marginal abatement cost curve (MP MACC) informs the design of sustainable climate change policies by showing how the MP MACC for the UK agriculture can differ from the GHG MACC. The analysis also highlights research gaps, and suggests a need to understand the wider environmental effects of GHG mitigation options and to reduce the uncertainty in pollutant damage cost estimates.

1. Introduction

Climate change mitigation is high on the environmental policy agenda as countries seek to meet emissions reduction commitments. Agriculture is an important source of GHG emissions, accounting for 10–12% of total global and 9% of UK GHG emissions (Smith et al., 2007; Thomas et al., 2011). The sector is thought to offer significant emission reduction potential through the deployment of a number of cost-effective mitigation and carbon sequestration measures. But the implementation of these measures can occasion other environmental impacts that need to be addressed in any overall assessment of measure cost-effectiveness.

Land based mitigation measures can be highly variable in terms of their emission reduction (abatement) potential and private cost of measure implementation. Moreover, some measures have wider environmental co-effects (external effects), that can be both positive and negative. Adding these co-effects to the private cost of measures defines a social cost that can be used to redefine the cost-effectiveness of measures (i.e. the costs of implementation relative to GHG benefits). This paper investigates the social cost of GHG mitigation measures and aims to outline a more accurate cost-effectiveness metric for ranking measures in a marginal abatement cost curve.

Marginal abatement cost curves (MACCs) are tools to identify relatively cost-effective mitigation measures (MMs) across the economy (Kesicki and Strachan, 2011). MACCs can also be used to define the economically optimal level of abatement, where marginal abatement costs are equal to the resulting marginal benefits (Pearce and Turner, 1990). In practice, the economically optimal level of GHG abatement is defined by comparing marginal abatement costs with a standard benefit benchmark such as the shadow price of carbon.

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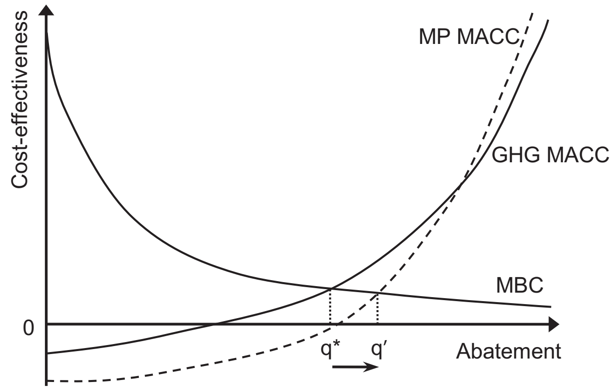

Fig. 1 – Effect of inclusion of co-effects on the GHG MAC curve and on the economic optimum of pollution control. MBC: marginal benefit curve. q^*, q': economic optimum of pollution reduction without and with co-effects, respectively.

Fig. 1 shows how adding external effects can alter the theoretical MACC. Positive co-effects reduce abatement costs, while negative ones increase the abatement cost, thus tilting the curve. The intercept of the MACC and the marginal benefit curve (MBC) indicates the economically optimal level of abatement (q^*). In case where the co-effects are mostly positive, the reduced abatement costs result in an increased abatement optimum (q'), or in decreased overall costs of achieving a targeted pollution reduction level.

GHG MACCs have been constructed for various sectors including energy and transport (Enkvist et al., 2007), and have galvanised wider debate and action on mitigation policy. MACCs have also been used to inform policy development on measures targeting various agricultural pollutants (see e.g. Webb et al., 2006 for ammonia, Haygarth et al., 2009 for phosphorous and Scholefield and Haygarth, 2004 for nitrates). But these studies have been limited in their treatment of any co-effects and hence the trade-offs and synergies between different agricultural pollutants (Reis et al., 2005).

There is a growing literature modelling multiple pollutants. Brink et al. (2001, 2005) analysed the co-effects of NH_3 and GHG mitigation options in European agriculture. Wagner et al. (2012) presented a multi-sector assessment of GHG mitigation options and their air pollution co-effects (SO_2, NO_x, $PM_{2.5}$) in Annex I countries to United Nations Framework Convention on Climate Change. Anthony et al. (2008) provided a cost-benefit assessment of six agricultural pollutants (nitrate, phosphorous, sediment, ammonia, methane and nitrous oxide) for the UK. In the US, Schneider et al. (2007) estimated the external effects of GHG mitigation options on soil erosion, N and P pollution. The optimisation approach in these studies is either based on a single pollutant, or provides the least-cost solution based on specified pollution reduction targets.

In contrast, a MACC can potentially facilitate the representation of the socially optimal abatement potential by accommodating multiple pollutants into a marginal cost curve. This single metric can be generated by monetising environmental co-effects, creating a multiple-pollutant (MP) MACC. Relative to a GHG MACC, an MP MACC also enables better representation of the social cost of integrated policies.

This paper considers the consequences of including available data on the monetary valuation of GHG mitigation measures' co-effects into the existing GHG MACC estimates developed for agriculture in the UK (Moran et al., 2011b). The external effects included are nitrate leaching, ammonia emissions, phosphorous and sediment pollution. We are unaware of any studies adding co-effects of mitigation effort to MACCs using a single metric of cost-effectiveness.

The rest of the paper is structured as follows. Section two provides more background to the MP MACC analysis in agriculture. Sections three and four outline a methodology for the paper and present results. Sections five and six provide a discussion and a conclusion, respectively.

2. Background

Agriculture is expected to make a contribution to the national mitigation effort in the UK that is being coordinated by the UK Committee on Climate Change and partly informed by sector-wide MACC analyses. Technically feasible measures for mitigating GHG emissions in the UK agriculture include, for example, improved resource use efficiency at farm level, generating greater output per unit of input. Higher efficiency can be achieved via selective breeding of livestock, optimised feeding strategies and judicious use of nitrogen fertilisers. Other MMs include changes in animal housing and manure storage, enhancing the removal of atmospheric CO_2 via sequestration into soil and vegetation sinks and replacing fossil fuel emissions with alternative energy sources.

Earlier GHG MACC analysis identified a financially feasible subset of measures, based on the private costs of implementation and on the abatement potential of the measures (Moran et al., 2011a). The analysis noted the particular biophysical complexities of agricultural mitigation and the likelihood of potentially large co-effects associated with the widespread implementation of many measures. These co-effects could include reduced (or increased) pollution to water, mitigation of other pollutants including ammonia, and more complex impacts to ecosystems functions.

Specific effects considered in this analysis are nitrate leaching, ammonia emissions, phosphorous and sediment pollution. These pollutants are drivers of environmental changes, leading to changes in ecosystem services. Nitrate