E-Forum on Full Cost Accounting of Food Wastage
Week 2: 28 October – 3 November 2013
Climate Change

Week two of the E-Forum addresses food wastage impacts on climate change and the related societal costs.

Food wastage impacts on climate change

Phase I of the Food Wastage Footprint (FWF) project estimated that greenhouse gas (GHG) emissions due to food wastage amounted to 3.3 Gt CO_2 eq per year (FAO, 2013). These calculations have been further refined in Phase II by:

- employing life-cycle assessment (LCA) for the agricultural production phase, including all relevant processes and their related emissions. Renewable/non-renewable energy use is differentiated using national energy supply data for electricity and fuels;
- including GHG emissions from commodities that were not covered in Phase I (e.g. sugar, coffee, alcoholic beverages);
- calculating detailed herd structures for cattle, pigs and chickens to differentiate the feed requirements and total emissions from animals at various ages and production levels;
- including GHG emissions from organic soils[1.]

Following these changes, the revised total GHG emissions due to food wastage are 3.35 Gt CO_2 eq per year. Furthermore, GHG emissions from deforestation have also been included (Tubiello *et al*., 2013). Adding deforestation[1] has the largest effect (0.35 Gt CO_2eq) compared to other amendments, bringing the total GHG emissions due to food wastage to 3.7 Gt CO_2eq per year. However, this number is lower than might have been expected, as wastage occurs mainly for commodities-regions combinations where deforestation is less important, while for regions where deforestation is more important, relevant key commodities have low waste shares. It should be emphasised that deforestation results are preliminary.

Social costs of food wastage impacts on climate change

Potential methodologies for evaluating the cost of carbon include the shadow price of carbon (SPC), marginal abatement cost (MAC), and traded/market price. We have chosen to use the social cost of carbon (SCC) approach as the most appropriate for the purposes of full-cost accounting (FCA).[2]

The SCC is the estimated cost of the global damages caused by an additional tonne of GHG emitted today (i.e. at the margin), over its lifetime in the atmosphere (100 years or longer). This approach reflects two specific characteristics of climate change. Firstly, as a global pollutant, GHG emissions from each country contribute to damages everywhere, not just

[1] Note on deforestation and organic soils: For the production part of the supply chain, deforestation emissions from food wastage are calculated by assigning a share of deforestation due to agriculture (global average of 80% from Kissinger et al*.,* 2012) and assigning these emissions to food wastage in proportion to the ratio of food wastage to total production. The methodology was adapted for post-production wastage to account for the fact that a part of the wastage occurs on imported quantities: the global deforestation for a commodity was evaluated and then divided by the total global production, giving an idea of the global average deforestation per commodity unit. This figure was used to assess the deforestation due to food wastage arising at post-production level. The same methodology was used for organic soils (Tubiello et al., 2013).

[2] Conceptually, the SCC measures the external costs caused by GHG emissions – the key objective of FCA. In pragmatic terms, the SCC has further advantages. For example, the SCC provides a global estimate of damage costs. In contrast, MAC is specific to sectors and/or countries and is not related to damage costs. Reliable data are unlikely to be universally available, especially for developing countries. Likewise, carbon markets are currently too 'immature' and/or not adequately designed to provide a reliable indication of the full cost of carbon emissions, as many externalities still go without price. For a more detailed overview of the merits and disadvantages of the different methodologies for assessing the cost of carbon, see: www.gov.uk/government/collections/carbon-valuation--2.

the source country. Secondly, GHGs emitted today continue to cause damages into the future, and the marginal cost of these damages increases at higher atmospheric concentrations of GHGs.

There is a wide range of variation in SCC estimates depending on the choice of certain parameters and the coverage of climate impacts and economic effects that are included. Given the range of uncertainty, total damage costs should be presented as a central value bounded by upper and lower estimates.

Some of the key issues are discussed below. Each of these parameters has a substantial impact on the results.

Coverage of climate impacts and economic costs

In practice, the SCC is a conservative estimate based on a partial sub-set of the full costs of climate change. Many impacts are unknown or uncertain and others cannot be quantified in monetary terms. A matrix of climate change impacts and economic costs is shown in Table 1. Most SCC studies only cover direct climate change impacts (associated mainly with temperature rise) and direct market costs[3] (green zone). Some more recent studies, such as Waldhoff *et al.* (2011)[4] include a wider range of impacts and costs that are more difficult to calculate (yellow zone). Stern (2007)[5] also models possible systems changes and surprises (orange zone). In the bottom right corner of the matrix, 'socially contingent' effects of climate change (red zone) include major catastrophes such as conflict, famine and poverty. Arguably, the large-scale loss of life and impacts on societies and economies are impossible to calculate; they involve ethical and equity dimensions that cannot be valued in monetary terms (e.g. Etkins, 2005).

Table 1: The Social Cost of Carbon Risk Matrix adapted from Watkiss (2008) illustrating the gradient of difficulty (from green to red) in taking different climate effects categories into consideration.

	Uncertainty in Valuation →			
Uncertainty in Predicting Climate Change ↓		**Market**	**Non-Market**	**(Socially Contingent)**
	Projection (e.g. sea level Rise)	Coastal protection Loss of dryland Energy (heating/cooling)	Heat stress Loss of wetland	Regional costs Investment
	Bounded Risks (e.g. droughts, floods, storms)	Agriculture Water Variability (drought, flood, storms)	Ecosystem change Biodiversity Loss of life Secondary social effects	Comparative advantage & market structures
	System change & surprises (e.g. major events)	Above, plus Significant loss of land and resources Non-marginal effects	Higher order social effects Regional collapse Irreversible losses	Regional collapse

[3] Watkiss et al. (2005) summarise the impacts and costs that are generally included/excluded at differing degrees of uncertainty for sea level rise, energy use, agriculture, water supply, health and mortality, ecosystems and biodiversity, extreme weather events, catastrophic events and major climate discontinuities.

[4] Waldhoff et al. (2011) includes: agriculture, forestry, sea level rise, cardiovascular and respiratory disorders related to cold and heat stress, malaria, dengue fever, schistosomiasis, energy consumption, water resources, unmanaged ecosystems, diarrhea, and tropical and extra tropical storms.

[5] Stern (2007) includes direct (non-market) damages to human health and the environment, and a simplified modelling of the risk of a catastrophic climate event occurring as temperatures increase.

Discount rate
Discount rates are based on the observation that people would prefer to have something valuable today rather than in the future. Because the compliance costs of climate change are incurred in the short-term and benefits of mitigation are mostly realised in the long-term, the choice of the discount rate has a significant influence in the analysis of climate impacts. It is important to emphasise that the choice of the discount rate involves a normative judgement, reflecting the present value we assign to future generations' welfare.

Equity weighting
The concept of equity weighting is based on the theoretical and empirical observation of diminishing marginal utility of wealth. This means that same amount of additional money has more utility to a poorer person than a richer one. In the context of climate change modelling, equity weighting implies that damages that occur in poorer countries/regions are weighted more heavily.

Assumptions in modelling of climate change and its impacts
Other assumptions relate to the modelling of climate change and its impact. Important choices include:

- Climate sensitivity: the magnitude of the temperature increase associated with a doubling of atmospheric CO_2 eq. For example, in Waldhoff *et al*. (2011), if climate sensitivities of 2.0°C or 4.5°C are used instead of the 3°C, the social cost falls to \$3/t CO_2 and rises to \$18/t CO_2, respectively.
- CO_2 fertilization: generally, higher CO_2 concentrations have a yield increasing effect on crops. This makes the costs of CO_2 lower than other GHGs for an equivalent amount of CO_2 eq. However, this effect is subject to large uncertainties.
- Total emissions profile over time: due to the relationship between marginal damage costs and the GHG stock in the atmosphere, damage cost estimates depend on scientific modelling of emissions profile. If emissions increase sharply, damage costs will also rise.

Draft approach to carbon monetization

To illustrate the approach to carbon monetization, we compare SCC values from Stern (2007) and Waldhoff *et al.* (2011). Both are recent studies from opposite ends of the spectrum of SCC estimates. An advantage of Waldhoff *et al.* (2011) is the differentiation between gases, which is necessary to account for the positive effects of CO_2-fertilization and the different decomposition rates of GHGs in the atmosphere. This is important for agricultural GHG emissions: direct emissions are roughly 55% CH_4 and 45% N_2O, while significant CO_2 emissions stem from deforestation and cultivated organic soils (Smith *et al.,* 2007). An advantage of Stern (2006) is the assessment of rare but catastrophic events in cost estimates. The method is further refined in Weitzmann (2007). Each model has been subject to critical review: Ackerman and Stanton (2010) critique the model used in Waldhoff *et al.* (2011); likewise, the Stern report triggered ample criticism (e.g. Nordhaus, 2007).

Waldhoff *et al*. (2011) reports a central value of 8 \$/t CO_2 eq (range: 2-240) for CO_2, 10 (2-160) \$/t CO_2eq for CH_4 and 20 (4-330) \$/t CO_2 eq for N_2O. Stern (2007) proposes a central estimate of 85\$/t CO_2 eq. The wide ranges are due to the uncertainties described above. Differences in discount rate and equity weights are particularly significant, as each can lead to estimates that differ by two orders of magnitude (e.g. when the discount rate varies from 0.1% to 3%). Combining several of these uncertainties results in an even wider range of values.

Using the numbers reported above, the total costs of GHG emissions due to food wastage, including deforestation, amount to 55 billion US\$ (with a range of 10-900) for Waldhoff *et al.* (2011) and 315 billion US\$ for Stern (2007). This wide range of costs reflects the wide range of GHG societal costs and possible valuation options presented above. This has to be seen in relation to the direct economic costs of food wastage, based on estimating the loss in economic value from wastage produce, which roughly amounts to 750 billion US\$.

Questions for Discussion

- Is the social cost of carbon the best approach to estimate carbon costs for the Full Cost Accounting of Food Wastage? If not, which methodology would you use?
- What are the merits and disadvantages of the specific studies: Stern (2006) and Waldhoff *et al.* (2011)? Are there other studies we should consider?
- Are there other specific issues to consider when looking at GHG emissions from food wastage? For example, we differentiate between the costs of different GHGs, as agriculture mainly emits non-CO_2 gases.
- Does the methodology and preliminary results for GHG emissions from deforestation due to food wastage seem appropriate?

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