Transport Policy 37 (2015) 31–43

Contents lists available at ScienceDirect

Transport Policy

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

The economic impact of greenhouse gas abatement through a meta-analysis: Valuation, consequences and implications in terms of transport policy

Silvio Nocera*, Stefania Tonin, Federico Cavallaro

IUAV University of Venice, Santa Croce 191 Tolentini, 30135 Venice, Italy

ARTICLE INFO

Article history:
Received 19 February 2014
Received in revised form
23 September 2014
Accepted 8 October 2014
Available online 11 November 2014

Keywords:
GHG emissions
Uncertainty
Economic valuation
Transport policy
Meta-regression analysis

ABSTRACT

To quantify the economic impact of greenhouse gas (GHG) emissions is considered one of the most important challenges in transport engineering towards the goal of sustainability. Current values, which are mostly provided by the use of Impact Assessment Models, can vary up to six orders of magnitude (from $-10.00/tC to $7,243.73/tC). Within this range, the choice of an adequate monetary value is extremely difficult. In this paper, we create a database with nearly 700 different observations coming from 60 studies on the economic valuation of GHG emissions. Subsequently, we use a meta-analysis to investigate the variation in emissions costs in order to significantly reduce the overall uncertainty. The results of the meta-regression analysis are then tested to assess three possible transport policies that can be implemented at 2050 European levels. A specific unitary economic value of GHG emissions is provided for each policy, thus aiding policy-makers to valuate the real economic impact of transport due to global warming.

1. Estimation of the economic impact of GHG emissions in transport

Transport policy is particularly aware of the problems related to environmental impacts and sustainable mobility. Transports account for about 30% of the European production of greenhouse gases (GHGs) and this number has been steadily increasing in recent years (EC, 2009). CO_{2eq}[1] is fundamental in a comprehensive analysis of infrastructural impacts (Wang et al., 2009): it represents one of the five main parameters to evaluate transport sustainability, together with the adoption of renewable fuels, congestion, criteria pollutants, and prevention of accidents and injuries (Black, 2010). In 2010, the European Commission launched the Europe 2020 strategy that sets three objectives for climate and energy policy to be reached by 2020: reducing GHG emissions by 20% compared to 1990 levels; increasing the share of renewables in final energy consumption to 20%; and moving towards a 20% increase in energy efficiency. All three objectives, somehow, are related to the transport sector and are also important to design the future of transport infrastructure. In addition, the EU continually updates the specific GHG emission values due to different transport modes (EEA, 2013a). Nevertheless, the traditional estimation techniques used in the transport sector are not suitable for the valuation of GHG emission costs.

Cost Benefit Analysis (CBA), among other applications, is normally used to analyse the environmental policies of the transport sector when a fair unitary price is given (De Borger et al., 1997; Turner, 2007). This method generally struggles at providing reliable results, because there is no general agreement about the internalization of costs and the value to assign for GHG emissions. Maibach et al. (2008) made significant attempts in this direction, by comparing the average values calculated in other studies and proposing a range (lower, medium and upper values). Nocera and Cavallaro (2012, in press-a) adopted a similar approach, based on avoidance and damage costs. Both of these articles suggest a deeper investigation of the emissions values, considering more accurate and statistically robust analyses.

Being aware of these critical issues, some authors (Zito and Salvo, 2011; Scarpellini et al., 2013) suggested the use of the *Multi-Criteria Evaluation* (MCE) as the most suitable method to evaluate the consequences of GHG emissions: MCE allows considering criteria in their own unit of measuring, hence disregarding monetization problems. Among its well-known advantages, MCE permits the selection of parameters to be considered by the stakeholders and may add qualitative criteria to the evaluation.

---

* Correspondence to: Department of Architecture and Arts, IUAV University of Venice, Dorsoduro 2206, I-30123 Venice, Italy.
E-mail address: nocera@iuav.it (S. Nocera).

[1] CO_{2eq} is the unity of measure that describes the Global Warming Potential (GWP) produced by GHGs, i.e. the concentration of CO_2 that would cause the same level of radiative forcing as that caused by the GHGs (Solomon et al., 2007).

http://dx.doi.org/10.1016/j.tranpol.2014.10.004
0967-070X/

Table 1
Classification of the IAMs according to their technical characteristics. *Source*: Ortiz and Markandya (2009).

Classification of the integrated impact assessment models according to their technical characteristics

Type	Acronym	Characteristics	IAM
Fully integrated impact assessment models	FIAM	Models that include an economic growth/dynamics (energy sector comprised), damage and climate modules.	DICE; ENTICE; RICE; FEEM-RICE; WITCH; MERGE; ICAM; MIND; DEMETER
Non-computable general equilibrium models	NCGEM	Models that include only the climate and damage modules. Occasionally, they consist of an energy module as well but without an economic optimization procedure and adopting scenarios provided by third parties.	FUND; PAGE; E3MG; DNE21+; GET
Computable general equilibrium models	CGEM	Models that focus the economic optimization procedure on a greater number of sectors but do not include a climate module.	AIM; EPPA; Imaclim-R; GREEN; ICES; GTAP-E

This allows for the measurement of intangible effects as well (Beria et al., 2012). CO_{2eq} can be included in environmental analyses with other impacts, such as visual ones and noise emissions, thus providing a more comprehensive analysis (Janic, 2003; Tudela et al., 2006). In this sense, MCE represents a holistic view for the evaluation of the external economic effects. However, it may be affected by subjective biasing, such as the choice of criteria (subjectivity, arbitrariness), the weights to be assigned and the risk of double counting (Browne and Ryan, 2011). Furthermore, even within the permissive view that the quantification of emissions leads to a plausible result (a hypothesis that can be stated with some difficulty, especially in the long-term-Nocera et al., 2012), the economic impact on the community still cannot be provided. For these reasons, this method can be considered a heuristic solution, which has not yet solved the issue with enough precision.

A similar argument can be extended to *Cost Effectiveness Analysis* (CEA). This method compares the costs of alternative approaches in producing the same (or similar) results. The outputs are expressed as the optimum abatement price of emissions, i.e. the intersection between the curves of marginal avoidance cost and marginal social damage. The result is a ranking of different solutions, which allows policy-makers an evidence-based comparative analysis. However, this method is limited only to the GHG emissions and cannot be extended to the parameters typically included in a CBA (accessibility, health impacts, security, etc.,) or in a MCE. This aspect makes the analysis restricted. Additionally, it presents some endemic problems. Kampman et al. (2006) suggested that comparisons are difficult if different assumptions and methodologies are considered, including timelines, locations, discount rates, costs and scales. Kok et al. (2011) confirmed this assumption, highlighting that differences up to $400/$tCO_{2eq}$ can be found according to the different scopes, costs, abatement costing approaches, type of measures, impacts, key assumptions and calculations.

An agreement about the quantification of GHG economic impacts has yet to be found, even if the CBA technique appears to be the more robust approach when a reliable unitary price is provided. The Integrated Impact Assessment Models (IAMs) could be useful for this purpose, because they try to link the unitary value with the physical changes caused by GHG emissions. However, with these models, current estimations can range up to six orders of magnitude (Tol, 2013; Nocera and Tonin, 2014). This range is too vast and can generate misleading results in transport planning and policy to the detriment of the community. In this context, we have been intrigued by the economical valuation of the effects of GHG emissions.

This paper presents the results of a meta-analysis (MA) to statistically measure the systematic relationships among the different GHG emissions reported in literature and the main attributes of the studies that generated the estimates. Section 2 describes, from a theoretical perspective, the IAMs and their main uncertainties. Section 3 introduces a database with a list of the most important studies and variables considered. A meta-analysis regression is then executed, which allows for a reduction in the uncertainty in GHG unitary price. Based on these results, Section 4 introduces a case study to valuate the economic impact of different transport policies in Europe until 2050. Some final notes, related to transport planning and GHG emissions costs, end the contribution.

2. Uncertainty in forecasting GHG emissions and their cost

As stated in the introduction, the assessment of the economic impacts derived from GHG emissions is ordinarily based on the use of IAMs. These models are used as support for the formulation of global and regional policies. Several IAMs, adopting very different premises and parameters, have been developed in the last twenty years. One of the most rigorous attempts to classify IAMs has been provided by Stanton et al. (2008), which identified five main groups: welfare optimization models, general equilibrium models, partial equilibrium models, simulation models and cost minimization models. However, the adoption of this subdivision caused some overlaps, as quoted by the authors themselves. Therefore, Ortiz and Markandya (2009) proposed a different and less ambiguous subdivision. The classification is based on a distinction between three sub-modules: economic growth/dynamics, energy and damage. Fully integrated IAMs (FIAMs) include all three sub-modules. Non-Computable General Equilibrium models (NCGEMs) usually include the climate and damage modules. Only occasionally do they include a simplified energy module, which lacks an economic optimization procedure and adopts scenarios provided by third parties. Last, Computable General Equilibrium models (CGEMs) focus the economic optimization procedure on a greater number of sectors but do not include a climate module (Table 1).

The range of six orders of magnitude determined by IAMs is too vast and does not provide a reliable economic value of global warming. This leads to doubts about if IAMs are helpful for such an aim (Pyndick, 2013). The main cause of this range derives from the adoption of different parameters and the choice of input values, which concur to determine a high degree of uncertainty[2] So far, the literature has not developed this aspect in detail; the uncertainty has been treated only as a marginal topic or as an additional physical variable (Funtowicz and Ravetz, 1993; Kuik et al., 2008). A deeper analysis of this theme is presented in this section. According to Natke and Ben-Haim (1996), we can distinguish two main groups of uncertainties, called respectively "objective" and "subjective". Before describing them, it must be noted that several scientific and economic aspects affect these groups

---

[2] For a comprehensive approach to the uncertainty from an epistemological perspective, see Van Asselt and Rotmans, 2002.