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Sensitivity analysis of total CO_2 emission intensities estimated using an input–output table

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Abstract

This study addresses the problem of uncertainties of total CO_2 emission intensities estimated using an input–output (I-O) table for a life-cycle inventory analysis. The validity of the total CO_2 emission intensities has been questioned mainly because the amounts of commodities are measured in monetary units, and because various commodities are produced in a single sector of an existing I-O table. In this study, first, a sensitivity analysis of total CO_2 emission intensities estimated using the Japanese I-O table was performed to identify the elements that significantly influence the total CO_2 emission intensity. If an influential element identified by sensitivity analysis varies widely, the total CO_2 emission intensity is greatly influenced. Secondly, how much total CO_2 emission intensities vary associated with the variation of those influential elements was evaluated. It was concluded that the evaluation of uncertainties using a stochastic approach as well as the improvement of accuracy by disaggregating the original I-O sectors, focusing on influential elements, are important.

1. Introduction

Life-cycle assessment (LCA) is an increasingly important tool to evaluate the environmental impacts associated with products, services and technologies. In performing life-cycle inventory (LCI) analysis, which is a basic component of LCA, process analysis has been used as the most common one among LCA practitioners.

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On the other hand, an input-output (I-O) table has been applied because it theoretically enables one to estimate both the direct and indirect emissions induced by the production of goods and services. However, the applicability of total emission intensities estimated using an I-O table in performing LCI studies has been questioned because of uncertainties associated with the inherent characteristics.

For example, regarding Japanese existing I-O tables, a range of goods and services that exist in society are classified into about 400 sectors. Therefore, the calculated total emission intensity corresponds to an *average good* virtually produced in a single I-O sector. In addition, all goods and services are measured not in physical units (e.g. kg, kcal) but in *monetary units* ('*yen*' in Japanese I-O tables). Taking these characteristics of I-O tables into consideration, it is reasonable to suppose that total emission intensities estimated using an I-O table are uncertain with some degree of variation. However, the degree of variation has not been evaluated so far. Therefore, some people remain skeptical about the application of the total emission intensities estimated using an I-O table in performing a LCI for a specific product. The question discussed in the present paper is about uncertainties arising from the inherent characteristics of an existing I-O table. It is the aim of this study to evaluate uncertainties of total emission intensities estimated using an I-O table and to examine the sources of these uncertainties.

The present paper is organized as follows: first, the sources causing uncertainties of input coefficients and direct emission intensities are shown these contribute to the variation of total emission intensities. Secondly, by performing a sensitivity analysis, those elements among all the input coefficients and all the direct emission intensities that significantly influence the total CO_2 emission intensity for each good or service are identified. When an influential element identified by sensitivity analysis varies widely, the total emission intensity is greatly influenced. Thirdly, the variations of some influential elements are quantitatively estimated, and then it is roughly calculated how much total emission intensities vary associated with the variations of these influential elements. Finally, conclusions are drawn in terms of the handling of uncertainties in the total emission intensities estimated using an I-O table.

2. The sources of uncertainties in total CO_2 emission intensities

Total CO_2 emission intensities can be calculated using an I-O table as follows:

$$\boldsymbol{\varepsilon} = \mathbf{e}^T(\mathbf{I} - \mathbf{A})^{-1}, \tag{1}$$

where $\mathbf{A}$ and $\mathbf{e}$ are an input coefficient matrix and a direct CO_2 emission intensity vector, respectively. T indicates transposition. In Eq. (1), imported goods are implicitly assumed to have the same production characteristics as comparable goods made in Japan. $\mathbf{A}$ can be derived from an I-O table and $\mathbf{e}$ can be estimated using various official statistics [2]. Let a_{ij} (¥/¥) be an element of $\mathbf{A}$ and e_i (g-CO_2/¥) be that of $\mathbf{e}$. When a_{ij} and e_i have uncertainties, those uncertainties are propagated in the total CO_2 emission intensities. The sources of uncertainties of a_{ij} and e_i are listed as follows: