Available online at www.sciencedirect.com
ScienceDirect
Atmospheric Environment 41 (2007) 5398–5409
ATMOSPHERIC ENVIRONMENT
www.elsevier.com/locate/atmosenv

A socio-economic method for estimating future air pollutant emissions—Chicago case study

Zhining Tao[a,*], Allen Williams[a], Kieran Donaghy[b], Geoffrey Hewings[c]

[a]*Illinois State Water Survey, Illinois Department of Natural Resources, University of Illinois at Urbana-Champaign, 2204 Griffith Dr., Champaign, IL 61820, USA*
[b]*Department of Urban and Regional Planning, University of Illinois at Urbana-Champaign, 111 Temple Buell Hall, 611 Taft Dr., Champaign, IL 61820, USA*
[c]*Regional Economics Applications Laboratory, University of Illinois at Urbana-Champaign, 607 S. Mathews #220, Urbana, IL 61801, USA*

Received 8 September 2006; received in revised form 9 February 2007; accepted 10 February 2007

Abstract

This paper presents the development of an econometric-emission model to formulate future anthropogenic emission inventories for different societal and climate change scenarios. Our approach is to formulate the emission projections for a given scenario into growth factors that can be used to project forward the 1999 National Emission Inventory (NEI99). The process involves (1) mapping NEI99 source classification code (SCC)-based emissions into the sector or standard industrial classification (SIC)-based representation used by the econometric model, (2) developing a sectoral emission intensity (EMI) defined as the sector emissions per unit of sector economic output and the mechanism to consider EMI variations over time, (3) using the resulting EMI with econometric models and future emission activities to project future emissions, (4) and then mapping the emissions back to the original NEI99 format. As a case study, we apply the model to project emissions in the Chicago metropolitan area. The results show that the model is a fast, flexible, yet reasonable tool to produce a wide range of emission scenarios that are specific to regions, and would prove valuable for future air quality and other impact studies.

Keywords: Emission intensity; Emission scenario; Regional input–output econometric model

1. Introduction

In recent years, different studies have investigated the consequences of emissions and climate changes on regional air quality (e.g., Prather et al., 2003; Hogrefe et al., 2004; Mickley et al., 2004; Leung and Gustafson, 2005). In order to achieve future detailed air pollutant emissions necessary for a regional air quality simulation, researchers (e.g., Hogrefe et al., 2004) generally grow the current emission inventory to target future years by applying scaling factors calculated from various scenarios such as the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES) (IPCC, 2000). However, such scaling factors are normally based on emission projections of a set of countries, e.g., in IPCC the Organization for Economic Cooperative Development as of 1990 (OECD90). Detailed sub-region features key to the

*Corresponding author. Tel.: +1 217 244 1917.
E-mail address: ztao@uiuc.edu (Z. Tao).

1352-2310/$ - see front matter
doi:10.1016/j.atmosenv.2007.02.013

formulation of an effective and feasible emission control strategy, such as local economic structures (for example, the composition of economic activity), regulations, transportation systems, and technology development levels, are not reflected in the aforementioned scaling factors (Prather et al., 2003). The present paper attempts to improve future emission scenarios by utilizing a regional environmental–econometric input–output (I–O) model to link pollutant emissions to economic activities, population, and transportation, and project future emissions that are based on forecasted regional changes.

The I–O analysis was developed by Wassily Leontief in the 1930s and since then has grown into one of the most widely used methods of economic planning and decision making. I–O analysis traces demand and supply linkages in the economy, and thus provides insight to the direct and indirect effects associated with changes of the final demand of an industry (Yan, 1969). Considering pollutants as by-products of economic activities, Leontief extended the I–O method to analyze air pollution (Leontief, 1970; Leontief and Ford, 1971). Following this pioneering work, the I–O analysis has been widely applied in economy–environment studies (e.g., Miller and Blair, 1985, and the references therein; Laitner et al., 1998; Kebede et al., 2002; Nansai et al., 2003; Wainger et al., 2004; Fung and Kennedy, 2005). The advantage of applying I–O analysis is its ability to integrate the overall environmental effects, e.g., pollutant emissions, and demand–supply interactions among economic sectors.

In this study, we extend our regional econometric input–output model (REIM) to examine air pollutant emissions. By establishing relationships between emissions and economic activity of each sector, we project future emissions based on specific regional changes in economic structures, transportation, and population. We account for the nonlinear feature of emissions–economy relationship by developing the time-dependent emission intensity (EMI) based on historical emissions and economic data. Our ultimate goal is to formulate the emission projections for a given scenario into growth factors that can be used to project forward the current inventory such as the 1999 National Emission Inventory (NEI99, http://www.epa.gov/ttn/chief/eiinformation.html). The projected inventory can then be processed by an emission modeling system, e.g., the sparse matrix operator kernel emissions (SMOKE, Houyoux et al., 2000) supported by the US Environmental Protection Agency (USEPA). During the initial stage, we apply the model to project future emissions for the Chicago metropolitan area. The system is presently being extended to simulate future emissions over the Midwestern US.

2. Methods

Emissions are determined by the EMI and levels of emission activities:

$$\mathrm{EM} = \mathrm{EMI} \times \text{activity}, \tag{1}$$

where EMI characterizes the emissions per unit of activity. In this study the primary emission activity is sectoral economic outputs (in constant monetary terms) from the econometric model. Since there is no economic sector in the model dedicated to private personal economic activity, we treat residential heating using a population-based activity designation. In addition, for transportation activity, vehicle miles traveled (VMT) is assumed for calculation of mobile emissions. Fig. 1 illustrates the overview of the modeling system. Our general procedure is to construct the historic EMI for each pollutant and use the past behavior that includes all factors affecting past emissions, e.g., economic activity, technological change, and emission control, to develop scenarios of future EMI behavior. In particular the strategy is to (1) utilize REIM to depict past, present, and future economic activities; (2) develop EMI based on available emission inventory and economic/social activities; (3) develop a mechanism to quantify changes in EMI related to shifts of energy and material usage, technological change, population change, and possible policy and regulation changes; (4) survey historical and projected changes in emission activities, e.g., energy, population, and VMT; (5) develop future emission

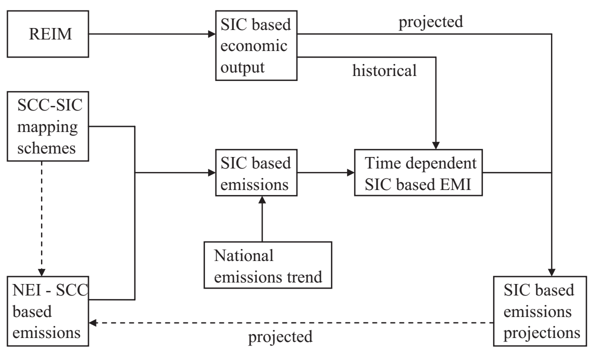

Fig. 1. Schematic overview of the econometric-emission modeling system.