ELSEVIER

Energy Policy 34 (2006) 1499–1507

ENERGY POLICY

www.elsevier.com/locate/enpol

Identifying key factors and strategies for reducing industrial CO_2 emissions from a non-Kyoto protocol member's (Taiwan) perspective

Sue J. Lin[a,*], I.J. Lu[a], Charles Lewis[b]

[a]Department of Environmental Engineering, SERC, National Cheng Kung University, Tainan 701, Taiwan, ROC
[b]Department of Resources Engineering, National Cheng Kung University, Tainan 701, Taiwan, ROC

Available online 12 September 2005

Abstract

In this study we use Divisia index approach to identify key factors affecting CO_2 emission changes of industrial sectors in Taiwan. The changes of CO_2 emission are decomposed into emission coefficient, energy intensity, industrial structure and economic growth. Furthermore, comparisons with USA, Japan, Germany, the Netherlands and South Korea are made to have a better understanding of emission tendency in these countries and to help formulate our CO_2 reduction strategies for responding to the international calls for CO_2 cuts. The results show that economic growth and high energy intensity were two key factors for the rapid increase of industrial CO_2 emission in Taiwan, while adjustment of industrial structure was the main component for the decrease. Although economic development is important, Taiwan must keep pace with the international trends for CO_2 reduction. Among the most important strategies are continuous efforts to improve energy intensity, fuel mix toward lower carbon, setting targets for industrial CO_2 cuts, and advancing green technology through technology transfer. Also, the clean development mechanism (CDM) is expected to play an important role in the future.

Keywords: CO_2 emission analysis; Divisia index; Emission coefficient; Energy intensity; Industrial structure; CO_2 reduction strategy

1. Introduction

Under the Kyoto Protocol of 1997, Annex I countries have agreed to adopt legally binding commitments with a view to cutting aggregate emissions of six greenhouse gases by an average of 5.2% below 1990 levels for the period 2008–2012. February 16, 2005 stood for the beginning of a new milestone in international commitment to reduce the global greenhouse gases emissions by the ratified Protocol entering into effect. Although Taiwan is not a member of the UNFCCC, the CO_2 emission of industrial sectors, which accounts for an average of 51% of total CO_2 emissions in Taiwan, has increased rapidly with an average annual growth rate of 6.07% during 1991–2001. This situation indicates that the CO_2 released from Taiwan during the past 10 years increased substantially, ranking 22nd in the world. The government of Taiwan anticipated the protocol's approval, and held a national energy conference in 1998 to investigate strategies and policies for CO_2 reduction. After ratification of the protocol, a recent National Energy Conference in June of 2005 focused on upgrading energy efficiency, adjusting electricity pricing programs, and identifying targets for CO_2 reduction. Consistent with these purposes, our study aims to identify the target sources and key factors related to industrial CO_2 emission changes in Taiwan by Divisia index approach, in order to have a more comprehensive understanding of the interrelationships of industrial productivity, energy consumption and CO_2 emission, and to explore relevant strategies for CO_2 reduction.

A number of studies have attempted to distinguish the relative contribution of different factors affecting changes in energy consumption or pollutant emission. For example, Rose and Chen (1991) used the simple

*Corresponding author. Fax: +886 6 2364488.
E-mail address: t15197@mail.ncku.edu.tw (S.J. Lin).

0301-4215/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2005.08.006

average Divisia method to examine factors affecting activity levels and energy intensity in freight energy consumption for the period 1972–1985. Howarth et al. (1991) utilized Laspeyres index and Divisia index to characterize energy consumption in the manufacturing sector in eight OECD countries during 1973–1987 and compared the advantages and disadvantages of these two methods. Torvanger (1991) selected five factors, including emission coefficient, energy intensity, fuel mix, production structure and international structure to decompose the industrial CO_2 intensity in nine OECD countries. He revealed that CO_2 intensity dropped by 42% from 1973 to 1987 in all nine countries and that this drop was caused primarily by reduction in energy intensities. Ang and Lee (1994) illustrated five specific methods and found that the adaptive weighting and the simple average Divisia index methods tended to yield smaller residuals in decomposition. Lin and Chang (1996) employed the Divisia index approach to examine emission changes of CO_2, NO_x and SO_2 of major economic sectors in Taiwan from 1980 to 1992 to suggest that economic growth had the greatest impact on the variation of emission intensities during this period, while the influence of fuel mix was much less obvious compared to the others. Ang and Pandiyan (1997) decomposed energy-related CO_2 emission in the manufacturing industry by Divisia index approach and found that the aggregate CO_2 emissions of China, Taiwan and South Korea were mainly influenced by intensity effect. The adaptive weighted Divisia index with a rolling base year was applied by Greening et al. (1999) to analyze the development of energy consumption and carbon intensity in the freight sector of 10 OECD countries. They concluded that the changes in fuel price and vehicle purchase taxes do not appear to be effective instruments for reducing energy consumption and CO_2 emission, while less-carbon intensive fuel and technological innovation appear to be better choices. Viguier (1999) analyzed SO_2, NO_x and CO_2 emissions in Hungary, Poland and Russia and three OECD countries (France, the United Kingdom and the United States) for 1971–1994. He divided the change in emission intensities into four components, including emission factors, fuel mix, economic structure and energy intensity, and found that the main cause of high emission intensities is due to high-energy intensities of industries. Nag and Parikh (2000) studied the commercial energy consumption evolution patterns in India, and concluded that income effect, electricity use-efficiency and coal quality all affect the carbon emission intensity. Davis et al. (2002) used Divisia decomposition and regression to distinguish the main reason for declines in energy and carbon intensity in United States. Gonzalez and Suarez (2003) decomposed changes of aggregate electric energy intensity in Spanish industry and found that a considerable reduction in intensity was mainly caused by both structural and intensity effects. Ang (2004) compared various decomposition methods and concluded that the multiplicative and additive logarithmic mean Divisia index (LMDI) methods are most recommended. However, Ang (2004) also pointed out that ease of use and simplicity are important considerations in terms of application. Additionally, Ang (2005) proposed a guide for using the LMDI methods and illustrated its use by examples of industrial energy consumption and CO_2 emissions.

Several decomposition methodologies, as mentioned above, have been used to analyze energy use, energy intensity and pollution emission. In general, all these methods try to decompose an object of interest into a multiplication of several components for identifying the key factors affecting its change. In our study, the simple average Divisia index method is adopted for reasons of simplicity, ease of use, and small residuals (Lin and Chang, 1996), since Taiwan's energy and the related CO_2 emission data varied greatly during 1991–2001. Furthermore, the simple average Divisia index method has been used for several previous publications/reports for governmental applications in Taiwan, and it is important that consistency be maintained for comparison purposes.

In this study, we applied the simple average Divisia index method to assess how energy-induced CO_2 emissions of industrial sectors in Taiwan are affected by the following factors: emission factor, energy intensity, structure share and economic growth. Furthermore, comparisons with other developed countries, such as USA, Japan, Germany, the Netherlands and South Korea are also made to gain more information about industrial CO_2 emission trends in these countries and to explore relevant strategies for our nation. The results are of value to provide a helpful reference for planning the national integrated CO_2 reduction mitigations in Taiwan.

2. Methodology

As mentioned earlier, the emission coefficient, energy intensity, structure share and economic growth are selected as major factors for decomposition of industrial CO_2 emission changes. The Divisia index method allows us to write aggregate emissions in a multiplicative form; therefore, the industrial CO_2 emission can be formulated as the following (Lin and Chang ,1996):

$$Q_{it} = U_{it} I_{it} S_{it} G_t, \tag{1}$$

where $U_{it} = Q_{it}/E_{it}$ is the emission coefficient of i sector in year t, $I_{it} = E_{it}/G_{it}$ the energy intensity of i sector in year t, $S_i = G_{it}/G_t$ the structure share of i sector in year t, Q_{it} the quantity of industrial CO_2 emission from energy use by i sector in year t, E_{it} the quantity of industrial