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Measuring CO_2 emission linkages with the hypothetical extraction method (HEM)

Yousaf Ali [a,b,*]

[a] Department of Management Science & Humanities, Ghulam Ishaq Khan Institute of Engineering Science and Technology, Topi, Pakistan
[b] University of Macerata, Department of Economics and Law via Crescimbeni 14, 62100 Macerata, Marche

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ABSTRACT

The issue of CO_2 emission has become a major issue causing greater concern to the global economies due to its potential environmental effects and impact on climate change. In order to address this issue and mitigate its harmful effects on the environment, it is imperative to reduce CO_2 emission drastically and fairly quickly. In this paper we have been focusing on alternative linkage methodologies for measuring CO_2 emission, which entails linkages among the productive sectors in an economy. Methods, dealing with inter-sectoral carbon linkage measures can be summarized into two main categories, i.e. (a) the concept of traditional backward and forward linkages and (b) hypothetical extraction method (HEM). The (HEM) method is used to hypothetically extract a sector from an economic system and examine the influence of this extraction on other sectors in an economy. In this study we will evolve the environmentally extended input–output model to measure the CO_2 emission linkages among the productive sectors in Italy using data obtained in 2011. Using the HEM method, the backward linkage emission and forward linkage emission are calculated to characterize the behavior of these sectors. The results obtained from these measures will enable us to formulate hypothesis about the direction and strength of the relationship between various linkages and will also indicate which key CO_2 emitter sector measures are most similar and which are most dissimilar. According to the size of the various linkage measures, all sectors of the economy can be grouped into four categories. These measures allow us to examine and identify those sectors, which deserve more consideration in formulating mitigation policies.

1. Introduction

It has been widely accepted that one of the major reason for climate change is the process of globalization, which has generated a significant growth in economic activities around the world. The variation of greenhouse gases (GHG) emissions in different countries is closely related to the level of economic development. Another notion is that, GHG emissions will generally grow along with the growth of real GDP per capita. Thus in the last few decades, mitigation of GHG emissions has become one of the hottest issues in sustainable development and is in the agendas of most decision makers of each country. These emissions of GHG and its connection to the economic growth have also led to a growing concern among economists and ecologists who have been integrating their ideas and concepts around GHG emissions and climate change. Their aims are to draw effective policies that reduce overall energy dependence on fossil fuels and improve the environment. In the context of the United National Framework Convention of Climate Change (UNFCCC), countries are required to submit National Emission Inventories (NEI) that measure a country's GHG emissions in a given year, to provide a benchmark for a country's emission reduction (Peters, 2008b). The results obtained from these measures are then used to evaluate various international policies for example EU strategy Europe 2020 and EU Emissions Trading Scheme (ETS). Concerning the sources of GHG emissions, field of research has tried to identify, since the end of 1990s, when industries are the biggest contributors to GHG emissions within a determinate national economy. Currently the Italian government and industrial organizations are making great efforts to reduce CO_2 emission and to develop renewable energy sources. Due to these efforts over the last decade Italy has made a considerable reduction in overall GHG emissions by 13% compared to 1990 level (EU, 2012).

* Correspondence to: University of Macerata, Department of Economics and Law, Via Crescimbeni 14, 62100 Macerata, Italy. Tel.: +39 3774553708; fax: +39 0733258396.
E-mail addresses: y.ali@unimc.it, yousafkhan@giki.edu.pk

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Nomenclature

Acronyms

HEM	hypothetical extraction method
GHG	greenhouse gases
NEI	National Emission Inventories
UNFCCC	United National Framework Convention of Climate Change
ETS	emissions trading scheme
WIOD	World Input Output Database
ESNA	European System of National Accounts
SNA	System of National Accounts
I–O	input–output
NACE	General Industrial Classification of Economic Activities within the European Communities

Symbols

A	technical coefficient matrix
B	output coefficient matrix
V	value-added vector
φ_i	direct CO_2 emission intensity of sector *i*,
I	identity matrix
C	total CO_2 emissions of the economy
M	matrix of total environmental pollution impact coefficients
$\mathbf{C}^*$	total CO_2 emissions of the economy from supply side
G	total direct and indirect CO_2 emissions due to the expansion of value added necessary for increasing a given sector supply
$\hat{\varphi}$	diagonal CO_2 emission intensity vector
Δ	represents the elements of Leontief inverse matrix
∇	represents the elements of Ghosh inverse matrix
$\mathbf{B}'$	represent the extracted direct coefficient matrix
$\mathbf{A}'$	represent the extracted technical coefficient matrix
φ 'E	extracted CO_2 intensity matrix
C'	the total CO_2 emissions related to the hypothetical productive relationships
C'^*	total CO_2 emissions related to the hypothetical productive relationships from a supply side
$\mathbf{i}'$	unit vector transposition
X	total output vector
f	final demand vector

Given the economic effort that emission mitigation entails, it is important to identify and assess the link between economic performance and CO_2 emissions in an economy. In order to fully understand whether the observed economic structural change can help Italy reduce CO_2 emissions and therefore mitigate climate change, it is essential to gain a better understanding of each sector's specification on CO_2 emissions and its role in Italy economic development. This paper provides a methodology to identify and explore the inter-industrial CO_2 emission linkages using the hypothetical extraction method (HEM) and the concept of traditional backward and forward linkages. A sector's relationships with the rest of the economy through its direct and indirect intermediate purchases and sales are described as the sector linkages (Miller and Lahr, 2001). The linkage analysis aims to evaluate the dependence between economic sectors and identify the key sector of the economy to formulate and adopt a suitable strategy for regional development in each sector (Andreosso et al., 2004). These sectors are important as they could be considered as the ones whose growth cause the growth in other sectors due to their technology and consequent dependences and generate higher income in the end (Temurshoev, 2004). Applying the environmentally extended input–output techniques allows us to trace the direct and indirect CO_2 emissions associated with a product. The idea of using I–O analysis to measure structural interdependence through backward and forward interindustry multipliers was first proposed by Rasmussen (1956). Further the familiar Chenery and Watanabe (1958) and Hirschman (1958) key sector analysis provided empirical evidence about the economic structure of sectors with in an economy. Thus environmentally extended key sector analysis and relevant transactions in terms of CO_2 emissions is useful for mitigation policy design, as it allows for the identification of sectors in which mitigation policies are likely to be most effective. Since then several authors attempted to improve and extend these methods in several ways. In particular Lenzen (2003) focuses on the economic structure of Australia by identifying key sectors and linkages that have large environmental impacts on the consumption of energy and water and on the generation of emissions of CO_2, NO_x and SO_2. Cellura et al. (2011) used input–output approach to study the energy and environmental impacts of Italian households consumptions; Fenga et al. (2014) analyzed drivers of CO_2 emissions and used a consumption based accounting approach to allocate all emissions along the production chain; Cellura et al. (2013) applied an Italian input–output model to assess the energy and environmental benefits arising from the Italian policy of tax deduction for energy retrofit actions of buildings. Similarly Yuan et al. (2013) and Yuhuan et al. (2014) used linkage analysis of sectoral CO_2 emissions based on the hypothetical extraction method (HEM). In this paper we extend the classical multiplier approach and focus on the linkage analysis based on the HEM, which has become increasingly popular Miller and Lahr (2001). The original idea of the HEM tries to extract a sector hypothetically from an economic system and examine the influence of this extraction on other sectors in the economy (Miller and Lahr, 2001). In a more precise way the difference in the output of the sectors before and after the extraction shows the linkages between the extracted sector and the remaining ones.

The main purpose of this paper is to analyze the CO_2 emission linkages structure of the Italian economy, using the input output Table 2011, which is the latest one released by WIOD.[1] This paper makes an attempt to empirically comparing the difference between the results derived from the different methods, and empirically examines the linkages of CO_2 emissions involved in the industrial sectors and the carbon effects of inter-sector linkages. Further findings on the basis of both analytical and empirical approaches are examined as part of this research to determine (a) which key sector measures are most similar and (b) which are most dissimilar. By considering key sectors and relevant transactions in terms of CO_2 emissions, the most effective policy measures aimed at reducing CO_2 emissions can be identified. Hence the policy implications that emerge from these findings are expected to be useful for the future mitigation policies. For the empirical identification of key sectors and relevant transactions in terms of CO_2 emissions our analysis is based on two main methods i.e., the hypothetical extraction method (HEM) and the traditional backward and forward linkage method.

In this paper, CO_2 linkages are divided into backward linkage (BL) and forward linkage, which are used to estimate the linkage effects of industrial sectors. In order to achieve the goal above this paper is organized as follows: Section 2 discusses the methodological background of the traditional multiplier approach and HEM method. In Section 3 the CO_2 linkage indicators for all the proposed methods have been calculated for the Italian economy. Fourth section compares the results of different methods and

[1] www.wiod.org.