Energy Policy 57 (2013) 381–388

Contents lists available at SciVerse ScienceDirect

Energy Policy

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

Which industry is greener? An empirical study of nine industries in OECD countries

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HIGHLIGHTS

- We analyze the relationship between CO_2 emissions and economic growth by industry.
- Wood, paper, and construction industries have an inverted U-shaped relationship.
- The turning points differ among industries according to the fuel type used.
- The policies for CO_2 reduction must consider differences in industrial characteristics.

ARTICLE INFO

Article history:
Received 3 November 2012
Accepted 5 February 2013
Available online 13 March 2013

Keywords:
Environmental Kuznets curve
CO_2 emissions
Industrial sector

ABSTRACT

This study analyzed the relationship between the CO_2 emissions of different industries and economic growth in OECD countries from 1970 to 2005. We tested an environmental Kuznets curve (EKC) hypothesis and found that total CO_2 emissions from nine industries show an N-shaped trend instead of an inverted U or monotonic increasing trend with increasing income. The EKC hypothesis for sector-level CO_2 emissions was supported in the (1) paper, pulp, and printing industry; (2) wood and wood products industry; and (3) construction industry. We also found that emissions from coal and oil increase with economic growth in the steel and construction industries. In addition, the non-metallic minerals, machinery, and transport equipment industries tend to have increased emissions from oil and electricity with economic growth. Finally, the EKC turning point and the relationship between GDP per capita and sectoral CO_2 emissions differ among industries according to the fuel type used. Therefore, environmental policies for CO_2 reduction must consider these differences in industrial characteristics.

1. Introduction

Clarifying the relationship between environmental emissions and economic growth has been a crucial issue for several decades (Stern, 2004; Azomahou et al., 2006; Kijima et al., 2010), largely because the ability to forecast emissions due to economic growth may be helpful in estimating the potential magnitude of environmental problems (Riahi et al., 2011). If we could detect conditions under which economic growth leads to increased environmental burdens, we might be able to treat the source of environmental emissions earlier and at a lower cost (Kuosmanen et al., 2009). Climate change is currently one of the most important environmental problems, and it must be dealt with adequately (Organization for Economic Cooperation and Development (OECD), 2009).

Although activities within an industrial sector can lead to economic growth, they often create significant carbon dioxide (CO_2) emissions. However, the structure of CO_2 emissions for an entire country is unclear. For example, emissions from the manufacturing sector might not be strongly correlated with population size because the sector produces products for the domestic market as well as for the global market through export (Perkins and Neumayer, 2012).

The environmental Kuznets curve (EKC) hypothesis has been applied to empirical and theoretical case studies to identify the relationship between environmental emissions and economic growth (Kijima et al., 2010).[1] In most studies, the applied data are cross-country (regional) or cover an entire industrial sector within one country. Unfortunately, this approach does not comprehensively consider individual industrial characteristics or fuel choices. Cross-country EKC analysis intends to show the close relationship between environmental emissions and gross

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0301-4215/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2013.02.011

[1] Cases of local environmental problems (e.g., acid rain or river pollution) often support the EKC. However, it is difficult to support an inverted U-shaped curve for emissions related to global environmental problems (e.g., CO_2 for climate change; Dinda, 2004).

domestic product (GDP) or related policy variables (Azomahou et al., 2006; Farzin and Bond, 2006; Wagner, 2008; Galeotti et al., 2009; Tsurumi and Managi, 2010). However, as Grossman and Krueger (1995) suggested, economic scale, technology level, and industrial composition effects are keys to understanding the shape of the EKC. The industrial composition effect is especially difficult to interpret with respect to the EKC (Tsurumi and Managi, 2010). Previous studies have controlled for the composition effect using the capital-labor ratio (Managi et al., 2009). These studies assume that capital-intensive industries discharge more CO_2 emissions than labor-intensive industries because capital equipment requires the use of more fossil fuel. However, this assumption fails to capture detailed industrial characteristics, such as intermediate fuel inputs and energy substitution tendencies.

To solve this problem, we propose an estimation of the EKC relationship by separately controlling for economic scale and technology according to the type of industry and type of fuel. We then discuss the EKC relationship considering the detailed composition differences in the industrial characteristics and fuel type.

In addition to previous studies in multiple countries, data from all industries in a single country were analyzed to test the EKC.[2] When the data were analyzed by country or entire industrial sector, the characteristics of the industrial structure largely affected the relationship between CO_2 emissions and economic performance because the technical difficulty of reducing CO_2 emissions differs across each industry. The capital equipment and labor requirements for reducing CO_2 emissions differ across industries because the types of fuel consumed as intermediate fuel materials also differ (Table 1).

Additionally, the manufacturing sector can be divided into upstream and downstream industries.[3] In general, upstream industries tend to demand more energy, especially from fossil fuels such as coal and petroleum. However, downstream industries generally consume more electricity and natural gas than coal and oil because most downstream industries use automated production systems fueled by electricity and natural gas. As shown in Table 1, natural gas and electricity have over a 90% share of total energy use in the machinery and transport equipment industries, which are categorized as downstream industries. In contrast, chemical and steel industries are categorized as upstream industries and use coal and oil more than downstream industries.[4]

We hypothesized that the EKC relationship between CO_2 emissions and economic growth would not be observed in the entire industrial sector because of (1) the unclear responsibility for environmental problems caused by CO_2 emissions and (2) limited available technology to treat CO_2 emissions. Because the purposes of fuel use differ among industries, the relationships between technological progress and economic growth also differ (Appendix 1). Therefore, we hypothesized limited support for the EKC across industries for two reasons. First, it is difficult to support the EKC when an industry uses fossil fuels as its main intermediate fuels because the intermediate fuel input increases proportionally with production growth. We therefore expected limited support for the EKC relationship between CO_2 emissions and economic growth from the steel and metal industry, which uses coal as its main intermediate fuels.

Table 1
CO_2 emission ratio by fuel combustion in 2006 in OECD country.
Source: International Energy Association, CO_2 emission fuel from combustion.

Industry type	Coal/peat (%)	Oil/petroleum product (%)	Natural gas (%)	Electricity (%)
Manufacturing industries and construction	14	19	18	48
Food and tobacco	8	11	37	45
Wood and wood products	1	16	17	66
Chemical and petrochemical	7	15	28	51
Paper, pulp and printing	8	11	17	65
Non-metallic minerals	3	4	31	62
Steel and metal	32	3	33	33
Machinery	1	6	20	73
Transport equipment	1	4	45	50
Construction	11	47	26	15

Note: Machinery and transport equipment are categorized as downstream industry.

Second, we focused on the global and domestic market sizes of products. If product demand is highly dependent on the global market, the domestic market size does not strongly affect the amount of production (Suri and Chapman, 1998). In general, the incentives to trade products with low value per weight across the country are weak because of high transportation costs. Thus, there is a decoupling relationship between national GDP and sectoral CO_2 emissions from industries that produce low value per weight product (e.g., wood products) if the country increases GDP through trade in high value per weight products (e.g., electric devices). Therefore, we hypothesized that the EKC relationship would be supported by specific industries, such as the wood and wood products industry and the paper, pulp, and printing industry, which do not use fossil fuels as intermediate fuels and whose product value per weight is lower than others.

Based on this background, we hypothesized that the EKC relationship observed in previous studies was mainly caused by industrial structural changes. To test this hypothesis, we analyzed CO_2 emissions data by industrial sector. No previous studies that have tested the EKC hypothesis have focused on the relationship between sectoral CO_2 emissions per capita and economic growth. We also analyzed the data by energy type because technological progress in energy consumption differs for different fuel types. Thus, we controlled for fuel characteristics to confirm the EKC relationship by energy type in each industry.

The main objective of this study is to examine the possibility of an EKC relationship between CO_2 emissions and economic growth under a controlling industrial structure composition effect. Another objective is to determine which industries experience decreased CO_2 emissions with increasing GDP (i.e., the identification of "greener" industries). The novelty of the study is found in empirically focusing on the relationship between sectoral CO_2 emissions and economic growth.

Additionally, previous research on the EKC focused on multiple factors behind the relationship between pollution and economic growth (e.g., Selden et al., 1999; Bruvoll and Medin, 2003; Stern, 2004). One advantage of decomposition analysis is to identify the contribution effect of each factor to emissions changes (Fujii and Managi, forthcoming). In the present study, we apply decomposition analysis to clarify the contribution of changes in CO_2 emissions to better understand the factors behind the relationship between CO_2 emissions per capita and economic growth.

[2] The EKC hypothesis has been tested in many countries, including the US (Franklin and Ruth, 2012), Canada (He and Richard, 2010), France (Iwata et al., 2010), Scotland (Turner and Hanley, 2011), Korea (Kim et al., 2010), Turkey (Akbostanci et al., 2009), and Israel (Yanai et al., 2010). Recently, several studies have targeted developing countries (Auffhammer and Carson, 2008; Jalil and Mahmud, 2009).

[3] Upstream industry is defined as industrial firms that process basic or raw material into an intermediary product that is then converted into a finished product by downstream industries. Downstream industry is defined as industrial firms that process the output of other firms into a finished or different product.

[4] The non-metallic minerals industry is categorized as an upstream industry and is highly dependent on electricity usage. This is because electricity is consumed at electric cement mills in the cement production process.