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Decouple indicators on the CO_2 emission-economic growth linkage: The Jiangsu Province case

Ming Zhang[a], Wenwen Wang[b,*]

[a] School of Management, China University of Mining and Technology, Xuzhou 221116, PR China
[b] School of Science, China University of Mining and Technology, Xuzhou 221116, PR China

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ABSTRACT

Jiangsu Province has become one of the most developed regions in China. Economic growth in Jiangsu has occurred along with rising energy-related CO_2 emission levels. Thus, the link between economic activity and environmental pressure represents a risk to the global efforts toward CO_2 emission reductions. This paper examines the occurrence of a decoupling between the growth rates in economic activity and CO_2 emission from energy consumption in Jiangsu from 1995 to 2009. The results indicate that: (1) Along with the rapid economic development, CO_2 emission in Jiangsu rose from $18{,}781.46 \times 10^4\,t$ in 1995 to $52{,}029.24 \times 10^4\,t$ in 2009, with an average annual growth rate of 7.54%. Our results also show that CO_2 emission in Jiangsu Province is dominated by the secondary, which accounts for about 80% of total CO_2 emission. (2) During the study period, the whole Jiangsu economy experienced weak decoupling and strong decoupling except 2003–2005. However the decoupling states for the secondary and tertiary industries are similar to that of the whole economy.

1. Introduction

Sustainable development has become an important topic in the 21st century. Nowadays, Jiangsu Province has become one of the most developed regions in China. Economic growth in Jiangsu has occurred along with rising energy-related CO_2 emission levels. Thus, the Jiangsu government should not only focus on pursuing economical efficiency, but should also enhance energy conservation and environmental quality. Thus the link between economic activity and energy-related CO_2 emission has raised the concern of energy analysts and policy makers. However, the decoupling index is a proper technique to accomplish this purpose.

The causal relationship between energy consumption and an aggregate of output, introduced at the end of the 1970 by Kraft and Kraft (1978), has generated much research interest. Different methods such as correlation analysis, simple regressions, divaricates causality, and unit root testing; multivariate co integration, panel co integration, and variance decomposition have been carried out in order to determine the strength of the causal link between energy consumption/CO_2 emissions and economic growth (Climent and Pardo, 2007). Budzianowski (2012) also analyzed CO_2 emissions from fossil fuel combustion and provided tools for estimating the target for national carbon intensity of energy by 2050.

The term decoupling was first adapted to environmental studies at the beginning of the 2000s by Zhang (2000) and presented as an indicator by the OECD (2002). Thus, the notion of decoupling has achieved global recognition as a significant conceptualization of successful economy–environment integration. Vehmas et al. (2003) constructed a comprehensive framework of the different aspects of decoupling. According to the framework, eight logical possibilities were presented by Tapio (2005) to distinguish decoupling state. Nowadays, the decoupling analysis is widely used by a variety of studies. For example, Climent and Pardo (2007) investigated the relationship between GDP and energy consumption in Spanish by taking into account several decoupling factors. Diakoulaki and Mandaraka (2007) evaluated the progress made in 14 EU countries in decoupling emissions from industrial growth. The occurrence of a decoupling between the growth rates in economic activity and CO_2 emissions from energy consumption in Brazil from 2004 to 2009 was examined by Freitas and Kaneko (2011). Liu (2011) used environmental Kuznets curve (EKC) to coins the term "environmental poverty" to refer to the lack of the healthy environment needed for society's survival and development as a direct result of human-induced environmental degradation. Luken and Piras (2011) studied the decoupling of energy use and industrial output in the Asian region. Ren et al. (2012) calculated the trend of decoupling effects in nonferrous metals industry in China by presenting a theoretical framework for decoupling. Many different concepts have been used to express the different aspects of decoupling. Up to now, eight kinds of measuring methods for decoupling

* Corresponding author. Tel.: +86 15262028260; fax: +86 15262028260.
E-mail address: wangwenwencumt@163.com (W. Wang).

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Table 1
Carbon emission factors and fractions of carbon oxidized.

Fuel	EF($t-C$/TJ)	O
Coal	25.8	0.90
Coke	29.2	0.90
Coke Oven Gas	12.1	0.99
Crude Oil	20.0	0.98
Gasoline	19.1	0.98
Kerosene	19.6	0.98
Diesel Oil	20.2	0.98
Fuel Oil	21.1	0.98
LPG (liquefied petroleum gas)	17.2	0.98
Refinery Gas	15.7	0.98
Other Petroleum Products	20.0	0.98
Natural Gas	15.3	0.99

Source: IPCC (2006) and Zhang et al. (2009).

exist. But there is no uniform about the decoupling indicators which is best method (Zhong et al., 2010).

Nowadays, many studies have focused on China's energy consumption and its energy-related CO_2 emission. As far as we know, no study has been devoted to analyze the decoupling of energy-related CO_2 emission from economic growth in Jiangsu Province. This paper serves as a preliminary attempt to apply the decoupling index presented by Tapio (2005) to examine the occurrence of a decoupling between the growth rates in economic activity and CO_2 emission from energy consumption in Jiangsu from 1995 to 2009.

The remainder of paper is organized as follows: The next section presents the methodology of the study. Section 3 discusses the choice of the data. The empirical results are presented in Section 4. The conclusions drawn are summarized in Section 5.

2. Methodology

2.1. Estimation of CO_2 emission

Following the method given by the IPCC (2006), total CO_2 emission is estimated based energy consumption, carbon emission factors and the fraction of oxidized carbon by fuel as follows:

$$C^t = \sum_i C_i^t = \sum_j E_{ij}^t \times EF_j^t \times (1 - CS_j) \times O_j \times M \tag{1}$$

where, C^t is total CO_2 emission in year t (in 10×4 tons), C_i^t denotes total CO_2 emission of the ith sector in year t; E_{ij}^t is total energy consumption of the ith sector based on fuel type j in year t; EF_j^t denotes carbon emission factor of the *jth* fuel; CS_j the fraction of the jth fuel is not oxidized as raw materials in year t; O_j is the fraction of carbon oxidized based on fuel type j; M denotes the molecular weight ratio of carbon dioxide to carbon (44/12).

Table 1 presents the carbon emission factors (*EF*) and the fraction of carbon oxidized (*O*). Because the 1995–2009 period analyzed in this paper is a relatively short term, the carbon emission factors of all energy forms listed in Table 1 are assumed constant in this paper. As changing in grade of fuels, these coefficients have changed over time; but these changes are so small that they are negligible when we analyze the macro changes in CO_2 emission.

The carbon emission factors of heat and electricity, however, are changing because the fuel mix used in the generation of electricity and heat is always changing, and technological improvements in generation are also always driving the decrease of coal consumption used in electricity and heat generation. The carbon emission factor of heat is calculated based on the use of individual fossil fuels used in power and heat generation and their generation. To overcome the question of border leakages of emissions of electricity use, the carbon emission factor of electricity is referred to the study by Zhang et al. (2013). The fuel used as a raw material for manufacture of products is excluded from the total energy consumption, here *CS* is zero. These values are assumed to be constant over the time period of the study (Zhang et al., 2009).

2.2. Decoupling index formulation

According to the definition given by Tapio (2005), decoupling index of CO_2 emission from economic growth D^t can be measured as the ratio of the percentage change of CO_2 emission to the percentage change of GDP in a given time period from a base year 0 to a target year t, as shown in Eq. (2):

$$D^t = \frac{\Delta C^t}{\Delta \mathrm{GDP}^t} \tag{2}$$

where GDP^t is the value added in year t; $\Delta C^t = (C^t - C^0/C^0)$; $\Delta \mathrm{GDP}^t = (\mathrm{GDP}^t - \mathrm{GDP}^0/\mathrm{GDP}^0)$.

The decoupling state takes the following eight cases:

(1) If $0 < D^t \le 0.8$, $\Delta C^t > 0$, $\Delta \mathrm{GDP}^t > 0$, denoting weak decoupling.
(2) If $0.8 < D^t \le 1.2$, $\Delta C^t > 0$, $\Delta \mathrm{GDP}^t > 0$, denoting expansive coupling.
(3) If $D^t > 1.2$, $\Delta C^t > 0$, $\Delta \mathrm{GDP}^t > 0$, denoting expansive negative decoupling.
(4) If $D^t \le 0$, $\Delta C^t < 0$, $\Delta \mathrm{GDP}^t > 0$, denoting strong decoupling.
(5) If $D^t \le 0$, $\Delta C^t > 0$, $\Delta \mathrm{GDP}^t < 0$, denoting strong negative decoupling.
(6) If $0 < D^t \le 0.8$, $\Delta C^t < 0$, $\Delta \mathrm{GDP}^t < 0$, denoting weak negative decoupling.
(7) If $0.8 < D^t \le 1.2$, $\Delta C^t < 0$, $\Delta \mathrm{GDP}^t < 0$, denoting recessive coupling.
(8) If $D^t > 1.2$, $\Delta C^t < 0$, $\Delta \mathrm{GDP}^t < 0$, denoting recessive decoupling.

3. Data description

The research period in this paper starts in 1995 and ends in 2009. In Jiangsu Province, the data has been collected from various issues of the Jiangsu Statistical Yearbook (JSY, 2011) and China Energy Statistical Yearbook (CESY, 1991–1996, 1997–1999, 2000–2002, 2003, 2004. 2005, 2006, 2007, 2008, 2009, 2010). The GDP is measured in 10*8 yuan in constant 1955 price. The energy consumption data is converted into standard coal consumption in 10*4 tce.

To prepare the data for undertaking the decomposition analysis by industrial sector, Jiangsu Province economy is divided into three aggregated industries, namely the primary, secondary, and tertiary industry. The primary industry includes agriculture and its related activities: farming, forestry, husbandry, secondary production and fishing. The secondary industry sector is comprised of mining, manufacturing, water supply, electricity generation and supply, steam, the hot-water and gas sectors, and construction. The tertiary industry sector is the rest.

Energy sources used by Jiangsu Province are aggregated into four groups: including primary energy, secondary energy, electricity and heat. The primary energy is composed of coal, oil, natural gas, hydro and nuclear energy. Secondary energy includes coke, coke oven gas, gasoline, kerosene, diesel oil, fuel oil, liquefied petroleum gas (LPG), refinery gas, other petroleum products. According to the study presented by Paul and Bhattacharya (2004), CO_2 emission from power and heat generation are assigned to three industrial sectors in the economy proportional to their consumption of electricity.

4. Results and discussion

4.1. Analysis of CO_2 emission

Jiangsu Province has experienced spectacular economic growth, with its GDP increasing at the average annual rate of about 12.6%