



Short communication

Study on decoupling analysis between energy consumption and economic growth in Liaoning Province

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HIGHLIGHTS

- The Tapio decoupling method is utilized to study what the decoupling status occurred in Liaoning Province.
- The generalized LMDI method is used to find the reason why the decoupling status appeared.
- The energy intensity decoupling effect played a positive role in the development of decoupling.

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ABSTRACT

Since 1978, Liaoning province has experienced spectacular economic growth, which has led to more energy consumption. The purpose of this paper is to explore the decoupling status between energy consumption and economic growth in Liaoning Province. Firstly, the generalized LMDI method is used to explore the driving forces governing production energy consumption in Liaoning province. Then, the combination of Tapio decoupling indicator and generalized LMDI method is utilized to study what the decoupling status occurred in Liaoning Province and why the decoupling status appeared. During the study period, only four decoupling status occurred: expansive negative decoupling, expansive coupling, weak decoupling, and strong decoupling. The energy intensity decoupling effect played a positive role in the appearance of decoupling. However, the economic structure decoupling effect and investment decoupling effect played a negative role in the appearance of decoupling. Over the study period, the energy structure decoupling effect and labour decoupling effect played a relative small role in the appearance of decoupling.

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1. Introduction

Currently, the global warming has become a serious issue in the world. However, energy-related CO₂ emission is the largest contribution to the greenhouse effect. Energy source is the main driving force of economic development. Along with spectacular economic growth, more energy has been consumed, which also results in seriously environmental pollution. Thus, whether an economy is becoming less dependent on energy consumption has been paid attention to by many researchers.

The influencing factors governing energy consumption and its environment emission can be explored by the decomposition techniques (Zhang et al., 2013). Currently, SDA (Structural Decomposition Analysis) and IDA (index decomposition analysis) are two

broad categories of decomposition techniques (Ma and Stern, 2008). The base of SDA approach is the input-output tables. The SDA can not only differentiate between direct and indirect energy demands, but also distinguish between a range of technological effects and structural effects. The SDA was used by Lin and Polenske (1995) to study China's energy use between 1981 and 1987. However, the input-output tables may only be available sporadically (Su and Ang, 2012). The advantage of IDA is the utilization of time-series data. IDA includes a variety of different indexing methods, such as the Laspeyres decomposition and LMDI method. By comparing various IDA methods, Ang (2004) concluded that the LMDI method was the preferred method. Because there are the logarithmic terms in the LMDI formulae, complications arise when the data set contains zero values. Ang and Liu (2007) presented eight strategies to handle zero values in LMDI method. By combining C-D production function and LMDI method, Wang et al., (2014) presented a new generalized LMDI method, which can be utilized to study many factors, such as fixed asset investment and labour.

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The relationship between energy use or related CO₂ emission and economic growth can be explored by many methods, such as simple regressions, correlation analysis, bivariate causality, panel cointegration, multivariate cointegration, unit root testing, variance decomposition and vector error correction modeling (Climent and Pardo, 2007). Among all the existing methods, the decoupling method is the best technique to characterize the dependence of economic growth (GDP) on energy consumption. The notion of decoupling was firstly introduced by Von (1989). However, Zhang (2000) firstly utilized the decoupling concept to explore the relationship between China's energy-related CO₂ emission and economic growth. In 2002, the OECD (2010) developed that concept into an indicator. Currently, two existing decoupling indexes have been widely used to figure out the dependence of economic growth (GDP) on energy consumption.

One is the Taipo decoupling index developed by Tapio (2005). Based on the elasticity concept, Juknys (2003) defined three kinds of decoupling. The primary decoupling is defined as the decoupling of natural resources consumption from economic growth. The secondary decoupling is defined as the decoupling of environmental pollution from natural resources consumption. If the primary decoupling and secondary decoupling happen at the same time, double decoupling will occur. Based on the Juknys's decoupling idea, Tapio (2005) redefined the Tapio decoupling indicator and three decoupling statuses (i.e., decoupling, coupling and negative decoupling), which was also utilized to explore the decoupling status in the European transport industry. To distinguish decoupling state rationally, Tapio divided three decoupling statuses into eight logical possibilities.

Due to the rational decoupling positions with eight possible combinations, the Taipo decoupling method has been widely used by many researchers (Ren and Hu, 2012). For example, Climent and Pardo (2007) used the Taipo decoupling indicator to investigate the causal relationship between energy use and Spanish economic growth. The Taipo decoupling indicator was utilized by Freitas and Kaneko (2011) to study the occurrence of a decoupling between Brazil's economic growth and energy-related CO₂ emission over the period 2004–2009. That indicator was also used by Zhang and Wang (2013) to study the decoupling status between GDP and energy-related CO₂ emission in Jiangsu province during the period 1995–2009.

The other decoupling indicator is defined based on the decomposition results received by IDA. Diakoulaki and Mandaraka (2007) firstly defined a decoupling model based on the result of the refined Laspeyres decomposition model, which was utilized to assess the real efforts undertaken in each country and their effectiveness in dissociating the economic and environmental dimensions of development. Using the decomposition results of LMDI method, Zhang and Wang (2013) developed a decoupling indicator, which was used to study the decoupling of electricity consumption from economic growth in China over 1991–2009. That decoupling method was also used by Zhang and Guo (2013) to evaluate the progress in decoupling energy consumption from per capita annual net income of rural households. But this decoupling method only defines three kinds of decoupling, i.e. weak decoupling, strong decoupling, and no decoupling.

As an important old industrial base in China, Liaoning province has experienced spectacular economic growth with the implementation of the development strategy for reviving northeast old industrial base, which has led to more energy use. Nowadays, the energy saving in Liaoning province has some problems, such as large energy gap, low resource utilization efficiency. Thus, it is necessary to explore the decoupling status between energy consumption and economic growth in Liaoning Province. The purpose of this paper is to explore the dependence of economic growth (GDP) on energy consumption in Liaoning Province over the

period 1995–2012. The Tapio decoupling indicator is used to complete that purpose. Then the generalized LMDI method provided by Wang et al. (2014) is used to find more affecting factors governing decoupling status between energy consumption and economic growth in Liaoning Province, which is the main contribution to the literature.

The remainder of this paper is organized as follows. Section 2 presents the methodologies of the study and related data. The main results are presented in Section 3. Finally, we conclude this study.

2. Methodology and data

2.1. LMDI method

The final energy consumption in year t (E^t) can be expressed as the following formula:

$$E^t = \sum_{i,j} \frac{E_{ij}^t}{E_i^t} \times \frac{E_i^t}{G_i^t} \times \frac{G_i^t}{G^t} \times G^t = \sum_{i,j} ES_{ij}^t \times EI_i^t \times S_i^t \times G^t \quad (1)$$

where t : the time in years; i : industrial sector; j : fuel type; E_i^t : energy consumption of the i th industrial sector in year t ; E_{ij}^t : energy consumption of the j th fuel type of i th industrial sector in year t ; G^t : the GDP in year t ; G_i^t : the GDP of the i th industrial sector in year t ; $ES_{ij}^t = \frac{E_{ij}^t}{E_i^t}$: the share of the j th energy form to total energy

consumption of the i th industrial sector in year t ; $EI_i^t = \frac{E_i^t}{G_i^t}$: the energy intensity of the i th industrial sector in year t ; $S_i^t = \frac{G_i^t}{G^t}$: the economic structure of the i th industrial sector in year t .

Nowadays, there exist a number of production functions in literatures. This paper tries to study the impact of investment and labour on energy consumption. However, the Cobb–Douglas (C-D) production function was widely used to represent the technological relationship between the amounts of two or more inputs, particularly physical capital and labour, and the amount of output that can be produced by those inputs (Wang et al., 2014). Thus, this paper selects the C-D production function to describe GDP. So the GDP can be expressed as the following Eq. (2)

$$G^t = A(K^t)^\alpha (L^t)^\beta \quad (2)$$

Where, A , α , β are unknown constant parameters. Commonly, $\alpha > 0$, $\beta > 0$. K : the fixed asset investment; L : the amount of labour input. Substitute Eq. (2) for the GDP on the right of Eq. (1), then we have the following Eq. (3)

$$E^t = \sum_{i,j} A \times ES_{ij}^t \times EI_i^t \times S_i^t \times (K^t)^\alpha \times (L^t)^\beta \quad (3)$$

According to the LMDI method given by Ang (2004), the change of energy consumption (ΔE_{tot}^t) between a base year 0 and a target year t can be decomposed into the following six factors: the energy mix effect (ΔE_{es}^t); energy intensity effect (ΔE_{ei}^t); economic structure effect (ΔE_s^t); labour effect (ΔE_l^t), investment effect (ΔE_k^t), and constant term effect (ΔE_a^t); as shown in the following formula.

$$\Delta E_{tot}^t = \Delta E_{es}^t + \Delta E_{ei}^t + \Delta E_s^t + \Delta E_k^t + \Delta E_l^t + \Delta E_a^t \quad (4)$$

Each factor in the right hand side of Eq. (4) can be expressed as follows:

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