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The nonlinear impacts of industrial structure on China's energy intensity

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ABSTRACT

Adjusting industrial structural is crucial for Chinese government's effort to reduce energy intensity. This paper, based on the fact that the Chinese industrial structure's two V-pattern evolutions and the nonlinear fluctuation of the declining rate of energy intensity, specifies a nonlinear threshold cointegration model for EI (energy intensity), IS (industrial structure), TECH (technological progress), and PRICE (energy price) in order to investigate whether, and under which conditions, industrial structure is beneficial for reducing energy intensity. Results show that IS has different effects on EI when IS is greater or smaller than 40.435%. Specifically, in 1980–1982, 1995–1997, and 2003–2008, IS and PRICE produced positive effects on EI, but produced negative effects in 1983–1994, 1998–2002, and 2009. TECH, including both capital embodied technological progress and Hicks-neutral technological progress, produced a negative effect on EI in 1980–2009. Thus, the industrial structure has a structural bonus or negative effects on energy intensity only when IS is smaller than 40.435%. Therefore, China should reduce the ratio of industry added value to the GDP and stimulate technological progress to continuously reduce energy intensity.

1. Introduction

Since China carried out its economic reform and opening policies in the late 1970s, its industrial structure (measured by the ratio of industry added value to the GDP) has fluctuated with two irregular V-shaped curves (see Fig. 1). However, its energy intensity (measured by energy consumption per unit of GDP, its inverse stands for energy efficiency[1]) follows a declining trend. Although this trend was temporarily reversed in some periods, such as in 1989 and 2003–2005, its decline rate is fluctuating dramatically. Thus, clarifying the possible effects of industrial structure on energy intensity and providing evidence for determining the possible direction for the decline rate of energy intensity are our motivation.

In the past, numerous studies were conducted on the relationship between energy consumption and economic growth in China by cointegration regression or Granger-causality test. Recently, more papers have investigated China's energy efficiency directly, specifically the relationship between China's energy intensity or efficiency and industrial structure changes, which is an important and challenges issue for policy makers [1]. Based on their approaches, these studies can be broadly divided into three categories (Table 1).

Firstly, most papers have used linear regression methods to analyze the effect of industrial structure on energy intensity and reported that structure upgrades are beneficial for decreasing energy intensity or improving energy efficiency. Fisher-Vanden et al. investigated energy intensity's fluctuation using panel data at the firm level, and concluded that structural change decreased energy intensity by 53% [2]. Wang & Yang used panel cointegration and showed that readjusted and optimized industrial structures would be beneficial for improving energy efficiency [3]. Wei & Shen argued that if the proportion of the secondary industry dropped by 1%, energy efficiency would be improved by 0.14% [4]. Yuan et al. adopted linear regression and found that energy intensity would decrease with an increase in the proportion of tertiary industry [5]. Feng et al. applied a linear cointegration model and found that

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[1] Energy intensity is the most popular index for energy efficiency. Industrial structure and energy intensity are formally defined in Section 2.

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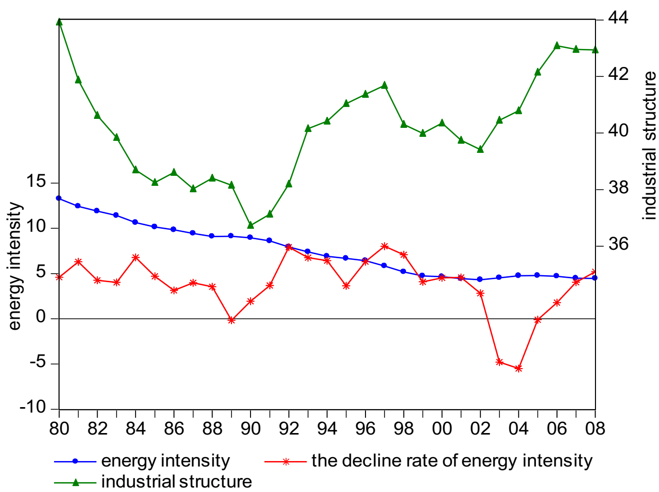

Fig. 1. Energy intensity and industrial structure in China, 1980–2009. Note: GDP is measured in 100 million Yuan in 1980 prices. Date source: National Bureau of Statistics of China (NBS).

increasing the proportion of the tertiary industry to the GDP could help reduce energy intensity, and the elasticity ratio was −0.588 [6]. Chen & Li used Tobit regression to analyze the effect of the proportion of industry added value to GDP on energy efficiency and revealed that the former had a negative impact on the latter [7]. Tan & Zhang adopted the state space model and linear cointegration and found that the proportion of the tertiary industry to GDP had a positive effect on energy intensity [8]. He et al. used linear cointegration analysis and had the same conclusion as Tan & Zhang [9]. Wu concluded that the structural transformation of the Chinese economy helped reduce energy intensity [10]. Using cointegration and scenarios analysis techniques, Lin & Moubarak found the structure of the Chinese paper industry played a key role in reducing the energy intensity and energy saving [11].

Secondly, with different index decomposition methods for different data, most papers reached similar conclusions, that is, industrial structure transformation is beneficial to reducing energy intensity. This implies there is a structural bonus for energy intensity in some periods. Qi et al. found through decomposition analysis that structure change was the main factor in declining energy intensity [12]. Liao et al. reported that the contribution from structural effects on the decline of energy intensity was −6% in 1997–2002 [13]. Li & Wang found that structure changes contributed a 7.5% decrease in energy intensity in 1995–2000 [14]. Ang & Liu (2001) argued that the LMDI (logarithmic mean Divisia index) method should be preferred to other decomposition methods with the advantages of path independency, ability to handle zero values and consistency in aggregation [15]. Ma & Stern adopted LMDI to decompose changes in energy intensity, and revealed that structural change at the industry and sector (sub-industry) levels increased energy intensity in 1980–2003 [16]. Wang & He (2009) used LMDI and found that the change in industry structure decreased energy intensity before 1998, but increased the intensity after 1998 [17]. Zhao et al. found that, although a heavier industrial structure did not help reduce China's energy intensity, energy efficiency improvement in energy-intensive sectors was mainly due to industrial structural policies implemented in 1998–2006 [18]. Wang et al. (2014) combined C-D production function and LMDI method and found energy intensity effect played the dominant role in decreasing energy consumption during 1991–2011 [19]. Fan and Xia used a SDA (structural decomposition analysis) based on six energy IO tables and found that industrial structure had major influence on energy intensity changes [20]. Zeng et al. (2014) revealed that industrial structure change had various impactions on energy intensity in different periods; in 1997–2002, it lead to a 2.4% decline in total energy intensity [21].

Thirdly, some studies have used statistical data to investigate the effect of industrial structure on energy efficiency, and concluded that a structural bonus exists for energy intensity. For example, Andrews-Speed provided empirical evidence that structural change was the main factor for the decline in energy intensity before 2002, but since 2002 it reversed [22]. Zhou (2010) provided an assessment of Chinese energy policies and programs, and argued it would play a critical role in China's energy and economic future [23]. Lin & Liu reported that adjustment and upgrading of the industrial structure can conducive for promoting energy efficiency [24]. From a statistic point of view, Zhang pointed that energy intensities were difference between sectors, which implied industrial structure changes played an important role in declining total energy intensity [25].

Clearly, some studies using China as a case study have shown that change in industrial structure is beneficial for improving energy efficiency, which indicates that a structural bonus exists for energy efficiency [2,3,7,10,12,14]. However, some papers have shown that no structural bonus existed in some periods [16,17,21]. What then is the real effect of industrial structure on energy intensity? We believe that the effect may be different in different periods due to the fluctuation of IS and EI and the rate of EI (Fig. 1). The relationship between them may not be linear. Thus, using linear regression models, including the linear cointegration model and its linear vector error correction model, cannot reveal the different influences of industrial structure on energy intensity. Decomposition techniques depend on formation and method for an index, implying a strict assumption that all decomposition factors have the same proportionate effects on energy intensity.

This paper extends the literature with a nonlinear threshold cointegration model of China's energy intensity in two ways. The

Table 1
Major studies of China's energy intensity.

Authors (year)	Study period	Method
Fisher-Vanden et al. (2004)	1997–1999	Divisia index and linear Regressions (firm level)
Wang and Yang (2006)	1985–2002	Panel cointegration (industry level)
Wei and Shen (2008)	1995–2006	Panel regression (regions level)
Yuan et al. (2009)	1982–2006	Linear regression
Feng et al. (2009)	1980–2006	Linear cointegration
Chen and Li (2010)	1990–2006	Tobit regression
Tan and Zhang (2010)	1978–2006	State space model and linear cointegration
He et al. (2011)	1999–2009	Linear cointegration
Wu (2012)	1980–2007	LMDI/Panel regression (regions level)
Lin and Moubarak (2014)	1985–2010	Linear cointegration
Qi et al. (2007)	1993–2005	IDA
Liao et al. (2007)	1997–2006	IDA
Li and Wang (2008)	1995–2006	IDA
Ma and Stern (2008)	1980–2003	LMDI
Wang and He (2009)	1994–2005	LMDI
Zhao et al. (2010)	1998–2006	LMDI
Wang et al. (2014)	1991–2011	LMDI
Fan and Xia (2012)	1987–2007	SDA
Zeng et al. (2014)	1997–2007	SDA
Andrews-Speed (2009)	1980–2007	Statistics analysis
Zhou et al. (2010)	1980–2008	Policies analysis
Lin and Liu (2011)	–	Policies analysis
Zhang et al. (2011)	–	Statistics analysis

Note: LMDI: Logarithmic mean Divisia index. IDA: Index decomposition analysis. SDA: structural decomposition analysis.
Source: Author's own compilation.

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