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Mitigation potential of carbon dioxide emissions in the Chinese textile industry

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HIGHLIGHTS

- We employed Johansen cointegration technique and scenarios analysis.
- The carbon intensity in the Chinese textile industry can be reduced by 60%.
- The CO_2 emissions reduction potential is estimated to be 44.8 million tons by 2025.
- Improving the technology and labor productivity will drive down the CO_2 emissions.
- Energy substitution is a promising method to cut down CO_2 emissions.

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ABSTRACT

We estimated the reduction potential of carbon dioxide emissions in the Chinese textile industry by forecasting the carbon intensity (CO_2 emissions/industrial value added) in different scenarios. The Johansen co-integration technique was employed in order to establish the long term equilibrium equation. Three scenarios (Business As Usual (BAU), medium and optimum) were designed to estimate the future trend of carbon intensity in the Chinese textile industry. The results showed that energy price, energy substitution, labor productivity and technology have significant impact on the carbon intensity. Estimated to 1.49 t CO_2/10,000 yuan in 2010, we found that for the BAU scenario, the carbon intensity will decrease to 0.5 and 0.29 t CO_2/10,000 yuan by 2020 and 2025 respectively. For the medium scenario, carbon intensity will decline to 0.12 t CO_2/10,000 yuan. Yet by the optimum scenario, the intensity is expected to considerably decrease to 0.05 t CO_2/10,000 yuan by 2025. Using the BAU forecast as baseline, the quantity of reduction potential in carbon dioxide emissions is estimated to be 44.8 million tons CO_2 by 2025. Considering this huge potential, we provided policy suggestions to reduce the level of CO_2 emissions in the Chinese textile industry.

1. Introduction

The carbon dioxide emissions in China has been increasing geometrically over the past thirty years. According to the 2010 estimates, the quantity of CO_2 emissions in China was equivalent to 25.1% of the global emissions [1]. In order to mitigate it, the Chinese government made a commitment to reduce considerably, the levels of emissions for the coming years and decided to give much priority to economic growth balanced with less pollution. According to the 12th Five-year plan presented in 2011, China is expecting by 2015 to reduce the energy consumption per GDP by 16%, to increase the share of non-fossil fuel in the total energy consumption by 11.4% and to cut down the carbon dioxide emissions per unit of GDP by 17%, compared to 2010. The realization of this plan will substantially boost China's contribution to the mitigation of carbon dioxide emissions at global level. In this paper, we analyzed the potential to reduce emissions in the Chinese textile industry. China became the world's largest producer of textile materials. Consequently due to this industrial expansion, the total energy consumption and CO_2 emissions grew annually by 4% and 2% respectively from 1985 to 2010. Energy consumption in the textile industry was estimated to be 73.45 mtce (million tons coal equivalent) in 2010; which was equivalent to 2.41% of the total energy consumed in China. In the meantime, carbon dioxide emissions represented 3.7% of the total emissions from the manufacturing sector [2]. The energy consumption was mainly driven by coal consumption due to its predominance as energy source employed in the production processes. Despite its progressive

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decline in proportion to the total energy consumed, the dependency on coal is not expected to drastically change in the short term (Fig. 1). Coal consumption increased from 18.68 mtce to 29.26 mtce during the study period. Moreover, coal has a high coefficient factor in term of CO_2 emissions. Thus, a combination of coal and other fossil fuels, namely coke and oil products led to high level of CO_2 emissions in the textile industry. As illustrated in Fig. 1, the CO_2 emissions were mainly due to the coal consumption; which represented an important proportion of the total energy consumed.

Through a series of questions orienting our research, we estimated the carbon intensity trends and the carbon dioxide reduction potential in several scenarios: (i) what variables have influence on carbon intensity in the Chinese textile industry? (ii) What are their degree of influence? and (iii) What will be the carbon intensity and is the reduction potential of CO_2 emissions? Answers to these questions will have significance for this paper; it will provide policy methods to reduce the carbon intensity, contribute to provide industrial strategy for the Chinese textile industry by cutting down CO_2 emissions while improving the industrial competitiveness.

2. Literature review

There have been several reports on carbon dioxide emissions reduction. These reports have been conducted using different approaches, leading to mixed conclusions. One popular and widely used method is the decomposition analysis. It has some convenience in studying the CO_2 emissions change. This method is based on analyzing the contribution of selected factors to the change in emissions. Sun et al. [3] studied the change of CO_2 emissions in China's iron and steel industry and concluded that energy consumption was the most important factor leading to a decrease in CO_2 emissions. Later, Xu et al. [4] analyzed the case of China's cement industry and Wang and Liang [5] focused on 12 key economic sectors. Similarly, Hatzigeorgiou et al. [6] analyzed the energy-related CO_2 emissions in Greece from 1990 to 2002.

From these studies, we denote that decomposition approach is convenient to study change in CO_2 emissions, however it is not appropriate for forecasting the future emissions level and reduction potential.

The data envelopment analysis (DEA) model has been also used in several studies. Guo et al. [7] focused on finding out the emissions performance of Chinese provinces and their respective reduction potential. Later, Choi et al. [8] attempted to determine the potential reduction and efficiency of CO_2 emissions in China. According to their results, the average marginal abatement cost of CO_2 emissions is about $7.2. However, the limitation of this study is due to the fact that there is no specific function form while using the nonparametric method.

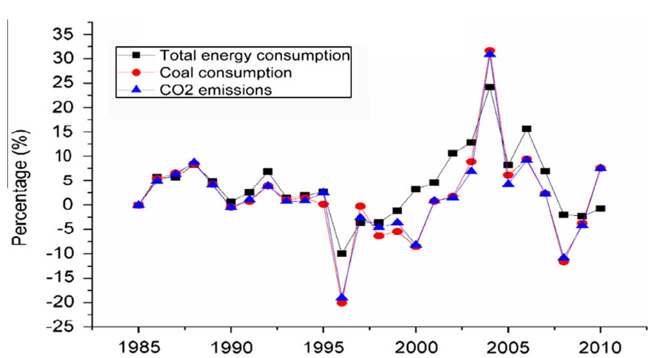

Fig. 1. Percentage of growth of coal consumption, total energy consumption and CO_2 emissions.

Hasanbeigi et al. [9] applied the bottom-up CO_2 abatement cost curves model which is a variant of the energy conservation supply curves methodology to determine the potentials and costs of CO_2 mitigation through abatement technologies from 2010 to 2025 in the Thai cement industry. They found that the abatement potential represented 15% of the total cement industry emissions in 2005. Similarly, Worrell et al. [10] analyzed the cost-effective energy efficiency and the carbon dioxide emissions mitigation potential in the US iron and steel industry between 1958 and 1994. They found a total cost-effective reduction potential of 3.8 GJ/t with a payback period of three years or less. Despite the wide use of this method, it has some limitations because it is focused only on the existing technology.

Using the scenario analysis method, Ke et al. [11] studied the energy saving and CO_2 emissions reduction potential in China's cement industry. They estimated that the carbon reduction potential represents 3.2–4.4 gigatonnes during 2011–2030 and that the energy efficiency is the key policy measure to drive down carbon emissions intensity in the cement's industry. Ari and Aydinalp Koksal [12] analyzed the reduction potential of carbon dioxide emission from the Turkish electricity sector. Based on four scenarios, they argued that a significant decrease in the amount of CO_2 emissions from electricity generation can be achieved if the share of the fossil-fueled power plants is lowered. Later, Özer et al. [13] used the Long-range Energy Alternatives Planning system (LEAP) model to investigate mitigation potential of emissions in the electricity sector. They found that cumulative CO_2 emission reduction between the BAU and Mitigation Scenarios from 2006 to 2030 is 903 million tons. He et al. [14] attempted to forecast the future CO_2 emissions from fossil energy combustion in China from 2010 to 2020; similar to Li et al. [15] who focused their research on shanghai city (China). Henriques et al. [16] analyzed the carbon dioxide (CO_2) emissions reduction potential from energy consumption in Brazilian industrial sector. Their conclusions showed that by improving energy efficiency, recycling and energy substitution, it will be possible to reduce carbon dioxide emissions by 43% in the industrial sector during 2010–2030 period. However, an important variable such as price was not considered.

Far to be exhaustive, several methods and variables have been used to determine the carbon emissions change and reduction potential. However to the best of our knowledge, studies conducted on reduction potential of CO_2 emissions in the Chinese industries are limited. Therefore, we extended the research on Chinese textile industry by conducting an in-depth study on mitigation potential of CO_2 emissions.

3. Methodology and data sources

3.1. Co-integration approach

The Johansen co-integration test has a property to determine the long term relationship among variables. It is employed to determine a long run relationship among carbon intensity, technology, energy price, labor productivity and energy substitution. Prior to the regression analysis, we verified that the variables are stationary in order to avoid spurious results. So, to determine whether these variables have the same integration order, the unit root tests were applied. The most common tests used are Augmented Dickey–Fuller (ADF) tests [17], Phillips–Perron (PP) tests [18] and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests [19].

Eq. (1) is the Augmented Dickey–Fuller (ADF) test representation to test the unit root hypothesis.

$$\Delta z_t = \beta_0 + \alpha_0 t + \alpha_1 z_{t-1} + \sum_{i=1}^{m} \beta_i \Delta z_{t-1} + \varepsilon_t \tag{1}$$