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Impacts of the coming emission trading scheme on China's coal-to-materials industry in 2020

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HIGHLIGHTS

- Present the latest developments in China's coal-to-materials industry.
- The coal-to-materials industry in China is a potential huge CO_2 emission source.
- Develop a Cournot-based model to analyze the contest between the coal and oil paths.
- The carbon price has a limited effect on mitigating emissions from the coal path.

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ABSTRACT

China will establish a national emission trading scheme (ETS) in 2017, and the excessive development of coal-to-materials may hinder China's emission reduction goals, specifically to reduce carbon emissions intensity by 40–45% from 2005 to 2020. In this study, the status of China's coal-to-materials projects is presented, based on which we forecasted the high, middle and low CO_2 emission scenarios for the coal-to-materials industry in 2020, which were determined to be approximately 580, 290, and 180 Mt CO_2, respectively. The high scenario is approximately equivalent to the total emission from Canada, the world's 11th-largest emitter in 2014. The main purpose of this study is to research the impacts of ETS on the coal-to-materials industry in 2020. Oil-to-materials is an ineluctable and powerful competitor to the coal-to-materials industry, complicating this matter. Therefore, the Cournot model was applied to quantitatively analyze the competition between these two monopolistic entities and determine the influence of oil, coal and carbon prices on CO_2 emissions from coal-to-materials. The visual simulation of the results shows that ETS can improve the competitiveness of oil-to-materials, resulting in a decline in production of coal-to-materials. However, the effect of the carbon cost with historical price range of Chinese ETS pilots on mitigating CO_2 emissions from the coal-to-materials industry is limited. High oil prices and low coal prices can increase the emissions from coal-to-materials significantly. Our study also provides a tool to analyze the feasibility of ETSs for a set emission reduction goal. Additionally, the necessary sensitivity analysis was also provided.

1. Introduction

Industrialization and urbanization promote the rapid growth of fossil fuel consumption and produce significant amounts of carbon dioxide [1]. The entire world is now paying attention to climate change linked to CO_2 emissions. With rapid economic development, China is now the world's largest primary energy consumer and CO_2 emitter [2]. In 2014, China consumed 23% of the global fossil energy and coal remains the largest proportion (66.0%) in China's energy structure [3]. China shoulders a sizeable responsibility for the CO_2 emission reduction. At the 2009 Copenhagen Summit, the Chinese government announced a commitment to reduce its carbon intensity in 2020 by 40–45% of the 2005 levels [4]. China began to establish pilot carbon emission trading schemes (ETSs) in 2013, and now, China has seven pilots including the cities of Beijing, Chongqing, Shanghai, Shenzhen, Tianjin, and the provinces of Guangdong and Hubei, collectively accounting for 27% [5] of the national GDP. Furthermore, China and the U.S. published a "Joint Announcement on Climate Change" in September 2015, and China promised to start the unified national carbon emissions trading market in 2017, a market that will be the largest

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Nomenclature

ETS	the emission trading scheme
P	the production of olefins, ethylene glycol and aromatics, Mt
P_{2020}	the production of coal-to-materials in 2020, Mt
e_1, e_2, e_A, e_B	the emission factor, t-CO_2/t-product
q_A, q_B	the production of enterprise A/B, Mt
q_1, q_2, q_3	the production of olefins, ethylene glycol and aromatics in 2015, Mt
p_A, p_B	the price from enterprise A/B, dollars/ ton
m, m_1, m_2, m_3	half of the market capacity, Mt
k	the price sensitivity, Mt/dollar
π_A, π_B	the profit of enterprise A/B, dollars
t	the carbon emission cost, dollars/t-CO_2
c_A, c_B	the product cost of enterprise A/B, dollars/t-product
a, a'	the price of coal/lignite, dollars/ton
b	the price of oil, dollars/barrel
G	the growth rate, %
E	the carbon emission, Mt
ΔE	the reduction in CO_2 emissions with an increase in t from \$0 to \$10, Mt
R	the decreasing rate of the CO_2 emissions, %
Δe	the reduction in CO_2 emissions when the carbon price is increased by one unit, Mt/dollar

in the world. ETS will play an important role in reducing carbon emissions and will have a profound effect on the development of high carbon emission industries in the near future.

Coal and oil provide human beings with a large amount of fuel and basic organic chemical raw materials, which are crucial for economic development. For fuels, the development of a new energy industry can provide suitable substitute products (solar energy, wind energy, biofuels, etc.), and China is now trying to implement new energy alternatives to reduce its dependency on fossil fuels [6]. However, for basic organic chemical raw materials generally obtained from fossil resources, there is currently no suitable alternative. The coal-to-materials aspect of the coal chemical industry and the oil-to-materials aspect of the petrochemical industry produce homogeneous products, including olefins, ethylene glycol and aromatics. These three products are important raw materials for modern industry, and their apparent consumption is in the top three among basic organic chemical raw materials [7]. The great demand for organic raw materials is observed worldwide and maintains sustained growth [8–10], especially for China, an important emerging economy and the second largest one in the world. China has a huge demand for basic organic chemical materials. However, China's production capacity is still unable to meet the domestic consumption demand of these three products (see Fig. 1). Adding to the plight of a single industry structure in the coal industry and the national resource characteristics, abundant in coal and deficient in oil, coal-to-materials has rapidly developed in recent years (see Table 1). Although olefins, ethylene glycol and aromatics are now mainly produced by oil-to-materials [11], with further industrialization of coal chemical technology, coal-to-materials will be a potential competitor to oil-to-materials [12].

However, the high CO_2 emissions from coal-to-materials are an unavoidable problem. From the perspective of elemental composition, the hydrogen/carbon (H/C) ratio in coal is 0.2–1.0, and the H/C ratio in oil is 1.6–2.0. The process of producing materials is generally accompanied by an increase in the ratio of H/C, meaning that the coal-to-materials discharge more CO_2 than oil-to-materials [13]. Moreover, coal-to-materials need a larger energy supply, such as coal-fired power or other fuels, which can also lead to more CO_2 emissions [14]. The coal (oil)-to-materials will be explicitly subsumed into the national ETS in 2017, meaning that they will pay for carbon emission. It is clear that compared to oil-to-materials, coal-to-materials will shoulder a heavier burden of carbon emission cost beginning in 2017. The development of coal-to-materials, under the national ETS, deserves academic concern and research because of its high CO_2 emissions.

The ETS is one of the two main cost-effective mechanisms for controlling carbon emissions; the other one is carbon tax [15]. In ETS, a total emission level is fixed for all of players within a group with each player being able to buy or sell the right to emit carbon as a tradable commodity, which is considered an effective mechanism to reduce CO_2 emissions with lower abatement costs [16]. The EU, Tokyo, California, Quebec and China's pilot cities all had established the ETS between 2005 and 2013 [17]. The EU-ETS is now the largest carbon trading market in the world and proved to yield satisfactory results in practice since 2005 [18–20]. Second only to the EU-ETS in size, China's ETS pilots made progress in construction of the carbon market and have obtained certain achievements, which have covered 743 Mt CO_2-e emitted by more than 2000 enterprises [21–24]. We found that studies on the ETS impact assessment can be divided into two categories. One category focuses on the impacts of ETSs on the economy and the environment of a country or region [15,25–33]. The literature indicates that the ETS can play an effective role in CO_2 emissions reduction and cost saving, which is beneficial to the economy and the environment of a country or region. Therefore, as China is the largest carbon emitter, the construction and operation of nationwide ETS in China is essential.

The other category focuses on the impacts of ETS on some industry sectors or enterprises. For example, Karali et al. [34] used the ISEEM modeling framework to analyze the roles of international carbon trading in the U.S iron and steel sector. Linares et al. [35], Linares et al. [36], and Kara et al. [37] studied the influence of EU-ETS on the power sector in different European countries. Li et al. [38] and Zhao et al. [39] investigated the impacts of carbon price and carbon market on China's power sector, respectively. Lee et al. [40] studied the impacts of three different CO_2 emission trading schemes on the cement sector in Europe. Jan et al. [41] employed a simulation model to estimate the economic impacts and ecologic effects of the EU-ETS in the aviation industry. However, no one has conducted research related to the impacts of ETSs on China's coal chemical industry. Based on the current production capacity (see Table 1), the CO_2 emissions from China's coal-to-materials are approximately 100 Mt, equivalent to the total emission from some countries, such as Belgium (100 Mt) and Chile (82 Mt) [42]. Furthermore, the previously analyzed sectors have no obvious extrinsic competitor. The coal chemical industry faces external competitive pressures from the petrochemical industry, which complicates the impacts of the ETS.

A study on the development of coal-to-materials under the national ETS should take the competition between coal-to-materials and oil-to-materials into consideration. The Cournot duopoly model is a theoretical model often used to study the competition between a small number of large enterprises. It can also be theoretically used to study the market competition of various industries or sectors. This model has been applied by Mulder et al., who analyzed the competition of two different power generation techniques in the electricity wholesale market [43]. Hu et al. used a Nash–Cournot model to study the competition of a plant