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The shadow price of CO_2 emissions in China's iron and steel industry

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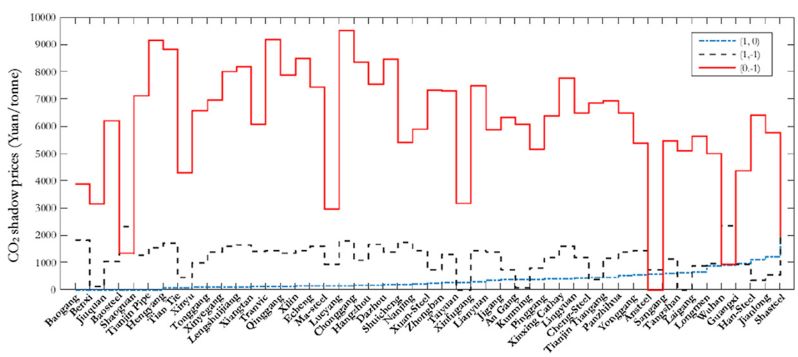
HIGHLIGHTS

- First attempt to estimate the abatement cost of CO_2 emissions in China's iron and steel industry.
- We use a unique dataset of China's iron and steel enterprises.
- The results show that the mean CO_2 shadow price is very sensitive to the choice of direction vectors.
- We find substantial heterogeneity in the shadow prices among China's iron and steel enterprises.
- We show that using an arbitrarily chosen direction vector may significantly underestimate shadow price heterogeneity.

GRAPHICAL ABSTRACT



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ABSTRACT

As China becomes the world's largest energy consumer and CO_2 emitter, there has been a rapidly emerging literature on estimating China's abatement cost for CO_2 using a distance function approach. However, the existing studies have mostly focused on the cost estimates at macro levels (provinces or industries) with few examining firm-level abatement costs. No work has attempted to estimate the abatement cost of CO_2 emissions in the iron and steel industry. Although some have argued that the directional distance function (DDF) is more appropriate in the presence of bad output under regulation, the choice of directions is largely arbitrary. This study provides the most up-to-date estimate of the shadow price of CO_2 using a unique dataset of China's major iron and steel enterprises in 2014. The paper uses output quadratic DDF and investigates the impact of using different directional vectors representing different carbon mitigation strategies. The results show that the mean CO_2 shadow price of China's iron and steel enterprises is very sensitive to the choice of direction vectors. The average shadow prices of CO_2 are 407, 1226 and 6058 Yuan/tonne respectively for the three different direction vectors. We also find substantial heterogeneity in the shadow prices of CO_2 emissions among China's major iron and steel enterprises. Larger, listed enterprises are found to be associated lower CO_2 shadow prices than smaller, unlisted enterprises.

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1. Introduction

Facing mounting pressure from increasingly environmentally conscious citizens as well as global community in climate negotiations, China has taken significant efforts in energy conservation and carbon emissions reduction in recent years. In 2009, China committed to reduce its CO_2 emissions per unit of GDP (i.e. emission intensity) by 40%–45% by 2020 from its 2005 level (Wang and Wei, 2016). China also implemented binding targets during its 12th Five-Year Plan (FYP) period (2011–2015) to reduce energy consumption per unit of GDP (i.e. energy intensity) by 16% and carbon intensity by 17% from its 2010 levels (SCC, 2011a). In the recently released 13th FYP period (2016–2010), the government pledged another 15% reduction in energy intensity and 18% reduction in CO_2 emission intensity by 2020 (SCC, 2016). China has also played an increasingly proactive role in international climate negotiations in recent years. For example, in 2015, the Chinese government made significant commitments at the Paris climate summit. China pledged to peak its CO_2 emissions no later than 2030, reduce its CO_2 emissions per unit of GDP by 60%–65% by 2030 from its 2005 level, and increase the proportion of non-fossil fuels in the total primary energy supply to 20% by 2030 (NDRC, 2015; Lomborg, 2016; Den Elzen et al., 2016). The Paris Climate Agreement was recently ratified by The Chinese government also ratified the Paris Climate Agreement at the G20 Summit in 2016. Emission reductions in energy-intensive industries are widely believed to be critical to fulfil these commitments. The focus on energy-intensive industries is also demonstrated by a series of administrative measures aiming to phase out outdated production capacity in these industries. However, given the context of a proposed national carbon trading market in an effort to improve mitigation efficiency, the extent to which energy-intensive industries should take on mitigation depends on their abatement costs of CO_2 emissions.

Iron and steel industry is one of the most energy-intensive industries in China that accounts for approximately 15% of China's total energy consumption, 12% of China's total CO_2 emissions, and 27% of the national industry emissions (Guo and Fu, 2010; Wang and Jiang, 2012; Xie et al., 2016). It is thus not surprising that energy saving and carbon emissions reduction in China's iron and steel industry has become a focal subject in recent literature. Worrell et al. (1997) compared the energy intensity of iron and steel industry in seven countries using a decomposition analysis based on physical indicators for process type and product mix. Their results show that the efficiency improvement is the main driver for energy savings in China's iron and steel industry. Wang et al. (2007) assessed the CO_2 abatement potential of China's iron and steel industry based on different CO_2 emissions scenarios from 2000 to 2030 and found that adjusting the structure of the industry and improving the technology played an important role in CO_2 emissions reduction. Zhang and Wang (2008) estimated the impact of energy saving technologies and innovation investments on the productive efficiency in China's iron and steel enterprises during the period 1990–2000 and found that the adoption and improvement of energy saving measures, such as pulverized coal injection technology, had attributed to productive efficiency growth. Guo and Fu (2010) did a survey about the development and current situations of energy consumption in China's iron and steel industry and found that its energy efficiency has significantly improved from 2000 to 2005. Tian et al. (2013) examined the trend, characteristics and driving forces of energy-related greenhouse gas (GHG) emissions in China's iron and steel industry from 2001 to 2010 and indicated that the production scale effect was the main driver for the growth of energy related GHG emissions in China's iron and steel industry. Similar to Wang et al. (2007), Wen et al. (2014) also assessed the potential for energy saving and CO_2 emissions mitigation in China's iron and steel industry but for a shorter period from 2010 to 2020. Hasanbeigi et al. (2013) constructed a bottom-up energy conservation supply curve to estimate the cost-effective and total technical potential for CO_2 emissions reduction in China's iron and steel industry during 2010–2030. Lin and Wang (2015) investigated the total factor CO_2 emissions performance and estimated the emissions mitigation potential in China's iron and steel industry during the period of 2000 to 2011. In another paper, they also analyzed the energy conservation potential of China's iron and steel sector using the co-integration method and scenario analysis (Lin and Wang, 2014). Xu and Lin (2016) also studied CO_2 emissions in China's iron and steel industry but focused on regional differences.

To sum up, most studies have shown that there is substantial potential for emissions reduction from this industry; however, the amount of actual abatement will largely depend on the marginal abatement cost (MAC). Under a carbon trading setting, firms from an industry with high MAC would rather purchase permit than actually engage abatement (even with large abatement potential). Despite the rapidly growing literature on CO_2 emissions in China's iron and steel industry, no work has attempted to estimate the abatement cost of CO_2 emissions in this industry, which seems an important gap to fill.

The estimation of the abatement cost of CO_2 emissions is fundamental to the design and implementation of carbon reduction policies. China's current emission reduction policies based on administrative targets of reduction in emission intensity is widely criticized to be lack of economic efficiency.[1] The government is taking measures to transit to market based instruments by establishing pilot carbon trading market and eventually a national trading market. However, the validity of the argument that a trading market is economically more efficient than intensity reduction targets depends very much on the heterogeneity of MAC especially at the firm level. The estimation of MAC is thus of great significance and attracts increasing attention in recent literature. Most studies have estimated China's carbon abatement cost at regional level including Wei et al. (2012), Wang et al. (2011), Choi et al. (2012), Zhang et al. (2014), Du et al. (2015), He (2015), Ma and Hailu (2016), Tang et al. (2016), Sun et al. (2015) and Wu and Ma (2017), or at industrial level such as Lee and Zhang (2012), Peng et al. (2012), Chen (2013), and Zhou et al. (2015). However, firm-level analyses are very limited due to the lack of high-quality firm-level data. The only few studies using firm-level data all focused on the electricity sector. Wei et al. (2013) evaluated the inefficiency and CO_2 shadow prices of 124 power plants located in Zhejiang Province in 2004. Du and Mao (2015) estimated CO_2 reduction potential and MAC of CO_2 for China's coal-fired power plants in 2004 and 2008. Du et al. (2016) investigated the carbon abatement cost of power plants based on a plant-level cross-sectional dataset (648 observations) for the year of 2008. To the best of our knowledge, there is no firm-level analysis on the MAC (i.e. shadow price) of CO_2 emissions in the iron-steel sector.

[1] During the 11th FYP period (2006–2010), the China's government proposed an administrative target to reduce energy intensity by 20% which was further assigned to each province. In the ending two years of this period, some industrial enterprises with high energy intensity and large difficulty in energy conservation had to switch out for power consumption limitation to reach this target, which can be extremely costly.