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An estimation of the effect of carbon pricing for CO_2 mitigation in China's cement industry

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HIGHLIGHTS

- This paper estimates mitigation effect of carbon pricing in China's cement sector.
- A total of 16 energy saving carbon mitigation technologies were included.
- The statistics and prediction dataset from China Cement Association (CCA) was used.
- Earlier introduction of a carbon pricing regime in China is advised.
- The interaction of carbon pricing with existing policies has been considered.

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ABSTRACT

This study estimates the effect of carbon pricing for CO_2 mitigation in China's cement industry. The statistics and prediction show that cement production initially experienced accelerated growth and is now expected to plateau out over the next few years. The energy saving and carbon mitigation technologies considered in this estimation are at different adoption stages. Full technology diffusion is expected within 10–20 years, and the remaining technology mitigation potential stands at about 8.8% by 2025 and 10.2% by 2030. Nevertheless, attaching a price to carbon would have a limited effect. Reductions of 9.9 and 12.9 Mt-CO_2 might have been realised in 2015 under respective prices of 60 and 100 Yuan/t-CO_2, compared to a non-pricing scenario. The reduction attributed to carbon pricing would be around 4.9 Mt-CO_2 in 2020 at both price levels, and around 70% of the mitigation may be at a marginal cost of 50 Yuan/t-CO_2 by 2020. The marginal cost for nearly 90% of the policy mitigation would be below 100 Yuan/t-CO_2 by 2030. This paper confirms the effectiveness of a command-and-control approach so far for energy saving in China's cement industry and advises early introduction of a carbon pricing regime with consideration of policy interactions.

1. Introduction

Cement production is an energy and carbon intensive process and responsible for around 5% of global CO_2 emissions. About 60% of these emissions come from the raw materials used in the process, i.e., limestone, and around 40% is from the energy use. Appropriate mitigation technologies are required in order to suppress this burden on climate change. According to the technology roadmap drafted by the International Energy Agency (IEA) and the World Business Council for Sustainable Development, the cement industry could reduce its current direct emissions by 18% by 2050, at a cost ranging from 350 to 570 billion USD in a low demand scenario to 520–840 billion USD in a high demand scenario. Much additional investment would be needed in developing countries [1]. For bridging the gap to 80% reduction by 2050, about 15% of the reduction could be achieved by replacing fossil fuels by biomass, with only a small fraction of this potential already used. Clinker substitution has a similar potential but with a larger variation across regions and a large share of this potential implemented between 1990 and 2011. There is little consensus on the potential from cement substitution, more efficient usage of cement and new cement types. About 40–60% of the reduction should come from Carbon Capture, Utilisation and Storage (CCUS) [2].

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After attaining the world's top spot in 1985, China's cement production rose to 2.42 billion tonnes in 2013, about 60% of the global total. New dry processes were added to 1715 clinker production lines in the same year, and capacities of over 5000 t-clinker/d represent 60% of overall capacity. During the eleventh five-year plan (FYP) period (2006–2010), China's cement industry reduced its energy consumption intensity by 42.9%, mainly via structural improvements and technology upgrades, and its average coal consumption per ton of clinker stood at 111.2 kgce (kg of standard coal equivalent) in 2013, a 22.7% decrease from the previous year [3]. China's cement industry is also a major source of CO_2 emissions due to the high production volume involved and the highly carbon-intense nature of the industry. The current level of technology used in China's cement industry is basically on a par with the global advanced level, but the average energy efficiency of the industry is about 10% lower. This means a large potential exists for CO_2 mitigation via further diffusion of low carbon technologies (LCT) [4].

In light of the key significance for energy saving and carbon mitigation in China, much research has been carried out on the cement industry, some of which covers CO_2 emissions. For example, Cui and Liu [5] calculated CO_2 emissions coefficients for production processes, results of which indicate that CO_2 emissions from raw material calcination, coal burning and electricity use individually account for 59%, 26% and 12% of the total. Lei et al. [6] quantified total direct emissions of air pollutants for 1990–2008, which revealed that this sector is responsible for approximately 1/8 of the country's total emissions. Wang et al. [7] inventorised CO_2 emissions and identified key factors. Total emissions were estimated at 1095.1 million tonnes of CO_2 (Mt-CO_2) in 2009, 592.8 Mt-CO_2 (54.1%) of which were process-related and 502.3 Mt-CO_2 (45.9%) were energy-related. Factors responsible for the increases emissions during 2005 and 2009 include the growth of clinker and cement productions, while improvements in energy intensity played a positive role in offsetting total emissions of the sector. Improvement in energy use structure was not the dominant factor leading to reduction in CO_2 emissions of the industry [7]. Cai et al. [8] evaluated CO_2 emissions from cement industry using the detailed information of China's total 1574 cement plants in 2013, and confirmed that state-owned and large scale companies dominate the emissions, respectively accounting for 59.4% and 61.9% of the sector's total. The average emissions of China's cement companies was 35 kg CO_2/t-clinker lower than the global average of the same year. Future policies are recommended to focus on medium sized facilities.

Cai et al. [9] is one of the earlier studies to quantitatively estimate CO_2 mitigation potential and the costs involved at the sector level in China, with the cement industry as one of the targets. Their scenario calculations, which covered 12 technologies and made use of the Long-rang Energy Alternative Planning System (LEAP) model, showed that two technologies ('conversion to multi-stage pre-heater kiln' and 'combustion system improvement') were found to have the highest mitigation potentials by 2020, and that most potentials might be realised at low and even negative costs. Due to lack of sufficient information, technology adoption rates were assumed arbitrarily. Further, analysis scenarios were defined solely based on administrative and regulatory approaches, and did not account for the effect of market-based instruments [9]. Applying the Energy Conservation Supply Curve (ECSC) model, Hasanbeigi et al. [10] surveyed 16 cement plants in Shandong Province and compared their energy use with domestic and international best practices in order to estimate the remaining energy saving potential, which was 12%, based on assumed operations at the best domestic level possible in 2008. This study was data-intensive and required detailed information from companies. Xu et al. [11] evaluated the effect of potential technological improvements to China's cement industry compared with the global IEA target on CO_2 emissions reduction up to 2050, and states that it appears feasible to achieve the IEA target using current best available technologies. Individually, the four technology levers—clinker substitution, CCUS, and energy efficiency improvement and alternative fuels—account for about 37%, 33%, 15% and 15% of the total potential [11]. Wang et al. [12] is one more recent research to quantitatively evaluate CO_2 reduction potential and the costs avoided via application of mitigation technologies in China's cement industry, which concludes that carbon emissions from the industry could be reduced mainly via energy efficiency improvements and alternative fuels, and that clinker substitution would provide a significant cost advantage. The analysis was based mainly on strong technology deployment, but the scenarios were somewhat simplistic and had no linkage in terms of specific policy measures [12]. Additionally, Wen et al. [13] developed a model based on the Asian-Pacific Integrated Model (AIM) and evaluated the potential for CO_2 emissions reduction in China's cement industry between 2010 and 2020. Technology promotion and sector structure adjustment are confirmed as the main measures, while structural adjustment is the most important approach to reduce the CO_2 emissions from this industry. Zhang et al. [14] developed an integrated assessment model to evaluate the energy saving potential of China's cement industry, and multiple benefits of mitigation of CO_2 emissions and air pollutants of energy efficiency measures at the provincial level during 2011 and 2030. Their results show significant heterogeneity across provinces. Applying an integrated assessment framework combining the Stock-based model and the integrated MARKAL-EFOM system of China (China TIMES), Li et al. [15] simulated the trends of energy consumption and CO_2 emissions of China's cement sector during 2010 and 2050. They conclude that China's cement sector's carbon mitigation will mainly rely on energy efficiency improvement in the near future, while the use of alternative fuels and CCUS will be of great significance from a long-term perspective.

As the studies with relevance in abroad, Rootzén and Johnsson [16] assessed the prospects for presently available abatement technologies to achieve significant reductions in CO_2 emissions from large stationary sources in the EU up to 2050, covering power generation, petroleum refining, iron & steel and cement production. The results confirm that the EU goal for reductions in the sectors under the EU-ETS, i.e., 21% reduction by 2020 compared to the levels in 2005, is attainable with the already available abatement measures. However, these sectors will fail to comply with more stringent reduction targets in both the medium term (2030) and long term (2050), requiring for novel low-carbon technologies and production processes. Rootzén and Johnsson [17] further assessed the prospects for Nordic carbon-intensive industries to significantly reduce direct CO_2 emissions up to 2050. The analysis covers petroleum refining, integrated iron & steel production, and cement manufacturing in the four largest Nordic countries, and highlights the importance of encouraging increased use of biomass and the utilisation of alternative raw materials in cement manufacturing. Bearing in mind the importance of cement industry in Croatia, Mikulčić et al. [18] estimated the potential to reduce CO_2 emission in the Croatian cement industry. The possible measures together with numerical investigations were confirmed to reduce the effect of cement manufacturing in Croatia on carbon emissions.

With the aim of understanding how low carbon technology diffusion would be affected by the pricing of carbon emissions, the authors of this paper surveyed China's cement companies in 2014 using a questionnaire in order to gauge the possibility of technology investment based on profitability. With use of historical adoption data for certain technologies as well as an epidemic model, the technology diffusion trajectories were depicted under the assumed carbon prices. Only three technologies were focused