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Carbon pricing for low carbon technology diffusion: A survey analysis of China's cement industry

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ABSTRACT

This study estimates the effect of using carbon pricing to promote the diffusion of low carbon technologies based on data collected from 78 cement companies in China. The analysis confirms that they are familiar with major energy saving and low carbon technologies in the sector and have made efforts in energy saving, but are lagging in terms of carbon management. An average payback time of 3.3 years is confirmed as the threshold for cement companies to determine technology investment. The adoptions of target technologies in this survey are at different stages; WHR (waste heat recovery power generation) systems have been largely diffused and the effect of carbon pricing is highly marginal for further adoption. On the other hand, levying a moderate carbon price, i.e., 60 Yuan/t-CO_2, may accelerate the diffusion of EMOS (energy management and optimisation systems), recently introduced in China's cement industry. This research goes some way to clarifying the diffusion of low carbon technologies and provides implications for climate countermeasures for the target sector in China.

1. Introduction

China is the largest GHG (greenhouse gases) emitter in the world and to realise its 20% reduction in energy intensity during the 11th FYP (five-year plan) period (2006–2010), it mainly relied on administrative approaches [45]. A similar policy framework continued into the 12th FYP period (2011–2015) to achieve a further 17% cut in carbon intensity. However, the country cannot rely on costly administrative measures to realise its pledge of a 40–45% reduction in carbon intensity by 2020 from 2005 levels or its commitment to cap GHG emissions by around 2030 under the joint climate statement between China and the U.S. announced on November 11, 2014. The importance of allowing the market to play a decisive role in resource allocation has been recognised by China's leadership, which calls for a ramp-up in use of MBIs (market-based instruments) as a complementary policy measure.

In practice, the NDRC (National Development and Reform Commission) approved the pilot GHG ETS (GHG emissions trading schemes) in late October 2011 for seven areas, including five metropolitan cities (Beijing, Shanghai, Tianjin, Chongqing and Shenzhen) and two provinces (Hubei and Guangdong) [38]. After preparations, Shenzhen began trading in June 2013 and the other pilot regions started between the end of 2013 and mid-2014. As a follow-up effort, NDRC announced that a nationwide carbon market would be established as early as 2016 [41], and the recently released interim measures for carbon emissions trading management was an additional step forward in this direction [40]. Meanwhile, over the last few years, experts at research institutes of related ministries have been discussing how to develop carbon tax policy in China, and they conclude that a carbon tax should be phased in gradually, and very conservatively, starting from 10 Yuan/t-CO_2 and increasing to 40 Yuan/t-CO_2 some years later [28].

Strong resistance from industry has been identified as the most significant barrier for the implementation GHG ETS and carbon tax. Nevertheless, scant empirical research clarifying just what would be acceptable for business in terms of carbon pricing has been carried out. Aiming to close this gap, Liu et al. [28] discussed carbon price levels that in theory would be tolerated by companies in Northeast Asia and China in particular. Extending this line of enquiry, this study estimates the effects of using carbon pricing to enhance diffusion of LCT (low carbon technology) in China's cement industry. According to the literature review in Section 2, many

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studies have attempted to empirically clarify the factors determining how business invests in LCT; however, scant literature concerning how policy functions in promoting LCT diffusion exists, especially for developing economies like China, and almost all the material concerns retrospective analyses of policies based on currently available historical datasets (e.g., [2,43]). This research differs in that it is a prospective policy analysis and uses fresh, and therefore up-to-date, information directly obtained from the companies concerned, and provides results that may contribute to understanding how Chinese companies might invest in LCT at different levels of carbon price—which in turn informs on the technology and policy solutions needed in order to bring about low carbon development of the target industry in the future.

Using a selection of main LCT according to their classification in the target industry, the information to be gathered by survey included: a) technology-specific data, e.g., historical adoption status, initial investment and energy saving potential; b) change in technology profitability with payback time as a proxy under assumed carbon prices; and c) change in business investment decision for technologies with different levels of profitability.

China's cement industry was targeted in this research due to its high potential for energy saving and carbon mitigation both domestically and globally. China has held the No.1 spot in cement production since 1985, and in 2013 had a 60% share, at 2.42 billion tonnes. Demand is still rising within the country, however, and isn't predicted to peak until 2018 to 2020 [22]. The industry is characterised by its relatively low concentration: in 2012, the top 21 cement companies accounted for just over one billion tonnes of clinker capacity per year, representing about 58% of the country's total clinker capacity [17]. Uneconomical cement plants with a total capacity of around 250 million tonnes per year are due to be shut down between 2013 and 2015 [13].

Cement production is a major source of CO_2 emissions in China owing to the large volume produced, thus estimations of its CO_2 emissions have attracted much attention. However, different studies have delivered highly differing estimates. Ke et al. [20] reported that the cement industry accounted for 13%–14% of China's total fossil-fuel emissions during 2005–2007, whereas Wang [49] gives a figure of around 11% of national gross CO_2 emissions in 2011. Although the domestically advanced values of comparable energy use are almost the same as those found abroad, the average energy efficiency of China's cement industry is about 10% lower, implying a large mitigation potential exists for LCT [33].

The remainder of this paper is structured as follows: Section 2 gives an overview of previous literature on LCT diffusions and describes the contributions of this research. Section 3 explains the research methodology, including the procedures and models applied for the simulations. Section 4 lists the major technologies for energy saving and carbon mitigation of China's cement sector and details three target technologies. Section 5 outlines the questionnaire, survey implementation and samples. As the main component, Section 6 discusses the results of this survey analysis. Lastly, Section 7 provides a summary and suggests topics for future research.

2. Literature review and contributions of this research

Previous studies indicate that accelerated technology development may reduce the costs for achieving stringent climate goals [31]. The diffusion of energy saving technologies is an important part of energy and climate policy, and the diffusion of innovation is influenced by various factors [48]. One of these factors is the pricing of carbon emissions, which would induce profit-oriented businesses to adopt LCT; however, conventional economic theory alone may not perfectly explain the diffusion of LCT in reality [15,19]. The factors determining the pace of LCT diffusion can be classified into two—one is associated with the uncertainty of climate policies and the other is the factors influencing technology growth in the presence of favourable climate policies.

Uncertainty in climate policies may induce a certain 'opportunity value' of postponing the technology adoption [18]. In particular, climate sensitivity, international commitments and the stability of carbon prices influence the behaviours of risk-averse and risk-neutral investors [7]. For example, producers facing market uncertainty over CO_2 prices might invest in carbon-saving technology earlier than if the actual price path were known beforehand. However, uncertainty over governmental policy would prompt them to adopt a wait-and-see approach, since the government's future commitment to climate policy is unknown [8]. The lack of appropriate regulatory framework for the transport and storage of CO_2 would likely impede the commercialisation of CCS (carbon capture and storage) [10]. Further, the high transaction cost of intellectual property and weak patent protection in developing economies hinder the transfer and diffusion of LCT from the developed world [4].

Besides policy uncertainty, lack of financial resources was confirmed to be an important barrier to the adoption of LCT, which usually incurs high upfront costs [4]. Cagno and Trianni [5] conducted a survey on small and medium-sized companies in northern Italy and identified access to capital as one of the chief barriers. Technology diffusion is also influenced by the preference of risk-averse stakeholders [21]—for instance, CCS might experience public opposition due to concern over CO_2 transportation and injection [24]. Characteristics of the industry such as market structure and internal information flow may also constrain the diffusion of LCT; it may take some time for the potential users to obtain information about the technology and adapt it to their own circumstances [19]. The business alliances influence the technology diffusion as means for knowledge transfer and information dissemination, and may reduce the risk of technology adoption [3]. The characteristics of individual companies also affect the diffusion of technology; whether or not a company adopts LCT depends on its capacity and whether the timing is appropriate in respect of other business cycles [35]. Prindle [44] distributed a questionnaire survey to a number of U.S. companies and identified a lack of funding, personnel with appropriate skills and technical information as common barriers.

Several studies have empirically investigated the historical growth of LCT, and some focus on the technologies in the energy sector. Kramer and Haigh [23] postulated on the growth of energy technologies over the last century and found that once an energy technology materialises, e.g., accounts for around 1% of total global energy, the growth changes to linear. They also found that most energy technology transitions occur at low rates. Lund [30] showed that the takeover time from a 1% to 50% share of market potential varies from less than 10 to 70 years for different technologies and that short takeover times below 25 years are mainly associated with energy end-use technologies. Other studies are related to energy efficiency technologies. Pizer et al. [43] examined the adoption of energy saving technologies by U.S. manufacturing companies, and found that once an energy saving technology has diffused to 10% of the companies, the remaining potential users would adopt within an average of about nine years, regardless of industry. It was also revealed that even dramatic changes in energy prices could only generate modest changes in energy efficiency—a policy that immediately raises energy prices without allowing companies to anticipate such change may result in reduced technology adoption, due to the reduced financial health of such companies [43]. Anderson and Newell [2] confirmed that companies adopted around half of the energy-saving projects recommended by the U.S. energy audit programme and that adoption rates were