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Projection of cement demand and analysis of the impacts of carbon tax on cement industry in China

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Abstract

Cement industry plays a vital role in the process of urbanization and industrialization in China. This paper disaggregates cement consumptions into five large subsectors: building, railway, highway, rural infrastructure and others. We suggest that cement demand will reach the peak of 2.5 billion tons in 2017, followed by a slowly reduction in the next 10 years and a gradually decrease from 2.3 billion tons in 2030 to 1.5 billion tons in 2050.Based on the scenarios analysis of China TIMES model, this paper shows that carbon tax doesn't work significantly on the technology choice and CO_2 emission reduction in the short term. However, in a long run, high carbon tax may increase the application of production with CCS or wasted heat recovery and cut down the small- and medium-sized plants. Moreover, tax on all industries acts more effectively than that only on the cement industry.

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Keywords: Cement Demand;Projection; China TIMES model; Carbon tax; CO_2 emissions

1. Introduction

As a basic raw material industry, cement industry is closely correlated with China's fixed-asset investment with obvious characteristics of demand-driven industry. In 2012, Chinese cement production reached 2.1 billion tons, accounting for approximately 58.1% of the world's total and CO_2 emissions from fossil fuel combustion in the cement industry in China achieves 0.3 billion tons. At present, some studies have been conducted about the future demand, energy consumption and CO_2 emissions of cement industry [1-3]. But few researches concern about the cement demands by sectors and the impacts of carbon tax on the cement industry. This paper predicts cement demands according to the discussion of

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development of sectors including those which are top consumers of cement like building, highway, railway and rural infrastructure and the one called others which contains all the rest demands. We also uncover the effects of imposing tax on CO_2 emissions in the cement industry or all industries in accordance with the results from the China TIMES model.

2. Methodology

2.1. Demand projection

This paper provides a detailed presentation of cement consumptions in the 5 main sectors (building, highway, railway, rural infrastructure and others), as shown in Fig.1 (a). To project future demands in building, highway and railway, we develop a stock-based model, which is used to describe and estimate evolution of a system [4]. Cement demand is equal to the product of demand of new products and cement intensity. Demand of new products can be split into two parts: additional demand and demand from end-of-life products. The additional demands of floor space of different types of building like urban, rural and commercial are obtained by projection of ownership per capita and population. The additional demand of highway is obtained from the national highway planning. The additional demand of railway operating mileage is obtained by projection of railway freight turnover. To project future demand in rural infrastructure, we obtain cement demand from the product of rural infrastructure spending and cement demand per unit of investment [3]. Other small parts like urban public transportation, electricity power construction and so on are merged in the sector called others, which is projected with a fixed share of total, equal to 17.4% in 2011.

2.2. Basic assumptions

Based on literature researches, this paper assumes average GDP growth rates in 2010-2020, 2020-2030, 2030-2040, 2040-2050 are representatively 7.5%, 6%, 4.5%, 3.5%. Future population will achieve the peak of 1.47 billion in 2035 and decrease slowly later to 1.44 billion in 2050. We also predict urbanization rate in 2050 is 75.8% through relationship between urbanization rate and GDP per capita. For industrial structure, this paper figures out future industrial structure through relationship between industrial added value and GDP per capita. Shares of primary, secondary and tertiary industry in 2050 are 4.7%, 29.2% and 66.1%, respectively.

Calculating the number of wasted products relied much on lifetime distribution. It's widely accepted that lifetime of building can be described using a normal distribution with standard deviations being 20% of the mean values [5]. According to the available literatures, that distribution above can be also used to describe railway and highway. In general, lifetime of products are determined by design standards. In China, lifetime of building is designed to be 50 years but researches point out most of alive buildings now can't not survive for more than 25-30 years, for which we assume lifetime of urban and rural building is namely 30 years and 25 years and achieves 50 years in 2030. Railway base is divided into ballasted and non-ballasted and lifetime of ballasted base is designed to be 15 years. For the reason that application of non-ballasted base in China is still in a relatively early stage, its lifetime is assumed to be 50 years. According to engineering standard, lifetime of express, first-class, second-class, third class and fourth class highway is designed to be 20,20,15,10 and 10 years.

Cement intensity is a key factor to link product demand to cement demand. In this paper, we assume that the cement intensity of urban building is 0.33 t/m^2, twice what is used in rural building [3]. Cement intensity of highway is related to cement type, the thickness and width of highway and strength requirement. For simplification, we use mean value here. Cement intensity of expressway is 4000-12000t, of which average is 9000t. Cement intensities of the other types of highway are obtained by lanes and strength ratio. Cement intensity of railway is about 1.6 thousand tons per kilometer. Predictions of future cement intensity contain lots of uncertainties. On one hand, cement intensities are increased to improve product strength in order to meet the requirements of higher life quality. On the other hand, cement intensities are decreased resulting from technological development and application of alternative materials. Compared to changes of product demand, difference between concrete types are relatively small and since cement demand is more affected by product demand, we assume current cement intensity will maintain till 2020 and decrease slightly to 0.95 of current value in 2050.

Cement demand for agricultural infrastructure is mainly affected by financial expenditure for agriculture. This paper adopts the comprehensive assumption that China's agricultural expenditure will reach the optimal scale, about 47.2% of agricultural GDP in 2020 [6]. Moreover, the optimal scale is assumed to be maintained after 2020. Due to optimizing of expenditure structure, more expenditure will be laid on rural science researches, improvement of social welfare and cultural, educational and medical construction, thus assuming the demand of cement per billion investment remains 27 thousand tons before 2020 and decline slowly to 5 thousand tons in 2050

2.3. China-Times introduction

TIMES is a model generator developed by the Energy Technology System Analysis Program (ETSAP) of the International Energy Agency (IEA). The model is a multi-cycle dynamic linear programming model which minimizes total energy system cost while meeting final energy service demands and external constraints. With a technology-rich basis and detailed definitions of different processes and emission factors, it's suitable for not only energy oriented issues but also energy-environmental problems. In this paper, China TIMES model is applied in 5-year intervals from 2010 to 2050 to analyse the impacts of carbon tax on production line and CO_2 emissions in the cement industry [7-10].

2.4. Scenarios definition

The reference scenario (REF) is defined as no carbon tax scenario. Carbon tax is imposed only on the cement industry in scenario 1 (S1) and 2 (S2) and in all industries in scenario 3 (S3) and 4 (S4) to investigate the differences of different tax scopes. Within each group there has a moderate carbon tax scenario (S1, S3) and a high carbon tax scenario (S2, S4) to examine the differences between different taxation levels. In the model we consider 3 kinds of cement plants: large-, medium- (IBUCEMM) and small-scale (IBUCEMS) plants. The large-scale cement plants are divided into 3 types: large-scale plants not applicable for wasted heat recovery (WHP) and CCS (IBUCEML), large-scale plants with WHP (IBUCEMLWHP) and large-scale plants with CCS (IBUCEMLCCS)

Table 1. Carbon emission tax in scenarios

$/ton	2015	2020	2025	2030	2035	2040	2045	2050
S1	10	13.9	19.3	26.8	37.3	51.8	72	100
S2	30	41.7	57.9	80.5	111.8	155.4	215.9	300
S3	10	13.9	19.3	26.8	37.3	51.8	72	100
S4	30	41.7	57.9	80.5	111.8	155.4	215.9	300

3. Modeling results

3.1. Cement demand

Results in Fig.1 (b) indicate that in 2050 China's railway mileage and highway mileage per capita are respectively 2.05km and 41.32km, which are respectively 2.85 and 1.33 times of those in 2013. In USA railway mileage per capita in 2011 is 7.2km and highway mileage per capita in 2012 is 209.04km and in UK railway mileage per capita in 2008 is 2.67km and highway mileage per capita in 2009 is 63.62km. In 2050 China's urban floor space and rural floor space per capita are respectively 50 m2 and 42.1 m^2, which are respectively 1.37 and 1.94 times of those in 2010. In 2012, floor space per capita are respectively 67 and 45 m^2. For building, highway and railway sectors, development of China in 2050 reaches the current level of some developed countries but still lower than the current level of USA, leaving some room to grow. Although China's financial expenditure for agriculture achieves optimal scale in 2020, with the growing agricultural GDP, the amount of financial support for agriculture is still growing, which achieves 3.6 and 5.78 trillion in 2030 and 2050.

China's cement consumption peak of 2.5 billion tons will appear in 2017 with cement consumptions per capita being 1.77 tons. Peak years from different literature vary from 2015 to 2020 and the peak vary from 1.9 to 2.7 billion tons [1-3]. The peak cement consumptions per capita of developed countries is lower than that of China in 2011. For example, that value of USA, Japan and Taiwan China are respectively 0.4t, 0.72t and 1.3t. The differences of cement consumptions per capita between China and other developed countries may be owing to different cement consumptions caused by different building structure, different cement types, different historical building stocks and different lifetimes. After reaching the peak in 2017, cement consumptions in China will have a ten-year slightly change period and it will remain higher than 2.4 billion tons before 2028. Most of developed countries experienced the similar plateau. It will see a gradual reduction from 2.3 billion in 2030 to 1.5 billion in 2050, with the cement consumptions of building rise from 41% in 2011 to 51% in 2050 and that of railway and highway decrease form 5.8% and 14.5% in 2011 to 3% and 7.3% in 2050. The decrease is mainly due to the reduction of construction. Cement demand in rural infrastructure increase first and then decrease, with the ratio being 21.3% in 2011 and 21.6% in2050, which are not quite different.

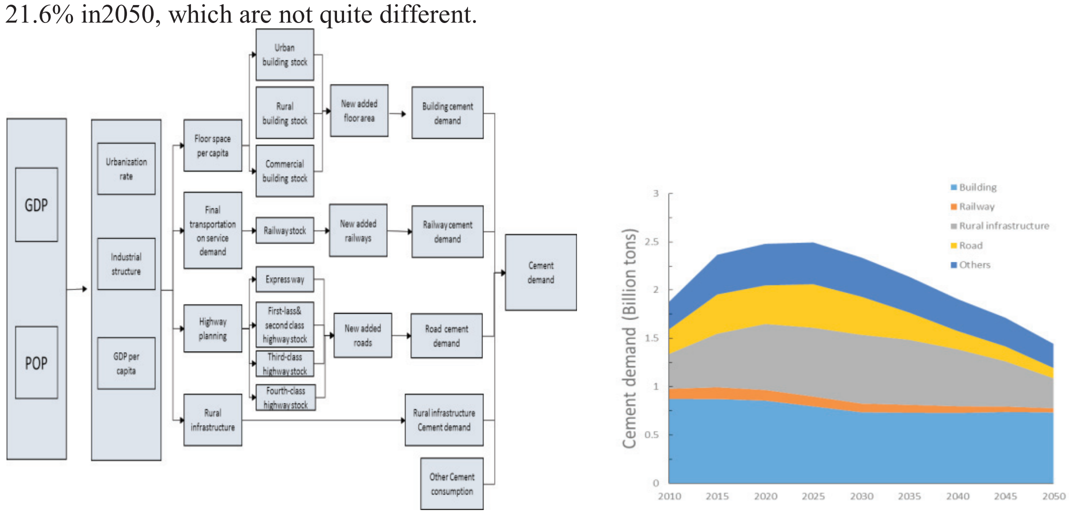

Fig.1 (a) Bottom-up analysis model of cement demand; (b) Future cement dement in China

3.2. Impacts of carbon tax

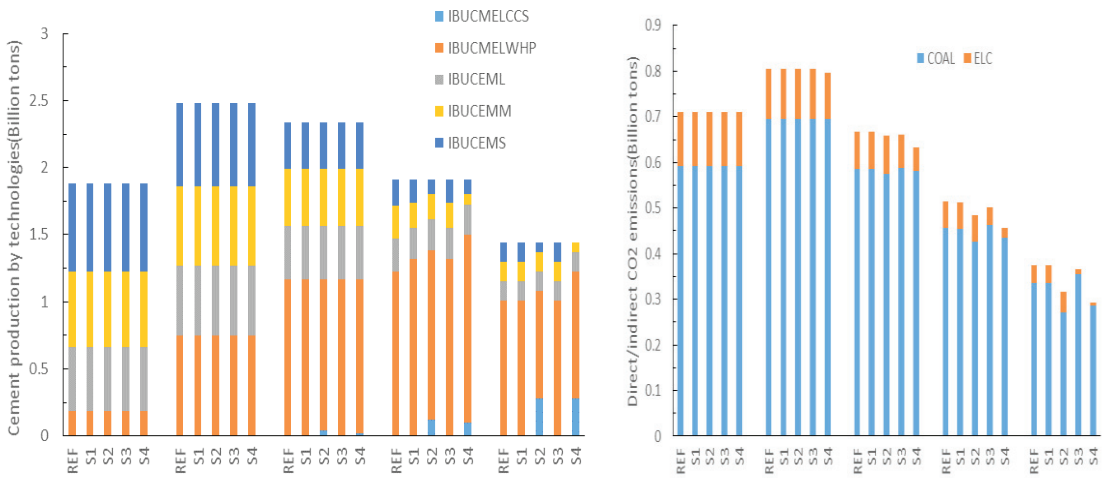

Fig.2 (a) Cement production of different technology; (b) CO_2 emissions of different input energy

Figure.2 (a) illustrates different technology choice in different carbon tax scenarios. In a short run carbon tax doesn't work significantly and have few impacts on production line choice before 2030. In 2010, the proportion of small-, medium-, large-scale, large-scale with WHP and large-scale with CCS are respectively 35%, 30%, 25%, 10% and 0. In scenario REF, S2 and S4, the share of small-scale cement plants decrease to respectively 10%, 5.4% and 0. The ratio of medium-scale of cement plants are respectively 10%, 10% and 5.3%. The percentage of plants with CCS are respectively 0, 19.4%, and 19.4%. The proportion of plants with WHP are respectively 70%, 55.2% and 65.3%. The higher carbon tax is, the lower proportion of small-scale and medium-scale cement production will be and most new-built capacity are large-scale production with WHP or CCS. Tax on all CO_2 emissions will reduce more small- and medium-scale cement production and establish more with WHP or CCS. The high ratio of application of WHP is reasonable as 70% of cement new dry process production line have a WHP system in Japan in the 1980s and Indian experts said most of new-built production lines in India apply WHP. Figure.2 (b) suggests the change in CO_2 emissions. CO_2 emissions from fossil fuel combustion and electricity usage in the cement industry is 0.71 billion tons (not including processing emissions). In 2050 CO_2 emissions from fossil fuel combustion and electricity usage in the five scenarios of REF, S1, S2, S3 and S4 are respectively 0.38, 0.38, 0.32, 0.37, 0.29 billion tons. As a result of decrease of cement demand and carbon tax, carbon emission will reduce and the higher carbon tax is, the larger the reduction is. Tax on all CO_2 emissions can reduce 0.03 billion tons more than that only on the cement industry in 2050.

4. Conclusion and discussion

This paper projects future cement demands by sectors and assesses impacts of carbon tax on production line choice and CO_2 emissions (not including process emissions). The results are as follows.

1) Cement demand will reach peak value of 2.5 billion tons in 2017 and decrease slightly to 2.4 billion tons in 2028. After that, it will reduce from 2.3 billion tons in 2030 to 1.5 billion tons in 2050 gradually. Cement consumptions in railway, highway and rural infrastructure firstly increase and then decrease and cement consumptions in building firstly remain stable and then decrease slowly.

2) Carbon tax doesn't work significantly in a short term. After 2030, the higher carbon tax is, the fewer small- and medium-scale cement plants there will be. Most new-built cement plants are large-scale plants with WHP or CCS. In 2050 CO_2 emissions in REF decrease to 0.38 billion tons. For tax only on cement industry, CO_2 emissions of medium tax and high tax are respectively 0.38 and 0.32 billion tons. For tax on all carbon emissions, CO_2 emissions of medium tax and high tax are respectively 0.37 and 0.29 billion tons.

To avoid excess capacity and excessive CO_2 emissions and achieve sustainable development, construction of new capacity of cement production should be planned properly, small- and medium-scale cement plants should be retired or reconstructed and large-scale plants with WHP or CCS should be encouraged.

Acknowledgements

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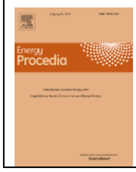

Biography

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