Carbon risk and optimal retrofitting in cement plants: An application of stochastic modelling, MonteCarlo simulation and Real Options Analysis

Luis M. Abadie a, Nestor Goicoechea b, Ibon Galarraga a, *

a Basque Centre for Climate Change (BC3), Spain
b Escuela de Ingeniería de Bilbao, University of the Basque Country UPV/EHU, Spain

A B S T R A C T

The cement sector is highly intensive in CO2 emissions and is the second biggest industrial sector in terms of emissions after the electricity generation sector. It emits CO2 from the combustion of fossil fuels, the calcination process and, indirectly, from electricity consumption. The ambitious climate change policy in the EU means that carbon prices and fuel prices are two very important sources of uncertainty that may affect the competitiveness of the sector. This paper focuses on understanding the risk associated with the future price of European Union Emission Trading System allowances. This is done by modelling a stochastic process with parameters calculated using market prices. Risks are valued with the Expected Shortfall and Value at Risk measures over the lifetime of a plant using MonteCarlo simulation: two well-known risk measures in financial economics. Risks are greater and returns lower in the wet process than in the dry one. The paper includes a sensitivity analysis of the effects arising from changes in the prices of allowances as a consequence of a hypothetical drastic change in climate policy, including jumps, withdrawing of free emission allowances and changes in future carbon prices. In this case impacts will also be higher in the wet process. Finally, the paper illustrates the optimal conditions for retrofitting a wet cement plant to convert it to a dry cement plant under uncertainty of the price of carbon allowances. This is done using Real Options Analysis. The trigger price is €114 million for a plant with remaining lifetime of 25 years and a production of one million tonnes.

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1. Introduction

The cement sector is highly emission-intensive. Apart from the use of fossil fuels, this is due to the calcination process itself, producing clinker that releases a considerable amount of CO2. In fact, this sector is considered to be the world’s second biggest source of anthropogenic emissions (Cembureau Activity Report, 2015).

Emerging countries produce a considerable amount of cement (Fig. 1). China in particular has emerged as an industrial superpower and has become the world’s second largest economy according to the economy ranking for 2010 (World Development Indicator Database, 2016). The total capacity of its 798 plants was 1409.8 Mtonnes of cement per year in 2013 (Global Cement Directory, 2015).

On the other hand, in regions where the industry has being going through a recession phase, such as Europe, production is much lower than capacity. This is the case of the cement industry in the EU 28, where a maximum of 190.8 Mtonnes of grey clinker was produced in 2007 (World Business Council for Sustainable Development, 2015) (See Table 1).

The economic crisis, climate policies and technological improvements in cement production have recently led to a significant drop in emissions in Europe. This trend is illustrated for the EU(28) in Fig. 2. Note that for the same production of 225 million tonnes of cement 1995 and 2009 the CO2 emissions are nearly 15% lower in the latter year. The drop experienced in cement production has also pushed down CO2 emissions significantly.

In order to better understand the source of CO2 emissions in the cement industry one must be aware that the calcination process is the decomposition of CaCO3 to CaO and CO2. The high quantity of emissions in this sector stems from this chemical reaction, where the source of CO2 is related to the carbonates and
the fuel used in a stoichiometric relationship in line with the law of conservation of mass (Masterton, 1989).

The raw materials used in the pre-burning stage, during slurry preparation, are calcareous materials including limestone, chalk, magnesium carbonate, silica and others. The two main groups of technology used are known as wet processes and dry ones, and the main difference between them is found at this stage, with raw material being mixed with water in the former.

At the burning stage the slurry is introduced into the kiln. The fuels most commonly used in kilns for pyroprocessing are coal, natural gas and petroleum coke. In a wet process more heat is required than in a dry process to obtain the same amount of clinker (Gartner, 2004).

In the last ten years the European cement industry has striven to
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