Is CCR a Viable Technology Option for Investors? A Multi-stage Model Analysis Under Uncertainties

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Introduction

Electricity sector contributes more than 41% of the total energy-related CO_2 emission of the world (IEA, 2013), and carbon capture and storage (CCS) is a critical technology option to realize large-scale CO_2 abatement in this sector (IEA, 2010). However, CCS investment seems not to be viable in its current stage and short-term future because of its high cost and high future risk. More specific, adding CCS increases capital costs as well as ongoing operating and maintenance costs, including additional capital expenditure, energy penalty, and additional cost for CO_2 transportation and storage, etc. In addition, CCS investors are facing many kinds of risk such as market uncertainty, technology uncertainty, policy uncertainty, etc (IEA, 2007a). In this situation, CCS technology diffusion might be restrained when new fossil fuel power plants are built without option for CO_2 abatement, and a large amount of CO_2 emission to the atmosphere would be 'locked-in' for many years (IEA, 2007b), especially in the emerging economies.

As a potential solution for this conundrum, the concept of 'carbon capture ready' (CCR) therefore comes into being. A CCR plant is one which can be retrofitted with CO_2 capture when the necessary regulatory or economic drivers are in place at a later date. It would have a higher initial capital cost than a conventional plant without CCR (No-CCR plant) but would cost less to be retrofitted with carbon capture. Conversely, a No-CCR plant would have a lower initial capital cost but a higher cost for future CO_2 capture retrofit, even there is no possibility for the plant to be retrofitted because of the lack of the necessary space for retrofit facilities and site for storage (IEA, 2007b). As a result, the investors of new power plants would face decision on choice between CCR and No-CCR plant currently[1]. In addition, because of high capital cost and irreversibility of the CCS investment, the potential plant investors may probably delay CCS retrofit and wait for better conditions even if the emission regulation has been in place faced with future uncertainty (Abadie and Chamorro, 2008). At last, as a result of higher operation and maintenance cost and energy penalty cost, as well as the additional transportation and storage cost, even after CCS retrofit, the investors can suspend CCS operation if market conditions were not favorable in future (Mo and Zhu, 2014), especially for the post-combustion capture technology. In summary, a newly-built power plant investment is a long-term multi-stage decision problem and the decision in each stage could be affected by the decision in subsequent stage.

With future uncertainties and a long term complex process, CCR investment decision is a challenging issue faced by potential investors. In this paper, a newly-built power plant investment decision model was built. As a case study, it was employed to evaluate the CCR investment in China[2], and the critical factors affecting the plant type choice were explored.

Model and Methods

We build a multi-stage power plant investment and operation decision model under multiple uncertainties.

It is assumed that power plant investment occurs *before* the ETS is in place, which is a realistic scenario for many projects in many countries, e.g. China. Then the plant lifetime was divided into three stages. The first stage is from the beginning of the decision until when the ETS is introduced. During this period, the investors would decide what type of plant to build. In the second stage, after ETS is introduced, the investors would decide whether and when to retrofit the plant with CCS. In the third stage after CCS retrofit is finished, in each period the investors would decide whether to run CCS to capture CO_2 or to suspend CCS operation temporarily according to market conditions, until the end of the plant lifetime. At last, the investors also have the option to permanently shut down the plant in each period if they expect that ongoing operation of the plant would lead to loss.

Three kinds of risk affecting future costs and revenues are considered. First is the policy risk, and time uncertainty on when to introduce a carbon emission regulation (e.g. emission trade scheme (ETS)) is considered. Second is the technology risk, and learning uncertainty of CCS technology is considered. Third is the market risk, including electricity price, fuel price (coal price), and carbon price. For the first two kinds of uncertainties, scenario analysis was conducted to analyze their effect on the CCR investment, and for the market risk, non-

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See footnotes at end of text.

stationary stochastic processes were employed to model the future price evolution.

To solve the model, least squares Monte Carlo simulation methods were employed (Longstaff and Schwartz, 2001).

Results and Implication

CCS operation flexibility means that the investors can choose CCS operation mode after CCS retrofit according to specific market conditions. For example, if the future carbon price is low, CCS-off mode may be optimal. CCS operation flexibility has a significant effect on CCS retrofit and CO_2 abatement, which means it would increase CCS retrofit probability, but would decrease the CO_2 abatement amount. Furthermore, CCS operation flexibility would also affect CCR investment decision by affecting CO_2 abatement and CCS retrofit decision, and it would decrease CCR investment probability, indicating that neglecting operation flexibility would overestimate the viability of CCR investment.

Carbon price has a significant effect on plant type choice decision. CCR investment would increase with carbon price being higher and carbon price risk being lower. Learning effect of CCS technology means that CCS investment cost would decrease in future, and CCR investment cost would decrease with learning effect being more significant. In addition, CCR investment would decrease with CCR investment cost being higher, while early implementation of a CO_2 emission regulation would promote CCR investment. These simulation results referred above have significant policy implication, and the details are as follow.

CCS operation flexibility would restrain current CCR investment for new power plants, and then the future CCS retrofit would be expensive and even impossible. However, CCS operation flexibility would render the current CCS investment less irreversible, and promote current CCS retrofit investment for existing power plant. These two effects of operation flexibility should be balanced: allowing for CCS operation flexibility can promote current CCS investment, but would restrain current CCR investment and then restrain the future CCS retrofit. For the policy makers, whether the operation flexibility is allowed should be assessed carefully.

Carbon price is an important driver for the CCR investment. For China, seven pilot ETSs have been built, and a national ETS is being planned. This would provide incentive for current CCR investment. However, the carbon prices in the pilot ETSs range from 20RMB/t CO_2 to 80RMB/t CO_2, and the average carbon price is about 50 RMB/t CO_2. At this carbon price level, CCR investment probability is low (far less than 50%) even in the low carbon price risk scenario. So it is inferred that China ETS pilots cannot support CCR investment, especially if the CCR investment needs large-scale capital expenditure. As a consequence, although CCR can make the power plant avoid “lock-in” risk and is optimal from the perspective of society, it may not be optimal for the private investors.

The simulation results also have important implication for R&D policy of CCS technology, and the potential interaction between CCS R&D policy and CCR investment policy should be carefully considered. More specific, if the government makes great efforts to reduce the future CCS investment cost by R&D, the current incentive to make investment in CCR may be undermined, and to promote current CCR investment, much more policy measures would be needed. As a result, the two policies should be coordinated in practice.

Footnotes

[1] Here it’s assumed that CCR is not mandated.

[2] China is the world’s largest CO_2 emitter, and electricity sector contributes about 49% of the total energy-related CO_2 emission (IEA, 2013). It is also expected that a significant quantity of extra capacity will be required in order to maintain power supplies in future. So CCR investment in China was chosen as case study.

References

IEA, 2007a. *Climate Policy Uncertainty and Investment Risk*. OECD/IEA, France.

IEA, 2007b. *CO_2 capture ready plants*. OECD/IEA, France.

IEA, 2010. *Energy Technology Perspectives 2010*. OECD/IEA, France.

IEA, 2013. *CO_2 emissions from fuel combustion*. OECD/IEA, France.

Abadie, L.M., Chamorro, J.M., 2008. European CO_2 prices and carbon capture investments. *Energy Economics,* 30(6):2992–3015.

Mo, J.L., Zhu, L., 2014. Using floor price mechanisms to promote carbon carbon capture and storage (CCS) investment and CO_2 abatement. *Energy and Environment* 25(3/4), 687–707.

Longstaff F., Schwartz E., 2001. Valuing American options by simulation: a simple least-squares approach. *Review of Financial Studies*, 14(1):113-147.