CONTRACTING RISKS AND DESIGN OF OPTIMAL INCENTIVES IN LARGE ENERGY INFRASTRUCTURE PROJECTS

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Overview

In this paper, we develop a framework to account for both the exogenous risks and the endogenous risks in evaluating risk management strategies for large energy infrastructure projects. Exogenous risks refer to the risk factors for which the probability distribution of the outcomes is not affected by the actions of the entities involved in the projects. On the other hand, endogenous risks are the risks arising from the weak contractual incentives leading to socially sub-optimal decision-making by the involved entities. We focus on the risks during the operational phase of the projects, and illustrate the risk management framework proposed in this paper through an application to carbon dioxide (CO_2) capture and storage (CCS) projects.

Both anecdotal and quantitative evidence on the performance of large infrastructure projects suggests that under-performance is more of a rule than an exception [Flyvbjerg et al (2003), Miller and Lessard (2000)]. These studies find that the primary reason for under-performance of infrastructure projects is not the exogenous risk factors, rather, the key reason for lower than expected performance is the endogenous risk arising from weak incentive structures in the contract terms. Endogenous contracting risks in large energy infrastructure projects arises from relation-specificity of the investment and the complexity of contracting due to the presence of information asymmetries [Williamson (1971), Klein et al (1978), Grossman and Hart (1986)]. It is well established in the contract theory literature, that the presence of relation-specificity and information asymmetries results in endogenous risks related to inefficient ex ante investment and inefficient ex post outcomes. The ex ante choice of governance structure and contracting terms needs to be optimized to minimize these endogenous risks.

In this paper, we focus on the risk management of CCS projects. The CCS value chain consists of three main stages: CO_2 capture, CO_2 transport and CO_2 injection for storage. In an integrated CCS project that comprises of the entire value chain, the different parts of the value chain are likely to be operated by different entities. Thus, risk management in CCS projects is not just about evaluating optimal decisions, but also each involved entity needs to be incentivized to make those optimal decisions.

We analyze the exogenous market risks in the CCS value chain, and evaluate the endogenous contracting risks under alternate contract structures for the CCS value chain in light of the incentives provided for optimal risk management. The exogenous risk factors analyzed include volatility in the price of oil recovered, the wholesale price of electricity, and the CO_2 emission penalty. Each of these risk factors impacts the overall project value, and the contract structure linking the parties determines who would bear the different risks along the different parts of the value chain. The resulting risk exposure of the individual entities will influence their ex post performance decisions. We find that inappropriate risk allocation leads to misalignment of interests among the parties, where the interests of the individual entities are not aligned with the common interest of the project. This leads to sub-optimal decision-making when contingencies arise. Furthermore if the parties anticipate these ex post inefficiencies, then the parties might not invest in the project ex ante even if the project is financially attractive on aggregate.

We focus on the design of optimal contract structures for the CCS value chain such that the risk allocation minimizes the endogenous contracting risks, and provides performance incentives to maximize the overall project value.

Methods

We model a prototype CCS project as involving three distinct operating entities: the power plant, the pipeline, and the oil field. The CO_2 is captured at a coal-fired power plant, and is transported via a dedicated pipeline to an oil field where it is injected for enhanced oil recovery (EOR). We have developed a cash-flow model that analyzes the cash flows generated by an integrated CCS project. The project ownership structure is such that the power plant and the oil field are owned by separate companies, and the pipeline is jointly owned by the two companies. The operation between the power plant company and the oil field company is integrated through a long-term contract for the delivery of CO_2. In order to evaluate the impact of the change in the market risk factors on the individual entities involved in the project, we analyze alternative contract structures for the CCS value chain.

To design contract structures for the CCS value chain, we draw on lessons from the natural gas industry, where long-term contracts have been used for gas supply transactions between the gas producers and the pipelines. Historically, in natural gas supply transactions, the risk of shift in gas demand has been distributed between the gas producers and the pipelines, through use of take-or-pay provisions in the gas supply contracts [Canes and Norman (1983)]. These provisions contractually specify the minimum quantity of gas that the pipelines need to pay for even if the gas delivery is not taken. This way, the impact of small reductions in demand till the take-or-pay level is entirely borne by the gas producer, and larger drop in demand is shared by both the producer and the pipeline. This risk-sharing protects both the gas producer and the pipeline against sharp fluctuations in future cash-flows and thus facilitates investments in the industry. Furthermore, Masten and Crocker (1985) argue that the take-or-pay provisions in natural gas supply contracts can be viewed as a means of incentivizing efficient performance by the pipelines. They show that these provisions induce the pipeline to refuse gas delivery only when it is efficient to do so, i.e. when the value of gas in its alternative use is greater than the value of gas to the pipeline.

Based on these lessons from the natural gas contracts, we analyze two alternate contract structures including a fixed price contract where the CO_2 contract price is fixed for the contract term, and an indexed price contract where the CO_2 contract price is indexed to the oil price. We evaluate these alternative contract structures in terms how they allocate the overall project cash-flows and risks among the different parties. To evaluate the incentives provided by the different contract structures, we look at questions such as - do the terms of sale of the CO_2 between the power plant company and the oil field company reflect changes in the market risk factors? Does the contract give the power plant company flexibility in the volume of CO_2 to be delivered? If so, how will the company exploit that flexibility to its own advantage as the margins on electricity production change?

Results

The results show that the market risk factors can significantly affect the overall CCS project value, and inappropriate contractual risk allocation can lead to ex post insolvencies. For example, when analyzing the oil price risk, we see that in the fixed price CO_2 contracts the oil field company bears the entire oil price risk, and hence there is a high likelihood that if the oil price drops then it would not be profitable for the oil field company to continue on the ex ante contract terms. This risk of ex post insolvency can potentially jeopardize the entire project. Whereas, using indexed price CO_2 contracts distributes the oil price risk between the involved parties, and thus reduces the likelihood of ex post dissatisfaction with the contract terms.

In response to the change in the risk factors, the different operating entities might re-optimize their operations. The results show that optimal contingent decision-making can significantly increase the overall project value. For example, we see that re-optimizing the CO_2 capture rate in response to the change in the oil price can save up to $190 million. As these contingent decisions will made by different entities owning and operating the different parts of the CCS value chain, the contractual risk allocation should provide incentives to each entity to make efficient ex post operating decisions. By, evaluating alternative contract structures, we find that the risk-sharing offered by the indexed price contracts gives incentives to each entity to optimize the CO_2 capture rate in response to the change in the oil price. On the other hand, the fixed price contracts would result in a suboptimal project value.

Conclusions

We evaluate alternative contract structures for the CCS value chain, and analyze how the different contract structures respond to the various market risk factors during the life of the project. The results show that the contract terms influences the ex post decision making by the involved entities and the value of the project, and hence determines the ex post value of the project. We show that standard CO_2 delivery contracts have weaknesses in terms of ex post insolvencies and poor incentive structures that result in a suboptimal ex post decision-making by the involved entities. An improper design of contract can potentially undermine the entire CCS value chain. Identification of the weaknesses and drawbacks of standard contracts aids in the design of optimal contract structures of the CCS value chain. We propose optimal contract structures that provide the appropriate incentives to enable optimal decision-making and continued performance on part of each entity, and maximize the overall project value.

References

1. Canes ME, and Norman DA. 1983. Analytics of Take-or-pay Provisions in Natural Gas Contracts. American Petroleum Institute Discussion Paper no. 029.
2. Flyvbjerg B, Bruzelius N, and Rothengatter W. 2003. Megaprojects and Risk: An Anatomy of Ambition. Cambridge University Press, Port Chester NY.
3. Grossman SJ, and Hart OD. 1986. The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration. Journal of Political Economy, Vol. 94(4), p. 691-719.
4. Klein B, Crawford RG, and Alchian AA. 1978. Vertical Integration, Appropriable Rents, and the Competitive Contracting Process. Journal of Law and Economics, Vol. 1(2), p. 297–326.
5. Masten SE, and Crocker KJ. 1985. Efficient Adaptation in Long-term Contracts: Take-or-pay Provisions for Natural Gas. The American Economic Review. Vol. 75(5), p. 1083-1093.
6. Miller R, and Lessard DR. 2000. The Strategic Management of Large Engineering Projects: Shaping Institutions, Risks, and Governance. MIT Press.
7. Williamson OE. 1971. The Vertical Integration of Production: Market Failure Considerations." American Economic Review, Vol. 61(2), p. 112–23.