Abstract submitted to 39th IAEE International Conference on January 14th, 2016.

Missing markets and missing pipelines: the problem of resource adequacy in a natural-gas-fired-dominated system

Inés Usera, Institute for Research in Technology, Comillas Pontifical University, Madrid, Spain, Ph.: +34915422800, <Ines.Usera @comillas.edu>

Pablo Rodilla, Institute for Research in Technology, Ph.: +34915422800, <Pablo.Rodilla@comillas.edu>

Ignacio Herrero, Institute for Research in Technology, Ph.: +34915422800, <Ignacio.Herrero@comillas.edu>

Javier García-González, Institute for Research in Technology, Ph.: +34915422800, <Javier.Garcia@comillas.edu>

Carlos Batlle, also with the MIT Energy Initiative, Cambridge, MA, USA, Ph.: +34915406306, <CBatlle@mit.edu>

Overview

Since the beginning of the century, US electric power systems have increasingly become dominated by natural gas-fired power plants. In this context, the traditional concern of electricity regulators to ensure that market agents take efficient power generation investment decisions expands to the gas system, as the system requires adequate investments also in pipeline or regasification capacity. The problem is that ensuring pipeline capacity, even or particularly under tight supply conditions, involves entering into very long-term firm transportation contracts, and therefore introduces a major source of risk for power generators: the possibility that electricity demand does not evolve as forecasted, or probably more importantly that renewable energy sources massively deploy in the future, creates a significant quantity risk to the gas-fired generator which as a result tend to just contract for interruptible gas supply.

This is particularly the case in New England (Black and Veatch, 2014), whose high dependency on natural gas has become troublesome in the last few years during cold winter months, due to the lack of natural gas pipeline capacity. When temperatures drop significantly, natural gas demand for both space heating and electric generation rises. Since most of New England's natural gas is imported through pipelines, high gas demand results in pipeline capacity shortage events that have a significant impact in the electric power system. Bringing new pipeline capacity to the system is seen as fundamental today.

In this paper we analyse this problem of the gas and electricity long-term planning coordination and the security of supply consequences. Since pipeline contracts are capital intensive and therefore subject to long-term risk, in the absence of any financial tools that allow investors to hedge the market price risk in the long-term, uncertainty in general reduces the incentives to enter into such firm contracts. We assess how a risk-averse natural gas power plant owner underinvests in pipeline capacity when no hedging tools are available. We discuss how this market incompleteness leads to a socially inefficient result, and how the gap could be bridged by creating markets for risk, for example via any sort of long-term capacity obligation,.

Methods

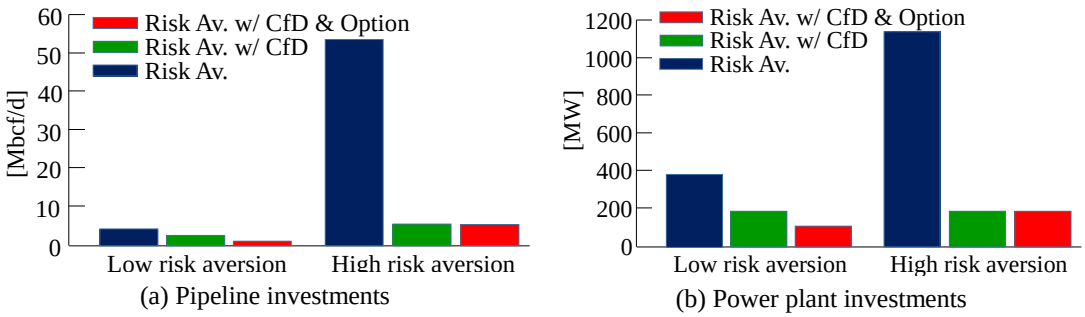
The present theoretical analysis addresses the investment problem in gas-fired thermal capacity and pipeline capacity in a context characterised by (i) perfect competition, (ii) risk-averse agents and (iii) missing long-term financial markets. It explores the impact derived from these missing markets, which translate into less socially efficient investments. The model simultaneously represents and solves the short-term electricity and gas markets. Following a similar approach as the one developed by Rodilla et al. (2009), four different settings are considered in the analysis:

- a (cost-minimizing) context with a risk neutral centralized planner who decides both the thermal capacity and the pipeline capacity to maximize social welfare. This framework constitutes the benchmark solution.
- a market in which risk-averse generators have to decide the thermal capacity to be installed and the firm pipeline capacity contracts to be signed to maximize their profit, and where no long-term financial instruments are available.
- a market setting similar to the previous one, but where a long-term forward contract for electric energy is available.
- a market setting similar to the previous one, but where both a forward and an option contract are available.

The market equilibrium models developed are stochastic (different demand and renewable generation scenarios are considered) and solved by means of an MCP. Risk constraints are modelled through the conditional value-at-risk (CVAR) (Rockafellar and Uryasev, 2000). The gas market is modelled in such a way that not generators which do not enter into contracts for firm pipeline capacity have still access to gas supply, but they are exposed to the short-term market price of natural gas (endogenously calculated). Agents must first take long-term investment decisions (in both pipeline capacity, and power plant investment), as well as the hedging instruments, and then they decide in the short term the hourly power plant production.

Results

The analysis is based on the comparison of the four cases previously mentioned, with the centralized social welfare maximization used as the benchmark reference. Some of the main results are presented below in Figure 1. Both graphs show how investment decisions deviate from those provided by the benchmark.



(a) Pipeline investments (b) Power plant investments

Figure 1: Investment decision difference with respect to centralized social welfare maximization

First and foremost, results show how completing the market providing investors with the ability to enter into long-term hedges leads the solution closer to the benchmark (the social welfare maximizing one). The figures also show that as risk aversion increases, decisions are drawn further away from the social optimum. Underinvestment in both pipeline capacity, and natural gas power plants has a system-wide impact causing a price increase both in the electricity and the gas spot markets, as well as a welfare decrease.

Nevertheless, if agents are offered risk-hedging instruments, such such as contract-for-differences (CfDs), results improve considerably, even more so if an option contract is added. This effect can also be observed in Figure 2, which shows the profit distribution along the different scenarios. While profits vary significantly from one scenario to another when agents are risk-neutral, and risk-averse with no financial markets, their distribution is flattened when risk-hedging instruments are included. Therefore, the risk is, to some extent, neutralized (slightly more when an option is included), as agents cannot perceive any low-profit scenarios.

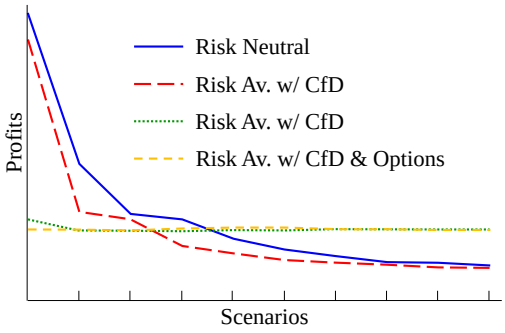


Figure 2: Profit distribution

Conclusions

Results show an equivalence between the central planner's welfare-maximizing decisions and the profit maximizing decisions of risk-neutral agents. Nevertheless, if agents are risk-averse and no risk-hedging instruments are available, results deviate from the central planner's. Risk-averse agents base their decisions on lower profit scenarios, rather than using expected profit, which generates long-term inefficient investment decisions.

However, when given the possibility to hedge their risk by participating in a forward market, agents' decisions come closer to replicating those of a central planner, thus improving social welfare. Moreover, if an option is included in addition to the forward market, results come even closer to the social optimum. These findings concur with Willems and Morbee (2010) where conclusions show that increasing market completeness is welfare enhancing.

References

Black and Veatch, 2013. "Natural gas infrastructure and electric generation: proposed solutions for New England". B&V Project no. 178511, 26 August 2013. Available at http://nescoe.com/.

Rodilla, P., García-González, J., Baíllo, A., Cerisola, S., Batlle, C., 2015. "Regulatory intervention to ensure an efficient medium-term planning in electricity markets". Energy Economics, vol. 51, pp. 365–382, September 2015.

Rockafellar, R. T. and Uryasev, S., 2000. "Optimization of Conditional Value-at-Risk". Journal of Risk, vol. 2, no. 3, pp. 21–41, 2000.

Willems B., Morbee J., October 2010. "Market completeness: How options affect hedging and investment in the electricity sector". Energy Economics, vol. 32, no. 4, 2010.