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Investment with incomplete markets for risk: The need for long-term contracts[☆]

Gauthier de Maere d'Aertrycke[a], Andreas Ehrenmann[a,*], Yves Smeers[b]

[a] ENGIE, Brussels, Belgium
[b] Université de Louvain, Louvain la Neuve, Belgium

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ABSTRACT

Barring subsidies, investment in the power generation sector has come to an almost complete halt in the restructured European power sector. Market and regulatory failures such as the well known missing money (see Joskow, (2006)) but also normal market features such as risk, possibly also affected by market failures like market incompleteness are mentioned as common causes for the situation. This paper discusses incomplete risk trading and its impact on investment. The analysis applies computable stochastic equilibrium models on a simple market model of the Energy Only type. The paper first compares the cases of complete and fully incomplete markets (full risk trading and no risk trading). It continues by testing the impact of different risk trading contracts on both welfare and investment. We successively consider Contracts for Difference, Reliability Options with and without physical back up that we add to our Energy Only market model. We test the impact of market liquidity on the results. Finally, we compare these methods to a Forward Capacity Market that we also add to the energy only model. We complete the paper by interpretation of these results in terms of hurdle rate implied by these risk-trading situations.

1. Introduction

European investment in non-subsidized generating capacities has now come to an almost complete halt. Recent years have even seen a shift from investing to mothballing and anticipative retiring of technologically advanced plants. Various reasons explain this evolution. The familiar "missing money", the lower demand due to the economic situation and energy conservation as well as several market imperfections are often mentioned. The uncertainty surrounding the restructuring and energy transition processes and the economic recovery also play a role. We focus on long-term demand risk in energy only markets (EOM) and discard other considerations.

The importance of risk in investment pervades corporate finance since the early days of Management Science. Valuations of risky assets can roughly be classified in two major approaches. One is based on the so-called Capital Asset Pricing Model (CAPM) and is mainly used for long-term investment. The other is based on contingency pricing and the literature of derivative pricing: it is commonly applied for hedging short and medium-term operations (see Cochrane (2005) for an extensive discussion of both approaches and Eydeland and Wolyniec (2003) for the application of derivative pricing to power and gas). Derivative pricing is also used to value flexible power plants. "Reliability options" is a particularly original application of derivatives to remedy the missing money (Vasquez et al. (2002), Oren (2005), Chao and Wilson (2004) and more recently Pöyry (2015) and several other authors).

CAPM and contingency pricing are technically different but commonly applied under similar fundamental assumptions: both rely on exogenous (econometrically estimated) price processes and risk premium. Both also generally neglect issues of market incompleteness (see Magill and Quinzii (2002) for an extensive treatment in finite horizons). These simplifications were probably sufficient in the past but may now be inadequate in the highly uncertain context of the restructured power market.

This paper contributes to the literature by presenting different stochastic equilibrium problems to quantify the impact of risk, market incompleteness and contracts in investment in power generation. These models are easily interpretable in standard investment criteria and are treated in a single computational framework. We illustrate the approach on a stylized stochastic equilibrium investment problem for which we assume exogenous processes of fundamentals (such as demand and fuel costs). In contrast with most of the literature, we

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* Corresponding author.
E-mail addresses: gauthier.demaeredaertrycke@engie.com (G. de Maere d'Aertrycke), andreas.ehrenmann@engie.com (A. Ehrenmann), yves.smeers@uclouvain.be (Y. Smeers).

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rely on the equilibrium context to endogenously derive stochastic electricity prices and risk premium together with investment (see Lopez-Pena et al. (2009) for an alternative treatment by System Dynamics). We also quantify the impact of various degrees of market incompleteness by introducing contracts in an otherwise incomplete market and assessing their impact compared to complete markets. While the underpinning economic notions (price taking agents, risk, market incompleteness, and hedging contracts) embedded in the model are standard, the equilibrium models and the underpinning computational approach are novel. They are general, based on powerful software and hence not limited to small examples.

The paper is formula free but based on fully formalized models. The mathematical formulation and its economic interpretation are given in de Maere d'Aertrycke et al. (2016). Technical results are presented in Abada et al. (2015) and (2016).

This paper analyses the impact of long-term demand risk on investment in energy only markets (EOM) where the missing money is corrected by a price cap. Taking stock of that basic framework we add risk mitigation instruments such as long-term contracts (contracts for differences (CfD), reliability options (RO) or forward capacity markets (FCM) under different assumptions of market liquidity). We complete the analysis by also considering a capacity market. We report welfare and investment levels. The analysis is conducted in an investment context; transposition to mothballing and anticipated decommissioning are more relevant today but probably also less usual in the literature. This transposition will be the subject of another paper.

The paper is structured as follows. Section 2 recalls the basic ideas underpinning investment problems in the different market settings. Section 3 introduces the methodology and the illustrative very simple physical model of generation and demand and the different instruments examined in the case study. We discuss the results in Section 4 with welfare and investment presented in unified graphic form for the different instruments. Section 5 reinterprets the analysis in more financial terms. Conclusions terminate the paper.

2. Background: investment problems in different market contexts

The discussion is conducted in a simple two-stage framework: one invests in period 0 and a power exchange (PX) clears the energy market in different time blocs in period 1.[1] Uncertainty is represented by a set of demand scenarios that each apply to the different times blocs of period 1. Each scenario reflect a load duration curve for a year (8760 h). The uncertainty is hence on the overall system evolution and not on the intra yearly uncertainty. Demand is exogenous and price inelastic. Agents are price taking.

2.1. The risk free world

Demand is deterministic and electricity prices are the sole drivers of investment in EOM. The standard criterion is to invest as long as the gross margin of the incremental equipment is greater than or equal to its capacity cost. The criterion depends on the cost of capital. It is equal to the risk free rate in a risk free world. As explained before the merit order determines electricity prices and generation quantities and hence revenue and operating costs and eventually gross margins.

The combination of the investment criterion and the merit order forms the equilibrium model in the risk free world. This equilibrium model can be solved by a standard capacity expansion optimization problem. From an economic point of the view the equilibrium model describes "perfect competition" where the producer and the consumer respectively maximize their profit and surplus taking prices as given. Note for the rest of the discussion that the equilibrium model simultaneously determines investment, operations and electricity prices. The endogenous price process is one of the important features of the equilibrium approach.

2.2. A risky world without contract

Economics and corporate finance have spent considerable effort for modelling risk and assessing its consequences. We restrict our discussion to a few elements. The standard practice is to account for risk by adding a risk premium to the risk free rate for computing the cost of capital. The risk premium is usually derived from historical data using the Capital Asset Pricing Model (CAPM). Future risk exposures in a restructured power sector undergoing the energy transition will be quite different from those of the past. We thus take the position that the computation of the cost of capital cannot be based on past data but must be endogenously determined by the model: new capacities influence their risk exposures, which implies that investment and cost of capital must be determined simultaneously. We briefly and verbally describe how this is done and refer the reader to Ehrenmann and Smeers (2011b), Ralph and Smeers (2015) and de Maere d'Aertrycke et al. (2016) for the technical development.

2.2.1. Risk neutral agents

Suppose first that investors facing the demand scenarios are risk-neutral. The investment criterion of the risk free world is modified as follows: one invests in some equipment as long as its expected gross margin computed for the different demand scenarios is larger than or equal to its capacity cost. This modified investment rule combined with the unchanged merit order rule defines the new equilibrium model.

This model simultaneously determines investment, generation and prices. These prices are defined for the different states of the world describing uncertainty and are endogenous to the system. Because agents are risk neutral the discount rate remains the risk free rate. The risk neutral stochastic model is well established (see for example Murphy et al. (1982) or Haurie et al. (1988)).

2.2.2. Risk averse agents

Neither investors nor consumers are risk neutral. The von Neumann-Morgenstern utility functions that appeared in economics in 1953 (van Neuman Morgenstern, 1953), and risk functions (Artzner et al., 1999) developed more recently in finance are two methods that associate a deterministic equivalent to risky payoffs. The latter is directly related to risk criteria used in risk management practice. We thus use a CVaR, which has become the most widely used coherent risk function (a function that satisfies the properties of monotonicity, sub-additivity, positive homogeneity, and translational invariance), and refer the reader to the general literature about coherent risk functions. The investment criterion is then restated as follows: one invests in a new equipment as long as the CVaR of its gross margin computed for the different demand scenarios is greater than or equal to its capacity cost. In other words in equilibrium for the investments decided by the model costs are equal to the risk adjusted expected gross margins hence the net present value is zero. Calculating the expected profit with the real probabilities ex-post leads to a positive net present value. The merit order completes this investment criterion to define the risk-averse equilibrium model. We mention for the sake of completeness that the model is no longer amenable to a solution by an optimization problem but can be written as equilibrium problems and refer the reader to our companion papers for further discussion.

Risk functions implicitly embed a risk premium: each agent discounts the expected value of the payoff by an endogenous premium that depends on its risk aversion and the risk pattern of its payoff. As with risk neutrality, prices are now defined in the different states of the world and are endogenous to the system. But because agents are risk averse the discount rate of each agent now becomes the sum of the risk

[1] In the real world, the investment stage (period 0) last 4–5 years while the operations phase (period 1) is 20 years long.