Market-design and the cost of capital for generation capacity investment

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Introduction

- Security of Supply concerns with Energy-Only markets
  - Debate since the beginning of the 2000's
  - Concerns have grown with variable RES development, as analysed by Joskow (2019), and coal phase-out
  - Capacity Markets (UK, France) and Strategic Reserves (Belgium, Germany) : 13 countries of Europe by 2020

- European Commission position : remove the price caps and Energy-Only works fine, besides possible temporary needs

- Financial risk as an impediment to capacity investment
  - RTE (2018), Artelys (2016) study for the European Commission : too much risk for peak capacity investment
  - Electricity Market Reform UK : CfDs in order to keep cost of capital low for low-carbon technologies

Research objective and main results

- Does a too high cost of capital, as measured by the CAPM, prevent enough investments being done, and do the proposed market-designs lower it ? Which ones are preferable ?

- Main results :
  - The cost of capital is lower with a CM or a CfD than in an Energy-Only market-design, provided that load demand and the market portfolio are positively correlated (false for SR)
  - The assumption that financial risk prevents enough investment in an EO design, without missing-money and with perfect competition, can be backed by datas
  - It is possible to respect a security of supply criteria and lower costs of production at the same time, through a lower cost of capital with the introduction of schemes akin to long-term contracts

From missing money to missing markets

- Missing money, induced by the presence of a price-cap, is the usual explanation for underinvestment in capacity
  - Joskow (2008), Cramton & Stoft (2005, 2008)
  - Lambin & Léautier (2018), Creti & Fabra (2007), Fabra (2018) : without a price-cap and with perfect competition, either no problem or welfare degradation with a CM

- Missing markets may be another explanation, preventing optimal risk-sharing between agents (Newbery 2016)
  - First-best only if markets complete : Gollier (2015) or David, Lebreton & Morillon (2011)
  - Only futures for horizon lower than 3-5 years, whereas any power plant has a lifetime greater than 20 years as noted by Willems & Morbee (2010, 2013)
  - Need for fixed-price contracts : Grubb & Newbery (2018) or de Maere, Ehrenmann & Smeers (2016)

The model

- This work
  - Previous work with IDEI/TSE, Léautier & Peluchon (2015)
  - Model identical to Lambin & Léautier (2018) or Creti & Fabra (2007), but with with endogenous cost of capital given by CAPM
  - Static model, one peak technology (but different technologies also in the paper)
  - No price-cap, hence no missing money

- Long term equilibrium with perfect competition in different market-designs :
  - Energy-Only (EO)
  - Capacity Market (CM) with a certain capacity price
  - Energy Contract for Difference (CfD)
  - Strategic Reserve (SR)

Setting

- One peak technology, costs are in €/MWh
  - Variable cost is c
  - Capacity cost is I (in €/MW divided by 8760 hours)
  - Value of lost load (VoLL) is V

- Inelastic load demand L
  - Distributed on $[0, +\infty[$ according to cumulative distribution $F(.)$ and density $f(.)$
  - If probability of load-shedding is α, then load shedding duration expectation is equal to $8760 \times \alpha$ hours per year
  - Equivalent to a screening curve on states of nature

- Investment decided at time $t = 0$, before load is known, at $t = 1$ production occurs
  - The price is set at c if load demand L is lower than capacity k
  - If load demand L is higher, then some rationing is needed and the price is set at V

Capacity investment and financial return

- For an investment of one unit of capacity, gross margin π is equal to the random variable (with m the capacity price, equal to zero in EO case) :

$$\pi(k) = (V - c)\,\mathbb{1}_{\{L \geq k\}} + m$$

- Cost of one unit of peak capacity at time $t = 0$ is I, gross return of peak capacity investment is R and is equal to the random variable :

$$R = \frac{(V - c)\,\mathbb{1}_{\{L \geq k\}} + m}{I}$$

- Expected gross return :

$$\mathbb{E}[R] = \frac{(V - c)\,\mathbb{P}(L \geq k) + m}{I}$$

Cost of capital with CAPM

- With the CAPM, the gross return R of a an asset is given by :

$$\mathbb{E}[R] - R_0 = \beta(\mathbb{E}[\eta] - R_0) = \frac{cov(R,\eta)}{var(\eta)}(\mathbb{E}[\eta] - R_0)$$

with R_0 the risk-free return and η the market portfolio gross return (given by an index such as S&P 500, CAC 40)

- We assume random variables belong to $\mathbb{L}^2(\Omega, \mathcal{F}, \mathbb{P})$

- The CAPM equation can be written in cash-flows :

$$\frac{1}{R_0}\left[\mathbb{E}[\pi] - cov(\pi,\eta)\frac{(\mathbb{E}[\eta] - R_0)}{var(\eta)}\right] = I$$

Free entry equilibrium

- We need to find the expression of covariance between gross margin π and the market portfolio return η
  - We use the orthogonal projection of η onto the subspace of $\mathbb{L}^2(\Omega, \mathcal{F}, \mathbb{P})$ spanned by 1 and $L - \mathbb{E}(L)$
  - We note : $p = \frac{cov(L,\eta)}{var(L)}$, $\varphi = \frac{[\mathbb{E}(\eta) - R_0]}{var(\eta)}$ and $\lambda = \varphi p$
- We find the following expression :

$$cov(\pi, \eta) = p(V - c)\mathbb{P}(L \geq k)\{\mathbb{E}[L/L \geq k] - \mathbb{E}[L]\}$$

- Free entry equilibrium is then given by the following equation :

$$(V - c)\mathbb{P}(L \geq k)[1 - \lambda\{\mathbb{E}(L/L \geq k) - \mathbb{E}(L)\}] + m = R_0 I$$

Equilibrium cost of capital

- If the correlation between load demand and the market is positive ($p > 0$), then :
  - Installed capacity is higher with CM than in EO
  - Equilibrium rate of return is lower in CM : lower cost of capital
  - For some parameters values, it is possible to get lower total costs with CM than with EO
  - We have the same result with a CfD

- A SR does not have the same risk reduction properties
  - Direct procurement of capacity by the TSO to complement what is built by private investors
  - Whenever the reserve capacity is needed, the spot price is set at VoLL, even with no curtailement needed
  - For private investors there is no risk reduction, but the cost of reserve must be added to total costs

Consequences for the whole generation mix

- Mid-merit and baseload capacity
  - Also benefit from a lower cost of capital with CM or a CfD for peak capacity when $p > 0$
  - But less reduction, since capacity price is a lower part of expected revenues than for peak capacity
  - They have a lower financial risk to begin with

- The lower the rank in merit-order, the lower the cost of capital
  - Generation technologies relative competitiveness should be assessed with different discount-rates, taking into account the differences in risk premiums (otherwise cross-subsidies)

- A decarbonized mix leads to a higher cost of capital
  - Only technologies with low or zero variable costs
  - Newbery (2016) : fixed costs must be covered by more volatile cash-flows

Assessment on datas

- Datas : France hourly load values from ENTSOE (2006-2015), and CAC40 as market-index / benchmark

- Market parameters are set at standard values, such as those given by RWE and E.ON in their Annual Reports
  - Equity Risk Premium (ERP) = 6 %, Real risk-free rate = 2 %
  - Market portfolio return standard error : 16 %
  - Correlation between load and market return = 0,05 (computation for 2011-2015, rough estimate) or 0,1 (computation for 2015 only)

- Costs OCGT (other technologies from IEA WEO 2016)
  - Variable cost : 80 €/MWh, capital cost : 550 000 €/MW, O&M fixed costs : 15 000 €/MW
  - Lifetime : 30 years, Value of Lost Load : 20 000 €/MWh

Energy-Only results for ERP = 6%, risk-free rate = 2 %

Technology	Cost of capital	Hours
Load-shedding	-	4 h 24
OCGT	12,9 %	
CCGT	10,8 %	
Coal SC	7,8 %	

Table: Correlation = 0,05

Technology	Cost of capital	Hours
Load-shedding	-	7 h 30
OCGT	24,7 %	
CCGT	19,6 %	
Coal SC	12,4 %	

Table: Correlation = 0,1

Capacity Market and energy CfD

- We now assess the impact of a 30 years capacity price and a 15 years energy CfD
  - The capacity price or the CfD strike price are set such that the Security of Supply criteria of an expected load-shedding of 3 hours is respected (as in France)
  - EO results are now shown with a peak generation only mix, in order to make the comparison easier between market-designs

- Costs for consumers
  - By assumption, the capacity price or the strike price are paid by consumers
  - The electricity bill is the expected total cost for consumers in each market-design, including the capacity price (or the strike price)
  - When divided by expected generation, this yields the expected average price paid by consumers

ERP = 6 %, risk-free rate = 2 %, load-shedding 3 h

Correlation	**0,05**	**0,1**
Capacity price (€/MW)	13 000	24 700
OCGT cost of capital	9,9 %	12,4 %
Expected price vs EO	- 2,8 %	- 11,0 %

Table: CM 30 years capacity price

Correlation	**0,05**	**0,1**
OCGT cost of capital	7,3 %	9,0 %
Expected price vs EO	- 5,3 %	- 14,5 %

Table: Energy CfD results, 15 years

Conclusions

- Financial risk may be an issue for generation capacity investment in an Energy-Only market, even in the absence of price-caps or market-power
  - The market failure is missing markets
  - Peak capacity obviously, but decarbonized electricity systems are bound to see the same problem for all generation technologies, as cash-flows will become more volatile
  - Some form of long-term price signals in complement to short-term wholesale market (hybrid designs) may help solving this problem by lowering the financial risk for investment

- Those market-designs can lower the costs of production, and thus benefit consumers
  - No subsidies : no paiement or guaranty from the State
  - More analysis is needed, as consumers surplus should be studied taking into account possible risk-aversion