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 administrative 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) or Artelys (2016) study for the European Commission : too much risk for peak capacity investment (but no CAPM)
  - Consensus that RES have lower costs of capital thanks to FiTs, as argued in Wind Europe position paper (2017)
  - Electricity Market Reform UK : CfDs in order to keep cost of capital low for low-carbon technologies, or hybrid RAB for new nuclear as advocated by Newbery, Pollitt, Reiner & Taylor (2019)

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 (but not for SR), provided that load demand and the market portfolio are positively correlated
  - 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 a change of market design
  - A decarbonized electricity system is bound to see higher costs of capital with an Energy-Only design, some form of long-term contracts may be needed to prevent this increase

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)
  - Only futures markets 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)
  - First-best only if markets are complete : Gollier (2016) or David, Lebreton & Morillon (2011)
  - Need for fixed-price contracts : Newbery et al (2019), 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
  - No fossil fuels prices volatility (they are exogenous)

- Long term equilibrium with perfect competition in different market-designs (no regulatory risk) :
  - 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 and stochastic 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 load duration curve on states of nature (*monotone*)

- 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, η the market portfolio gross return (given by an index such as S&P 500, CAC 40) and β the asset-beta (no financial structure taken into account)

- 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 capacity defined by equality between expected risk-adjusted gross margin and discounted investment cost

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 : security of supply is not respected

Technology	Cost of capital	Asset beta	Hours
Load-shedding	-		4 h 24
OCGT	12,9 %	1,8	
CCGT	10,8 %	1,5	
Coal SC	7,8 %	1,0	

Table: Correlation = 0,05

Technology	Cost of capital	Asset beta	Hours
Load-shedding	-		7 h 30
OCGT	24,7 %	3,8	
CCGT	19,6 %	2,9	
Coal SC	12,4 %	1,7	

Table: Correlation = 0,1

Capacity Market

- We now assess the impact of a 30 years capacity price
  - The capacity price is set such that the Security of Supply criteria of an expected load-shedding of 3 hours is respected (as in France)
  - Price known with certainty for 30 years : it is not the case in practice for some CM (15 years in UK), the results thus tend to overestimate the risk reduction
  - 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 is paid by consumers
  - The electricity bill is the expected total cost for consumers in each market design, including the capacity price
  - When divided by expected generation, this yields the expected average price paid by consumers

A Capacity Market lowers the cost of capital

Correlation	**0,05**	**0,1**
Capacity price (€/MW)	13 000	24 700
OCGT cost of capital	9,9 %	12,4 %
OCGT asset beta	1,3	1,7
Expected price vs EO	- 2,8 %	- 11,0 %

Table: 30 years capacity price

Correlation	**0,05**	**0,1**
OCGT cost of capital	12,9 %	24,7 %
OCGT asset beta	1,8	3,8

Table: EO results reminder

Contract for Difference

- We now assess the impact of 15 years energy CfD
  - The CfD strike price is set such that the Security of Supply criteria of an expected load-shedding of 3 hours is respected (as in France)
  - It is an energy price : revenues for the power plant will vary with actual production
  - The CfD only lasts 15 years (for a 30 years power plant lifetime), then the market reverts to Energy-Only

- Costs for consumers
  - By assumption, the strike price is paid by consumers
  - The electricity bill is the expected total cost for consumers in each market design, with the strike price for the first 15 years and the expected spot price for the last 15 years
  - When divided by expected generation, this yields the expected average price paid by consumers

Contract for Difference : an even lower cost of capital

Correlation	**0,05**	**0,1**
OCGT cost of capital	7,3 %	9,0 %
OCGT asset beta	0,9	1,2
Expected price vs EO	- 5,3 %	- 14,5 %

Table: 15 years energy CfD

- The CfD does not suppress all the risk : even if the price is fixed, variations in demand mean that gross margins are still volatile

Correlation	**0,05**	**0,1**
OCGT cost of capital	12,9 %	24,7 %
OCGT asset beta	1,8	3,8

Table: EO results reminder

A lower cost of capital can be welfare improving

- The social discount rate must be computed in order to show that a lower cost of capital, as induced by a CfD, is efficient
  - Cherbonnier and Gollier (2018) provide a method to compute it for electricity generation in a Consumption-based CAPM (or CCAPM)
  - Normative approach, since the utility function of a representative agent is used (CRRA)

- With their calibration, the social discount rate for a peak power plant is much lower than for EO competitive equilibrium
  - Hinges on a very low market risk premium
  - Quinet report (2013) has a different CCAPM calibration

- Lowering the cost of capital through a market design reform then seems to be a welfare improving measure, as it allows investment to be more in line with the first-best outcome

Conclusions

- Financial risk seems to 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