Capacity mechanism and explicit cross-border participation: a bad idea to fix a non-existing problem

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The development of capacity mechanisms in the EU

- Capacity markets are developping across Europe
  - In operation : Belgium, France, Italy, Ireland, Poland, UK
  - Considered : Denmark, Germany, Netherlands, Sweden, Spain
  - Germany was previously opposed, but had a strategic reserve instead, as Sweden

- Capacity Remuneration Mechanisms (CRM) can take different forms
  - Strategic Reserve (SR): out of market capacities directly procured and operated by the TSO
  - Capacity payment (CP): the price of capacity is set by regulators, in order to reach a capacity target
  - Capacity market (CM): a capacity target is set by regulators, then the price of capacity is determined by some competitive schemes (auctions, secondary market, etc.)
  - CM is the currently favored form of CRM in Europe

An evolution of the regulation in the EU

- The European Commission position about capacity mechanisms has evolved following the 2022-2023 energy crisis: the 2024 Electricity Market Design directive states that capacity mechnisms are no longer transitory measures but have a "structural" role

- It renews the debate about their design
  - Centralized vs decentralized, definition of targets, centralized demand function definition, etc.
  - How to take into account exchanges with neighbours
  - Mandatory european exercise, the European Resource Adequacy Assessment (ERAA), is perfomed every year by ENTSO-E

- Security of Supply (SoS) metric Loss of Load Expectation (LOLE)
  - Different across countries : an expectation of 3 hours in Belgium, France, Italy, Poland, UK ; 4 hours in Germany and Netherlands

Cross-border participation

- The Clean Energy Package requires that foreign capacities can participate in a national capacity market
  - Formal condition for European Commission aprobation of a CM, approbation required since a CM is seen as a State aid
  - Requirement seen as logical consequence of a non-discrimination principle

- This participation can be
  - Implicit: the national capacity target is assessed taking into account the possibilities of exchanges with its neighbours
  - Explicit: capacities in the neighbouring countries can participate in the national capacity market and be explicitely remunerated, at the same capacity price or another one
  - The explicit mode is the one mandatory for the European Commission

Litterature review

- An Energy Only (EO) market design may not lead to the necessary level of investment, due to the existence of a price cap (missing money) or to financial risk for peak capacity, in a perfect competition setting
  - Joskow (2008), Cramton & Stoft (2005, 2008), 4000 €/MWh price cap in EU (but can increase)
  - Financial risk : Peluchon (2019, 2021), Ehrenmann & Smeers (2011), de Maere Ehrenmann & Smeers (2016), Sisternes & Parsons (2016)
  - RTE, France's TSO, has argued a CM is a welfare improving measure due to a lower cost of capital for capacity investment

- Lambin & Léautier (2019) or Menegatti & Meeus (2024): a CM has negative consequences for an EO neighbour ("negative externality") in a perfect competition setting
  - EO country capacity decreases, while CM country sees an increase (one for one for Lambin & Léautier (2019) in the case with unlimited interconnection)

Litterature review and research objectives

- "Negative externality"
  - Widespread idea in many papers, but usually mixed with other imperfections (strategic behavior, myopia, etc.)
  - Finon (2014): for the European Commission, capacity displacement is the main reason to establish an explicit participation requirement (provide EO country capacity a supplementary remuneration)

- Menegatti & Meeus (2024): explicit mode brings no benefit compared to the implicit one (the price of non-domestic capacity is zero)

- We extend their results in an analytic model
  - Perfect competition long-run equilibrium: best setting to analyse whether incentives can be correctly set by a regulation (Lambin & Léautier 2019)
  - Interconnection capacities endogenous: disentangle impact of cross-border participation mode from interconnection level

The model

- Model identical to Lambin & Léautier (2019), Creti & Fabra (2007) or Peluchon (2019), but with a discrete set of states of nature
  - One peak generation technology (but easily extended to different technologies)
  - No price-cap, hence no "usual" missing money, we simply assume the level of investment in EO is insufficient

- Inelastic and stochastic load demand D
  - States of nature t with probability τ_t
  - 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

- Capacity and interconnection investment decided at time $t = 0$, before load is known, then at $t = 1$ production occurs and the realization of demand is known

Setting

- Costs : Variable cost is c ; generation capacity cost is f ; interconnection capacity is T with cost of development of one unit of capacity c_T

- Value of Lost Load (VoLL) is V. It is the gross surplus of electricity consumption, that is the level of price or cost for which consumers are indifferent between consuming or not consuming electricity (Joskow & Tirole 2007)
  - Equivalence between minimizing total costs and maximizing consumers surplus, since with inelastic demand consumers' gross surplus is equal to total consumption times VOLL
  - Load shedding represented as a fictional technology with zero fixed costs, unlimited capacity and a variable cost equal to VOLL allowing to fullfill demand

First-best for two countries in EO

- The first-best for the EO case is found by minimizing total expected costs under capacity, demand and exchanges constraints for country A and country B (dual variable between brackets)
  - We note def_{it} the volume of load shedding for country i in state of nature t
  - q_{it} is production in country i in state t for domestic consumption, q^x_{it} for export
  - x_i is generation capacity in country i, T the interconnection capacity

$$min_{q_{it},q^x_{it},x_i,def_{it}} \ \mathbb{E}(cost) = \sum_i \sum_t \tau_t(vq_{it} + vq^x_{it} + Vdef_{it}) + f \sum_i x_i + c_T T$$

$$D_{it} \leq q_{it} + q^x_{jt} + def_{it} \ \ (\lambda_{it}) \ \ \forall t \ \forall i \in [A, B] \ j \neq i$$

$$q_{it} + q^x_{it} \leq x_i \ \ (\mu_{it}) \ \ \forall t \ \forall i \in [A, B]$$

$$q^x_{it} \leq T \ \ (\alpha_{it}) \ \forall t \ \forall i \in [A, B]$$

First-best for two countries in EO

- This problem is a perfectly standard linear program, has a unique solution, and also defines the perfect competition equilibrium in the EO case
  - Equilibrium is uniquely defined by a set of complementarity equations

- We get the usual results
  - Fixed costs are equal to the sum of inframarginal rents
  - The price in a country is either v when demand is lower than domestic capacity plus imports or V when some load shedding is needed
  - Prices are equal in the two countries when there is no congestion ($\alpha_{it} = 0$)
  - The sum of congestion rents is equal to the cost of interconnection capacity

Capacity Market

- The capacity market can be integrated in one of the two country (now noted CM) by adding a capacity target $\hat{x}_{CM}$ and the following constraint to the previous problem :

$$x_{CM} \leq \hat{x}_{CM} \ (\eta)$$

- A new complementarity equation is added :

$$0 \leq x_{CM} - \hat{x}_{CM} \perp \eta \geq 0$$

- We can remark that the price of capacity η is zero if installed total capacity is higher than the capacity target. In other words the capacity requirement does not create additional costs if the Energy Only investment level is already sufficient to meet the SoS criterion. The previous first order conditions on capacity are modified thus:

$$0 \leq f_{CM} - \sum_{t} \mu_{CMt} - \eta \perp x_{CM} \geq 0 \ \forall i$$

Implicit participation

- In the case of implicit participation, the capacity target $\hat{x}_{CM}$ is assessed taking into account the possibilities of exchanges with EO country. We simply take it as a given

- The equations defining the equilibrium for capacity and energy prices are :

$$0 \leq f - \sum_t \mu_{CMt} - \eta \perp x_{CM} \geq 0$$

$$0 \leq f - \sum_t \mu_{EOt} \perp x_{EO} \geq 0$$

$$0 \leq x_{CM} - \hat{x}_{CM} \perp \eta \geq 0$$

$$0 \leq \tau_t v + \mu_{it} - \lambda_{it} \perp q_{it} \geq 0 \qquad \forall i \in [CM, EO], \forall t$$

$$0 \leq \tau_t V - \lambda_{it} \perp def_{it} \geq 0 \qquad \forall i \in [CM, EO], \forall t$$

Implicit participation

- We then have the equations linking the two countries through exchanges :

$$0 \leq \tau_t v + \mu_{it} + \alpha_{it} - \lambda_{jt} \perp q^x_{it} \geq 0$$

$$\forall i \in [CM, EO], \forall j \in [CM, EO], j \neq i, \forall t$$

$$0 \leq c_T - \sum_i \sum_t \alpha_{it} \perp T \geq 0$$

Then the supply - demand balance equations for capacity and energy :

$$0 \leq x_i - q_{it} - q^x_{it} \perp \mu_{it} \geq 0 \qquad \forall i \in [CM, EO], \forall t$$

$$0 \leq q_{CMt} + q^x_{EOt} + def_{CMt} - D_{CMt} \perp \lambda_{CMt} \geq 0 \qquad \forall t$$

$$0 \leq q_{EOt} + q^x_{EOt} + def_{EOt} - D_{EOt} \perp \lambda_{EOt} \geq 0 \qquad \forall t$$

Explicit participation : border auctions

- The capacity market in CM country is implemented through a national capacity target and Maximum Entry Capacity (MEC), i.e. the maximum level of non-domestic capacity that can participate given interconnection constraints
  - The MEC can be equal to capacity interconnection or lower taking into account the correlation between electricity demands in the two countries
  - If EO country capacities are greater than the MEC, then the price of capacity for non-domestic assets will be zero

- Indeed, the constraint is:

$$x_{EO} \geq T \text{ or } x_{EO} \geq MEC$$

- This will be always true as soon as demand in EO country leads to a greater installed capacity level

Explicit participation : border auctions

- We make this assumption, as it is true in practice for France and its neighbours
- Since the price of capacity for non-domestic power plants is zero, then the equilibrium is identical to the implicit participation case
  - Same set of complementarity equations defining the equilibrium
  - Remark that almost no assumptions are needed to get that result
  - Same conclusion than Menegatti & Meeus (2024)
- We can then confidently conclude that the explicit participation mode does not bring any benefit with border auctions (and adds a lot of complexity)

Explicit participation with a unique capacity price

- We can envision that non-domestic capacities get the same capacity price than domestic ones
  - But only a part of them will be able to be remunerated, given interconnection constraints
  - Hence we assume once more that installed capacity in EO country is greater than the MEC

- We note x_{EO_1} the capacities able to get this additional remuneration, and x_{EO_2} those who are not
  - For the demonstration, we assume that the capacity price p that capacities x_{EO_1} receive is exogenous (and such potentially different from capacity price η)
  - The maximum level of EO country capacity that can receive p is MEC and ξ is the dual variable associated to this constraint

Explicit participation with a unique capacity price

- Complementarity equations defing the equilibrium are then:

$$0 \leq f - p - \sum_t \mu_{EO_1 t} + \xi \perp x_{EO_1} \geq 0$$

$$0 \leq f - \sum_t \mu_{EO_2 t} \perp x_{EO_2} \geq 0$$

$$0 \leq MEC - x_{EO_1} \perp \xi \geq 0$$

- For capacities EO_1 we have the equality:

$$f - p - \sum_t \mu_{EO_1 t} + \xi = 0$$

Explicit participation with a unique capacity price

- As $\xi > 0$, we have:

$$p + \sum_t \mu_{EO_1 t} > f$$

Capacities EO_1 get a remuneration greater than their total costs

- Moreover, we also have:

$$\sum \mu_{EO_1 t} = f = \sum \mu_{EO_2 t}$$

Given that capacities EO_1 and EO_2 have identical variable costs

- It is obvious that the additional remuneration p only creates a rent without having an impact on investment incentives in EO country. This is true for whatever value of p, which can then be set equal to η without loss of generality.

Explicit participation with a unique capacity price

- Investment incentives unchanged in EO country
  - Marginal gross margin for new capacity does not include p
  - Hence, EO capacity is the same than previously
  - Since EO capacity is the same, this is also true for CM capacity and capacity price η

- A rent is created for some capacities, which has no economic legitimacy

- But the CM consumers have to pay more (the capacity price is included in consumers' bills), since more capacities are paid the capacity price : $k_{CM} + MEC$ instead of k_{CM}

A negative externality ?

- Let's examine now the idea that establishing a CM in one country leads to negative consequences for its Energy Only neighbours (the negative externality already mentionned in the introduction).

- It is obvious that CM country capacity has increased compared to the case where the two countries are Energy Only, EO country capacity has decreased
  - by the same amount if interconnection capacity is unlimited (same result than Lambin & Léautier 2019), but then SoS criterion not respected
  - by a lower amount if interconnection capacity is endogenous and demand probability distributions are the same in the two countries

- A CM with EO neigbours need interconnection constraints to be able to reach LOLE target

Different demand distributions

- Equilibrium when the two countries are EO is caracterised by the following equality:

$$f = \sum_t \mu_{At} = \sum_t (\lambda_{At} - \tau_t v) = \sum_t \mu_{Bt} = \sum_t (\lambda_{Bt} - \tau_t v)$$

$$f + \sum_t \tau_t v = \sum_t \lambda_{At} = \sum_t \lambda_{Bt}$$

- We also have:

$$f + \sum_t \tau_t v = \sum_t \lambda_{At} = \sum_t \lambda_{Bt} - \sum_t \alpha_{At} + \sum_t \alpha_{Bt}$$

- Thus :

$$\sum_t \lambda_{At} = \sum_t \lambda_{At} - \sum_t \alpha_{At} + \sum_t \alpha_{Bt}$$

$$\sum_t \alpha_{At} = \sum_t \alpha_{Bt}$$

Different demand distributions

- The sum of congestion rents balance between the two countries, which is logical since costs are identical. We have furthermore:

$$c_T = \sum_t \alpha_{At} + \sum_t \alpha_{Bt}$$

$$\sum_t \alpha_{At} = \sum_t \alpha_{Bt} = \frac{c_T}{2}$$

- With one country CM, and the other EO, using the same equations, we get:

$$f + \sum_t \tau_t v = \sum_t \lambda_{CMt} + \eta = \sum_t \lambda_{EOt}$$

- Revenues generated by wholesale prices in CM country are lower than the revenues generated by wholesale prices in EO country (since the LOLE target is met), the capacity price is positive

Different demand distributions

- We also have:

$$\sum_t \lambda_{CMt} + \eta = \sum_t \lambda_{EOt} = \sum_t \lambda_{CMt} - \sum_t \alpha_{EOt} + \sum_t \alpha_{CMt}$$

$$\eta = -\sum_t \alpha_{EOt} + \sum_t \alpha_{CMt}$$

- As capacity price is strictly positive, congestions from CM to EO are greater than those from EO to CM. It allows to show that total capacity on the two countries has increased

- EO country probably becomes a net importer compared to the case where the two countries are EO (but formal demonstration needs further assumptions)

There is no negative externality

- Can we talk about a security of supply degradation for country EO ?
  - No, since expected lost load is the same for this country whether the two countries are EO or the other implements a capacity market
  - It has less installed capacity, but CM country capacity has increased by a higher value, and as a consequence it can import more

- In a way, it gets the same security of supply without bearing the same costs of investment
  - The costs for EO consumers are unchanged, since the equation ensuring equality between total costs of generation (including lost load) and the expectation of wholesale prices remains valid
  - Taking about a negative externality is thus unwarranted (we should even talk about a positive externality !), thus negating the main justification for the requirement to remunerate cross border capacities.

Conclusions

- Explicit participation, today required by the European Commission, risk degrading the economic efficiency of a capacity market
  - The price will be either zero or will have no impact on cross-border capacities
  - Hence the additional complexity yields no benefit or even create an illegitimate rent which increases costs for the CM country consumers

- It is not warranted to talk about a negative externality
  - Any EO country with a neighbour implementing a capacity market does not see its security of supply lowered, even if its installed capacity decreases
  - Obtained through an analytic model, hence the conclusions are general
  - Since it is the main argument in favour of an explicit participation requirement, it seems legitimate to alleviate this requirement in order to allow european capacity market to operate efficiently