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Microeconomix

The electricity capacity adequacy problem: Assessing dynamic effects of capacity remuneration mechanisms

In April 2015, the DG Competition launched a state aid sector inquiry into electricity capacity mechanisms in Europe[1]. Like France, many European countries have decided to implement a new mechanism to ensure capacity adequacy in the power system, meaning having enough generation and demand-response capacity to serve the expected highest level of electricity demand in a reliable manner. However, the adopted solution is not unique: for instance, France and Great Britain implemented a capacity market whereas Sweden and Belgium chose a strategic reserve mechanism. These different choices raise the question of which mechanism is optimal from an economic point of view in order to solve the capacity adequacy issue.

The present paper studies this question and compares the social welfare of both aforementioned mechanisms from a dynamic point of view relying on a home-made model of investment behavior as a reaction to prices from the energy market and the implemented adequacy mechanism. Considering the dynamic aspect is particularly relevant due to the cyclical tendencies which are prone to appear in investments in generation and demand-response capacity in the electricity markets.

Cyclical tendencies in electricity markets

Liberalization of power systems in previous decades has changed the way electricity is sold and capacity investment decisions are made. From a previous centralized system where only one regulated player was involved, the power system is now opened to competition regarding the generation and sale of the commodity, i.e. the electricity. Consequently, market players perform their own development planning and investment decisions in reaction to complex and hardly predictable price signals, aiming to earn the highest profit.

These decentralized energy-only markets (markets where only energy, i.e. the generated electricity, is remunerated) **can experience strong capacity cycles**, with phases of undercapacity (during which installed capacity is lower than electricity demand) following by phases of overcapacity (when installed capacity is greater than load) and **a long-term equilibrium might not be reached**.

These tendencies, known as boom-and-bust cycles, are dramatically prejudicial to society and reduce social welfare in two ways. First, during the undercapacity phases, more shortages than optimal are required, i.e. it would be less costly to build additional power plants than to curtail some customers' consumption. This is particularly detrimental for the economy as a whole because it prevents the production of goods and services[2]. Second, during the overcapacity phases, more plants than optimal are available on the market, which incurs higher investment and operational costs. Thus, **from a social welfare point of view, capacity cycles should be avoided**. However, several specific characteristics of the power system and of investors make the cyclical tendencies likely in current markets.

Undercapacity phases are explained by the tendency of investors to delay their investments. This is mostly due to uncertainties (e.g. regarding fuel prices, regulation decisions…), impossibility to predict futures prices in a perfect way and risk aversion. Investors tend to wait for clearer signals regarding the profitability of their plant projects. Long lead times, capital intensiveness and irreversibility of investments also intensify these effects. As a result, new power plants come in operation too late, after major shortages appeared.

Conversely, once investments seem to be profitable enough, players are prone to overinvestment. This can be explained by a herd behavior. Without any coordination practice, investors can over-react to high prices in the energy market. In particular, they can fail to take into account the likely investment decisions of other competitors. Such underestimation can be intentional - investors being skeptical about completion of competitors announced power plants - or unintentional - investors having limited information about competitors' decisions.

Analogies with other markets, which share particular characteristics with the power market (e.g. capitalistic investments, long lead time…) and experience cyclical behaviors (e.g. the aluminum industries, the real estate market…) can confirm this reasoning. It is also supported by empirical evidence (e.g. in Chile or England[3]).

[1] At the time this article was written, the results of this inquiry had not been published yet.

[2] The value of unserved energy (known as the value of lost load) is estimated at around 26,000€/MWh in France by RTE, approximately 200 times higher than the average cost of electricity in this situation.

[3] Cf. Arango, S., Larsen, E., 2011. *Cycles in deregulated electricity markets: Empirical evidence from two decades*. Energy Policy, vol. 39, issue 5, 2457-2466.

In current power markets, the undercapacity phases and the resulting shortages appear to be the most concerning aspect of capacity phases. It results in a capacity adequacy issue (i.e. installed capacity cannot deal with the peak demand) which justifies the implementation of new mechanisms. However, it should be noted that, from a social welfare point of view, overcapacity phases are also damaging and should be avoided as well.

Capacity Remuneration Mechanisms (CRM) to solve the adequacy issue

Given the aforementioned flaws of traditional energy-only markets and the specific characteristics of power systems and investors, the economic literature discussed the **implementation of new mechanisms, called Capacity Remuneration Mechanisms (CRM) to solve the capacity adequacy issue**. These new mechanisms aim at **reducing the undercapacity phases and the associated shortages by ensuring to have enough installed capacity** to deal with peak consumption. Several CRM designs have been discussed and implemented in some power markets around the world. Among these, the debates and discussions currently taking place in Europe mostly focus on two mechanisms, **the capacity market and the strategic reserve mechanism**.

In the capacity market, an obligation of available capacity is computed several years in advance (obligation borne either by the TSO[4] or by the suppliers). This obligation, equal to the peak demand forecast plus a capacity margin, ensures that enough installed capacity will be available to deal with the expected load and uncertainty (and thus to avoid shortages). Moreover, capacity certificates are issued to capacity operators such as power plants or demand side management based on their contribution to reduce the shortages risk. Thus, having defined a demand and supply for capacity, a new market for this product is created, juxtaposed to the commodity energy market. A capacity price is then determined, which creates complementary revenues for capacity providers. This design has been implemented for more than one decade in several US markets and recently in France and in Great-Britain.

The functioning of the strategic reserve mechanism is quite different, since no new capacity product is introduced and players' decisions are only based on revenues from supplied energy (like in the energy-only market). However, in this mechanism, the TSO can react in case future shortages are expected. In this case, it constitutes strategic reserves by contracting through a competitive tender some capacity which will be taken out of the energy market and deployed only as a last resort to avoid shortages (e.g. if the energy market price reaches a given level). This mechanism has been implemented in Sweden, Finland and recently in Belgium. Germany is expected to choose this design too.

One of the key questions in the current literature involves **assessing the performances of these two CRMs and comparing them to select and implement the optimal one**[5]. In Europe, this choice must comply with State aid guidelines under the scrutiny of the DG competition. From an economic point of view, such CRMs have to **be compared regarding their social welfare**, i.e. the combined consumer and producer surplus. Since CRMs are implemented in order to attract investments, social welfare should be assessed over a long time period (e.g. 20-30 years) to perfectly consider the economic effects of CRMs. In a simplified way, two types of costs can be considered to assess the impact of CRMs on social welfare: 1) the cost of unserved energy for the society, i.e. **the cost induced by shortages**[6] (referred as **effectiveness**) and 2) the **total generation cost of installed capacit**y, i.e. investment, operations and maintenance (O&M) and variable costs[7] (referred as **efficiency**). A trade-off appears between these two costs: installing more generation capacity would reduce the frequency and costs of shortages but it would increase the generation costs as additional capacity needs to be built and operated. Then, an optimal CRM should minimize the sum of these two costs (and not only aiming at reducing shortages). Moreover, given the importance of the cyclical tendencies as mentioned previously, **this comparison has to be made from a dynamic point of view**.

Dynamic comparisons of both CRMs

To study the dynamic tendencies when a capacity market or a strategic reserve mechanism is implemented and to compare the social welfare in both cases, Microeconomix has developed a simulation model, based on system dynamics modeling. It simulates the investment and shutdown decisions made by market players in a liberalized market regime for three different sets of market rules: the energy-only market (as a reference case), the capacity market and the strategic reserve mechanism. Moreover, simulations are run for several stochastic scenarios of load growth. The logic of the model is described on a simplified causal-loop diagram, depicted on figure 1[8]. The (+) symbol describes a positively related effect (an increase in the first variable will cause an increase in the second one) whereas the (-) symbol specifies the contrary.

[4] Transmission System Operator: it is in charge of operating, maintaining and developing the power transmission grid, as well as managing the security of the power system in real time.

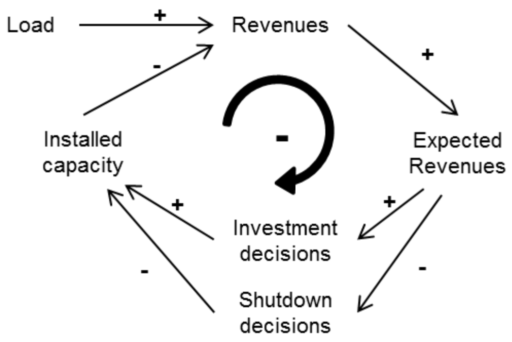
[5] For instance, see Finon, D., Pignon, V., 2006. *Electricité et sécurité de fourniture de long terme. La Recherche D'instruments Règlementaires Respectueux du Marché Electrique*. Revue ISMEA Economie et Société, série Energie, no. 10 ; De Vries, L., Heijnen, P., 2008. *The impact of electricity market design upon investment under uncertainty: the effectiveness of capacity mechanisms*. Util. Policy 16 (3), 215–227 ; Hasani, M., Hosseini, S.H., 2011. *Dynamic assessment of capacity investment in electricity market considering complementary capacity mechanisms*. Energy 36 (1), 277–293.

[6] For each year, this cost is computed based on the volume of unserved energy and the value of lost load (see footnote 1)

[7] For each year, these costs are computed based on the investment costs if new plants are built during this year, O&M costs if capacity is available to produce electricity and generation costs if it produces.

[8] More details about the model and data used can be found in Hary, N., Rious, V., Saguan, M., 2016. *The electricity generation adequacy problem: Assessing dynamic effects of capacity remuneration mechanisms*. Energy Policy 91, p113–127

Figure 1. Simplified causal-loop diagram of the model



Each year, revenues (from the energy market and/or from CRM) are computed. These revenues are used by players to assess expected revenues and future profitability of their plants and then to make investment and shutdown decisions (as O&M costs increase with the age of the plant, players have to decide whether to close them based on expected revenues). These decisions will in turn impact the installed capacity, which will result in changes in revenues. Then, a negative feedback loop can be noticed, which could lead to an equilibrium in theory.

Study of the cyclical tendencies in the three markets

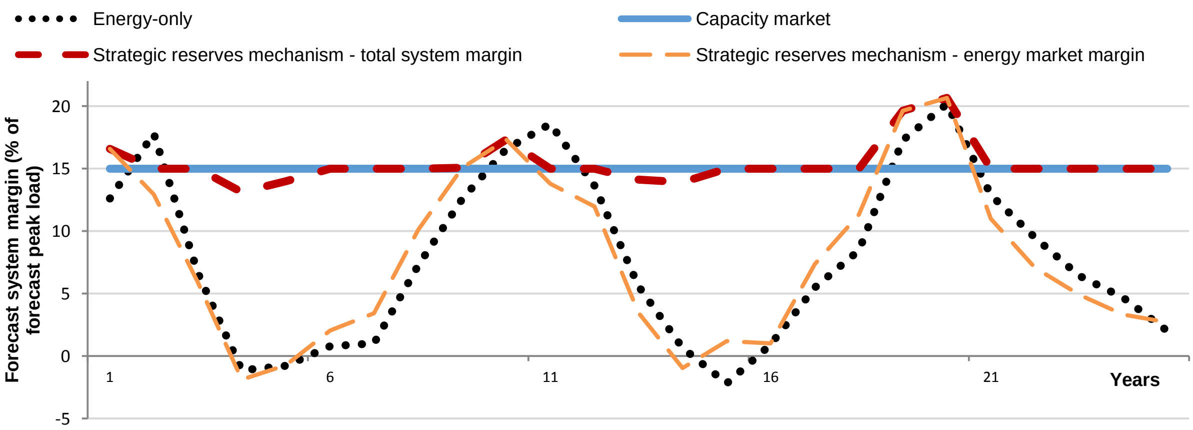
Our model enables to test the cycle hypothesis of the energy-only market and the two considered CRMs. Figure 2 describes the evolution of the expected system margin for 25 years for one scenario of load growth. The system margin is defined as the extra capacity over the peak load, i.e. the ratio (Installed capacity - Peak load) / Peak load. Due to maintenance operations and outages, this margin has to be strictly positive to avoid shortages. Here, a target margin of 15% is considered in the design of both CRMs.

The dynamic performances of each market present major differences. In this scenario, **the energy-only market experiences high cyclical tendencies**. These cycles are mainly due to herd behavior, bounded rationality and incomplete information (about future load and competitors' decisions). Moreover, it is also observed that the average margin, which is around 7-8%, is well below the 15% target. Indeed, revenues earned from the energy market when margin is equal to 15% are not high enough to attract new investments. Thus, the implementation of a CRM is required if policy makers want to reach this target margin and avoid non-optimal shortages.

When a CRM is implemented, the cyclical behavior is well reduced and the system experiences fewer shortages. For the capacity market, the system margin is always equal to the 15% target margin. This result is logical since this target is explicitly defined in the design of the mechanism. If there are not enough plants initially, the capacity market selects the required amount of capacity to reach the target by raising the capacity price so that capacity providers (new plants or existing plants) break even. Conversely, in case of overcapacity, the capacity price will decrease to force expensive plants to close or to postpone investments.

The results of the strategic reserve mechanism (considering the red line on figure 2), **if better than those of the energy-only market, show a lesser ability to reduce cycles compared to the capacity market**. Regarding the **undercapacity phases**, the TSO can avoid most of the shortages, but in a different way than the capacity market. Here, there is no explicit target for the system margin and the energy price is the only signal to coordinate decisions and to give incentives to invest, like in the energy-only market. Therefore, it leads to the same consequences (i.e. cyclical behavior and a mean margin well below the 15% target, which can be noticed with the orange line on figure 2). The TSO is however able to react as a last resort by contracting old generators in strategic reserves to avoid shortages (the action of reserved capacity can be noticed through the difference between the orange and red lines). Thus, phases of **undercapacity** are reduced compared to the energy-only market, but in a less effective way than the capacity market since the total system margin is not always equal to the 15% target margin. Indeed, several parameters limit the well-functioning of the reserved capacity in this respect and lead to an important difference between the capacity required to reach the target margin and the capacity which is actually accepted. Even if large shortages are expected, the TSO cannot contract above a certain amount of existing capacity to avoid disturbing the functioning of the energy market; since only capacity which will be decommissioned can participate to the reserves auctions, offers can be lower than the TSO's demand.

Figure 2. Evolution of the expected system margin for the three market designs

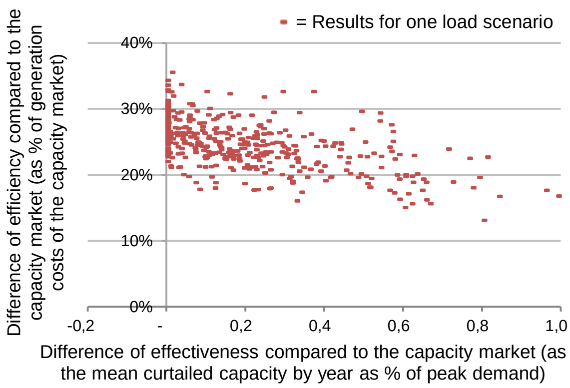


Moreover, when focusing on the overinvestment phases, the strategic reserve mechanism does not perform any better than the energy-only market (e.g. in year 20). Overinvestments are still likely to happen if investors expect large profits. Indeed, there is no signal to avoid this and the TSO cannot force players to postpone their investments.

Social welfare comparisons of the capacity market and the strategic reserve mechanism

Both CRMs are also compared dynamically for 400 different load scenarios, according to their efficiency (i.e. the total generation costs during the 25 years of the simulation) and their effectiveness (i.e. the total volume of shortages, which is considered proportional to the shortage costs[9]). Results are displayed in figure 3, based on the comparisons of the capacity market's effectiveness and efficiency with those of the strategic reserve mechanism. In most of the scenarios, both differences are strictly positive, meaning that the **capacity market provides a higher level of adequacy with lower generation costs.** In the remaining scenarios, both mechanisms lead to the same level of adequacy but the capacity market is still less expensive.

Figure 3. Comparisons of social welfare for both CRMs



Regarding the effectiveness indicator (i.e. shortages), the superiority of the capacity market has been explained in the previous section[10]. Regarding total generation costs, the superiority of the capacity market is clear. Generation costs are about 25% higher with a strategic reserve mechanism than with a capacity market, for three reasons. Firstly, the overcapacity phases, prone to appear in the strategic reserve mechanism, result in higher investment and operational costs. Secondly, the costs of capacity reserved to avoid shortages are high since this reserved capacity consists of old plants which are decommissioned from the energy market, and whose O&M costs are important. Finally, in the capacity market, plants are younger (and the corresponding O&M costs cheaper) since an arbitrage is made between existing capacity and new capacity during the capacity auctions. If the existing capacity is too old and then more expensive than new capacity, it will close and new investments will take place. In the strategic reserve mechanism, such an arbitrage is not possible and old plants can continue to produce even if new plants are cheaper (provided that producers expect them to be profitable). All these points lead to **significantly higher costs and larger shortages for the strategic reserve mechanism than for the capacity market**.

Conclusion

Based on these simulation results, both CRMs succeed in reducing the cyclical tendencies which appear in the energy-only market, in particular regarding the underinvestment issues. However, contrary to the capacity market, the strategic reserve mechanism cannot deal with overinvestment and can still experience some undercapacity phases. Thus, the capacity market appears to experience fewer shortages and, at the same time, to present lower total generation costs than the strategic reserve mechanism, i.e. the social welfare is higher with a capacity market.

These results have direct implications for policy-makers when they decide which CRM to implement. Regarding the case studied in this paper, implementing a capacity market will result in a higher social welfare. At the opposite of these conclusions, the European Commission recommended in 2013 the implementation of a strategic reserve mechanism which it assesses as less distortionary for the energy market and easier to implement.

These results also highlight the importance of assessing the dynamic aspects of the capacity mechanisms. Due to several specific factors, the achievement of an equilibrium state in power systems regarding the investment issue is not certain and some cyclical tendencies may appear in the energy-only market. That is why capacity mechanisms have to be assessed and compared not only from a static point of view but also considering dynamic aspects. The same consideration holds when assessing other aspects of CRMs, such as the impacts of cross-border participation to these mechanisms or their ability to provide enough flexibility in a context of increasing amount of intermittent generation. Our model is a first step to answer these questions and can be completed accordingly.

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The authors contributed to the economic works of the team of economists which worked on this issue in collaboration with several European energy utilities. They express themselves here from a strictly personal point of view and do not bind the position of Microeconomix clients.

[9] Since there is no consensus on the value of lost load in the literature, the effectiveness criterion is studied using the volume of shortages as an equivalent. This choice does not change the conclusions of this paper.

[10] One should also notice that the differences are weak (about 2% of peak load every 10 years on average). Two reasons can explain that: firstly, the strategic reserve mechanism succeeds in providing enough reserved capacity most of the time, as well as the capacity market ; secondly, since shortages are assumed to happen below a 10% margin, this mechanism can provide less than the 15% target and still not experience any shortages.