Lappeenranta
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IMPACTS OF CAPACITY REMUNERATIVE MECHANISMS ON CROSS-BORDER TRADE

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ABSTRACT

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The European ambitious targets to increase the share of renewable generation pose a challenge to the generation adequacy. Many European member states are concerned that energy-only markets alone might not be able to deliver sufficient capacity required to meet the future electricity demand and back up shortfalls of energy from renewable energy sources (RES) during periods of low wind and sun. Many EU members consider to re-design their energy-only markets and establish different forms of capacity remunerative mechanisms (CRMs) to maintain the security of supply. There is a certain concern that market design changes at the level of EU member countries might conflict with the European goal of a single market. As soon as many European markets are highly interconnected, uncoordinated CRMs might create negative cross-border effects and hinder the achievement of the Internal Electricity Market in Europe. The pros and cons of capacity markets are well examined at the national level. However, the cross-border effects of capacity markets within the European market aiming at higher integration have received less attention. This doctoral dissertation examines the cross-border effects of unilateral implementation of CRMs applying both theoretical and case study analyses. The results show that capacity remunerative mechanisms (CRMs) may cause negative cross-border effects, especially if they are implemented unilaterally.

Keywords: *electricity market, capacity remunerative mechanisms, market integration*

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Lappeenranta, August 2015

Olga Gore

List of the original articles

I. Gore, O., Viljainen S., Makkonen, M., and Kuleshov, D. (2012), "Russian electricity market reform: Deregulation or re-regulation," *Energy Policy*, Vol. 41, pp. 676–685.

II. Gore O., Viljainen S., Kylaheiko K., Jantunen A. (2012), "Profit optimization of the cross-border trade between the Nordic and Russian electricity markets," *Operations Research Proceedings*, pp. 169–175.

III. Gore, O. and Viljainen S. (2014), "Challenges of cross-border trade between two markets with different designs," in *Proceedings of the European Energy Market Conference*

IV. Ochoa, C. and Gore, O. (2015) "The Finnish power market: Are imports from Russia low cost?" *Energy Policy*, Vol. 80, pp. 122–132.

V. Meyer, R. and Gore, O., (2014), "Cross-Border Effects of Capacity Mechanisms: Do Uncoordinated Market Design Policies Countervail the Goals of European Market Integration?", *Bremen Energy Working Papers*, No. 17, June 2014

Contents

Nomenclature

Roman letters

AC	Annual costs
ARR	Annual required revenue
CO_2	Carbon dioxide price
C_p	Capacity price
D	Demand
FX	Fixed costs
IC	Investment costs
IMR	Inframarginal rents
MC	Marginal cost
VOLL	Value of Loss Load

Greek letters

Acronyms

ACER	Agency for the Cooperation of Energy Regulators
ATS	Administrator of Trading System
CRM	Capacity Remunerative Mechanism

CWE	Central West European electricity market
EC	European Commission
EMG	Energy Minister Group
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
IEM	Internal Electricity Market
PJM	Pennsylvania–New Jersey–Maryland Interconnection
RES	Renewable Energy Sources
SR	Strategic reserve
TSO	Transmission System Operator

1. Introduction

Electricity markets across Europe are facing challenges posed by the ambitious European climate and energy targets. The high penetration of renewable energy sources (RES) expected in most European electricity markets has reinforced the debate on generation adequacy in energy-only markets. The low marginal cost RES suppress electricity wholesale prices and reduce the operating hours of conventional generation while pushing it off the merit order. As a result of the reduced number of operating hours and suppression of real scarcity prices peak generators fail to recover their fixed costs. Investment prospects, aggravated by uncertainties about future electricity, fuel and CO_2 prices, the number of operating hours of conventional power plants (or load factors), and regulatory interventions in the form of price caps preventing scarcity prices from reflecting the reasonable value of lost load (VOLL), may endanger supply security in the long run (Joskow, 2006). In the long run, weak investment incentives in new capacity required to back up an increasing share of RES with the high variability and low predictability of the output, together with continuous depreciation of the existing plants may lead to a resource adequacy problem in energy-only markets. As a result, there is a concern that energy-only markets alone may not be able to deliver sufficient capacity required to meet the future electricity demand and back up shortfalls of energy from renewable energy sources (RES) during periods of low wind and sun; this has motivated many countries to reconsider their market designs and think about introducing capacity remunerative mechanisms (CRMs) (Cepeda & Finon, 2013; Eurelectric, 2011; Meulman & Merey, 2012; Nicolosi, 2012; CREG, 2012).

The Internal European Energy Market is a key part of the EU 2020 strategy, as it is considered an important tool to ensure affordable, secure, and sustainable electricity supply in the future (European Commission, 2010). It aims to enhance competition by opening the national markets to foreign participants, thereby increasing supply security and cost efficiency (Booz & Company et al., 2013; Creti et al., 2010; Jamasb & Pollitt, 2005; Pellini, 2012). However, the European Commission has recently raised concerns that these goals may be undermined by national market design adjustments that are weakly harmonized across Europe (European Commission, 2013). Uncoordinated CRMs may distort the cross-border trade and hinder the achievement of the Internal Electricity Market in Europe (ACER, 2013).

The pros and cons of capacity mechanisms are analysed in detail at national levels, but the issues of cross-border effects within a European market that is heading towards a stronger integration have yet received little attention. Only a few recent studies focus on the impact of CRMs in Europe on cross-border trade and show that unilateral implementation of capacity mechanisms may cause cross-border effects and threaten the efficiency of the internal electricity market (Sweco, 2014; Thema, 2013). There is still a lack of understanding whether and to what degree CRMs may cause cross-border effects and thereby conflict with the European goals of an Internal Market for Electricity. This doctoral dissertation picks up the discussion and analyses the cross-border effects against the background of the European market integration.

1.1. Outline of the work

The doctoral dissertation consists of two parts; the first part gives an overview of the work and delineates the research objectives and results, and the second part provides the research papers that address the research questions within the scheme and objectives of the study. In the first part, Chapter 2 provides an overview of the main principles of the competitive pure-market design and the CRMs in liberalized electricity markets, and discusses the rationale for CRMs in EU/non-EU member states. The objectives of the research approach and the motivation for the research are given in Chapter 3. Chapter 4 summarizes the research publications and the key findings. Chapter 5 provides a discussion on the topic and the main conclusions from the work presented in the dissertation.

The doctoral dissertation consists of five original refereed articles. Two of the articles were presented in international conferences; two of them have been published in scientific journals. One article is under review. The articles and the author’s contribution to them are summarized below.

Publication I *Russian electricity market reform: deregulation or re-regulation?*

Publication I introduces the capacity market in Russia designed to promote investments in the generation sector and ensure supply adequacy, examines the impact of a capacity mechanism on the competitive landscape of the market, and further, analyses market and regulatory failures in the capacity market design and their impact on the efficiency of the market. The findings suggest that regulatory failures in the market design, such as a price cap policy and capacity payments favouring investments of existing players create barriers and close the market from new entries, making the market less liquid and threatening its competitive landscape. The author was the principal author of the publication.

Publication II *Profit optimization of the cross-border trade between the Nordic and Russian electricity markets*

Publication II evaluates the impact of the CRM on cross-border electricity trade, while presenting the methodology to estimate the optimal cross-border flow if the right to use the transmission capacity is assigned to a cross-border trader and the trader operates between energy-only and energy-plus capacity markets, namely the Nordic energy-only market and the Russian energy-plus capacity market. The findings suggest that the CRMs together with an explicit access to the transmission capacity can notably reduce the cross-border electricity trade and lead to inefficient use of the transmission capacity. The author was the principal author of the publication.

Publication III *Challenges of cross-border trade between two markets with different designs*

Publication III Aside from the findings presented in the previous publication, this publication presents the implications of capacity markets, cross-border allocation mechanisms, and opportunities of cross-border capacity participation for the cross-border trade and market welfare by applying an analytical model where two markets with different market designs, namely the Nordic energy-only market and the capacity-based Russian market, are interconnected and operate under different transmission capacity allocation schemes (explicit and implicit). The findings suggest that having an energy-only market on one side and a capacity-based market on the other side of the border may impede cross-border trade and result in underusage or misusage of the transmission capacity in the case of an explicit cross-border access to the transmission capacity. Implicit access (market coupling), in principle, would increase the efficiency of the cross-border trade, but it may result in distributional effects, that is, involving a free-riding effect. Consumers in the country with a capacity market may pay for an increase in generation capacity that partly leaks to the neighbouring market. Given the integration of markets through market coupling, consumers in the “passive” market may act as free-riders as they benefit from an increase in reliability and lower energy prices without having to pay for the additional capacity. The author was the principal author of the publication.

Publication IV *The Finnish power market: Are imports from Russia low cost?*

Publication V focuses on the long-term impacts and cross-border effects of capacity adequacy policies, while modelling the likely long-term dynamics of the interconnection Finland-Russia. The results show that the benefits of market integration depend on the cross-border capacity allocation principles, capacity expansion policies and the security of supply measures. The study suggests that in order to achieve the maximum benefits of market integration, cross-border allocation principles should be market-based, and strong coordination of market changes and confidence in the neighbouring markets are required. CRM policies may reduce the benefits of market integration. The author acted as a co-author in the publication. A simulation model based on the work of Ochoa and van Ackere (2014) was used to examine the long-term dynamics of the interconnection Finland-Russia. The author of the doctoral dissertation drew up policy scenarios, calibrated the data for the model, and analysed the results. Half of the paper is written by the author of the doctoral dissertation.

Publication V *Cross-Border Effects of Capacity Mechanisms: Do Uncoordinated Market Design Changes Countervail the Goals of European Market Integration?*

This paper analyses the cross-border effects of a strategic reserve (SR) and reliability options (RO) based on a two-country simulation model. By adopting a game-theoretic approach, the countries’ policy options for capacity remunerative mechanisms (CRMs) are analysed with respect to the welfare and distribution effects. A unilateral implementation of CRM may have negative cross-border effects. This is due to the fact that the missing-money problem is further aggravated in the passive market, which in turn will put further pressure on this country to also adjust its own market design. In order to avoid at least temporary negative effects that conflict with the idea of the EIM, coordination of policy measures is advisable. The author acted as a co-author in the publication. The authors have contributed equally to the building of the model and analysis of the results[1].

[1] The topic is further discussed in the recently published journal paper: Meyer, R. and Gore, O., (2015), "Cross-Border Effects of Capacity Mechanisms: Do Uncoordinated Market Design Changes Contradict the Goals of the European Market Integration?" *Energy Economics* 51(2015), 9-20.

2. Energy-only versus energy-plus capacity markets

Liberalized electricity markets are expected to provide incentives for both short-run economic efficiency and long-term generation adequacy. In "energy-only" (EO) markets, generators are paid for the volume of electricity (kWh, MWh or GWh) produced, and generators are not compensated for keeping capacity available. Energy payments should generate sufficient revenues to cover both variable and fixed costs of the power plants. In the absence of market distortions, these revenues should suffice to attract new investments to ensure generation adequacy in the long run. In contrast to energy-only markets, in energy-plus capacity markets generators are paid separately for producing electricity and for being available to produce. The aim of the capacity remunerative mechanism is to ensure the profitability of the existing power plants and to guarantee or at least support investments in new power plants.

This chapter presents an economic analysis of perfectly competitive energy-only and energy-plus capacity markets while determining the optimal mix of generating technologies using a graphical technique of combining the screening curves and the load duration curve. Market interventions in the form of a price cap or penetration of renewable energy sources are examined to illustrate their impact on the short-term profitability and the long-term investment incentives of generators in perfectly competitive energy-only markets. Further, the chapter discusses how capacity remunerative mechanisms can be used to correct the failures of the purely energy-only markets and elaborates on the rationale for the introduction of CRMs in the EU/non-EU. However, to the author's knowledge, an analysis of the short- and long-term impacts of the capacity remunerative mechanisms such as capacity markets and strategic reserve within this graphical method of combining the screening curves and the load duration curve has not been published elsewhere before.

2.1. Energy-only markets

A perfectly competitive market ensures the short-term efficiency, that is, that the demand is met by the least-cost dispatch of power plants in the market. In a competitive energy-only market, generators bid their short-run marginal costs, and the hourly market clearing price equals the marginal cost of the last generating capacity or the demand response resource that clears supply and demand given that the demand does not exceed the available capacity (as illustrated by 'Demand 1' in Figure 1). The fixed costs of dispatched generators are recovered through the inframarginal rents given by the area between the market clearing price ('Price 1' in Figure 1) and the marginal costs of the generators. In a relatively small number of hours per year there will be scarcity situations when the demand exceeds the available capacity ('Demand 2' in Figure 1). In this case, demand is curtailed at the maximum price. Under competitive scarcity conditions, the maximum price at the day-ahead market should reflect the value of lost load (VOLL); the price that consumers place on reducing consumption by a significant amount. Generators then earn "scarcity rents" that amount to the area between the VOLL and Price 2 in Figure 1. For peak capacities operating mainly during scarcity conditions, scarcity rents are an important source of revenue to cover the fixed costs.

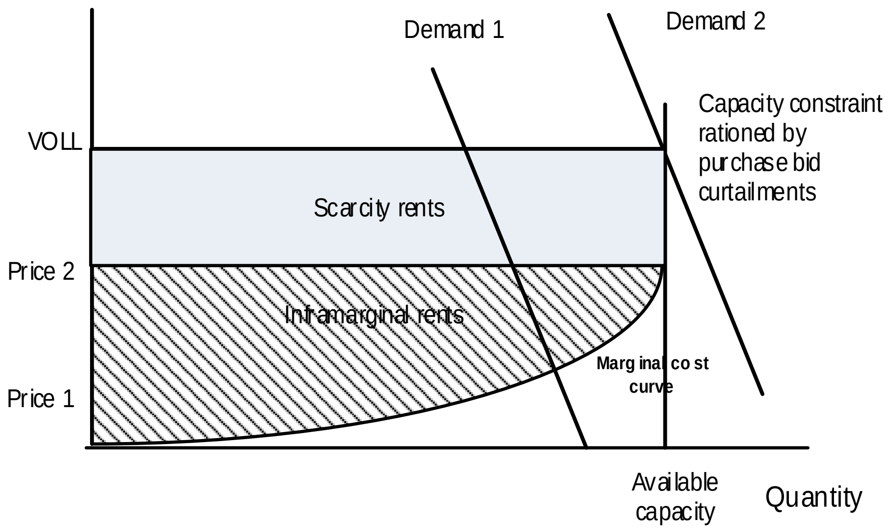

Figure 1. Short-term market equilibrium (adapted from Joskow, 2006)

2.1.1. Long-term equilibrium in energy-only markets without policy interventions

In theory, in the absence of market failures, a perfectly competitive energy-only market will in the long-term induce the optimal mix of technologies and the optimal amount of load shedding to guarantee the recovery of the total supply costs, in other words, the market will reach the long-term equilibrium. The method that uses screening curves and a load duration curve to determine the optimal mix of technologies is presented in Figure 2 (Green, 2005). The screening curves represent the annual costs (AC) of a particular technology depending on the number of running hours a year. Let us assume that there are two alternative technologies available in the market: the baseload and peak ones. The base load technology has relatively high fixed costs and low variable costs, while the peak technology has low fixed costs and high variable costs. The annual costs curves can be found by Eqs. (1–2). The intercept of the curves represents the annual fixed costs of a technology (FX_{base}, FX_{peak}), while the slope of the curve represents the marginal generation cost of the technology (MC_{base}, MC_{peak}).

$$AC_{base} = FX_{base} + MC_{base} * T \quad (1)$$
$$AC_{peak} = FX_{peak} + MC_{peak} * T \quad (2)$$

Demand curtailment can be seen as a third technology with zero capital costs and marginal costs equal to the VOLL, the price that consumers ask as a compensation for being curtailed. The intersections of the screening curves give a minimum number of running hours a year that the technology should generate in order to be cheaper than the other one. The base load technology is less expensive than the other technologies whenever it has to run more than T2 hours a year. The peak technology is cheaper than other technologies whenever it has to run more than T1 but no less than T2 hours a year. It is cheaper to curtail consumers and pay curtailed consumers the VOLL than building peak capacity if the running hours are less than T1. Optimal capacities of the base load and peak technologies (IC_{base}, IC_{peak}) can be derived by projecting the intersections of the screening curves on the load duration curve. The load duration curve is a curve that shows how many hours per year the demand exceeds a certain level. Knowing that the market price is set by the marginal technology, we can obtain the market price duration curve, illustrating how many hours a year the market is cleared at the marginal cost by a particular technology. According to the market price duration curve, the base load power plant will set the price (8760–T2) hours a year, and the peak load power plant will set the price during (T2–T1) hours a year. For T1 hours a year, the demand is above the available capacity in the market, and thus, the demand is rationed in order to match the available supply, and the market price will reach the VOLL. From the SMC, the annual revenues of the base load and peak capacities can be estimated by Eqs. (3–4).

$$AR_{base} = MC_{base} * 8760 + (MC_{peak} - MC_{base}) * (T2 - T1) + (VOLL - MC_{base}) * T1 \quad (3)$$

$$AR_{peak} = MC_{peak} * T2 + (VOLL - MC_{peak}) * T1 \quad (4)$$

Knowing that the tangent of the angle between the screening curves and the axis is the slope of the AC curves, the fixed costs of the technologies can be estimated (see Eqs. 5–6). Inserting Eqs. (5–6) in Eqs. (1–2), and comparing them with Eqs. (3–4), we can see that the revenues exactly compensate the incurred costs, that is, the market is in the long-term equilibrium.

$$FX_{base} = (MC_{peak} - MC_{base}) * (T2 - T1) + (VOLL - MC_{base}) * T1 \quad (5)$$

$$FX_{peak} = (VOLL - MC_{peak}) * T1 \quad (6)$$

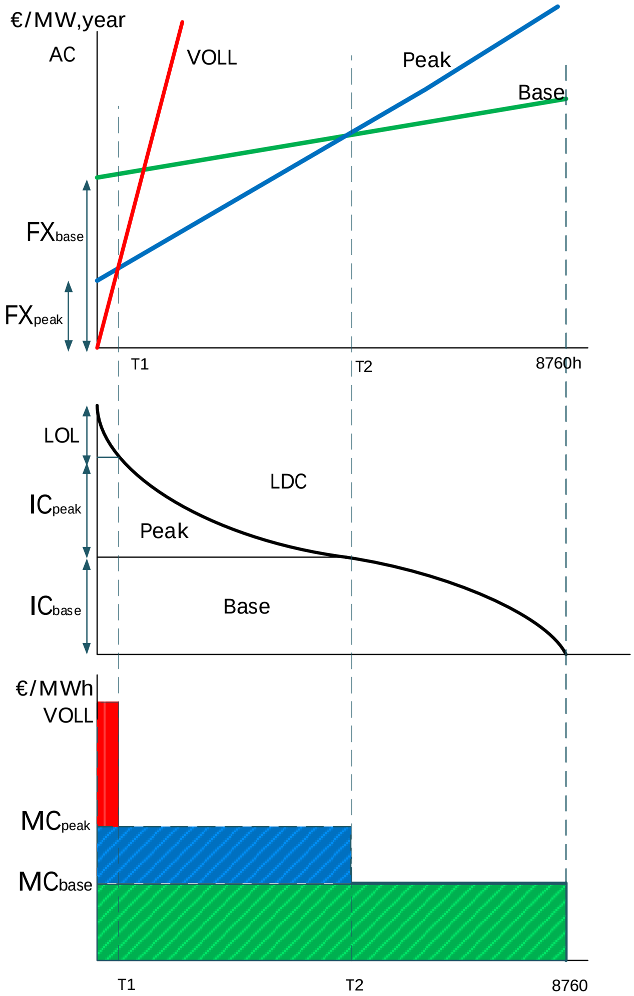

Figure 2. Screening curves, load duration curve, and price duration curve

2.1.2. Short- and long-term impacts of a price cap policy

As it was illustrated above, scarcity prices play an important role in recovering the fixed costs of generators. However, a threat of market power abuse may force regulators to set a price cap in the energy-only market, reducing the scarcity revenues and causing a missing-money problem for generators. In the long-term, capped scarcity prices may not be able to provide sufficient investments in generation, making difficult to ensure supply adequacy. Using the previously illustrated methodology of screening curves, the short- and long-term impacts of a price cap policy are illustrated in Figure 3. We assume that the market is in the long-term equilibrium before the price cap policy is introduced. The regulator sets a price cap on the energy market, meaning that in scarcity conditions, the market is cleared at the price cap rather than at the VOLL. In the short-run (left figure), capacities are not affected by a price cap and remain constant. However, the price cap lowers scarcity prices from the VOLL to the price cap, resulting in reduced scarcity revenues of both the base load and peak capacities. The annual shortfall at (VOLL–Price cap)*T1 represents the missing money, that is, a lack of revenues to cover the fixed costs. This shifts the system from its equilibrium, where it is assumed that the generators earn enough to cover their total costs. Therefore, in the long-term, installed capacities of peak technology will decrease until the resulting prices are sufficient to pay for the total costs. The market will reach a new long-term equilibrium (right figure) with less peak capacity and increased hours of load curtailment.

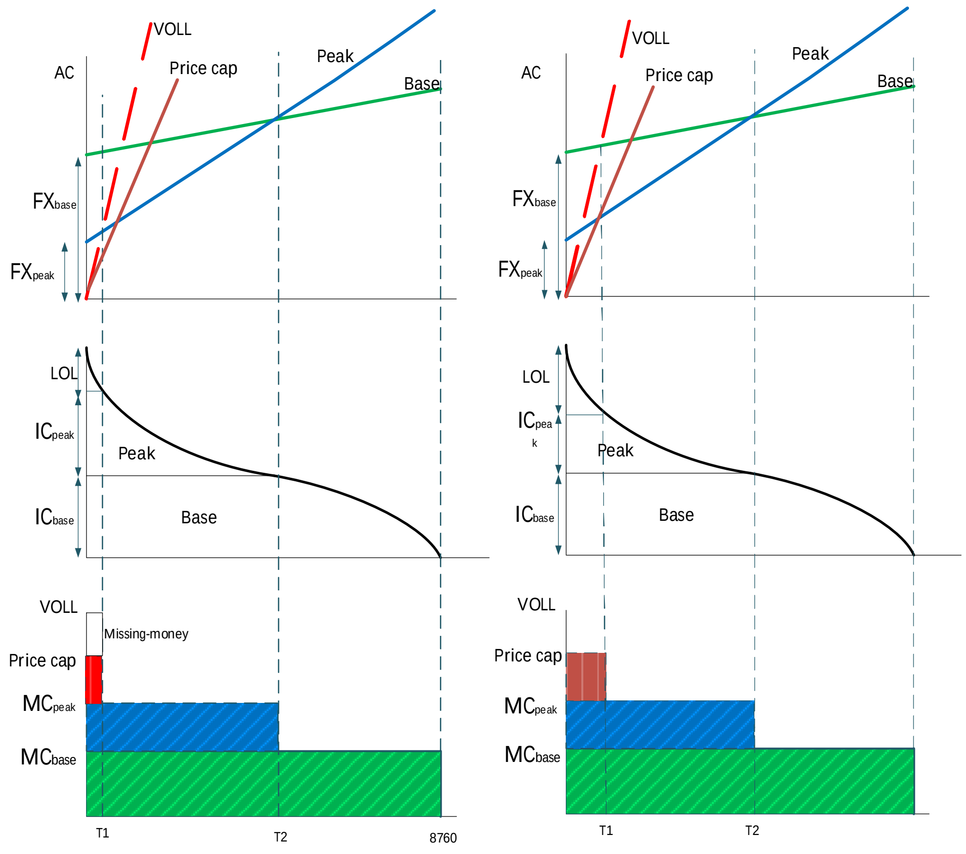

Figure 3. Short-term equilibrium (left figure) and long-term equilibrium (right figure) owing to a price cap

2.1.3. Short- and long-term impacts of RES

Since the capacity credit of wind energy is very low and unpredictable and wind has zero variable costs, the modelling of RES cannot be as that of conventional power plants. Instead, because of its stochastic nature, it must be modelled as demand itself. Thus, hourly wind production should be subtracted from the hourly demand. As a result, we obtain a residual demand curve, which the conventional technologies face. We assume that the system is in its long-term equilibrium before the RES penetration. The short-term effect (left figure) and the long-term effect (right figure) of the RES penetration is shown in Figure 4. In the short-term, penetration of renewables reduces the operating hours of peak power plants from T2 to T2´, resulting in a loss of inframarginal rents for base load power plants. Further, it reduces the hours of load curtailments T1 to T1´, consequently reducing the scarcity revenues of the base load and peak capacity. Given the missing-money problem, it will result in decreased installed capacities of base load power plants in the long term. The market will reach a new long-term equilibrium (right figure). It should be noted that considering that the RES variability is influencing the scheduling regime and increasing the need for cycling of conventional generation, the utilization effect presented with the screening curve method should be supplemented with the flexibility effect so as to incorporate a representation of the cycling operation of conventional power units and cycling costs into a long-term expansion problem (Batlle&Rodilla, 2012). However, in our analysis we neglect the flexibility effect and only focus on the utilization effect.

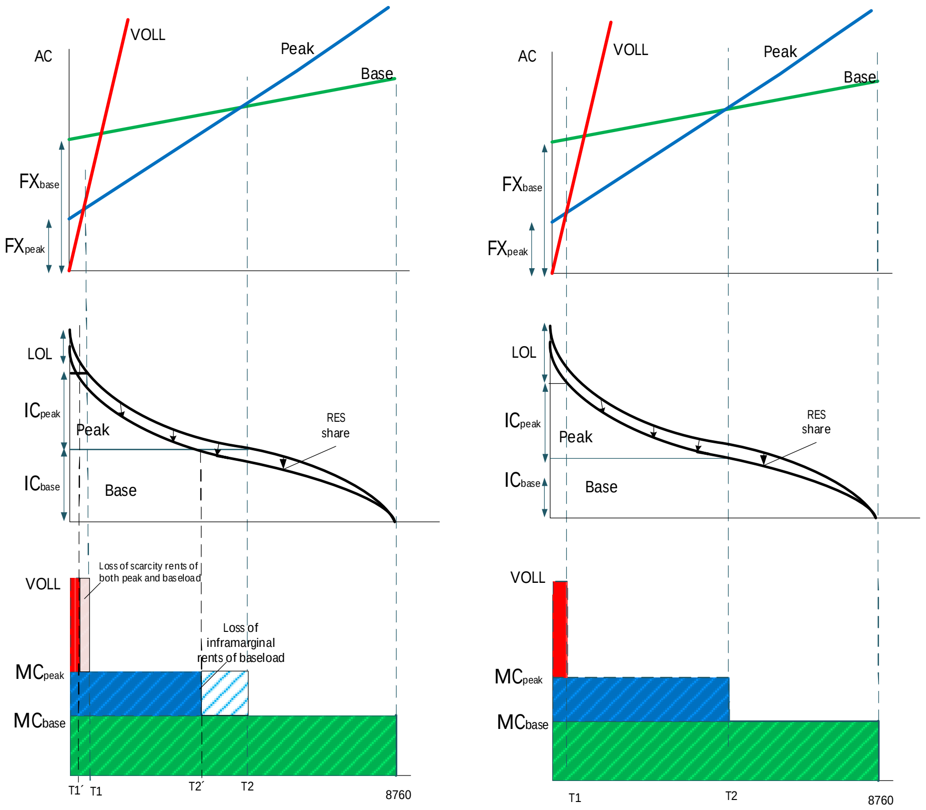

Figure 4. Short-term equilibrium (left figure) and long-term equilibrium (right figure) owing to RES

2.2. Energy-plus capacity market

Different regulatory interventions such as a price cap and penetration of RES decrease investment incentives in conventional technologies, resulting in insufficient generation to meet the peak demand. Allowing prices to rise to a reasonable VOLL seems to be unacceptable for many regulators. Thereby, many energy-only markets today operate under a price cap (3000 euro/MWh in Nord Pool, while the reasonable VOLL is 12000–20000 euro/MWh). For example, the peak capacity with annual fixed costs of 80000 euro/MW, year will need 800000/20000=4 hours of scarcity prices a year in the case of a VOLL against 800000/3000=26 hours of scarcity prices in the case of a price cap in order to be able to recover its fixed costs or decide to invest. However, how to ensure supply adequacy and, at the same time, the total cost recovery in the energy-only market? One solution is to restore the missing money through additional market elements, the capacity remunerative mechanisms (CRM). The CRM refers to a group of mechanisms designed to provide an extra capacity-based revenue stream, that is, additional revenue that does not depend on the electricity produced, but rather on the power plant availability (or installed capacity) to power producers as a complement to the energy-only market. The aim of capacity remunerative mechanism is to ensure the profitability of power plants and to guarantee or at least support investments while restoring the missing money. Providing stable revenues in the form of capacity payments, capacity mechanisms aim to increase both the short-run reliability and the long-run adequacy of power supply (Cramton and Ockenfels, 2012; De Vries, 2007; Joskow, 2008).

2.2.1. Overview of capacity remunerative mechanisms

Capacity mechanisms can be divided into two categories: price-based and quantity-based mechanisms. A price-based mechanism incentivizes investments by providing direct support for investments in the form of capacity payments. In a quantity-based mechanism, a regulator sets a desired amount of installed capacity, and the price evolves from the market clearing.

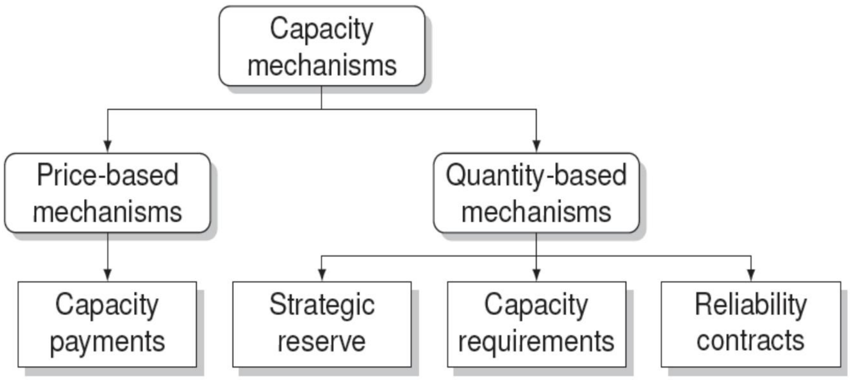

Figure 5. Capacity remunerative mechanisms

Capacity payments. Capacity payments are direct payments to generators according to the installed or available capacity, producing a stable revenue to generators regardless of the generated electricity. Capacity payments are estimated by the regulator and may vary with the technology, thus favoring one technology over another. This type of a capacity mechanism is easy to implement in order to incentivize new investments. Typically, the level of capacity payments depends on the assumption on future demand and investment response to the payments, which may be difficult to predict. Therefore, there is a high risk of a regulatory failure related to under- or overprocurement of the capacity, resulting in a higher total cost for capacity or opposite, or unwanted power interruptions as a result of generation inadequacy. This can be considered one of the drawbacks of capacity payments.

Strategic reserve. The goal of the strategic reserve is to ensure that a certain amount of reserve capacity is available in addition to the ancillary service capacities contracted by the TSOs to ensure security of supply. The main part of the market remains energy only, while in addition, a strategic reserve is established to remain available to be used in the day-ahead market in scarcity situations. The required volume of strategic reserve is determined and tendered by a central authority, which is typically the transmission system operator (TSO) or the energy market regulator. The TSO does not own the strategic reserve, but rather contracts power plants to provide availability when needed. The total cost for maintaining strategic reserve is collected through grid charges or balancing market charges. Generators selected for strategic reserve are withheld from the spot market, and the strategic reserve is activated only in scarcity situations. The crucial issue is the price at which the market is cleared whenever the strategic reserve is activated, because this price will affect both the short-term profitability and the long-term investment incentives in the market capacity. Strategic reserves are introduced in Sweden and Finland. However, the reserve is rather small and activated only a few hours per year at the most.

Reliability options. Reliability options are a quantity-based capacity remunerative mechanism. The optimal (target) level of capacity is provided by an auction process. Unlike a strategic reserve, however, the auction is not physical but only financial by means of call options. The TSO purchases call options (reliability contracts) from generators on behalf of consumers. The volume of reliability options subject to procurement is defined as a forecasted peak demand plus the reserve margin. Generators submit their capacity bids to the auction, stating the volume of capacity they want to sell and the price. The auction is cleared and all accepted generators receive the price of the last accepted bid in the case of the uniform auction, or each generator receives the price of its bid in the case of the pay as bid auction. All generators accepted at the auction are obliged to guarantee their availability; non-availability is penalized when the option is called. In addition, the TSO or the regulator sets the strike price on the energy market slightly higher than the marginal cost of the most expensive unit in the system in order not to discourage other generators in the system from producing. Whenever the price in the energy market becomes higher than the strike price, the generators that have been accepted in the capacity auction must pay the difference between the actual price and the strike price for each MW sold in the capacity auctions to the TSO and indirectly to the consumers. Generators' loss of peak revenues above the strike price is now compensated by a more stable and predictable premium received by selling reliability options. Both producers and consumers are hedged against price spikes, though in the opposite direction (Bidwell, 2005; de Vries, 2007; Vázquez et al., 2002; Vázquez et al., 2003).

Capacity obligations. Capacity obligations are a decentralized scheme, where the obligations to contract a certain level of capacity required to cover the peak demand are imposed on consumers. Consumers can fulfill the obligation through own capacity or bilateral contracts with capacity providers at the price agreed between the parties; thus, the price for capacity is set in a decentralized manner. Contracted generators are required to make the contracted capacity available to the market in scarcity situations, otherwise they can be penalized. By imposing a reserve requirement on each load serving entity, this mechanism provides a direct incentive to increase demand response. The main disadvantage of this design is that it does not provide backup capacity procurement by the system operator required to ensure system reliability in the case of noncompliance of obligations of the load-serving entities. Thus, an additional explicit capacity procurement mechanism in the form of a centralized capacity auction could be established to procure backup capacity by a system operator to maintain reliability (The Brattle Group, 2009).

Forward capacity market. The purpose of a forward capacity market is the procurement of enough capacity to meet a certain reliability level. A central body decides upon and buys the level of capacity based on its own demand forecasts and data about the state of the power system. Capacity suppliers offer their capacity to the centrally organized capacity auction. The auction is cleared at the price paid to both new and existing capacities. The main disadvantage of a capacity auction compared with capacity obligations is the risk of overprocurement of capacity in the case of demand overestimation. Centralized capacity markets are implemented in the US, by PJM and ISO-NE, and in Colombia (The Brattle Group, 2009).

2.2.2. Short- and long-term impacts of capacity markets

The short- and the long-term impacts of the capacity markets are introduced in Figure 6. Let us assume that generators, in addition to the income from producing and selling electricity to the energy market, receive an additional capacity-based revenue, equal to the capacity price multiplied by the installed or available capacity. The capacity price can be determined by the regulator in the case of a price-based capacity mechanism or defined by the result of a capacity auction. Let us assume that the capacity price Cp (€/MW,year) equals the annual fixed costs of the peak technology, and the same price is given to the base load and peak capacities in the market. Provision of capacity-based remuneration to generators will reduce the annual revenue required (ARR) from operating in the energy market on the value of the capacity price, because part of the annual fixed costs of both the base load and peak generators is covered with capacity payments. The screening curves of both the peak and load capacities will decrease at the value of Cp (left figure). In the long run (right figure), provision of capacity payments to generators will induce more investments in peak capacity, sufficient to cover the peak demand and eliminate scarcity situations. The market will reach a new long-term equilibrium, where the peak capacity covers its total annual fixed costs with a capacity payment, and therefore, there is no need for scarcity rents, and the base load capacity covers one part of its annual fixed costs with a capacity payment and the other part with inframarginal rents.

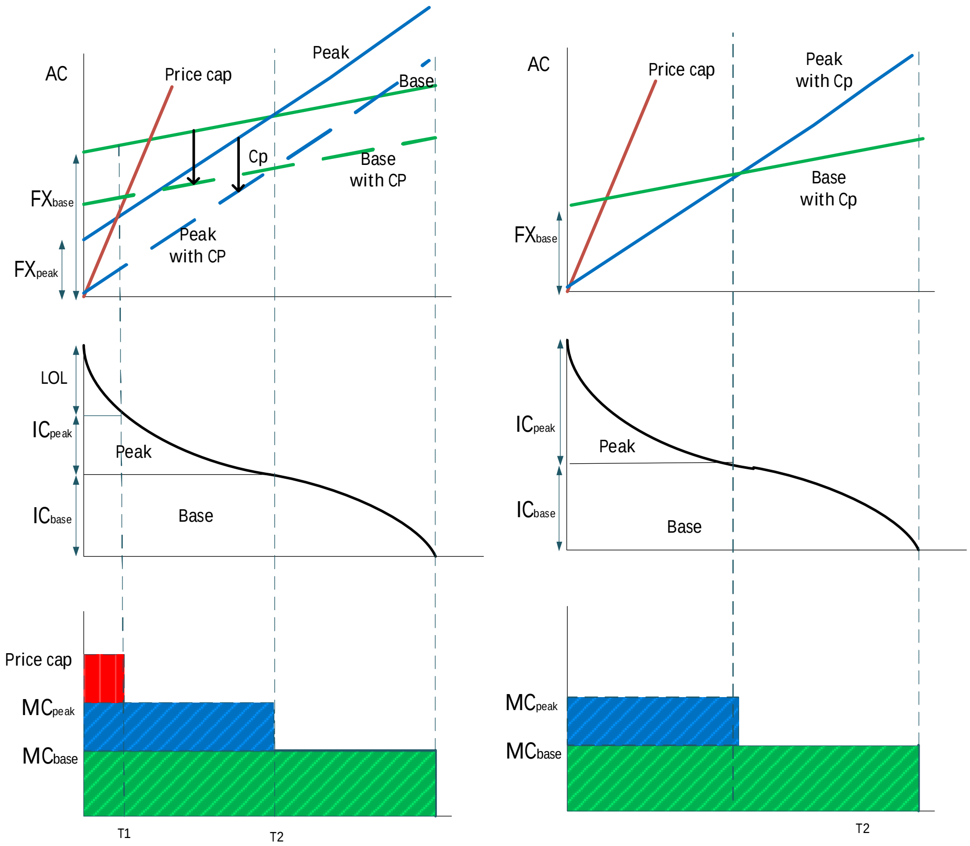

Figure 6. Short-term equilibrium (left figure) and long-term equilibrium (right figure) owing to capacity markets

2.2.3. Short- and long-term impacts of strategic reserve

Defining the proper size of the strategic reserve and the dispatch price are crucial elements in the design of a strategic reserve. We assume that the optimal volume of the strategic reserve (SR) is defined as the peak demand minus the market capacity ($SR = D_{peak} - IC_{base} - IC_{peak}$). This means that whenever the market capacity decreases, the volume of the strategic should be adjusted (the TSO should contract more generators in the SR) in order to ensure that the peak demand is always met. The key issue is the price at which the market is cleared when the reserve is activated, in other words, the dispatch price. In theory, the strategic reserve should be dispatched only at a price equal to the value of lost load in order not to distort peak prices during shortages and thereby investment incentives (Brunekreeft et al., 2011). If the strategic reserve is dispatched at a price below the average value of lost load, it will eliminate scarcity pricing in the spot market and thus result in reduced income and investment incentives for generation participating in the spot market, which in turn should be compensated for by a larger volume of strategic reserve. Figure 7 presents the long-term impacts of the strategic reserve in the case when the dispatch price equals the VOLL and in the case when the dispatch price is below the VOLL (right figure). Setting a dispatch price at the VOLL will not affect investment decisions in market capacities, and thus, the long-term market equilibrium (left figure). The only difference is that in scarcity situations, that is, when the market capacity is not sufficient to meet the peak demand, the TSO will activate the strategic reserve to meet the demand rather than curtail the demand. However, setting the dispatch price below the VOLL (right figure), in the short term, reduces scarcity revenues for both the base load and peak capacities. In the long term, it will lead to a decreased peak capacity, which should be compensated for by an increased volume of the strategic reserve. The lower the dispatch price, the more investments will be suppressed and the larger the reserve needs to be (Brunekreeft et al., 2011).

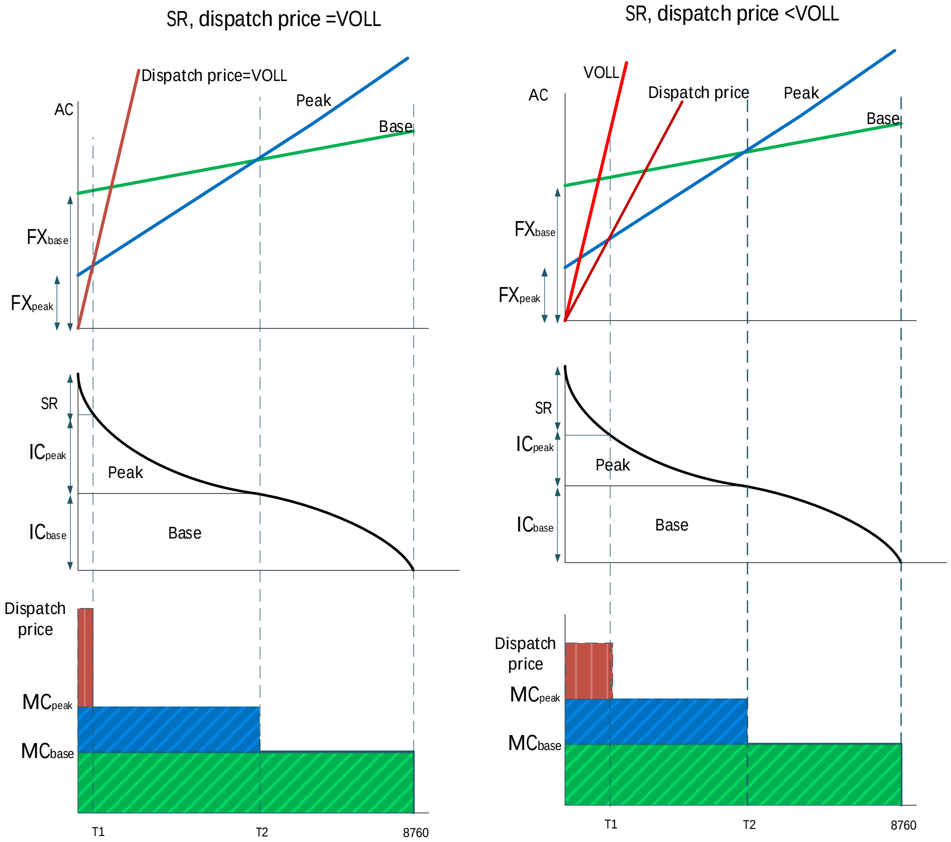

Figure 7. Short-term equilibrium (left figure) and long-term equilibrium (right figure) owing to a strategic reserve

2.4. Rationale for CRMs in the EU member states

In order to ensure the short-run reliability and long-run adequacy of power supply, member states in Europe are considering implementation of different types of CRMs, where capacity mechanism that under consideration in Europe are illustrated in Figure 8. Many questions on proper capacity market design remain unsolved since the current missing-money problem in Europe is not simply based on the classical price-cap argument. The recent decline in the generators' profitability is mainly due to excess power generation caused by the growth in the RES capacity, which, because of their intermittency, still needs conventional backup capacity. The current discussion on capacity markets addresses the issue of how to ensure that there is enough capacity to back up the growing share of RES in the long term.

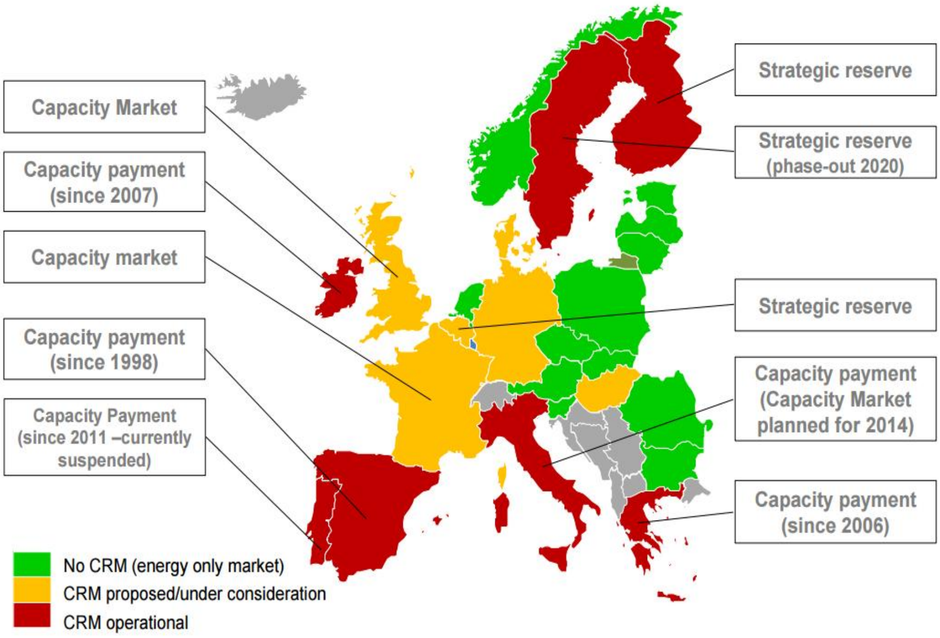

Figure 8. Capacity markets in Europe (ACER, 2013)

The missing-money problem resulting from the rapid penetration of renewable generation raised a discussion on the introduction of the strategic reserve in Germany. Generators fail to recover their fixed costs as a result of a reduced number of operating hours, suppression of real scarcity prices because of oversupply, and scarcity price capping when the market is tight. As a result, even the most modern gas-fired power plants do not operate on a profitable basis. In Germany, at least one CCGT decommissioning is announced but not yet approved by the regulator. Even though the decision on the implementation of the strategic reserve is not yet approved in Germany, the German Association of Energy and Water Industries has issued a conceptual Framework for Implementing a Strategic Reserve in Germany (BDEW, 2013). Again, the introduction of a capacity mechanism in France is motivated by the concern over the future security of supply because of the continuously growing peak demand together with uncertainties regarding the profitability of investments in generation technologies. The current low electricity prices, as a result of the growing share of RES, discourage investments, and moreover, make the operation of the existing gas-fired power plants unprofitable and increase the risk that the total available power will not be sufficient to meet the demand in the future (RTE, 2013). The French government decided to implement a capacity mechanism that would stress the responsibility of electricity suppliers for capacity adequacy. A capacity remuneration mechanism based on capacity obligations is under consideration. Each supplier evaluates its own capacity needs based on the forecast consumption. In order to meet the obligation, the supplier has to contract either its own generation or to sign up a bilateral agreement on the purchase of capacity credits with capacity providers. This mechanism aims at developing the demand response, because suppliers can also sell certificates on the market by contracting their customers on the amount of energy the customers are ready to reduce during hours of peak demand.

The UK government considers the security of supply, as about a fifth of the existing capacity is expected to close over the next decade, and more intermittent (wind and solar) and less flexible nuclear power will be built, which has forced to take actions over the implementation of a capacity mechanism in the UK (UKERG, 2010). The UK government has made a decision to implement the capacity auction capacity mechanism. The peak demand will be forecasted by the TSO Ofgem. The total amount of capacity needed to ensure the security of supply will equal the forecasted peak demand plus a reserve margin. The capacity providers will participate in the auction (demand-side resources such as energy storages can also participate). The capacity selected by the result of the auction will enter the capacity agreement and will receive predictable revenues during the period specified in the capacity agreement (ten-year contracts to support new investments and one-year contracts for existing generators). In return, the capacity providers are obliged to ensure the availability of their committed capacity; otherwise, the non-presence of availability is subject to penalties. The costs of capacity will be shared between electricity suppliers in proportion to their peak demand. The capacity that is under the RES support schemes will not be eligible to participate in the capacity market; however, it will be taken into account in calculating the targeted capacity level. The interconnection capacity is also excluded from participation in the UK Capacity market (CREG, 2012).

In order to subsidize fossil-fuelled back-up generation to make sure that there are enough fossil-fuelled plants online to back up the growing renewable generation, Italy will adopt a capacity mechanism according to reliability options based on a pay-as-bid auction, open to new and existing capacity. The quantity of capacity to be made available will be determined by the Italian TSO Terna based on the expected consumption and reserve requirements. The capacity suppliers receive an annual fee in €/MW,year and are obliged to present their availability (CREG, 2012).

2.5. Capacity markets and internal market for electricity

An internal market for electricity is a key part of the EU 2020 strategy (European Commission, 2010). Efficient cross-border trade facilitates the efficient use of resources and an increase in the social welfare. The sharing of resources enables consumers in high-cost regions to have access to low-cost electricity generation in other regions, resulting in a more efficient use of resources and increasing the probability that the demand is met by the least-cost production. Moreover, opening the national markets to foreign participants would enhance market competition and strengthen the security of supply (Creti, 2010; Jasamb and Pollit, 2005; Booz&Co, 2013; Pellini, 2012). However, in order to facilitate the efficient cross-border trade, cross-border capacity allocation methods should be market based rather than discriminatory, meaning that the interconnector capacity is allocated by means of auctions rather than on a discretionary basis. In Europe, explicit and implicit auctions are used to allocate the interconnection capacity. In explicit auctions, the available transfer capacity of the interconnector is sold separately for each direction to market participants by a uniform-pricing auction of transmission capacity on a yearly, monthly, or daily basis. After obtaining transmission capacity rights, traders are allowed to trade energy through the interconnector. However, as a result of trading costs resulting from separate markets for transmission and energy together with the asymmetry of information on electricity prices in the trading markets, explicit auctions produce such inefficiencies as misusage (commercial flow against price differential) or underusage of transmission capacity (flows lower than the available capacity when there is a price difference) (Newbery and Mc Daniel, 2002, Kristiansen, 2007, Bunn and Zachmann, 2010). In implicit auctions (or market coupling) there are no separate auctions for transmission capacity, and the flows on the interconnectors are determined by the clearing of the energy markets. Implicit auctions ensure that the use of cross-border capacity is welfare maximized. Efficiency gains of introduction of market coupling are examined in detail in (Creti et al., 2010; Hobbs et al., 2005, Pellini, 2012). Market coupling is the target model for the cross-border capacity allocation in the EU member states.

Numerous EU member states are currently considering moving from energy-only markets toward capacity-based markets (CREG, 2012). However, as soon as many European markets are highly interconnected, uncoordinated CRMs may create negative cross-border effects and hinder the achievement of the Internal Electricity Market in Europe. There is a certain concern that market design changes at the level of EU member countries might conflict with the European target of a single market. As soon as many European markets are highly interconnected, uncoordinated CRMs might create negative cross-border effects and hinder the achievement of the Internal Electricity Market in Europe (ACER, 2013). However, the degree to which individual CRMs could impact the cross-border trade depends on the degree of interconnectivity between markets, the correlation of prices and scarcity situations between the markets, and coordination on the possible cross-border impacts with the neighbouring market (ACER, 2013; Meyer et al., 2014; Sweco, 2014; Thema, 2013). There are a few real-life examples of the interaction of energy-only and CRM markets: PJM and the Midwest ISO control areas in the US, Ireland and Great Britain, Russia, and the Nordic market. Inefficient cross-border trade has been observed in all the above cases because of the CRM (Gore at al., 2014; Lawlor, 2012; McInerney and Bunn, 2013; Viljainen et al., 2013). Experiences in these markets demonstrate how challenging the integration of electricity markets with different market designs can be.

3. Research design

3.1. Research questions and objectives

The pros and cons of capacity mechanisms have been analysed in detail at national levels, but the issues of cross-border effects within a European market that is heading towards stronger integration have yet received little attention. The doctoral dissertation aims to fill this research gap. The research question of this dissertation is "What are the cross-border effects of the unilateral implementation of capacity remunerative mechanisms (CRMs)?"

The research is divided into four more detailed research questions, which are answered in Publications I–V:

1) What distortions may market and regulatory failures in CRMs design create?
2) What are the cross-border effects of unilateral implementation of CRMs?
3) What are the threats of CRMs to the achievement of the benefits of market integration?
4) How can cross-border capacity participate in national CRMs?

The research design, illustrating how the research questions are answered in the publications, is presented in Figure 9.

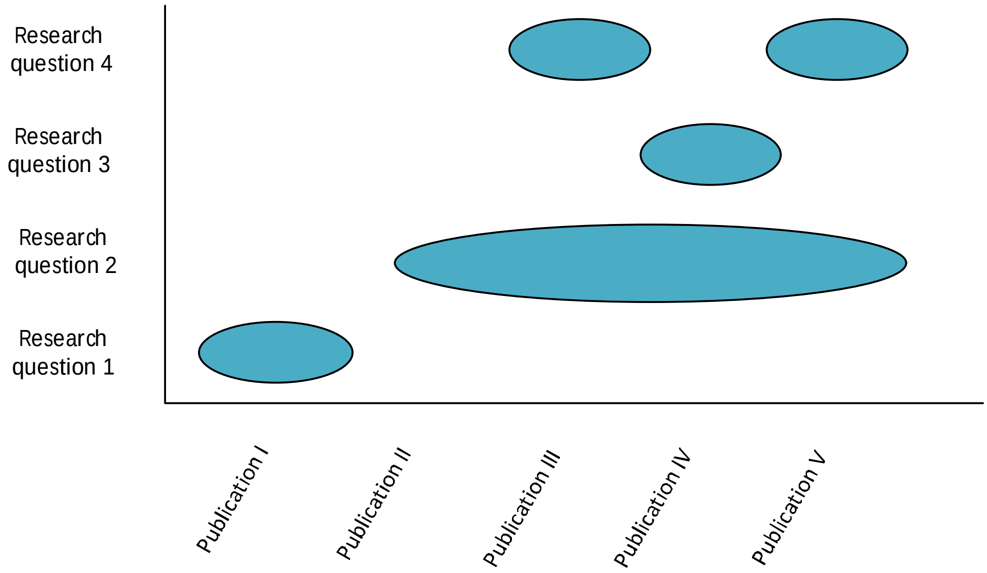

Figure 9. Research design

3.2. Research approach

The growing interest in a liberalized electricity market has enhanced the development of different methodologies and modelling approaches for electricity market research. Electricity market models can be divided into optimization, equilibrium, and simulations models according to Figure 10.

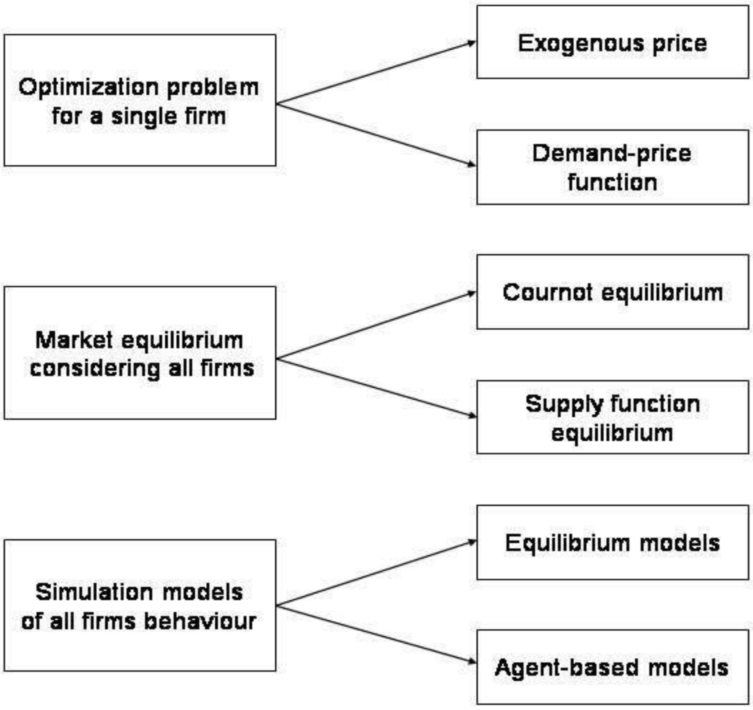

Figure 10. Research approaches to the electricity market modelling (reproduced from Ventosa et al. 2005).

Optimization models maximize or minimize a specific objective function, that is, the profit function of a single firm subject to technical or economic constraints or total welfare maximization or cost minimization under the given supply and demand functions, assuming perfect or imperfect competition. Under assumed prefect competition, the market price is an exogenous variable, while under assumed imperfect competition the market price is an endogenous variable, and the market player can influence the market prices. Equilibrium models are able to address different players' market behaviours and several market participants' profit maximization simultaneously; for optimization models, instead, this is possible only to a limited extent. Simulation models are regarded increasingly as an alternative to equilibrium models when the problem under consideration is too complex (for example, too nonlinear or dynamic) to be addressed within a traditional equilibrium framework. Simulation models, such as agent-based models or system dynamics focus on accessing systems away of equilibrium and, opposite to static equilibrium approaches, are able to model the market dynamics. Approaches used in the publications are illustrated in Figure 11.

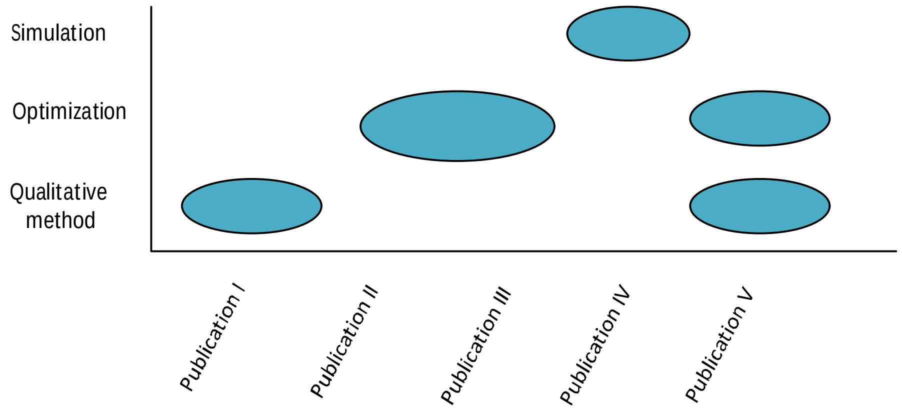

Figure 11. Research methods

3.3. Research data

The research data used in publications to calibrate the supply and load duration curves of the Finnish and the Russian electricity markets were collected from different official sources. The data used in the dissertation are presented in Table 1.

Table 1. Data and sources used in the dissertation

Data	Source
Finland:	
Electricity Supply by source	Finnish Energy Industry
CAPEX, OPEX of power technologies	IEA, 2010
Hydro reservoirs	Nord Pool Spot
Wind load profiles	Data provided by VTT consulting
Hourly electricity consumption	Nord Pool Spot
Fuel prices	Statistics Finland
Russia:	
Electricity Supply by source	System Operator
CAPEX, OPEX of power technologies	IEA, 2010
Hydro reservoirs	RusHydro
Hourly electricity consumption	ATS
Fuel prices	Gazprom, Suek

4. Summary and the results of the publications

An overview of the publications is presented in Table 4. It summarizes the objectives and findings of the papers included in this doctoral dissertation.

Table 4. Summary of the papers.

Title	***Objective***	***Findings***
Russian electricity market: deregulation or re-regulation?	Identify possible market and regulatory failures in the design of CRM and evaluate their impact on the competitive landscape and efficiency of the Russian electricity market.	Regulatory failures in the market design, such as price cap policy and favouring investments of existing players in the market create barriers and close the market from new entries, making the market less liquid and threatening its competitive landscape.
Profit optimization of the cross-border trade between Finland and Russia	Identify the cross-border effects of CRMs in case of explicit access to the interconnection capacity, i.e. assuming the right to use the transmission capacity is assigned to a cross-border trader and the trader operates between energy-only and energy-plus capacity markets.	The findings suggest that the CRMs together with an explicit access to the transmission capacity can notably reduce the cross-border electricity trade and lead to inefficient use of the transmission capacity, and, thus, reduce the total welfare benefits of market integration.
Challenges of cross-border trade between two markets with different designs	Evaluate the short-term cross-border impacts and distributional effects of capacity markets of interconnected energy-only and energy-plus capacity markets operated under different cross-border allocation schemes.	The findings suggest that having energy-only market on one side and a capacity-based market on the other side of the border may impede cross-border trade and result in underusage or misusage of the transmission capacity in the case of explicit cross-border access to the transmission capacity. Implicit access (market coupling), in principle, would increase the efficiency of the cross-border trade but it could result in distributional effects, i.e. involving a free-riding effect.
"Finnish power market: Are imports from Russian really low cost?"	Examine the factors affecting the benefits of market integration and threats of CRMs to the achievement of the maximum benefits of integration	The results show that the benefits of market integration depend on cross-border capacity allocation principles, capacity expansion policies and security of supply measures. CRM policies might reduce the benefits of market integration.
Cross-Border Effects of Capacity Mechanisms: Do Uncoordinated Market Design Changes Harm the Internal European Market for Electricity	Analyses cross-border effects of a strategic reserve (SR) and reliability options (RO) based on a two-country simulation model.	Cross-border effects are most likely negative for consumers and producers in total in the case of a unilateral implementation of a CRM, and market design changes should be coordinated

4.1. Publication I Russian electricity market reform: deregulation or re-regulation?

Publication I analyses the competitive landscape of the Russian electricity market by assessing the ownership structure of electricity generation, price drivers, and the government involvement in the electricity wholesale market in Russia. In particular, it analyses the impact of regulatory and market failures in the capacity mechanism on the competitive landscape and the efficiency of the market. Russia has been reforming its electricity supply sector for ten years. The reform is perhaps the most ambitious reform in the world because of the enormous size of the market, both geographically and in terms of electricity consumption. The reform has meant vertical and horizontal unbundling of RAO UES (state-owned monopoly company), privatization of generation assets (excluding nuclear and hydro power) and opening of the electricity generation sector to competition. To date, the main goals should have been achieved: an investment-friendly business environment, competition in electricity generation and a reduced role for the government in the electricity supply sector with prices expected to be driven by competition. In a competitive electricity market, there should be a market-based merit order for generators, easy market entrance and exit, and a sufficient number of actors in the market. One reform goal, achievement of investment, conflicts with the other two goals: a reduction in the government participation and attainment of a fully competitive market. When extensive investments are needed immediately, it may not be possible to wait for market-based investment incentives. Instead, investments have to be enforced, for instance, through regulatory actions. The government has adopted a strong role in promoting new investments in the electricity generation sector by signing contracts with generators and guaranteeing returns on generation investments for 10–20 years ahead. These agreements, to some extent, close the market from new entrants (Gore et al., 2012). This conflicts with the idea of free competition, which assumes easy market entrance with equal conditions for all market actors. Thus, the regulatory failures in the market design such as a price cap policy and guaranteed capacity payments giving investment advantages to already operating generating companies in the market close the market from new entries and make the market less liquid.

4.2. Publication II Profit optimization of the cross-border trade between the Nordic and Russian electricity markets

Publication II evaluates the impact of the CRM on cross-border electricity trade, while presenting the methodology to estimate the optimal cross-border flow in the case of explicit access to the transmission capacity, that is, whether the right to use the transmission capacity is assigned to a cross-border trader (or multiple traders). The cross-border trader operates in two markets with different market designs; the import market A is the energy-only market (Nordic market), and the export market B is the energy-plus capacity market (Russian market). The cross-border trader buys electricity in the energy-plus capacity market, and sells it in the energy-only market. In both day-ahead markets, electricity is traded on an hourly basis. During predefined peak hours, the cross-border trader also faces a capacity charge in the energy-plus capacity market. The cross-border trader’s capacity charge is the maximum export in any of the peak hours of the day multiplied by the capacity price. The cross-border trader’s profit strongly depends on the day-ahead price difference and the capacity costs. At the current capacity price levels, the capacity costs constitute a large part of the cross-border trader’s total expenditure if it chooses to export during the peak hours. The value of the energy-only price spread should be greater than the value of the capacity payment to incentivize export. The objective of the cross-border trader is to find the optimal volumes that it should export to the import market A in peak hours in order to maximize its hourly profits. Our findings suggest that under the explicit access to the use of the transmission capacity, capacity market may impede cross-border trade and result in inefficient use of the interconnector capacity. This hinders the efficient sharing of resources, which is the rationale for the interaction or integration of the markets in the first place. Opening the cross-border trade to multiple players (introduction of explicit auction) would reduce the single player’s ability to acquire monopoly rents. However, it would not eliminate the problem of limited cross-border trade because the incentives to reduce exports during peak hours to avoid high capacity costs would remain. This phenomena is also observed in the cross-border trade between the Irish energy-plus capacity market and the British energy-only market, where the treatment of the capacity payment created an effective deadband where the energy-only price spread has to be greater than the value of the capacity payment to incentivize export (Mclnerney and Bunn, 2013).

4.3. Publication III Challenges of cross-border trade between two markets with different designs

Publication III presents an analytical model of two interconnected markets A and B and the cross-border trade between them in order to evaluate the short-term cross-border impacts and distributional effects of capacity markets under different cross-border allocation principles (explicit and implicit auctions). Both markets are presented by their supply curve and load duration curves, which were calibrated using the data on average electricity production, marginal costs of particular technologies, and hourly demand statistics. Explicit access to the transmission capacity is represented by the profit maximization function of a single trader with the given supply and demand functions. Implicit access to the transmission capacity (or market coupling) is represented by the total welfare maximization function under the given supply and demand functions subject to technical constraints. By repeatedly solving the profit maximization and market coupling optimization for the full range of demand levels, we obtained the results for cross-border trade, volume of cleared generation, market clearing electricity prices, and welfare indicators (consumer and producer surpluses) for different cross-border allocation principles. The resulting values for production, trade, prices, and surpluses are summed up, weighted by the respective number of hours per demand level given by load duration.

The results show that under explicit access to the transmission capacity, CRM creates barriers to cross-border trade, resulting in considerable underusage of transmission capacity. Even though the electricity price spread justifies cross-border trade, capacity market prevents it, creating deadbands or price intervals when it is not rational to transmit electricity between two markets. Inefficient use of transmission capacity produces considerable welfare losses among market participants. Providing the opportunity for cross-border traders to receive capacity payments in the case of importing to energy-plus capacity market poses a problem of inverse cross-border flows (flow a high- to low-price area), which can be considered an inefficiency of the cross-border trade and have a negative welfare impact on the market participants in both markets. It is assumed that the foreign capacity can receive capacity payments only if it ensures the full availability, which can be provided through reservation of transmission capacity.

Under the market coupling defined on the basis of the price difference in the day-ahead markets, the capacity payments would not create a barrier to trade. The result is more efficient utilization of the interconnector and an increase in the total welfare compared with the explicit access to the transmission capacity. However, problematic distributional effects could arise if consumers in the energy-only market were considered to benefit at the expense of the consumers in the capacity-based market. For example, the capacity markets typically tend to reduce electricity prices by replacing the sole energy-based remuneration of generators with two-part payments consisting of an energy-based payment and a capacity-based payment. In such a case, the consumers in the neighbouring energy-only market would benefit from the lower day-ahead electricity price without having to take part in "subsidizing" the generators in the capacity-based market. The difficulty is to "marry" a capacity market to cross-border trading, since the cost of exporting capacity cannot be directly passed on to the importing consumers in a system of market coupling that is based on electricity prices only. Furthermore, there is no straightforward way to identify the exporting capacity under implicit auctioning. Attempts to allocate part of the capacity costs to the consumers in the neighbouring energy-only market are likely to give rise to new questions about the distributional effects: "Why should the consumers in the energy-only market subsidize firm capacity in the neighbouring country?"

4.4. Publication IV The Finnish power market: Are imports from Russia low cost?

Publication V models the long-term dynamics of the Finnish- Russian cross-border electricity trade using a simulation model developed by Ochoa and van Ackere (2014) in order to understand the potential benefits and risks of integration. We analysed the impact on the long-term evolution of the Finnish electricity market of different policies regarding cross-border trade (single trader who does not trade during peak hours in order to avoid capacity payments, a trader who does trade during peak hours and market coupling), and different regulatory measures for generation capacity expansion in Finland such as strategic reserves, a carbon tax, a feed-in premium, and a feed-in tariff. The analysis shows that potential benefits of integration strongly depend on the cross-border allocation mechanism and degree of reliance on the neighboring markets. The discriminatory access to the interconnector (trader) reduces the Finnish consumers' benefit of having Russian imports at peak hours, because imports do not necessarily ensure low prices and threaten the security of supply. The reason is that during some periods (especially in tight supply situations), the trader has an incentive to reduce imports, consequently raising electricity prices in the importing market. By underusing the link, the trader captures consumer benefits. Moreover, because of the unreliable nature of imports in the trader case, keeping a strategic reserve seems to be a reasonable policy that would prevent power shortages and the associated consumers' losses. However, consumers must pay to maintain strategic reserves, which raises even more doubts about the benefits of Russian imports during peak hours. The introduction of market coupling would reduce supply costs. Nevertheless, the reliability concern would not be eliminated by replacing the current cross-border trade with market coupling, since the country would be still vulnerable to the dynamics and decisions of its neighbour. Changes in the demand-supply situation or policies in any of the interconnected countries may influence the availability of imports and threaten the security of supply. This requires strong confidence in the neighbouring countries. At the same time, Finnish policies to avoid dependency on Russian imports such as keeping a strategic reserve may reduce the benefits of market coupling. The study draws general lessons for Europe and supports the argument that in order to achieve the maximum benefits of market integration, cross-border allocation principles should be market based, and strong coordination of market changes and confidence in the neighbouring markets are required.

4.5. Publication V Cross-Border Effects of Capacity Mechanisms: Do Uncoordinated Market Design Policies Countervail the Goals of European Market Integration?

Publication V analyses the cross-border effects of a strategic reserve (SR) and reliability options (RO) based on a two-country simulation model. The model simulates two interconnected markets, both of which suffer from a missing-money problem and consider the implementation of a capacity remunerative mechanism (CRM), and measures the effects if one or both countries change their market design in favour of a CRM. We look at the problem from a game-theoretic perspective: policy makers in both countries act as strategic players aiming to maximize their own market's welfare. The resulting market outcomes are analysed in terms of producer and consumer surplus, trade, and electricity prices. The two CRMs analysed are a strategic reserve (SR) and reliability options (RO) as described in the previous section. The analyses show that that a unilateral implementation of CRMs has negative cross-border effects. A strategic reserve

(SR) may have negative cross-border effects, if it replaces imports from the neighbouring country. This may happen in the case of a price-based dispatch, that is, if the activation of the reserve is triggered by the day-ahead price. If this trigger price is lower than the maximum export price of the neighbouring market, an SR leads to a crowding out of imports. This crowding out of imports can be avoided by either setting a higher dispatch price or switching to a quantity-based dispatch of reserves. In this case, no cross-border effects would appear. An unilateral implementation of reliability options has negative cross-border effects. This is due to the fact that the missing-money problem is further aggravated in the passive market, which in turn will put further pressure on this country to also adjust its own market design. Hence, market design changes should be made simultaneously to avoid temporary negative effects of unilateral market design policies.

5. Discussion and conclusions

In this doctoral dissertation, both theoretical and case study analyses are presented in order to analyse the cross-border effects of unilateral implementation of capacity remunerative mechanisms. The research questions are answered as follows:

What distortions may market and regulatory failures in CRMs design create?

Moving toward the introduction of capacity markets, European policy makers should bear in mind that CRMs are yet another form of regulation. Proper design and functioning of capacity markets is a key element to achieve efficiency gains in delivering appropriate prices and security of supply. Therefore, trying to correct market imperfection by increasing regulation may bring new regulatory failures rather than solutions. Thereby, when designing capacity markets in Europe, it would be a question of which of the market failures or possible regulatory failures in the CRM design generate the largest distortions. The decision on an adequate market design should consider potential problems of regulatory failures that might lead to further market distortions. This is related to the estimation of the missing-money problem, a competitive auction design, and liquidity in the capacity and energy markets. The Russian capacity market experiences teach some lessons, where the huge investment need in the development of the generation capacity led to the strong government involvement, and some regulatory failures in the design of the capacity market had a negative impact on the competitive landscape of the market. One of the market failures is poor competition in capacity markets resulting from high barriers for new capacity to enter or the exercise of market power by existing capacities with dominant position. If capacity auctions are valid for a number of years, the market may prevent new entrants and become much less liquid, increasing the possibilities to exercise market power by existing generators. Regulatory failures may include regulatory interventions in the form of price caps designed to reduce the potential of existing generators to exploit market power, which may also create barriers to entry and threat competition. Finally, we note that the risk of regulatory failures includes a possible under- or overprocurement of capacity, for instance, by under- or overestimating the missing-money problem. This, again, would result in a higher total cost for capacity or unwanted power interruptions as a result of generation inadequacy. The risk of regulatory failures seems to be larger in the case of full capacity markets (forward capacity markets, reliability options) compared with the case that only involves small adjustments to the market design.

What are the cross-border effects of unilateral implementation of CRMs?

In this doctoral dissertation, both theoretical and case study analyses are presented in order to analyse the cross-border effects of unilateral implementation of capacity remunerative mechanisms. Capacity mechanisms can affect both the short-term pricing and long-term investments. In the short term, CRMs may lead to cross-border effects if the regulation directly affects the bidding behaviour or market pricing in the energy market. Moreover, in the long run, CRMs may have impacts on investment decisions and thereby affect the long-term generation mix, electricity prices, and electricity trade between markets. The main findings are that unilateral implementation of CRMs may have several cross-border effects, depending on the treatment of CRMs in the cross-border trade and the cross-border transmission capacity allocation principles under which interconnectors operate. CRMs can have multiple cross-border effects:

- *Inefficient use of the interconnectors.* A capacity market may create negative cross-border effects and result in an inefficient use of the interconnector capacity, including underusage or misusage of the transmission capacity. This issue may be relevant to many European markets considering implementation of CRMs and operating under explicit auctions. Under the explicit access to the use of the transmission capacity, the prospects for cross-border trading can be undermined by the treatment of the capacity payments imposed on cross-border traders, resulting in considerable underusage or misusage of the transmission capacity. For example, the CRM that is under consideration in France may bring cross-border trade distortions to interconnectors with Germany or Italy. It may also question the prudence of the extensive transmission network development plans in Europe – why build new interconnectors if the prospects for using them are not very promising? Short-term inefficiencies in cross-border trade can be eliminated by changing the cross-border allocation principle over to market coupling, but problematic distributional effects might arise such as a free-riding effect.
- *Free-riding effect.* In the case of positive externalities, the introduction of capacity markets involves a free-riding effect. Consumers in the country with a capacity market may pay for an increase in generation capacity that partly leaks to the neighbouring market. The capacity markets typically tend to reduce electricity prices by replacing the sole energy-based remuneration of generators with two-part

payments consisting of an energy-based payment and a capacity-based payment. In such a case, the consumers in the neighboring energy-only market would benefit from the lower day-ahead electricity price without having to take part in "subsidizing" the generators in the capacity-based market. Attempts to allocate part of the capacity costs to the consumers in the neighbouring energy-only market are likely to give rise to new questions about the distributional effects: "Why should the consumers in the energy-only market subsidize firm capacity in the neighbouring country?".

- *Negative externalities*. Uncoordinated, unilateral implementation of a capacity mechanism may have negative welfare effects on the neighbouring market. A reduction in price spikes in the CRM market limits the export prospects of the neighbouring market. The generators now depend on domestic price spikes, which may aggravate the missing-money problem. In other words, a capacity market in one country may partly export the missing-money problem to the neighbouring country, forcing it to change its own market design. Hence, there are strong reasons for the coordination of market design policies to avoid at least temporary negative effects on the internal market. National policy makers would typically base their decision on their own country's welfare, thereby neglecting cross-border effects on their neighbouring countries. Obviously, this is not in the interest of the European Union aiming at a European Internal Market for Electricity.

What are the threats of CRMs to the achievement of the benefits of market integration?

The potential benefits of integration strongly depend on the cross-border allocation mechanism and degree of reliance on the neighboring markets. In order to achieve clear benefits of market integration, harmonization of national market designs and introduction of one common mechanism for cross-border capacity allocation across the national borders are required (Creti et al., 2010). At present, however, the single market is still far from being accomplished. Rather, the European market is fragmented into a number of poorly harmonized regional markets featured with their own market arrangements and different cross-border trade allocation schemes (European Commission, 2013; Glachant and Ruester, 2014). Efficient trade can be facilitated by implementing non-discriminatory and market-based interconnection capacity allocation methods. Implicit auction (or market coupling) has proven to be the best mechanism to allocate transmission capacities and ensure the most efficient use of resources. Yet, many interconnections currently operate under other trading arrangements. In terms of strengthening the security of supply, there is a concern that market integration creates challenges to ensure it. Investment decisions in generation depend, among others, on the prospects of importing or exporting; therefore, net importer countries may be more prone to risks of insufficient local capacity to meet the peak demand. The development of regional rather than individual criteria of generation adequacy and high reliance on neighbouring countries may reduce capacity requirements in the integrated markets. However, low confidence in the integrated markets to deliver security of supply and the self-sufficiency mind-set that most countries still retain may lead to an explicit consideration of resource adequacy policies at a national level to guarantee independence, which may reduce or eliminate the benefits of market integration.

How can cross-border capacity participate in national CRMs?

In the new guidelines on the EU State Aid Environmental Protection and Energy, the Commission puts forward a requirement for capacity remuneration mechanisms to be open to all capacity that can effectively contribute to meeting the required generation adequacy and coordination in the development of regional rather than individual criteria of generation adequacy, including capacity from other member states (European Commission, 2013). Several studies focus on the development of different options for cross-border participations in capacity markets and examine the pros and cos of these approaches (Frontier Economics, 2014; Tennbakk & Noreng, 2014). However, no common regulation is developed, and the Commission does not provide guidance on the practical participation of the cross-border capacity in national CRMs and recognizes its practical difficulties. One of the concerns is how to ensure the fulfilment of the commitments of external generators in national capacity markets. As long as the availability of domestic capacity and the availability of foreign capacity is not easily comparable in reliability terms, participation of external generators in a national capacity mechanism may be dangerous in terms of ensuring their availability when required, especially in the case of simultaneous shortage situations in integrated systems. At the same time, guaranteeing availability through physical reservation of the cross-border transmission capacity by foreign capacities (explicit access to the interconnectors) may be inconsistent with the target model for cross-border allocation, that is, market coupling, and may bring inefficiencies to the cross-border trading. The implicit cross-border allocation principle, which is shown to be the best mechanism to allocate transmission capacities and is the target model for cross-border allocation in the Internal Electricity Market in Europe, limits the opportunities of foreign capacities to participate in national CRMs as it completely excludes the options to reserve the cross-border transmission capacity by market participants for the purposes of ensuring availability in the CRMs. However, without direct reservation of the transmission capacity for the purpose of cross-border participation in CRMs, the availability of the foreign capacity could be difficult to ensure, as there is no straightforward way to identify the exporting/importing capacity under implicit auctioning. Thus, explicit auctions would be the only solution enabling cross-border participation, despite the short-term inefficiencies in cross-border trade they may bring. Future research will propose options for cross-border participation and examine the impacts of cross-border capacity trading on short-term and long-term operation of electricity markets.

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