Beyond the borders of electricity

Cross border effects of a German Capacity market on The Netherlands

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ABSTRACT

In electricity markets serious concerns exist whether a competitive electricity market will provide the necessary incentives for investment in generation capacity. Recent electricity shortages in California, New Zealand, Italy and Scandinavia supported this concern. A capacity market provides a possible solution to this problem of generation adequacy but the effectiveness of the various different mechanisms is disputable and one-to-one comparison is nearly impossible. With Germany deciding on the implementation of a capacity market, concerns arise regarding the cross border effects on the Dutch market. This paper provides a method to simulate a capacity market in Germany based on an existing electricity market model, Power2Sim. Analysis of the results show that the Dutch electricity market is affected by a German capacity market, although the extent of the effects differs per scenario and performance indicator. The aim of this research is to provide insights in the cross border dynamics of a capacity market which can be used by policy makers in the Netherlands. In order to improve the current understanding of capacity markets, directions for further research are provided.

Keywords: Electricity markets; Generation adequacy; Capacity market; Cross border effects; Simulation

1. Introduction

Availability of power generation capacity in an electricity market is one of the key issues in energy-only markets. An energy-only market does not differentiate in payments between capacity and price. The market is entirely based on the electricity price and the marginal costs of production. However, serious concerns exist whether a competitive electricity market will provide the necessary incentives for investment in generation capacity (Oren, 2003; De Vries & Heijnen, 2008). The first indication of this deficiency appeared during the 2000 and 2001 electricity crisis in California as discussed by Turvey (2003) and Weare (2003) and these concerns were supported by shortages in New Zealand, Scandinavia and Italy in more recent years (De Vries, 2007).

In theory, in a competitive electricity market, optimal incentives for investments in generation capacity are provided by the market (Joskow & Tirole, 2007). However, practice shows that this is not always the case. Currently there are several factors that together influence the performance of the electricity sector. Increased shares of renewables, increased interconnection between countries and low carbon prices impact the current electricity sector in North-western Europe (Elberg, 2013; Meulman, 2012; ACER, 2014).

Currently, the implementation of capacity mechanisms in Europe is a major topic with several member states being on the edge of deciding upon implementing a capacity mechanism (Eurelectric, 2013) . Germany is currently discussing the implementation of a capacity market (Calaminus, 2014). This would mean that Germany together with the UK, will be the first country with a capacity mechanism that is directly physically connected to the Netherlands. Given the importance of the electricity exchange between these countries, the implementation of a capacity mechanism in Germany might have consequences for the Dutch electricity market as well. The discussion on the effects of a capacity market is enhanced by the recent worries of the Norwegian TSO regarding the profitability of a new 1.4GW transmission cable between Germany and Norway (Bloomberg, 2014).

This research aims at providing knowledge, insight and information that can contribute towards helping policy makers anticipate and develop policies taking into account the cross border effects of capacity markets. The research question that addresses the current issue of generation adequacy in Germany and The Netherlands is:

"*To what extent does the implementation of a capacity market in Germany influence the performance of the Dutch electricity market*"

For this study an existing model, Power2Sim, was used as a starting point for developing a capacity market module. Power2Sim is a fundamental electricity model including 29 countries in Europe and is based on merit-order economic dispatch. The input data for this model are based on empirical data retrieved from electricity markets all over Europe.

In order to answer the research question, the text is built up in the following way. Section two provides insight in the performance indicators that can help to assess the cross border impact of a capacity market in Germany on the performance of the Dutch electricity sector. Section three describes the existing base model Power2Sim as well as the capacity market model, which is added for the purpose of this study. Section four elaborates on the experiments that have been set up and the scenarios that have been selected. In section five the results of this research are presented. The Conclusion and discussion are described in the final section of this paper. In this part also the limitations of this study and directions for future research are discussed.

2. Performance indicators

Several literature reviews are available discussing the attractiveness of capacity mechanisms for the market? in which the capacity mechanism is implemented. For this study, the articles by De Vries (2004), Oren (2005), Cramton and Stoft (2006) and Joskow (2006) were used to identify the performance indicators.

The main purpose of a capacity market is that is should provide a reliable electricity system by incentivizing investment in generation capacity. Translated to a cross border context, it would be interesting to look at cross border investment as well as to see whether Dutch investors are affected by the implementation of a German capacity market.

A second pair of performance indicators is the price level and volatility of electricity prices in a neighbouring country. Related to this indicator are the import and export of electricity since this is inseparably related to the electricity price.

Due to the overcapacity in the Dutch electricity sector, a number of gas power plants has entered a stage of cold reserve due to the difficult market circumstances. Whether their business case is improved or worsened can also be taken into account when assessing cross border impact.

Besides the indicators above, the Dutch government has three main policy goals when it comes to the electricity market. These goals are: reliability, affordability and sustainability. It is interesting to look at the effect of a German capacity market on these public goals as well. These have been translated into the number of unserved hours and the reserve margin for the goal of reliability. The affordability is expressed as the total consumer costs in the system and sustainability is measured in the amount of CO_2 emission in the Dutch electricity sector.

3. Model description

I. Power2Sim

Power2Sim is the model that is used in this research. It is a model that aims at calculating detailed hourly electricity prices given a certain scenario. Power2Sim is a fundamental model based on merit order principles of European energy-only markets. It outputs hourly electricity prices as well as predictions for future CO_2 prices and electricity trade. The Power2Sim model is based on 29 nodes or prices zones in EU27 plus Swiss and Norway. Demand in 2020 is modelled by using historical data on demand patterns. Supply is modelled as a scenario variable in the model of which the starting point is a detailed list of power plants in Europe. Renewable energy generation is modelled through renewables patterns based on empirical data. A regression analysis is performed by the model on historic data and rescaled according to the scenario input. By basing wind patterns on historic data, correlation between renewable locations at a particular hour is taken into account.

The Power2Sim model does not include indigenous investment. Neither does it include evaluation of a capacity market.. This means that two separate models need to be implemented in the model, namely an investment module, and a capacity market model. Since the model itself is designed by a third party, access to the source code is not possible. Therefore both the investment module and the capacity market module are designed in Excel. In order to have the separate modules communicate, a visual basic code was written which automatically ran the Power2Sim model in combination with the two external modules.

II. Investment module

Investment can be implemented in various ways. For this study, the basic investment algorithm is based on literature by Stoft (2002). Stoft argues that an investment is profitable if the revenues of a particular reference year are equal to the amortized overnight cost of a power plant. In other words, if the revenues are at least equal to the discounted investment costs. The formulas below show how the amortized investment costs and revenue from electricity market are calculated.

$$AI = \frac{r*IC}{1-\frac{1}{(1+r)^T}} \quad (1)$$

$$Profit = P_e - MC \ \ if \ P_e \geq MC \quad (2)$$
$$Profit = 0 \ if \ Pe \leq MC \quad (3)$$

$$AP = \sum_0^R Profit \quad (4)$$

Where:
AI = *annual investment*
IC = *investment costs (overnight costs)*
r = *interest rate*
T = *Power plant lifetime*
Pe = *electricity price*
MC = *marginal cost of production*
R = *nr of hours in a year*

An investment is considered attractive if the AP is larger than the AI. In some cases, multiple power plant technologies will be attractive. Next to the AI and AP, a return on investment is determined for all profitable technologies. The technology with the highest return on investment is now the preferred investment alternative.

The standard model structure is assumed to be optimal. However, section 1 already indicated that this is not the case when looking at empirical evidence regarding energy-only market functioning.
According to De Vries and Neuhoff (2004), producers may be risk averse which means that they want a higher premium on riskier investments. This differs from the optimal market in which all investors are risk neutral. A second reason for the market to be non-optimal is the existence of a price cap. A price cap limits the revenues for power producers and thus makes it more difficult to recover fixed costs. These two aspects of market failure have been implemented in the model. The investment module therefore is subjected to a price cap in the market of €3000/MWh, equal to the price cap in the German market (Epexspot, 2014). The discount rates are based on a linear interpolation of the capital costs of a technology therewith steering towards less capital intensive technologies. Input data for these assumptions were retrieved from the EIA (2013).

III. Capacity market module
The capacity market module is based on the NYISO capacity market in the United States. It consists of a sloping demand curve capped by the cost of new entry for an OCGT power plant time a factor f (generally between 1 and 2). A regulator in the system determines a reserve margin for the system. For this study the reserve margin is equal to 15%. The target capacity in the system is calculated with the following formula.

$$C^* = (1 + R^*) * D_{peak} \quad (5)$$

Where:
*C** = *required capacity*
*R** = *reserve margin*
Dpeak = *peak demand*

This target capacity is used to determine the sloping demand curve of the capacity market. The slope prevents the capacity market from having bipolar price forming which is present when using a fixed demand curve. In the figure below a sloping demand curve is presented. R represents the reserve margin determined by the regulator. For this study, a value of 0.15 was taken. The figure shows that the value of the capacity decreases when the available capacity is higher.

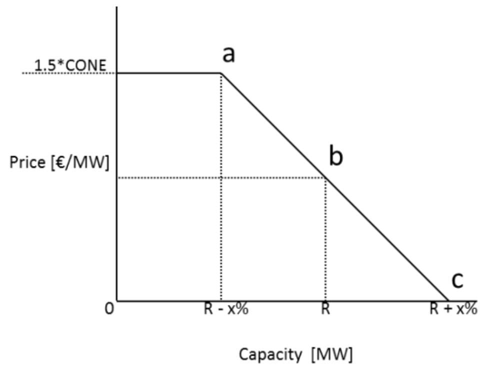

Figure 1 Sloping demand curve

An important factor in the capacity market design is the way that power producers bid into this capacity market. Since the capacity market is a market that incentivises reliability, the market should compensate a power plant just enough to at least stay online. The main concept used here is the annual fixed operating and maintenance costs (fixed O&M). In other words, the cost that do not vary with the plants operational hours and electric output (eia, 2013). However, if a power plant receives enough revenue from the energy-only market it does not need to be compensated to stay online. Therefore, a plant will only bid the difference between the revenues from the energy-only market and the fixed O&M costs. The bid of a single power plant is described by the following formulas. Please note that only a capacity bid price larger than zero exists if the fixed O&M costs are larger than the revenues from the electricity market. In all other cases, the bid price for capacity equals 0.

$$CapBidPrice = Annual\ revenue - Fixed\ O\&M\ costs \qquad (6)$$

Every bid is accompanied by the volume corresponding to this bid price.

4. Experiment design

In order to assess the effects of the introduction of a capacity market in Germany in a structured way an experimental design is made. In order to include scenarios in the model, first a sensitivity analysis regarding CO_2 fluctuations was performed. Six different CO_2 prices were analysed. The results show that CO_2 has an influence on the technology mix within the investment algorithm. Three different kinds of behaviour were observed out of six experiments. Therefore three scenarios have been set up with CO_2 prices of respectively €10/tonne, €30/tonne and €50/tonne. Since the model has no random variables, it is not necessary to run scenarios multiple times. In order to provide an answer to the research question, the following hypotheses have been set up:

H1: A capacity market in Germany has an impact on the performance of the Dutch electricity sector

H2: A capacity market in Germany, combined with a large share of renewables, has an impact on the performance of the Dutch power sector.

H3: A large interconnector capacity will increase the cross border impact of a German capacity market on the Netherlands.

For the experiments the investment and capacity module have been used as described in section 3. In order to be able to compare the experiments, a base case is executed in which the markets of The Netherlands and Germany are simulated without capacity market. The investment scenarios for the countries other than Germany and The Netherlands are based on an EC report (European Commission, 2013). The data on individual power plants in Europe are retrieved from Energybrainpool (2014). Nuclear power plants and renewable energy is assumed to be policy driven and are therefore excluded from the investment algorithm. Power plant data on new investments in conventional technologies are based on CE Delft (2011) and Electropaedia (2005). For the simulation, the following technologies have been taken into account: gas CCGT, gas GT, oil, lignite and hard coal.

5. Results and Interpretation

The first results show that a capacity market in Germany leads to different investment behaviour in the system. This is presented in figure 1.1. Consequently this leads to different results on the performance indicators since they are all to a certain extent related to the investment mix, the electricity price and volatility.

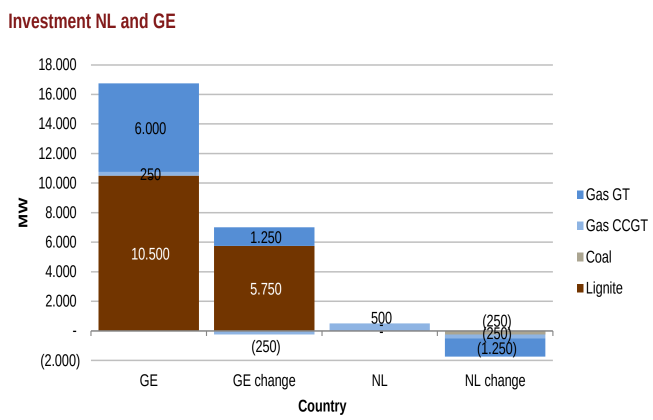

Figure 1.1 Investment in generation capacity

In figure 1.1, the investment with and without capacity market is presented. It can be observed that a shift in investment towards is Germany present. This can be explained by the improved business case of German power plants compared to the Dutch power plants. The corresponding result of this increase in investment is a drop in electricity price in both countries as well as a drop in volatility. This drop in electricity price is mainly caused by peak shaving of the Dutch electricity price whereas the price duration curve does not show changes over the entire range of prices. Another consequence of the investment shift is the increase in cross border trade and in particular the flow of electricity from Germany to the Netherlands. This signals that the Dutch electricity system is getting increasingly dependent on German capacity when a German capacity market is implemented.

With regards to reliability, the results show both positive and negative results. The reserve margin is decreasing as a direct result of the investment shift while the actual number of loss of load hours decreases. A secondary analysis on the increased dependence on German capacity showed that cutting of the interconnection for a period of one year would result in an increase in loss of load hours from 2 to 97 hours in a year. Although this is not likely to happen it still is an indication of this dependence.

The impact of a capacity market on the total consumer costs shows the opposite behaviour of the investment and it presented in figure 1.2 . The total consumer costs in the Dutch system decrease while the German total consumer costs witness a net increase caused by a capacity payment and a need for change in renewables subsidies. The German consumers are in that sense paying for the free rider benefits of the Dutch system.

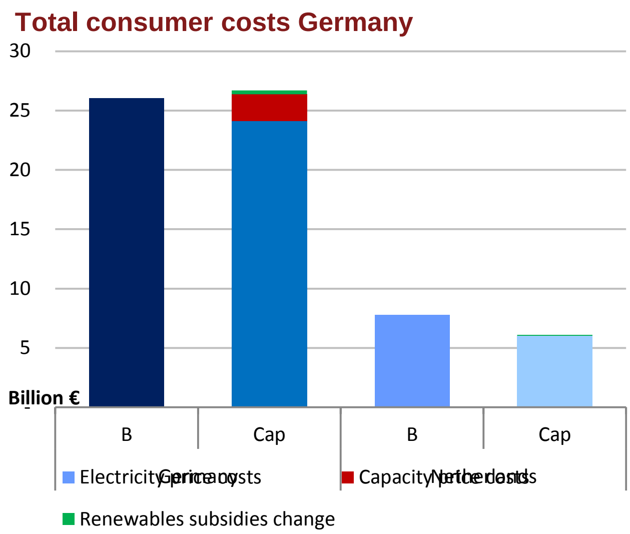

Figure 1.2 Total consumer costs

Sustainability of the Dutch electricity system is improved with a German capacity market. Electricity is produced in Germany and consumed in the Netherlands leading to a net decrease in CO_2 emissions in the Dutch system.

The actor group that will be harmed most are the electricity producers in the Netherlands. The implementation of a capacity market put more pressure on the margins because of the decrease in electricity price. Secondary analysis show that this could lead to 1400 MW of capacity market being mothballed which might threated long term reliability of the Dutch electricity system.

Increasing the interconnector capacity enlarges the consequences previously described. The Dutch system will be more dependent on German capacity, but at the same time the total consumer costs, the CO_2 emission and the loss of load hours are positively impacted. Again the producers will be even hit harder with 4700 MW of capacity to be mothballed as a result.

The effect of CO_2 prices on the capacity market is analysed as well. In general, CO_2 prices result in investment in more, relatively cleaner technologies. A particular interesting interaction between CO_2 prices and a capacity market occurred in the €50/tonne CO_2 scenario. In this scenario investment increased to a large extent because gas CCGT plants pushed almost all other technologies out of the market under these conditions. The cause was to be found in a dominating position of investment leaving no room for investments in other technologies.

6 Recommendations

The results and interpretation lead to valuable insights for policy makers in the Dutch. The three policy goals, affordability, reliability and sustainability, are used to base the recommendations on. The general question that a policy makers need to ask themselves whether they value independency of the Dutch electricity system more than they value the benefits for the Dutch system a capacity market in Germany implies.

A second recommendation is to determine which of the three public goals is valued highest. The trade-offs that are present within those three goals imply that a situation of improving on all points at the same time is impossible. Regarding the affordability of the electricity system, a capacity market results in an improved situation considering total consumer costs. The policy makers should aim at increasing the interconnection capacity which results in even higher level of affordability.

The sustainability is affected positively due to the shift of electricity production to Germany. CO_2 is now emitted in Germany while the electricity is consumed in the Netherlands. Again, increasing the interconnector will improve this situation.

The reliability is affected in two ways decreasing the reserve margin but decreasing the number of loss of load hours as well. The main decision to be made is to look at the long or short term consequences of a capacity market in Germany. In the short term, the decreased number of unserved load hours is an improvement to the system. However, in the longer term, the implementation of a capacity market results in mothballing of capacity. The amount of mothballed capacity is influenced by the size of the interconnector between the Netherlands and Germany. This means that the reserve margin is likely to be under severe pressure on the long run due to the mothballed capacity that can reach 4700 MW with an increased interconnection capacity.

The producers in the Netherlands are negatively impacted by a German capacity market. The larger, the interconnector, the lower the electricity price in the Netherlands and thus the lower the revenues. Currently, already a large amount of capacity is mothballed. At the same time, Germany is investing in capacity and the produced electricity is exported again. The issue that arises is whether it would be possible to let Dutch mothballed capacity bid into the German capacity market. This would imply that investment costs of around €3b could be saved. The exact design of this bidding in a foreign capacity market is not taken into account.

7 Conclusion

With Germany deciding upon implementing a capacity market, the discussion about the consequences increases. Besides internal consequences neighbouring countries can also be affected by the implementation of a capacity market. The research question that has a central role in this paper was formulated as follows:

"To what extent does the implementation of a capacity market in Germany influence the performance of the Dutch electricity market"

The process started with setting up performance indicators from literature. These performance indicators were extended with performance indicators related to the three public goals in the electricity market: reliability, affordability and sustainability.

The model results show that the implementation of a capacity market in Germany affects the performance of the Dutch electricity sector. Several positive and negative effects can be observed of which the most important ones are discussed here. A capacity market leads to higher investments in Germany at the cost of investment in the Netherlands. This shift in investments in generation capacity towards Germany has several other consequences. The total costs of consumers in the Netherlands decrease. The total costs of electricity in the wholesale market in Germany decreases as well, but the decrease is compensated and even surpassed by the capacity payment and the change in need for renewables subsidies, ultimately leading to a net increase in total consumer costs. The shift in investment shifts the production as well resulting in a decrease in CO_2 emissions in the Netherlands and an increased amount of imported electricity from Germany. The reliability of the system shows ambiguous behaviour in the sense that the reserve margin is decreasing while the actual number of loss of load hours decreases as well.

Increasing the interconnection capacity enlarges the magnitude of the changes that occur in the general capacity market scenario. The larger the interconnection gets, the larger the dependence on German capacity will be.

The recommendations for policy makers in the Netherlands that follow up on the results of this study are dependent of the perspective you take as policy maker. The three electricity policy goals include trade-off which makes it impossible to improve them all at the same time. The main question that policy makers should as themselves is whether they value the independency of the Dutch electricity system more that the free-rider benefits of neighbouring a capacity market has. This study has limitations as well. The number of scenarios that have been taken into account is rather limited. Next to that, the investment algorithm is still quite basic, possibly having an impact on the results.

Concluding on this research, several contributions have been realised. Regarding the Power2Sim model, this study showed that it is possible to extend the model with additional modules. This can be interesting for policy makers willing to test new combinations of capacity markets in different countries.

Secondly, the two models provided insight in the cross border dynamics of a capacity market in Germany. Furthermore this study also validates previous literature on the effectiveness of a capacity market in general.

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