Valuation of Physical Transmission Rights - An Analysis of Electricity Cross Border Capacities between Germany and the Netherlands

Magnus Wobben*

First version: March 30, 2009
This version: May 5, 2009

* Funded by DFG (Deutsche Forschungsgesellschaft), Department of Economic Theory, Westfälische Wilhelms-Universität Münster, Germany. E-mail: Magnus.Wobben@wiwi.uni-muenster.de
Valuation of Physical Transmission Rights - An Analysis of Electricity Cross Border Capacities between Germany and the Netherlands

First version: March 30, 2009
This version: May 5, 2009

Abstract

The purpose of this paper is to discuss market-coherent valuation of physical transmission rights for cross-border capacities between Germany and the Netherlands. Aiming at a fair valuation of these contracts, the most important stylized facts of electricity prices such as mean reversion, spikes and correlations of regional prices have to be considered. We present different approaches to the valuation of physical transmission rights and perform a quantitative analysis of the results. On the one hand various challenges of modeling regional price spreads are analyzed. On the other hand we indicate a structural undervaluation of physical transmission rights in all model constellations, i.e. market prices are below theoretical prices of PTR’s flexibility. We discuss several reasons for this undervaluation and finally state that regulatory modifications have to be made to avoid missing incentives for the extension of cross border capacities.

Keywords: physical transmission rights, cross border capacities, risk-neutral valuation, European options

JEL: G14, Q48
Valuation of Physical Transmission Rights - An Analysis of Electricity Cross Border Capacities between Germany and the Netherlands

Magnus Wobben*

First version: March 30, 2009
This version: May 5, 2009

Abstract

The purpose of this paper is to discuss market-coherent valuation of physical transmission rights for cross-border capacities between Germany and the Netherlands. Aiming at a fair valuation of these contracts, the most important stylized facts of electricity prices such as mean reversion, spikes and correlations of regional prices have to be considered. We present different approaches to the valuation of physical transmission rights and perform a quantitative analysis of the results. On the one hand various challenges of modeling regional price spreads are analyzed. On the other hand we indicate a structural undervaluation of physical transmission rights in all model constellations, i.e. market prices are below theoretical prices of PTR's flexibility. We discuss several reasons for this undervaluation and finally state that regulatory modifications have to be made to avoid missing incentives for the extension of cross border capacities.

Keywords: physical transmission rights, cross border capacities, risk-neutral valuation, European options

JEL: G14, Q48

* Funded by DFG (Deutsche Forschungsgesellschaft), Department of Economic Theory, Westfälische Wilhelms-Universität Münster, Germany. E-mail: Magnus.Wobben@wiwi.uni-muenster.de
1 Introduction

Effective competition in power markets is based largely on unrestricted network access. This is true not only for national markets, but also on the international level in the context of a joint, intra-European market. A key factor of any successful international power trade therefore is the ability to transfer power across borders, i.e. the ability of non-discriminatory purchase of so-called “cross border capacities”. Due to the scarcity of these transmission capacities, transferring power across borders is somewhat restricted such that price adjustments will align with physical limits. Generally, markets for cross border capacities are natural monopolies, controlled by one transmission system operator (TSO).

Certain explicit and implicit auctions exist in order to comply with the appropriate power trade ordinances.\(^1\) Both methods have a preventative function, i.e. they are implemented to avoid shortages in advance. In an explicit auction, physical transmission rights are allocated individually in order to coordinate two separate markets, in which spot pricing occurs independently. Before the actual physical power trade, the cross border capacities are distributed in the form of options or obligations. Explicit auctions of physical transmission rights (PTR) have developed into a European-wide standard, while implicit auctions, where resulting “electricity prices” reflect both, the cost of energy and the cost of congestion in each area. Implicit auctions mainly occur in the context of market coupling, i.e. an agreement between two or more power exchanges to ensure that all the available trading capacity is utilized with power flowing towards the high price area by simultaneously clearing all participating areas.\(^2\)

\(^1\) European Parliamentary Ordinance No. 1228/2003 and the June 26, 2003 Council regarding the conditions for network access in cross-border power trading.  
\(^2\) For example, NORDPOOL (cf. http://www.nordpoolspot.com/).
PTR can be interpreted as a bundle of European call options on regional electricity price spreads.\(^3\) Therefore, the contracts involved can be evaluated in two fundamentally different ways. Besides the approach that models price spreads directly, it is also possible to model the two regional spot prices separately. When using the second approach, the correlation of all stochastic processes included in the model must be estimated according to historical data. These estimations determine the options price to a great extent, but they can be flawed due to an insufficient data basis or the inability to observe and separate jump components. Tracking longer periods of time generally requires considering a regime switch (a structural modification, such as a new combination of power plants or a change in the political conditions), which would only subsequently “inflate” a model.\(^4\) Thus, extending the period of time under consideration will not per se improve the quality of information gained for future price developments.

A second disadvantage of the correlation model is that it is impossible to derive closed form solutions for a positive strike price in simple diffusion models. This is why a substantial portion of the research focuses on approximate approaches. Poitras (1998) derives an approximate solution for two price paths in the Black-Scholes world\(^5\), and Carmona and Durrleman (2003) expand these approximations

---

\(^3\) As a general rule, electricity is not a tradable asset in the classical sense, as arbitrage dealings are considerably limited by the absence of sufficient storage potentials and the inability to sell short. Goods in this sort of incomplete markets are referred to as exotic underlyings. The research and literature concerning exotic underlyings suggest several different models for calculating options, only a few of which will be addressed and modified here.

\(^4\) At this point, it is worth mentioning the different phases of the European emissions trading scheme (2005-07 & 2008-12), which will be considered below through the introduction of dummy variables.

to simple Gaussian mean reversion processes. Lima (2005), however, shows that these approximations do not produce satisfying results, since the difference between two random, log-normal distribution variables cannot be approximated particularly well based on one normally distributed random variable.

In many cases, it is possible to quote closed form solutions for so-called exchange options, i.e. spread options with a strike price of zero. Margrabe (1978) derive a simple closed-form solution using two correlated geometric Brownian motions, while Hikspoors and Jaimungal (2007) derive closed form solutions for the Lucia-Schwartz model and for a two-factor model with jumps. The authors calibrate their models based on oil prices with short term delivery. Although relatively complex and time-consuming, the calibration routine actually delivers satisfactory results for oil prices, which are less volatile than electricity spot prices.

Because of the above-mentioned disadvantages and complicated necessary calibrations, Benth and Šaltytė Benth (2006) decide to model spark spreads (the difference between electricity and gas prices) directly. They derive a closed form solution for spread options with a positive strike price, but also admit the drawback that in fact the aggregated information regarding price relationships is included in model parameters, but can no longer be separated for individual interpretation. The models discussed in this article draw on Benth’s and Šaltytė-Benth’s as well as Hikspoors’s and Jaimungal’s approaches, but are geared at modeling regional price differences.

---

2  Marketing Cross Border Capacities

2.1  Option contracts

Whereas the electrical forward market is primarily responsible for power delivery in the more distant future, the much smaller spot market handles the majority of trading for short-term surplus quantities, i.e. additional demand as well as surplus production reserves. Forward contracts can be described entirely in terms of their payout profiles, which must correspond to the actual value of the contract at the point it reaches maturity. These contracts can be split into two categories: contingent claims and non-contingent claims. Contingent claims (including all forms of options) leave the holder free to choose whether the transaction will be completed or not, while non-contingent claims (primarily forwards, futures and swaps) are binding for both parties. An option contract gives the holder the right to buy (call option) or sell (put option) an underlying asset (e.g. stocks, commodities or electricity) at a certain strike price $K$ at a certain point in time or for a certain length of time. When a seller of a call option releases the option premium, then he is obligated to transfer the underlying asset at the strike price, whenever the buyer wishes to exercise his right.

Conversely, when a seller of a put option releases the option premium, than he is obligated to accept the underlying asset at the strike price, whenever the buyer wishes to exercise his right. If the option can be exercised at any given point in time before reaching $T$ (its maturity date), then it is referred to as an American option; if it can be exercised only at time $T$, then it is called a European option.

An option’s value $V$ on the expiration date $T$ depends on the price of the underlying asset $P$ and its strike price $K$, the difference of which makes up the option’s payout
profile. Before maturity, this difference is referred to as the intrinsic value. If an option’s intrinsic value is positive, then it is referred to as being “in the money”; otherwise, it is “out of the money.” The holder of a European call option will only take advantage of his right on the date of maturity if the strike price is lower than the price of the underlying asset. Otherwise, the option has zero value. Conversely, the holder of a put option will only act when $K$ is greater than the price of the underlying asset.

The option’s maturity can also influence its value. The longer the option is left to mature, the higher its so-called time value, i.e. the probability that the underlying value will push in the desired direction within a certain time frame.

At the term’s end, the time value is zero, or in other words, by the expiration date, the option’s value reflects its intrinsic value. Volatility, as a measure of an underlying’s margin of fluctuations, has a similar effect on an option’s value. The higher it is, the higher the expected profit when the underlying value develops positively for the options holder. The value of options at any given point in time before their maturity date will be addressed in the following section. It is important to first understand the most influential factors in establishing the price of electricity.\footnote{For a detailed analysis of this subject, see also Janssen and Wobben (2008) and Janssen and Wobben (2009).}

### 2.2 Stylized Facts

Two important characteristics in electricity pricing are a strong connection to the seasonal cycle and a certain variable volatility\footnote{Price volatility is generally understood as the range of fluctuation around a deterministic but possibly time dependent level. In econometric applications, the concept of volatility is limited to}. *Mean reversion* refers to the process...
by which prices return to a stable seasonal level (\textit{mean reversion level}) after fluctuations. Particularly large increases are labeled as jumps, or in extreme cases, as spikes. Spikes are abrupt or unanticipated price peaks that cross a certain threshold for a certain length of time. For electricity, the threshold relative to seasonal levels is higher than for gas, and the time interval is shorter. This can be attributed to the inability of storing electricity and the fact that randomly occurring generation outages and infrastructure capabilities have a more extreme effect on electricity prices than for other commodities. On the other hand, electricity markets are often able to correct strained supply conditions within 24 hours (the time period between day-ahead auctions), whether it be through additional imports or through the activation of power sources.

Another important aspect of spot market prices is the installed price floor rate (usually 0 \(€/\text{MWh}\)). At certain times, negative electricity prices make more sense technically and economically, and can include important incentive signals for load shifting. Thus, the European Energy Exchange (EEX) in Leipzig, Germany, introduced negative electricity prices in the European market for the first time in October 2008. This allows producers to pay their buyers, when electricity production is extremely high and demand is very low, and when the buyers accept the electricity anyway to help the producers avoid the costly expense of shutting down their plants.

The analysis of price spreads shows that in contrast to actual electricity prices, it is not clear a priori that they are determined by seasonal factors and that they exhibit a lower level of volatility than the individual prices. Furthermore, the sign of price spreads changes much more frequently than that of spot prices. The magnitude of the spikes essentially depends on the correlation between the two prices under the range of fluctuation in a time series, adjusted for jumps and seasonal trends.
consideration (see Figure 1). Because two regions may have differing combinations of power generation, there may also be structural differences in the pricing of forward contracts in the two regions. This can serve as a motivating factor for the trade of physical transmission rights between two regions.

2.3 Physical Transmission Rights (PTR)

This article concentrates on the monthly auctions between Germany and the Netherlands and the corresponding chronology, which illustrates the option’s character of physical transmission rights (see Figure 2)

\footnote{Illustration 2 contains monthly as well as day-ahead auctions for physical transmission rights. The latter will not be explored here in greater depth.}.

Data available at \url{http://www.apxgroup.com/} and \url{http://www.eex.com/en/}.
ity (ATC) refers to the transmission capacity available for commercial purposes. Monthly auctions between Germany and the Netherlands are held on the 10th workday of each month preceding delivery, in which user rights for the available transmission capacity for the entire calendar month are auctioned. In fact, the available transmission capacity is random, which has to be estimated by the supplier, i.e. the TSO. Although there is also a day-ahead market for PTRs, the month contracts cannot be firm at any given time, due to the fact that the TSO, as a natural monopoly, is not allowed to act on the demand side of the market for physical transmission rights. Hence the TSO is not allowed to repurchase oversold PTRs and has to minimize the risk of overselling. This kind of risk could influence the consumer’s willingness-to-pay for monthly PTRs.

Figure 2: Explicit auctions using the example of power transmission between Germany and the Netherlands.

According to http://www.tso-auction.org/.

---

10 A bulk of these capacities is used implicitly for physical transmission. This is exactly the case, when electricity production (above all wind power) and network topology do not harmonize in one region. For example, when wind power feed-in is extremely high in the north of Germany, the available transmission capacity between Germany and the Netherlands is accordingly small.
Bids must be entered with the auction office by noon on the day prior to the auction, where each bidder can enter multiple offers within the same auction. Bidders are informed of the auction results within three hours of the last bid entry. Until 8:00 am on \( d - 4 \) (four days before actual physical delivery), rights can be returned to the transmission system operator or re-sold to a third party. Should the owner return the physical transmission rights to the transmission system operator, then he will be compensated with the price established in the next auction minus a trading fee. Yearly and monthly capacities not allocated by 8:00 am on \( d - 1 \) automatically return to the monthly and daily auctions respectively without compensation (*use it or lose it*). The price paid for monthly PTR therefore is based on the expected spot price spreads for each day in a calendar month. Long-term PTR (monthly and annual rights) can be read as a bundle of European calls between two zones’ price spreads.\(^{11}\)

Chapter 3 will discuss various approaches to valuation, before Chapter 4 examines data descriptions and numerical implementation.

### 3 Model Setup

#### 3.1 Models

This section will derive models for electricity prices and price spreads that mutually affect each other. Generally speaking, electricity prices and price spreads depend on two components. The deterministic (time variable) component \( f(t) \) includes all predictable structural factors in determining the price, as well as the level of availability in the power generation network and other seasonal influences. The stochastic components are modeled as the sum of the stochastic processes, which fulfill cer-

\(^{11}\)Strictly speaking, this is only true assuming that price spreads are known at the point in time when rights are nominated.
tain stochastic differential equations (SDE) in the applications presented here. As mentioned in the introduction, two different approaches are possible when modeling spreads. We will compare the results of both a diffusion and jump-diffusion approach.

Below, the underlying price $P_t$ represents the spread between two prices or the logarithmic price in a given region, respectively. It is then true for $X_t$ and $Y_t$ in certain standard circumstances\(^\text{12}\) that:

\[
\begin{align*}
P_t &= f(t) + X_t + Y_t \\
dX_t &= -\kappa X_t \, dt + \sigma \, dW_t \\
dY_t &= -\beta X_t \, dt + J_t \, dN_t
\end{align*}
\]

Thus, the spread $S_t$ equals $P_t$ in the case of a spread model, while $S_t = P^1_t - P^2_t$ in the context of a correlation model (see Table 1). In these formulas, $W_t$ represents a Wiener process, $N_t$ a Poisson process with intensity $\eta$, and $(J_t)_{t \geq 0}$ is a family of independent and identically distributed random variables with the parameter $\mu$ for exponential distribution and with parameters $\delta$ and $\varepsilon$ for normal distribution.

\(^\text{12}\)See also Korn and Korn (2001), pp. 10-12.
processes $W_t$, $J_t$, and $N_t$ are stochastically independent.\textsuperscript{13} In the following section, several concrete model specifications will be discussed and applied in evaluating physical transmission rights.

### 3.2 Valuation of PTRs

As described in the introduction, physical transmission rights can be understood either as a bundle of European call options in spot price spreads (models S1 and S2), or as a bundle of European spread options in the spot prices of the two regions (models C1 and C2, see Table 1.). While a closed form valuation is possible in model S1, the PTR values in other models can only be established numerically.\textsuperscript{14}

When deriving the valuation formula in model S1, the stochastic differential equation

$$dX_t = -\kappa X_t dt + \sigma dW_t$$

must first be solved in order to deduce the price process $S_t = f(t) + X_t$, the conditional expected value $E[S_t|\mathcal{F}_{t_0}] = E_0[S_t]$ and the conditional variance $\mathbb{V}[S_t|\mathcal{F}_{t_0}] = \mathbb{V}_0[S_t]$. Here, $\mathcal{F}_{t_0}$ is the filtration of $X_t$ containing all market information up to time $t_0$ shortly before the PTR-auction. Some measures under which the expected value could be calculated will be discussed in Chapter 4.2. Using one of these so-called valuation measures $\mathbb{Q}$ leads to the valuation of market-coherent option prices based on the information included in forward contracts in both regions. Regardless of the model used, the value of a single call option at the time $t = t_0$ with strike price $K$ is given by the following formula:

$$C_0^T = e^{-rT}E_0^\mathbb{Q}[(S_T - K)^+]$$


\textsuperscript{14}For model C1, a closed form solution can only be calculated when the strike price is 0.
The strike price \( K \) should a priori have a value near zero, since the holder of the PTR is not obligated to pay anything at the point where rights are nominated. Nevertheless, transaction costs could arise for the holder. These costs depend on the risk of network failure and the gap between the auction and the awarding of the PTRs. The latter are direct transaction costs that immediately arise in physically hedging the PTRs with forward contracts (bid-ask-spreads) as well as hidden transaction costs in the form of a positive risk premium, since the PTR-deal and the physical hedge cannot be closed simultaneously. The simplest hedging strategy, which incidentally does not take the product’s flexibility into account, would be to buy futures in low price regions as soon as the PTRs are awarded and to sell them in high price regions. The problem therefore is that the spread between prices at the time of the awarding of the PTRs is unknown at the time of bidding.\(^{15}\)

For model S1, the value of the physical transmission rights \(^{16}\) can be established according to the following formula:

\[
PTR_{0}^{[T_1, T_2]} = \int_{T_1}^{T_2} C_{0}^{T} dT \\
= \int_{T_1}^{T_2} e^{-rT} \left( e^{-\frac{1}{2} d^{2}} \sqrt{\mathbb{V}_0[S_T]/2\pi} + \left( \mathbb{E}_0^{Q}[S_T] - K \right) \cdot N(-d) \right) dT. \quad (3)
\]

In this equation,

\[
\mathbb{E}_0^{Q}[S_T] = f(T) + X_{t_0} e^{-\kappa(T-t_0)} + \alpha^{*} (1 - e^{-\kappa(T-t_0)}),
\]

\[
\mathbb{V}_0[S_T] = \frac{\sigma^{2}}{2\kappa} \cdot (1 - e^{-2\kappa(T-t_0)}),
\]

\[
\frac{(K - \mathbb{E}_0[S_T])}{\mathbb{V}_0[S_T]} = d
\]

and \( N(\cdot) \) is the distribution function for standardized normal distribution. \( F_{t_0}^{[T_1, T_2]} \) denotes the difference in futures prices between the Netherlands and Germany in

\(^{15}\)For the cross border capacities in consideration here, there is a gap of at least two hours between the auction and the awarding of the PTRs.

\(^{16}\)For a detailed analysis, see Dieckmann (2008), pp. 142-44.
$t = t_0$. Both futures deliver during $[T_1, T_2]$. $\alpha^* = -\lambda \sigma / \kappa$ stands for the difference in risk premiums between the Netherland and Germany, i.e. $\lambda$ denotes the (constant)\textsuperscript{17} market price per unit risk linked to the state variable $X_t = S_t - f(t)$. For model C1, Hikspoors and Jaimungal (2007) claim a closed form solution for the simple case of $K = 0$. Because options in this model are to be calculated with a positive strike price, the expected value in models S2, C1 and C2 are best determined numerically, e.g. with a Monte Carlo simulation or a PDE method.\textsuperscript{18}

4 Numerical Examples

This chapter will concentrate on a fair PTR value in the last 12 months according to each model, beginning first by calculating the price dynamics under the real world measure. Because this measure is not particularly useful for the valuation of derivatives, we will calibrate the process with the aid of appropriate forward data under a valuation measure $Q$. As we are concerned with the base product in monthly physical transmission rights, we estimated our model based on daily average prices (12 am - 12 am including weekends) as published by the EEX and the APX group. The first monthly auction examined here took place on October 12, 2007 (November product), and the last one on September 12, 2008 (October product). The physical calibration was based on an estimated seasonal curve $f(t)$. To this end, the spot prices for the last three years preceding the respective day of valuation were examined. A risk-neutral calibration was completed based on regional futures price differences. Each auction took place on the tenth workday of each month; thus, the last available information for the futures curve differentials was based on the end of

\textsuperscript{17}We assume that $\lambda$ is constant. In general, it could be a function of the state variable $X_t$ and time $t$.

\textsuperscript{18}PDE = Partial Differential Equation. For various valuation methods, see Duffy (2006), or for a thorough introduction, see Günther and Jüngel (2003).
the ninth workday.

In order to avoid distorting the estimated seasonal curve, spikes must be iteratively filtered out of the data. An abort criterion on the one hand and a tolerance threshold for data correction on the other hand must be assigned to the algorithm. For the abort criterion, we chose an upper bound on the difference between the seasonal functions of two sequential iterations, and as a tolerance threshold, we choose a multiple of the standard deviation of de-seasonalized data. In doing so, the season is modeled as the sum of indicator and trend functions. Correspondingly, dummy variables are estimated for each month and each week. Finally, both phases of carbon trade are considered through two linear trend functions.

4.1 Estimation Procedure under the Real World Measure

Valuation begins with an estimation of the parameters in the stochastic processes $X_t$ and $Y_t$. To complete such an estimation, we must separate the data to a certain extent, so that we can derive the respective portions from $X_t$ and $Y_t$ based on an observed spot price spreads $S_t$. One possibility is to use a recursive filter on the de-seasonalized prices in order to identify spikes at precisely the points where logarithmic price increases exceed a multiple of their standard deviation (see Figure 3). In estimating $\eta$, we can divide the total number of the observed spikes by the number of observations. The height of each spike can be calculated with the help of a maximum likelihood estimate (ML), while the spike process’s mean reversion speed can be estimated via the autocorrelation function.

The remaining process $X_t$ is also estimated by using a ML routine.\textsuperscript{19} This process serves as the basis of all the models and does not consider the stochastic spike

\textsuperscript{19}For a detailed description, see Bibby and Sørensen (1995).
component. In models S1 and C1, a $Y_t$ value of zero is assumed. Because the expected magnitude of the spikes is positive,\textsuperscript{20} it can be assumed that the models S1 and C1 tend to result in an undervaluation of physical transmission rights.

### 4.2 Estimation Procedure under a Risk-Neutral Measure

Because power markets are incomplete, there is more than one possible risk-neutral measure that can be used for the valuation of options without generating arbitrage. Thus, the important question how to select the “right” risk-neutral measure, or in other words, how to define a risk-neutral dynamic for these processes arises. One possibility would be to make assumptions on the market participants’ utility function and to derive a valuation measure based on that. Because risk-neutral products, more

\footnotesize\textsuperscript{20}According to the correlation models the averaged spikes are higher in the Netherlands than in Germany
precisely month futures, are available for the PTR’s period of delivery, we choose a valuation measure that explains these futures and is equivalent to the real world measure. This can be achieved by integrating risk premiums from the individual risk sources taken into consideration in each model. The calibrated risk premiums then correct two different phenomena: first, the estimation error of the deterministic component $f(t)$, which is based on historical data rather than on current information about the PTR’s period of delivery, and second, the varying risk preferences for market participants in the two regions.

4.3 Evaluation and Comparison of Models

In evaluating model S1, we make use of the closed form solution (3) and, for the other models, we make use of a Monte Carlo simulation with 50,000 simulation paths in an hourly discretization. The transaction costs for (simultaneously) balancing out futures can be estimated according to bid-ask spreads. The estimated total costs of (simultaneously) balancing out and the auction results are depicted in Figure 4. The partially not negligible differences in auction results between RWE Transportnetz - TenneT and E.ON Netz - TenneT already hint at inefficiencies in the system. Furthermore, the results reveal that the flexibility that a physical transmission right offers customers is hardly reflected by the price.

Figure 5 depicts option prices that have been generated according to the various models under the assumption, that physical transmission rights are firm at any given time. Keeping in mind, that we have additionally neglected the fact that spot prices are not known when nominating physical transmission rights, this assumption tends to result in a (theoretical) maximum value for the monthly physical transmission rights. The strike price is calculated based on transaction costs, as in futures

21 They typically average around 0.50 €/MWh.
Figure 4: Auction results for the monthly PTRs between E.ON and TenneT as well as RWE and TenneT and total costs for the physical hedge with futures.

calculation. The spread models (S1 and S2) produce a substantial undervaluation, since the data for the $X_t$ and $Y_t$ processes were filtered progressively until they conformed to the underlying distribution hypothesis. This is necessary to avoid calculating option prices with non-significant parameters, i.e. it would be impossible otherwise to interpret the results. The prices generated in model S2 exceed those from model S1 because the expected magnitude of the spikes in price spreads (NL-G) is positive. In the correlation model C2, the data does not need to be filtered, i.e. flexibility is valuated as market-coherent. Model C1 was not included in the graphic because although it adequately valuates the diffusion risk, it ignores the spikes and is thus difficult to interpret. The C1 values lie between those in S1 and C2, and the C2 prices range 8% to 17% higher than S2 prices and approximately 20%-60% higher than E.ON’s and TenneT’s PTR prices. Since model C2 includes the necessary flexibility as market-coherent, the results produced in this article indicate an undervaluation of transmission rights for cross border capacities.
5 Conclusion and Outlook

The valuation of physical transmission rights is in essence nothing more than the valuation of so-called spread options. To that end, the most important characteristics in the price spreads between Germany and the Netherlands were collected in four different models, and the differences between them were compared. Although the correlation models were more complicated in estimation, they were in the end able to reflect the distribution of price spreads. Approaches in which price spreads are modeled directly, and thereby are treated as underlyings, tend to undervalue PTRs compared to correlation models. The same results are produced in models that do not take price spikes into consideration. All models however demand a precise knowledge of the deterministic component. This is available to market participants in the form of a prognosis, but must be comprehensible to a third party through historical data and forward curve information. The quality of this estimation is largely dependent on the chosen form of the seasonal curve and represents a way of approaching
possible improvements to the analysis presented here.

The model results show that the consumers of physical transmission rights between Germany and the Netherlands do not fully pay for these products’ qualities as options. The more realistic a valuation model is chosen, the more the actual prices deviate from the (theoretically fair) model prices. Together with the consideration that the monthly PTR auction results on the RWE Transportnetz - TenneT substantially differ from those on the E.ON Netz - TenneT, it becomes clear that the market for cross-border capacities is less than fully efficient. In summary, it can be claimed that the same product exhibits two different prices, neither of which accurately reflects the product’s actual qualities.

In contrast, the low number of market participants and the related preferential treatment of strategic bidding habits, as well as limited possibilities for the duplication of PTRs could cause non model-coherent prices. The latter explanation can occur, for example, when daily options, which constitute a monthly PTR, cannot be traded on the market at a fair price at any given time. Particularly, the most plausible reasons for the fact, that prices do not reflect the products qualities as daily options are the PTR’s non-firmness as well as the time gap between the nomination of PTR’s and the spot price publications. Conversely, monthly physical transmission rights reduce to a bundle of forward options included a default premium according to the risk that the contract is partially non-firm. We leave this argument for future research.

In conclusion, it can be stated that the shortfall in auctioning physical transmission rights is conditioned by undervaluation and diminishes the profit margin of future investment in cross-border capacities, thereby impeding incentives for the further development of these opportunities.
References


