Chapter 8: Modelling of the Electricity Futures Market *

Anatoliy Swishchuk
University of Calgary
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*Book Review: 'Stochastic Modeling of Electricity and Related Markets' by F. Benth, J. Benth & S. Koekebakker, 2008, World Sci. Publ.

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Intro

In this Chapter 8 they conduct an empirical study of financial electricity contracts traded on Nord Pool.

Empirical investigations of forward curve models in commodity markets have been done by, among others, Cortazar and Schwartz (1994), Clewlow and Strickland (2000).

Intro

Cortazar and Schwartz (1994) studied the term structure of copper futures prices using principal component analysis (PCA) and found that three factors were able to explain 99% of the term structure movements.

Clewlow and Strickland (2000) investigated the term structure of NYMEX oil futures and found that three factors explained 98.4% of the total price variation in the 1998-2000 period.

Intro

The first factor (explaining 91% of total variation) shifted the whole curve in one direction. They termed this a *shifting factor*.

The second factor, called the *tilting* factor, moved the short and long term contracts in opposite directions.

The third factor, coined the *bending* factor, influenced the short and long end in opposite direction of the midrange of the term structure.

Intro (Nord Pool-Wikipedia)

The Nord Pool market (the Nordic Power Exchange) is the single power market for Norway, Denmark, Sweden and Finland. It was the world's first multinational exchange for trading electric power. As of 2008, Nord Pool is the largest power derivatives exchange and the second largest exchange in European Union emission allowances (EUAs) and global certified emission reductions (CERs) trading. The derivatives and emission allowances and credits market is operated by Nord Pool ASA while the physical electricity market is operated by Nord Pool Spot AS.

Intro (Nord Pool-Wikipedia)

The international derivative products, the clearing house and the consulting services are provided through the cooperation with NASDAQ OMX Commodities (NASDAQ OMX Group, Inc. (NASDAQ: NDAQ) is a United States public company that owns and operates the NASDAQ stock market and seven European stock exchanges in the Nordic and Baltic regions under the OMX banner. It is headquartered in New York City, and its Chief Executive Officer is Robert Greifeld)(Wikipedia).

Intro

In the paper by Koekebakker and Ollmar (2005) Nord Pool data was analysed using PCA techniques. The authors computed smooth forward curves using the technique described in Chapter 7. Their data set consisted of fixed delivery forward contracts (points on the forward curve) that mimicked the term structure of actual traded electricity futures. The results from the PCA analysis using data for the period 1995-2001 showed that the first three factors accounted for 80% of the price variation.

Intro

Only the the first two factors (shifting and bending) seem to be common across all maturities. On order to explain more than 98% of the variation in the empirical covariance matrix, more than 10 factors were needed. Also, the authors reported evidence that factors explaining a large proportion of the return variations in the long end of the curve, seemed to have very low explanatory power in the short end of the curve.

Intro

Audet *et al.* (2004) suggested a simple model where each contract is driven by a Brownian motion, and the return on this contract is correlated with other contracts along the term structure by a negative exponential function. They estimated their model in the short end only (four closest weekly contracts).

Frestad (2007b) investigated empirically the model of Audet *et al.* (2004) using contracts across the complete term structure. The author found that the negative exponential function is too simple to explain the correlation structure across a broader set of contracts in this market.

Intro

Frestad (2007a) futher investigated the idea of common and unique risk factors at Nord Pool. In the proposed incomplete market model, electricity futures price returns are driven by some Brownian motions common to all traded contracts, together with a unique Brownian motion to each maturity.

Intro

In this Chapter 8 they perform PCA on daily Nord Pool electricity futures price data for the period 2001-2006. They prepare data set of electricity futures prices following the lines described in Chapter 7. Based on these data, we re-establish the results of Koekebakker and Ollmar (2005) and Frestad (2007a) for the total market. We then take a less ambitious approach and analyse individual market arguments. That is, weekly, monthly, quarterly and yearly electricity futures prices are given individual treatment.

The Nord Pool Market and Financial Contracts

In this section we describe relevant issues for the market structure and the data available at Nord Pool. We obtained daily closing prices for all electricity futures contarcts traded at Nord Pool from 2 January 2001 until 1 December 2006. The power contracts refer to 1 MW load during every hour (base load) for a given delivery period. The trading period stops when the contracts enter the delivery period. The size and trading period vary considerably for the contracts available. We will give a brief description of weekly, monthly, seasonal and yearly contracts below.

The Nord Pool Market and Financial Contracts

The weekly contracts are specified with a delivery period of seven days (168 hours). The delivery period starts Sunday at midnight and ends midnight the following Sunday. The contracts with delivery the following week are lasting until the preceding Friday. Earlier, four new weekly contracts were introduced every fourth Monday, meaning that a maximum of seven and a minimum of four weekly contracts were traded at any given time. This has changed. Now a new weekly contract is introduced in the long end, as the contract in the short end enters the delivery period.

The Nord Pool Market and Financial Contracts

Block contracts had four week delivery periods, but they do not exist anymore. These contracts were not traded in the month prior to delivery. They were broken up into separate weekly contracts. Since these contracts had delivery periods of 28 days (four weeks), each year was divided into 13 block contracts, 10 of which traded simultaneously.

The Nord Pool Market and Financial Contracts

But 13 blocks do not exactly add up to one year ($4 \times 28 \times 13 = 364$), and therefore the December block contract had one day longer delivery than the others (two days extra in a leap year). Since 2003, no new block contracts have been introduced in the market. They have been replaced by monthly contracts with delivery periods consistent with the days in the particular months.

The Nord Pool Market and Financial Contracts

The seasonal contracts have also changed. Earlier, each year was divided into three seasons: V1-late winter (1 January-30 April), S0-summer (1 May-30 September) and V2-early winter (1 October-31 December). The setup of three seasons has been replaced with the more common four season system, with three months for each season. The first quarterly contracts were listed 2 January 2004 for each quarter of the year 2006.

The Nord Pool Market and Financial Contracts

Now quarterly contracts have replaced all old seasonal contracts. There are between 8 and 11 quarterly contracts traded at any time. A new contract is introduced in the long end as the closest one enters the delivery period. Currently, quarterly contracts span more than two years.

The Nord Pool Market and Financial Contracts

Finally, the market trades in yearly contracts. As of 2007, yearly contracts for the following five years are available for trading (2008, ..., 2012). These contracts have delivery periods of $24 \times 365 = 8760$ hours (8784 hours in a leap year). Each year contract is traded for five years, until it expires in late December prior to the start of the delivery period 1 January.

The Nord Pool Market and Financial Contracts

In the beginning of January each year a new yearly contract is introduced with delivery period starting in five years. Yearly contracts were introduced in 1998. Then only three years contracts were traded. In this Chapter 8, in data set they only use three yearly contracts, as contract starting delivery in four and five years have a very limited history.

The Nord Pool Market and Financial Contracts

Prior to 2003 all contracts traded at Nord Pool were dominated in NOK. It was decided to change denomination to EUR.

In 2003 all new long term contracts were listed in EUR. This transition is now complete, and all contracts are currently denominated in EUR.

Preparing Data Set

In Benth and Koekebakker (2005) closing prices of actual electricity futures prices were used when estimating their one-factor model. This approach becomes impractical when more advanced multi-factor models are considered. In this chapter, they follow the approach that is standard in the literature on estimating dynamic term structure models, where yield curves are estimated from real world fixed income assets (typically treasure bonds).

The Nord Pool Market and Financial Contracts

The major advantage in working with estimated data, is that on each day the term structure can be specified to have a fixed delivery structure. They wish to preserve the market's delivery structure of each day through-out the sample period for their data set.

Preparing Data Set

This is accomplished in the following way.

1) All electricity futures prices at Nord Pool in the period 2 january 2001 until 1 December 2006 (1479 trading days) are collected (except contracts with 24 hours delivery period). Zero coupon bond prices in NOK and EUR are collected from Reuters.

2) During the sample period Nord Pool has made a complete transition from contracts denominated in NOK to EUR. All electricity futures prices are converted to EUR using the formula in Prop. 4.5.

Reminder: Currency Conversion for Forward and Swap Prices: Swaps

The proposition below shows how foreign and domestic swap prices arwe related through a change of currency.

Proposition 4.5. Suppose that

$$\begin{array}{rcll} E_Q[\int_{\tau_1}^{\tau_2} |w(u,\tau_1,\tau_2)X(u)|du] & < & +\infty & and \\ E_Q[\int_{\tau_1}^{\tau_2} |w(u,\tau_1,\tau_2)S(u)|du] & < & +\infty. & \end{array}$$

Foreign and domestic swap prices are realted in the following way

$$F(t,\tau_1,\tau_2) = \int_{\tau_1}^{\tau_2} w(u,\tau_1,\tau_2) f_{FRA}(t,u)du \times F^*(t,\tau_1,\tau_2).$$

Preparing Data Set

3) We estimate a smooth curve for each day in the sample period using the maximum smoothness approach described in Chapter 7.

4) Finally, we use the smooth forward curve to compute electricity futures prices with delivery structure specified below.

Preparing Data Set

They prepare different data sets. The first four are individual data sets for weekly, monthly, quarterly and yearly contracts, respectively. They introduce a sequence of delivery periods for the different contracts

$$\{[\tau_1^b, \tau_1^e], ..., [\tau_C^b, \tau_C^e]\},$$

where the following conditions apply:

$$\begin{aligned} i) \tau_c^b - \tau_c^e &= \Delta, \quad for \quad c = 1, 2, ..., C \quad (\Delta \quad is \quad a \quad constant) \\ ii) \tau_{c+1}^b &= \tau_c^e, \quad c = 1, 2, ..., C. \end{aligned}$$

Preparing Data Set

The first condition implies that the data consist of contracts with delivery period of equal length. The second condition implies that the market is such that the end of the delivery period for one contract coincides with the start of the delivery period for the contract which is next in line along the term structure. The condition ensures that the contracts are non-overlapping and mimicking the real world contracts traded at Nord Pool.

For each data set we have

$$\tau_c^b = (c-1)/\Delta \quad and \quad \tau_c^e = c/\Delta \quad for \quad c = 1, 2, ..., C.$$

Preparing Data Set

The first contract starts delivery immediately. The next contract along the term structure trades for a period Δ until it enters the delivery period. The third contract along the term structure trades for 2Δ, etc. The delivery structure for their four data sets is summarized in Table 8.1 (next slide).

Descriptive Statistics

See additional pdf-file with Tables and Figures (sections 8.3-8.7)

The End

Thank you very much for your attentiona and time!

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Go, Canada, Go!