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Electricity Futures Prices: Indirect Storability, Expectations, and Risk Premiums☆

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ABSTRACT

The goal of this paper is to examine to what extent electricity futures prices contain expected risk premiums or have power to forecast spot prices and whether this might be dependent on the type of electricity supply. We analyse futures prices from the Dutch market, a market in which power is produced with storable fossil fuels, and futures prices from the NordPool market, where electricity is mostly produced by hydropower. We show that futures prices from markets in which electricity is predominantly produced by imperfectly storable fuels such as hydro, wind and solar contain information about expected changes in the spot price of electricity, whereas futures prices from markets in which electricity is predominantly produced with perfectly storable fuels contain information about both expected price changes and time-varying risk premiums. These findings provide insight in the applicability of forward price models; one cannot apply the same model to all electricity markets. Forward models for markets with imperfect indirect storability should depend heavily on price expectations and models should include time-varying risk premiums for markets with perfect indirect storability.

1. Introduction

In this paper, we focus on the prices of electricity futures contracts.[1] When a buyer and a seller trade an electricity futures contract, the buyer agrees to purchase an amount of electricity during a future delivery period from the seller and to pay a fixed price per MWh. This is called the futures price which is agreed upon at the moment of the trade.

(Fama and French, 1987) summarise the two views on commodity futures prices. The first is the theory of storage which points out that traders can offset the risk of positions they have in forward contracts by holding a long or short inventory in the underlying commodity. For instance, when a trader sells a forward contract that involves the delivery obligation of some commodity at a future date against a price fixated today, she can purchase the commodity directly on the spot market, store it, and deliver it at the maturity date directly from inventory. Her delivery obligation is then covered and, hence, the prices she quotes for delivery at that future time period depends on the current spot price of the commodity, financing costs (interest), warehousing costs, and a convenience yield that accounts for the expected additional value of inventory. The second theory, the expectations theory, does not explain forward prices from storability. It describes that the forward price of a commodity equals the expected spot price of the underlying commodity during the delivery period plus an expected risk premium that compensates producers for bearing the uncertainty of delivering against fixed prices. Fama and French (1987) argue that the two theories are not mutually exclusive as variation in expected future spot prices or in the expected risk premium under the expectations theory translates into variation in the interest rate, warehousing costs and the convenience yield.

The expectations theory is the starting point for many electricity forward price models. This view is dominant because electricity is not directly storable and it makes therefore sense to start out from the expectations theory instead of the theory of storage. The price of an electricity forward contract is seen to reflect the expected spot price during the delivery period plus or minus a risk premium. The literature focuses therefore on modelling expectations or risk premiums.

Lucia and Schwartz, (2002) focus primarily on expectations. They derive a formula for the forward price of electricity by modelling the expected spot price during a future time period. The expected spot price equals the sum of two prices: an equilibrium long-term spot price level and a mean-reverting short-term price. In addition to these expectations, they assume a constant risk premium.[2] They

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[1] We assume no differences between futures and forward contracts and we shall use both words in the text as synonyms.

[2] Two risk premiums actually: one for each source of uncertainty (long-term and short-term price uncertainty).

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successfully fit their model to NordPool (NPX) electricity futures prices. This approach origins from the factor models was introduced by Schwartz (1997) and the later extension into a long-term / short-term price model by Schwartz and Smith, (2000).

Others focus more on (variation in) the risk premium instead of expectations. By subtracting average realised spot prices during the delivery periods from historically observed forward prices and assuming that trader expectations are unbiased in the long run, risk premiums can be studied empirically. This approach is applied by Wilkens and Wimschulte, (2007) who examine futures prices on the German EEX market. They find positive but highly volatile risk premiums for futures contracts with times to maturity up to six months. Kolos and Ronn (2008) confirm this result as they find positive risk premiums for EEX forward prices as well. Regarding futures prices in the Nordic market, Gjolberg and Johnsen (2001) and (Botterud et al. (2002) identify positive risk premiums for futures contracts with a time to maturity up to one year. Lucia and Torró (2008) find significant positive risk premiums in weekly NPX electricity futures contracts. Weron (2008) determines the market price risk in the NPX futures market using stochastic models. The author finds decreasing risk premiums with increasing time to maturity. These empirical studies shed light on the sign and variability of the risk premiums. Other studies provide insight in factors that explain risk premiums. Benth et al. (2008) provide a framework that explains how the market risk premium depends on the risk preferences of market players and the interaction between buyers and sellers. The authors argue that the risk premium for the EEX forward contracts depends on two factors; the level of risk aversion of buyers and sellers and secondly on the market power of producers, relative that of buyers. Bessembinder and Lemmon (2002) study the electricity forward risk premium by modelling the industry and the demand and supply of forward contracts. Forward prices are biased predictors of future spot prices and the forward risk premium is negatively related to the variance and positively related to the skewness of expected electricity spot prices. Longstaff and Wang (2004) conduct an empirical analysis of the forward risk premium by using hourly prices. They state that the risk premiums are time-varying and directly related to economic risk factors, such as the volatility of unexpected changes in demand, spot prices, total revenues and the risk that the electricity transmission system reaches its capacity limit. These findings are consistent with Bessembinder and Lemmon (2002). The results of Cartea and Villaplana (2008) are also in agreement with the model of Bessembinder and Lemmon (2002). Interestingly, Cartea and Villaplana (2008) find negative risk premiums, indicating backwardation, in the American PJM, English and Welsh and Nordic NPX markets. Bühler and Müller-Mehrbach (2009) develop a dynamic generalisation of the static model by Bessembinder and Lemmon (2002). In the empirical analysis end-user demand is included and the cost function depends on the water reservoir level. The authors find for the NPX market on average, positive risk premiums for week futures and negative risk premiums for block futures. Besides Bessembinder and Lemmon (2002), Routledge et al. (2001) also consider an equilibrium pricing model with rational expectations for electricity prices. In particular, they observe that the potential storability of electricity in the form of fuels has stimulated the exploration of the relationship between electricity and fuel prices. Douglas and Popova (2008) and (Bloys van Treslong and Huisman (2010) relate empirically forward risk premiums to indirect storability as they show that higher natural gas inventory levels reduce the forward risk premium in the PJM market, especially during extremely warm and cold periods. Redl and Bunn (2011) conduct a multi-factor analysis to study how the risk in spot price formation induces a counteracting premium in electricity forward contracts. The authors show that the forward premium in electricity is a rather complex function of fundamental, behavioural, dynamic, market conduct and shock components. The main findings are that the market price of risk in electricity is actually that of its underlying fuel commodity gas and that increased oil price volatility also increases the forward premium. From this we can conclude that indirect storability of power influences forward risk premiums.

All these studies model electricity futures prices as a combination of an expected spot price and a risk premium, the two components suggested by the expectations theory. Either the expected spot prices are explicitly modelled or the risk premiums. From literature it is obvious that electricity futures prices contain expected risk premiums or have power to forecast spot prices, however it is unclear whether this might be dependent on the type of electricity supply. This is the goal of this paper. We follow the method proposed by Fama and French (1987) and Fama (1984) and examine whether we find evidence for forecasting power and/or expected risk premiums in electricity futures prices with a difference in marginal fuel. According to the generation stack function the price is set at the marginal cost of the last unit called when all demand is satisfied. The marginal fuel will eventually determine the price, because in perfect markets prices equal marginal production costs.

In order to examine the relation between the type of power supply in a market and the extent to which futures prices contain forecasts and/or premiums, we distinguish between two types of electricity supply. The motivation from this comes from the theory of storage. Electricity is not (yet) directly storable, but at least it is indirectly storable in the sense that (fossil) fuels can be stored and evidence that traders use this to value electricity forward prices is found by Douglas and Popova (2008) and Bloys van Treslong and Huisman (2010). This holds for fossil fuels such as natural gas, coal, and heating oil. These fuels are storable and can be traded in relatively liquid spot and futures markets. Traders use these characteristics to their discretion. For instance, when an electricity producer sells a futures contract on electricity, she can directly fulfill the delivery agreement by purchasing the amount of fuels needed in the spot market and store it until the delivery period, during which she converts the stored fuel into electricity with a power plant. Equivalently, she can purchase a futures contract on the underlying fuel instead of storing it.[3] These characteristics are different for renewable energy supply such as wind, solar, and hydro. A wind power producer that sells an electricity futures contract cannot store the wind needed on beforehand to produce electricity at a later date nor can she trade in a wind futures contract. There is more flexibility in hydro power since water can be stored in basins, however capacity in the long run depends on unexpected weather conditions such as rainfall. Run of the river can also generate hydro power, however with this type even considerably smaller water storage or none is used to supply a power station. Futures contracts on water are also absent.

When traders sell a forward contract they anticipate on the expected level of water in the basins and therefore on expected rainfall and such. It is more difficult for them to hold an exact inventory of water needed to fuel their power obligations. We therefore distinguish between two types of indirect storability in the electricity market, perfect indirect storability when the underlying fuel can be stored and futures on the underlying fuels can be traded and imperfect indirect storability when the underlying fuel capacity depends on expectations (such as windspeed, solar output and rainfall) and futures contracts on the fuels are not traded (at least not in a relatively liquid market).

We expect that the extent to which electricity futures prices contain expected risk premiums and/or forecasts of expected future spot prices differs between electricity futures prices in case of perfect indirect storability and imperfect indirect storability. In order to examine this, we analyse prices from two markets: the Netherlands

[3] In fact, storing the underlying fuel is then likely undertaken by the seller of that futures contract.