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Electricity long-term contract valuation using rollover hedging*

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Abstract

This paper proposes a market-based method to provide a selling price for long-term contract on electricity market. In market-based approaches, one searches to fulfil a given long-term commitment only by selling and buying available futures contracts on the market. The price of the contract is then given by the cost of the best available hedging strategy. Here, the hedging strategy is based on rolling futures of the longest maturity, i.e. successively selling and buying back the futures with the same maturity. To implement this rollover strategy, we extend a two-factor model of the forward curve to be able to model prices for newly quoted contracts. Prices for new maturities are generated with a random process. Since this whole modelling process results in an incomplete market, the price for the long-term contract is defined by a risk criterion. The standard Value at Risk measure is used. The efficiency of this methodology is assessed both using Monte-Carlo simulations and a real life experiment of what would have occurred if this method had been applied in the past. We show that, in standard market conditions, a mid-term contract between five to ten years maturity base load contract can be sold at a 95% risk level with a premium not exceeding 5% of the current price of the longest futures maturity. We also show that liquidity constraints do not increase signficantly this risk premium.

Keywords: long-term contract, electricity market, reference price, rollover strategy, hedge.

JEL Classification: G12; G23. **AMS Classification**: 91B28.

The objective of this paper is to present how a market-based method provides a market reference price for electricity long-term contract. In the electricity and gas industry, producers often try to hedge their physical assets of which lifetime considerably exceeds the market longest maturity by selling their output with long-term contracts. For instance, contracts with a maturity of 25 years are not uncommon. Since electricity markets do not give any hint on what could be the price for a delivery beyond three years, both parties (producer and customer) are facing a difficult problem when they want to find an agreement on a price. On one side buyers argue that prices should allow producers to recover all their costs (investment, fuel, M&O and capital). On the other side, producers who are exposed to the spread between fuel and electricity prices fear a raise of the first and a collapse of the second. Hence, they

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would like to get a premium to cover these risks. The contract price will result in an equilibrium that depends on current economic conditions and on the relative risk aversion of both parties. Generally reference prices for long-term contract are established using a cost-based approach.

In a cost-based approach the contract price is settled using the investment cost of a specific generation asset. The asset valuation is traditionally performed by a net present value estimated at a risk-adjusted rate of return to take into account the cost of capital of the firm. Cost-based approaches do not exclude complex pricing formulas and the use of market prices of fuels. One can find, for instance, in Joskow's work [Joskow, 1985] a detailed description of the different ways the electricity industry tackles this problem in the case of coal firing plants. The solutions may involve pure fixed-price contract, indexation formulas on fuel prices and inflation, cost-plus approach and mixtures of these three pricing techniques. Nevertheless, this approach presents some drawbacks. The development cost of a specific asset is computed w.r.t. a given lifetime whereas long-term contracts maturities may significantly differ from it. Moreover this approach implies to compute a reference price per asset and cannot be straightforwardly generalized to the global long-term cost function of the producer. And finally, it is conservative, i.e. it provides the minimum price allowing producers to recover their costs but, it generally produces a reference price which has little relation with the current level of electricity market prices. These methods do not provide any information about the market value of the long-term contract.

Market-based approaches allow to overcome this difficulty. In their framework, the price of a long-term commitment is defined as the cost of the best available hedging strategy. A given long-term commitment is fulfilled only by selling and buying available futures on the market. Those methods give thus a hint about the market value of a long-term commitment. Generally, the hedging strategy requires rolling a position, i.e. selling and buying back contracts of the same maturity. It is well known that one should be cautious when trying to hedge a long-term commitment with short-term futures. In the early 1990s, such an attempt led to a financial disaster on the oil market (see comments & discussions on Metallgesellschaft disaster in Culp and Miller [1995], Mello and Parsons [1995], Kuprianov [1995], Miller [1996], Pirrong [1997], Verleger Jr. [1999]). Nevertheless, this attempt was based on the assumption that the forward curve for the Western Texas Intermediate (WTI) would stay in backwardation and was not based on a modelling effort of the forward curve dynamic and a quantitative analysis of the financial risk of the operation. And Galli and Lautier [2010] recent work shows that this methodology is currently used in the oil market.

In this paper, we propose to show that the methods proposed by Galli and Lautier [2010] can provide information on the commercial value of a long-term contract for baseload power delivery. Modelling the forward curve dynamic and measuring the financial risk are the two pillars of market-based approaches for long-term commitments valuation. To model the forward curve dynamic of electricity, one can either follow Schwartz's seminal work [Schwartz, 1997, 1998] that was used to price long-term contracts on oil or copper or turn to a direct modelling of the forward returns as in Clewlow and Strickland [2000, chap. 8] or in Benth et al. [2008, chap. 6]. Schwartz [1998]'s approach consists in modelling the commodity spot price with a two-factor model. The first factor represents the spot price itself and the second one represents the convenience yield. This model succeeds in reproducing some important stylised facts about commodities price behaviour such as mean-reversion and volatility term structure. Moreover, it allows analytic computation of the entire forward curve, even for maturities for which the market does not provide a price. Sensitivities of a long position w.r.t. a movement of any maturity of futures prices admit also closed-form formulas. Thus this framework makes it possible to compute easily both a market price of a long-term commitment and the quantity of futures, one has to sell or buy to hedge the position. Moreover since this framework results in a complete market model, any commitment can be perfectly hedged and there is no need to introduce a risk criterion. Nevertheless in our context, this model presents some drawbacks. The problem does not come from the modeling of spot price of electricity. Since we deal only with baseload forward contracts which can be hedged with baseload traded futures, the difficulties involved in the modelling of hourly electricity spot prices (seasonality, spikes...) are not an obstacle. More important to our problem, Schwartz's two-factor model cannot reproduce the futures prices curve observed at the time of the valuation. In his framework, the futures prices are deduced from the current spot value and the estimation of the parameters of the model. Hence, quoted futures prices and model values may differ.

Market operators generally prefer models in which derivatives prices are consistent with the current observed prices to avoid potential arbitrages. For this reason, direct models of the observed forward curve as proposed in Clewlow and Strickland [2000, chap. 8] are more frequently used. In this framework, futures returns are given by a relation such as:

$$\begin{aligned} \frac{dF}{F}(t,T) &= \sum_{i=1}^{N} \sigma_i(t,T) \cdot dz_i(t) \\ F(t_0,T) &= F_0(T) \end{aligned}$$

where N is the number of random factors, T represents a given term (and not a constant maturity), $\sigma_i(t,T)$ are the volatility functions, and $F_0(T)$ is the initial forward curve. Generally, two factors are enough to recover a large part of the forward curve dynamic (see Clewlow and Strickland [2000] chap. 7 for an application on the oil market). Nevertheless, contrary to Schwartz's model, this framework cannot provide a price for all maturities. It only provides a modelling of the current quoted contracts. It needs to be adapted to take into account the evolution over time of futures contract prices that are not available at time t_0. This adaptation is made necessary here since the hedging strategy for long-term contracts involves rolling a position with constant maturity contracts. In the standard case, long-term commitment will be hedged using Three Year-Ahead contracts (3YAH). Most of the contracts used in the rollover hedging strategy are not available at the valuation date. Thus as in Neuberger's approach [Neuberger, 1999], we introduce an innovation process to determine the first quotation price of these contracts. In our model, the new 3YAH contract price is valued as the previous 3YAH contract plus a random innovation. Although small w.r.t. the current quoted price, this random innovation represents nonetheless an issue for long-term contracts valuation because they cannot be hedged and may have a cumulative effect over time (see section 1.3). In our model, they are represented as a simple Gaussian noise. Nevertheless, our whole modelling process of the futures prices results in an incomplete market. We defined then a risk criterion to determine the reference price. We have chosen to use a standard Value at Risk criterion. Moreover, we have also developed an hedging strategy to take into account liquidity constraints. Indeed, the liquidity of 3YAH contracts is rather small compared to the possible need of a hedger. The open interest for 3YAH base load contract is about ten, whereas 1YAH contract is one thousand, and Month Ahead contract is three thousand contracts[1]. We sudy then an hedging strategies based on the rolling of Month-Ahead contracts to take into account liquidity constraints. This alternative hedge method allows us to analyse the cost of liquidity in the long-term contract valuation.

The paper is organised in the following way. In section 1, the precise long-term electricity contract to hedge and price is described, together with the forward curve model. Section 1.3 is devoted to description of the different hedging strategies and the definition of the hedging price. Numerical tests are

[1] See www.eex.com for data on open interest for futures contract on electricity.

presented in section 2. Those tests consist in both Monte-Carlo simulations and a real life experiment process which shows what would have occurred if this method had been applied in the past. We finally conclude in section 3 on the interests and limits of this methodology.

1 Problem, price model and hedging strategies

In this section, we present the characteristics of the long-term contract to be hedged (section 1.1), together with the electricity forward price models (section 1.2) and the different hedging strategies we used (section 1.3). For a description of electricity market products and clearing mechanisms, we refer the reader to Clewlow and Strickland [2000], Eydeland and Wolyniec [2002], Géman [2007], Burger et al. [2008]. For a detailed descriptions of statistical properties of electricity prices, we refer the reader to [Benth et al., 2008]'s book, Geman and Roncoroni [2002] and Meyer-Brandis and Tankov [2008]. Here, the main features of electricity market the reader has to know is that forward electricity contracts correspond to delivery of power during a given period and not at a single date. They involved both a delivery term (T) and a delivery period (θ). Contracts being exchanged on markets (either OTC or through a clearing house) are named according to the date of the delivery and the period of a delivery. The contract December09 Baseload refers to the delivery of one MW during each hour of all the days during the month of December, 2009, whereas the contract 1Q10 Baseload refers to the delivery of one MW during each hour on the period of time going from January, 1st 2010 00:00 am and ending on March, 31st, 2010, 12:00 pm. The shortest maturity exchanged in electricity markets is the Week Ahead maturity (Nordpool), but our study will be conducted using public data available on the French power market PowerNext [2] and only Month-Ahead contracts can be traded there. The longest maturity quoted on PowerNext is the 3 Year Ahead contract (3YAH). In the context of long-term electricity commitment, the problem mainly depends on forward contracts with a yearly period delivery and we do not have to deal with specificities of hourly spot prices (spikes).

1.1 Long-term commitment

We consider an electricity long-term contract between a retailer (seller) and a customer. This contract implies the delivery of a constant power during the delivery period, starting at the beginning of a future year T and ending at the end of this year. Since the maturity T exceeds the market maturity, our problem is to find at which constant price K, the retailer is ready to sell this contract. The sale price K depends on both the uncertainties on electricity future prices and the chosen hedging strategy. The main issue is that the long-term delivery cannot be hedged directly on the electricity futures market. As mentioned before, the long-term commitment is a forward contract that will be quoted three years before T. Hence, the retailer knows that the market will determine the value of its commitment at time $T-3$ and that she will be able to buy it. Nevertheless the retailer hedging strategy must take into account two constraints of futures market for electricity. There is a time horizon constraint: the set of available futures does not immediately contain the long-term delivery period. And there is a liquidity constraint: the 3YAH futures contract is not liquid and only short term contracts are liquid. The time horizon constraint is handled with a rollover mechanism: buying and reselling 3YAH as soon as a new contract appears. The liquidity constraint is handled by replacing the 3YAH contract in the rollover strategy with shorter maturity contracts.

[2] see www.powernext.fr for details on available data.

1.2 Price model

Figures 1 and 2 column (a) illustrate the price dynamics of futures contracts on electricity. One can see that month-ahead products are more volatile than quarter-ahead contracts, which are themselves more volatile than year-ahead contracts. Moreover, the prices of a given maturity (month, quarter or year-ahead) follow a geometric Brownian motion when it corresponds to a given contract. Prices are perturbed by jumps each time the contract expires and is replaced by a new one with the same maturity (see Figure 1).

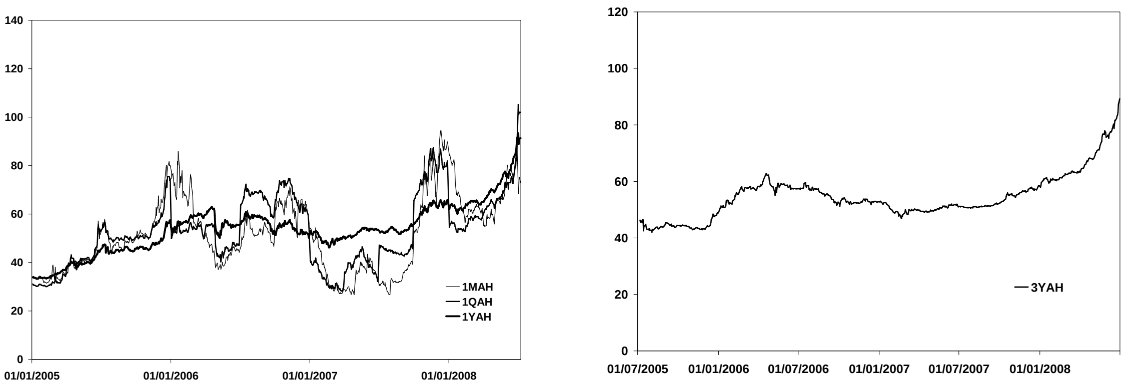

Figure 1: Historical prices of the 1MAH, 1QAH, 1YAH and 3YAH from 01.01.05 to 12.31.08 - Powernext data.

To reproduce these features, the price model used in this framework is based on the classical two-factor model developed by Clewlow & Strickland (see [Clewlow and Strickland, 2000] chap. 8) for the price dynamics of quoted futures contracts:

$$\frac{dF}{F}(t,T,\theta) = \beta_L \cdot dz_L(t) + \beta_C \cdot \alpha(T-t,\theta) \cdot dz_C(t) \tag{1}$$

where $F(t,T,\theta)$ is the price of the forward contract at time t, that will expire in T for a period of delivery equal to θ. The increments of Brownian motions dz_L and dz_C are correlated:

$$dz_L(t) \cdot dz_C(t) = \rho(t) \cdot dt.$$

In this model, the first random term affects all of contracts in the same way, independently of their maturities. On the contrary, the second one allows to model the fact that short-term products have a larger volatily. The function α is choosen so that its effect is neglegible on long-term contracts. We use:

$$\begin{aligned} \alpha(T-t,\theta) &= \frac{1}{\theta}\int_0^\theta e^{-a(T+x-t)}dx \\ &= \frac{e^{-a(T-t)}}{a\cdot\theta}(1-e^{-a\cdot\theta}) \end{aligned}$$

where the parameter a is the mean-reversion coefficient.

This setting has to be completed to take into account the apparition of new quoted contracts. Indeed the last contract of which price can be modeled with relation (1) is the 3YAH contract. Therefore we

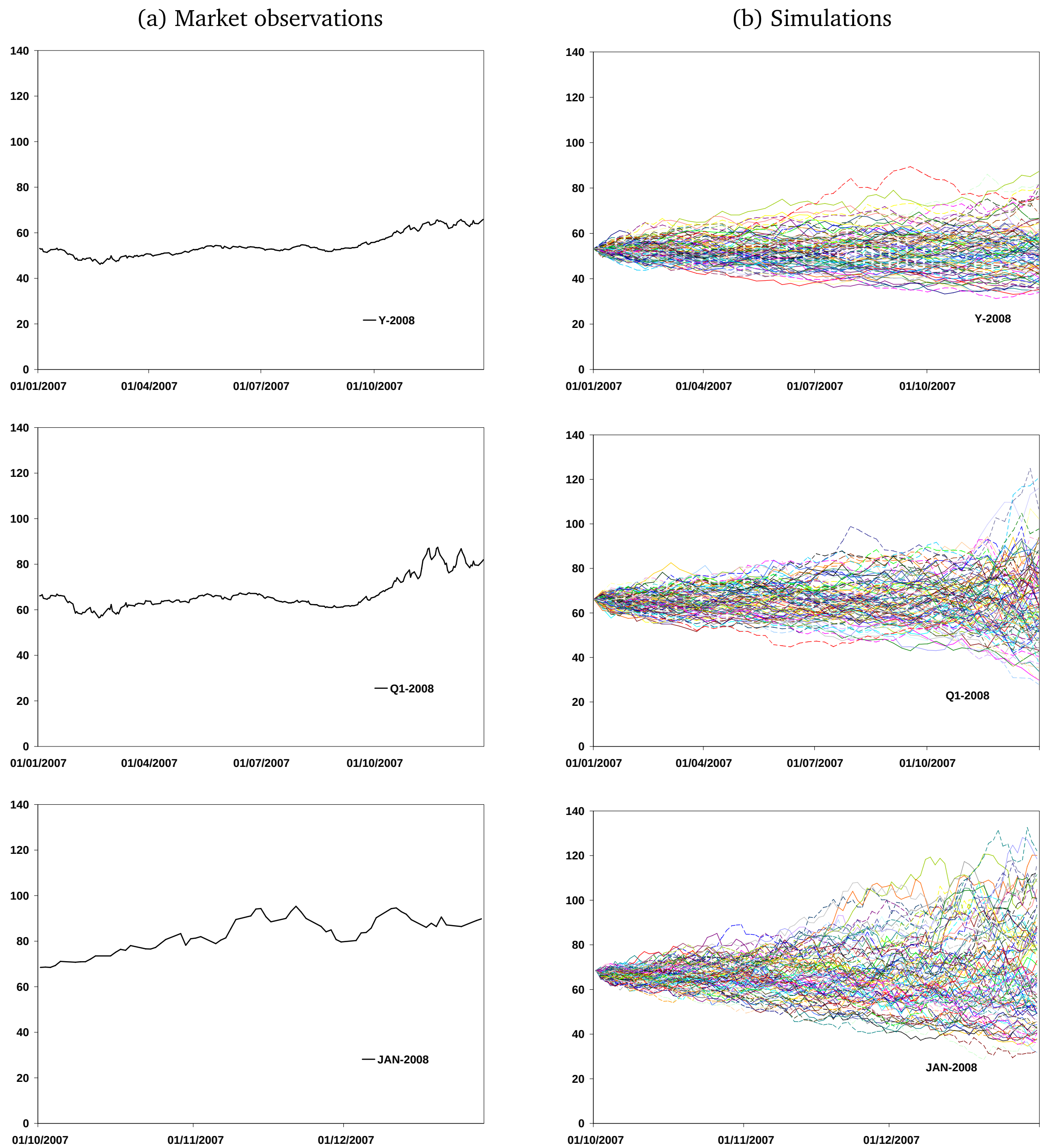

Figure 2: (a) historical prices for the contracts JAN08, Q12-2008 and Y2008 (Powernext data); (b) simulated prices obtained using model (1).

use the following procedure to model the price of newly quoted contracts. At time $t_1 > t_0$, there are two possible situations for new quoted contracts:

- the product did not exist at t_0 but was a part of a quoted product that was already available. It is the case for the first quotation of a 3MAH, which was embedded in a 1QAH contract. Then we use historical seasonal coefficients to deduce the price from the embedding product.

- the product did not exist and was not embedded in any other contract. It is the case, every first day of the year, for the 3YAH contract. In this case, the price of the new quoted contract is given by the sum of the last quotation of the former 3YAH plus a gaussian innovation.

These rules together with the model (1) allow us to generate and simulate prices beyond market horizon. Figure 3 shows an example of the 3YAH contract dynamic obtained using this feature with an exagerated level of volatility for the jumps. We took a volatility of 15% to make their effect visible. On the 3YAH prices observed on PowerNext from July, 6th 2005 to June, 30th 2008, the average value of the annual jumps represents 1% of the current 3YAH price. Although small with respect to the range of the 3YAH returns which are of a magnitude of 2% (see Figure 3), these jumps have a cumulative effect on the value of a long-term commitment as we will see in section 2.

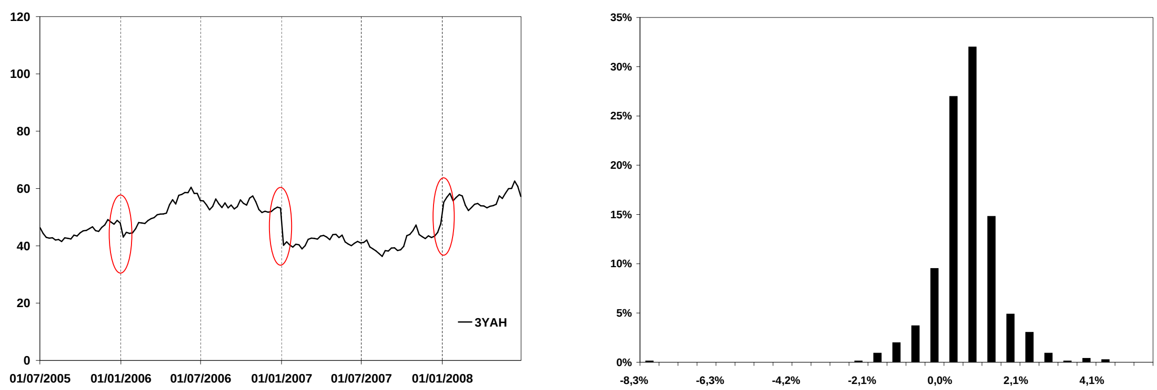

Figure 3: 3YAH contract simulated price, from January 2005 to June 2008 with a null mean and a volatility of 15% for the jumps; frequency diagram of observed returns for the 3YAH.

1.3 Hedging strategies for a long-term contract

To hedge a long-term commitment, the rollover strategy consists in buying a certain percentage of available futures contract according to futures prices fluctuations. Each time a new futures of the same maturity is made available by the market, we should sell our long position to buy this new available contract. This general strategy can be implemented in two ways whether liquidity is taken into account or not. When liquidity is neglected, the rollover strategy is implemented by selling and buying only the futures of the longest maturity available. Since we made the assumption that the price of new quoted contract are given by the sum of the price of the futures of longest maturity and a random jump, one can hedge the fluctuations of this contract, and only these fluctuations, by buying one futures. We will refer to this strategy as Perfect Rollover Strategy. In that case, the selling price depends only on the innovation jumps. When liquidity is considered, one has to replace the insufficiently liquid available longest futures by a combination of two liquid short-term futures. Given two contracts characterized by their respective maturities T_1 and T_2 and their delivery periods θ_1 and θ_2, according to our two factor model (1), there exists $w_1(t)$ and $w_2(t)$ such that:

$$dF(t,T,\theta) = w_1(t)\cdot dF(t,T_1,\theta_1) + w_2(t)\cdot dF(t,T_2,\theta_2). \tag{2}$$

The weight coefficients w_1, w_2 are given by:

$$w_1 = e^{-r(T-T_1)} \cdot \frac{F(t,T,\theta)}{F(t,T_1,\theta_1)} \cdot (1 - \frac{\alpha(T-t,\theta) - \alpha(T_1-t,\theta_1)}{\alpha(T_2-t,\theta_2) - \alpha(T_1-t,\theta_1)}) \tag{3a}$$

$$w_2 = e^{-r(T-T_2)} \cdot \frac{F(t,T,\theta)}{F(t,T_2,\theta_2)} \cdot \frac{\alpha(T-t,\theta) - \alpha(T_1-t,\theta_1)}{\alpha(T_2-t,\theta_2) - \alpha(T_1-t,\theta_1)} \tag{3b}$$

where r is the risk free rate. We will refer the strategy that uses two futures contracts with the former hedging ratio as the Illiquid Rollover Strategy.

2 Numerical application

The efficiency of the rollover strategies described in the preceeding section is measured using both Monte-Carlo simulations (section 2.1) and a real-life experiment consisting in a back-testing procedure (section 2.2). The effect of liquidity is assessed in both situations. Moreover, the rollover strategy is compared in both cases with the naive strategy consisting in waiting for the apparition of the futures corresponding to the long-term commitment. Although somehow unrealistic, this comparison allows seeing the drastic risk reduction procured by a rollover strategy.

2.1 Monte Carlo simulation

Monte-Carlo simulations were performed using electricity futures prices described by the model (1) and where the parameters have been estimated on PowerNext data. Table 2.1 provided the values of the different parameters for the two-factor diffusion process and the innovation jumps for the 3YAH. The short-term volatility (β_C) has an effect only when the illiquid rollover strategy is used. We made the assumption that the innovation jumps was a white noise ($\mu = 0$). Moreover the mean-reversion coefficient (a) corresponds to a half time of fifty days, which is a rather fast decaying speed for the futures prices. But it corresponds to current observations and values used in the literature (see [Clewlow and Strickland, 2000] chap. 2.9 for the mean-reversion of gas prices).

β_C	β_L	a	ρ	μ	σ
120%	20%	5	0	0	1%

Table 1: Parameters value for the two-factor diffusion process of futures prices and innovation jumps.

All simulations start on June 30th 2008 and hedge the long-term commitment consisting in the 2020 contract. At that date, the 3YAH was quoted 89.3 euros/MWh. The risk premiums are given as a percentage of the 3YAH price quoted at the beginning of the study period. The Perfect Rollover Strategy uses only 3YAH contracts to hedge the Year 2020 whereas the Illiquid Rollover Strategy uses a combination of 1MAH and 1YAH whose weight are given by relations (3). The hedging strategies are implemented with a frequency of one hedge per week. This low frequency is considered to be more realistic from an operational point of view, since hedging a ten-year contract with a daily frequency would lead to important transaction costs. To measure the benefit for a retailer of the effort involved in these two strategies, we compare it with a simple Wait & See strategy. This last strategy consists in waiting for the apparition of the futures contract corresponding to the long-term commitment, and then, buying the contract. In this case, the price $K_{w\&s}$ is also determined such that it guarantees that the cash-flows from the retailer are positive in 95% of the cases. Using this strategy, the retailer would ask for a risk premium of 144% (the selling price would be as high as $K = 213$ euros/MWh) to be able to recover a positive cash-flow at maturity in 95% of situations (see Figure 4 for the distribution of the Y2020 on January, 1st 2017). This price is more than twice the current price proposed by the market for the 3YAH.

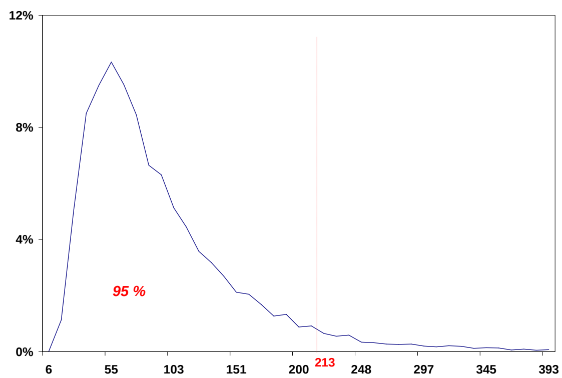

Figure 4: Distribution of the simulated price of the Year 2020 on January, 1st 2017 as seen from June, 30th 2008 and corresponding reference price for a Wait & See strategy

On the contrary, rollover strategies propose a selling price, which is close to the current quoted 3YAH. As it can be seen on Figure 5, the perfect rollover strategy leads to a risk premium of nearly 5% (the selling price would be 94 euros/MWh). When illiquidity is taken into account with a hedge frequency of one transaction per week, the premium increases to 6% (the selling price would be 95 euros/MWh). This difference is quite non significant compared to the selling price. And in fact, the sensisity analysis performed on the hedge frequency (see Figure 6 (b)) shows that the increase of hedging frequency can drastically reduce the risk premium required to hedge the long-term contract but all this reduction effect is captured with a weekly hedge. The volatility for the innovation is fixed at its nominal level of 1%. The risk premium can be drawn down from a level of 8% for a lazy monthly hedge to a range of 5% by implementing at least a weekly hedge. No significant gain is obtained by increasing then the hedge frequency.

We also performed a sensitivity analysis on the innovation volatility. This sensitivity analysis is performed considering a Perfect Rollover Strategy with a weekly hedge. Its effects are presented in Figure 6. The premium grows linearly w.r.t. the volatility of the jumps. This point is not surprising since our risk criterion is a quantile of the cash-flow distribution and that the quantile depends linearly on the standard deviation of the innovation jumps.

Finally we measured the effect of the time to delivery of the long-term commitment on the risk premium. We performed rollover strategies for different terms (4YAH, 5YAH, 6YAH, 7YAH, 8YAH, 9YAH, 10YAH, 15YAH, 20YAH, 30YAH) with a weekly hedge. We observed on Figure 7 that the premium required to hedge a long-term commitment grows as $\sqrt{T}$ which is consistent with a Gaussian model for the innovations of the 3YAH. The growth rate depends more on the level of the innovation risk (1%

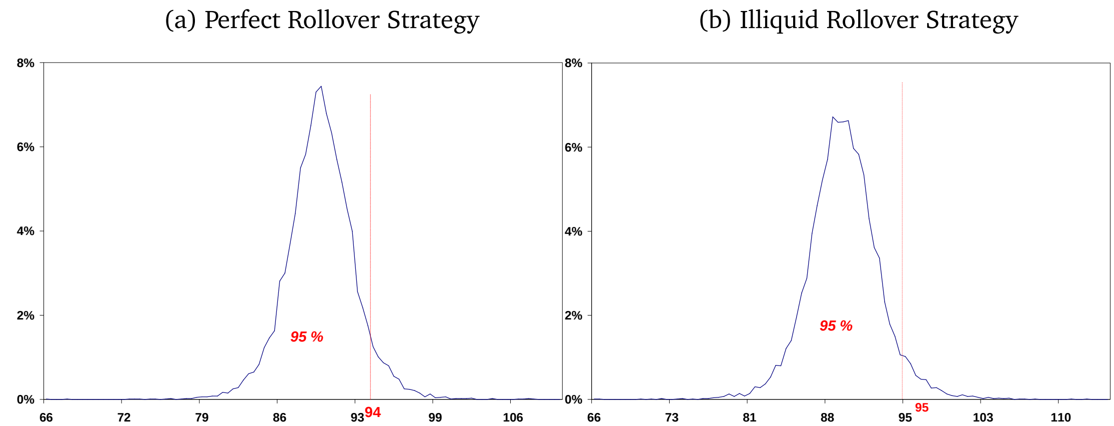

Figure 5: (a) Distribution of the simulated supply costs to hedge the Year 2020 as seen from June, 30th 2008 with the Perfect Rollover Strategy (b) Same result with the Illiquid Rollover Strategy.

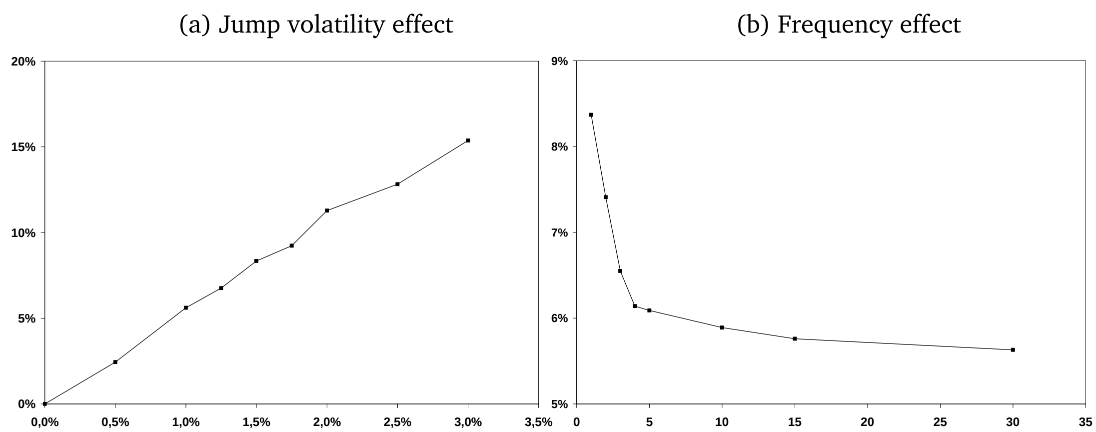

Figure 6: (a) Risk premium to hedge the Year 2020 with a Perfect Rollover Strategy as seen from June, 30th 2008 expressed as a percentage of the quoted 3YAH at that date for different levels of jump volatility (b) Liquidity risk premium to hedge the same contract with a Illiquid Rollover Strategy with 1% jump innovation for different replication frequencies going from 1 time per month to 30 times per month.

vs 2%) than on the hedging conditions (Perfect vs Illiquid Rollover). This remarks allows performing a simple computation to give an estimation of the risk premium for a contract for delivery during 10 years by interpolation of the missing premiums (11YAH, 12YAH, 12YAH). In the case of a model with 1% innovation, it gives a premium of 3.5% for both rollover strategies.

We can summarize our different findings in this way: In current market conditions given by model parameters as in Table 2.1,

- it is possible to deliver a baseload power contract with a time to delivery of 10 years with a risk premium not greater than 5%of the current 3YAH baseload contract by implementing a rollover hedge with a frequency not greater than one hedge per week,
- increasing the hedging frequency beyond a weekly hedge does not provide significant gain,

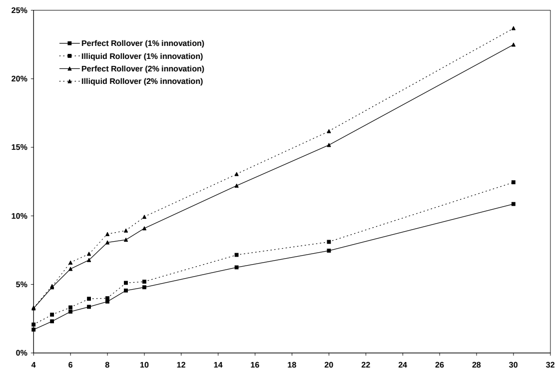

Figure 7: Premium as a percentage of the current quoted 3YAH as a function of the long-term contract time to delivery for two different levels of innovation volatility

- liquidity constraint does not increase signficantly this risk premium,
- the risk premium is proportional to the volatility of the innovation jumps.

2.2 Real life experiment

To assess the efficiency of the rollover pricing and hedging methods for long-term contract described above, we performed a real life experiment. The idea is to go back in time and to use the rollover hedging strategy to price and hedge a futures contract on baseload power that was not quoted at that time but that has been finally quoted. We choose to go back in June 2005, the 8th. At that particular date, PowerNext was quoting the years 2006 (1YAH), 2007 (2YAH) and 2008 (3YAH). The 3YAH contract was quoted 39.6 Eur/MWh. The years 2009, 2010 and 2011 were not quoted yet. For each of these years, we computed then the price proposed by our two rollover strategies (Perfect and Illiquid) using our model with parameters given by Table 2.1. We applied the hedging strategy on the realised historical data until the first quotation of the years 2009, 2010 and 2011 (resp. on the January, 2nd 2006, January 2nd 2007 and January, 2nd 2008). Each selling price was obtained under the hypothesis that a hedging strategy would be implemented with a frequency of one hedge per week, as in the Monte-Carlo simulation case. The total sourcing cost of the contract is then obtained as the first quoted price of the futures contract minus the cash flows resulting from the hedging strategy. A positive cash flow means a gain whereas a negative one means a loss. The efficiency of the strategy is measured by the relative error between the selling price given by the strategy and the sourcing cost of the contract. A positive relative error means a benefit whereas a negative relative error means a loss.

The results of this experiment are presented in Table 2.2. Let us consider the case of the contract Year 2009 priced with a Perfect Rollover Strategy to see how these results can be read. The Perfect Rollover strategy proposed for the Year 2009 a selling with a risk premium of 1.65% above the 3YAH quoted on June 8th 2005. The corresponding selling price is 40.3 Eur/MWh. The sourcing cost (39.1 Eur/MWh) decomposes in the first quotation of the Year 2009 (49.6 Eur/MWh) minus the cash flows generated by the weekly hedge (10.6 Eur/MWh). Here, the hedging process led to a benefit because of the bullish trend of the power market during the period going from 2005 to the beginning of the financial crisis in mid 2008. The valuation method mispriced the year 2009 contract sourcing cost with a relative error of 3.1% ($(40.3 - 39.1)/39.1$).

		Y2009	Y2010	Y2011
Perfect Rollover	Risk Premium	1.65	2.38	2.92
	Selling price	40.3	40.5	40.8
	Sourcing Cost	39.1	39.6	39.0
	Relative Error	3.1	2.3	4.6
	First Quoted Price	49.6	52.8	58.0
	Hedge Cash-Flows	10.6	13.2	19.0
Illiquid Rollover	Risk Premium	1.97	2.62	3.47
	Selling price	40.4	40.6	41.0
	Sourcing Cost	37.5	40.4	40.1
	Relative Error	7.8	0.5	2.3
	First Quoted Price	49.6	52.8	58.0
	Hedge Cash-Flows	12.1	12.4	17.9

Table 2: Results of a real life experiment of both rollover strategies for the contracts for delivery on 2009, 2010 and 2010 as seen from June, 8th 2005. Prices, costs and cash-flows in Eur/MWh, relative errors and premia in percentage.

One can observe that in the case of the implementation of Perfect Rollover Strategy, the risk premium for the three maturities does not exceed 3%. This result is in line with the risk premium estimation as a function of the contract maturity (Figure 7) Moreover, the hedging strategy performs with rather small relative errors. One should not consider that the Perfect Rollover Strategy produces benefits: this is only due to the general trend of the market during this period. One can assert that in a bearish period, the strategy would produce some negative relative errors within the same range of absolute value.

In the case of the Illiquid Rollover Strategy, we observe with no surprise that the selling prices are close to the selling prices proposed by the former hedging strategy. Moreover, the relative errors presents a larger span than the Perfect Rollover Strategy. Indeed, contrary to the former strategy, it is important for the Illiquid Rollover method that the market prices follow the model given by relation (1). The hedge ratios telling how much quantity should be bought or sold for the 1MAH and 1YAH depend on all the model parameters. In particular, this model is designed for normal market conditions. Shocks in quoted futures prices are not taken into account. During the back-testing period, a negative shock occurred in the power futures markets in April 2006 because of the sudden collapse of the Carbon Emission prices (see Figure 1 right). This led to a negative abnormal return that explains the small gain occurred in the implementation of the Illiquid Rollover Strategy. The hedging process for the Year 2009 stopped in January 2006 before the collapse of the Carbon market while it was not the case for the other two contracts. This shock led to the smallest gain of the hedging strategies and could have led to loss if the shock would have been larger. Hence, we clearly observe here the effect of the limits of our model in the case of market shocks.

3 Conclusion

The pricing and hedging method developed for other commodities market has been adapted in this paper to the case of long-term contract for electricity. The short-term properties of electricity such as spikes are of no-incidence for this problem, allowing us to use the current rollover strategy to hedge long-term commitment on electricity market. Given a volatility of Year-Ahead contract of 20%, numerical simulations as well as real life experiment show that given a rather small risk premium within a range of 5% above the current longest maturity quoted on the market, one is able to deliver a forward baseload contract of maturity not exceeding ten years.

Nevertheless, this result should be taken cautiously. Our real life experiment was based on the hedging of forward contrat with a maturity of six years. For such a period, treasury constraints involved in margin calls as well as transaction costs may be neglected. This may not be the case for much longer maturity contracts.

Extensions of this preliminary work thus are numerous in this setting. A better treatment of treasury constraints is of first concern for very long term contract. Moreover, one could think of using a real options valuation method to be able to evaluate long-term contract backed by physical assets as electricity producers do. Since real options methodology needs a price model to perform its valuation, one could take advantage of the capacity of the price model used in this study to model prices for new quoted contracts to implement a long-term real options valuation method.

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