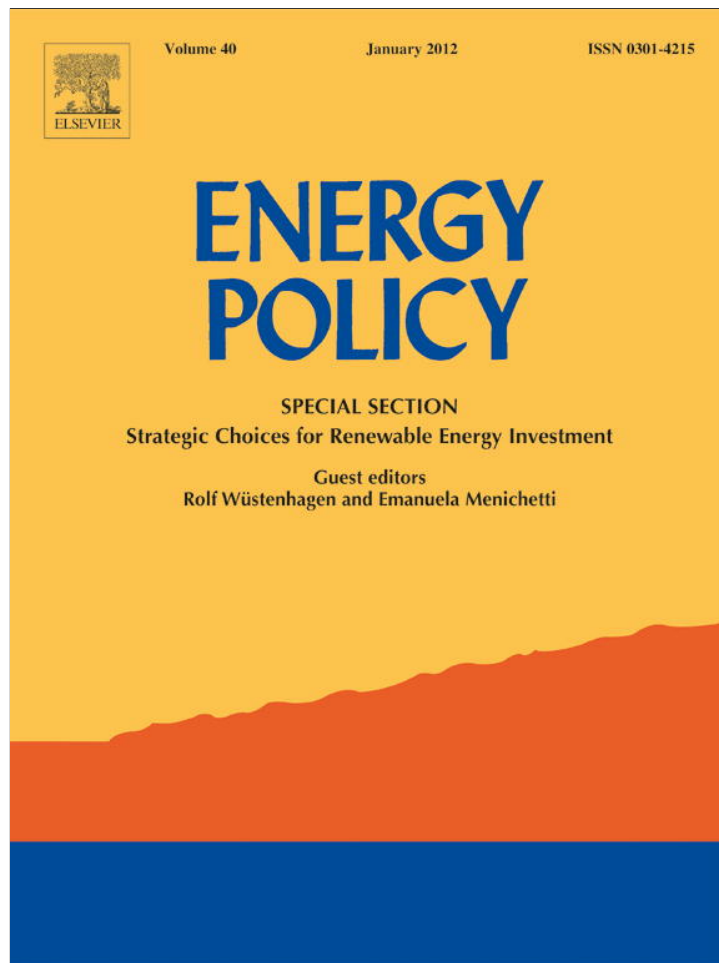


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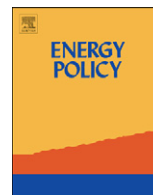


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Retailers' risk management and vertical arrangements in electricity markets

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ABSTRACT

The failure of the asset-light retailer's organizational model is indicative of the incapacity of this organizational structure to manage efficiently the combination of sourcing and market risks in the current market environment. Because of the structural dimensions of electricity's market risks, a retailer's level of risk exposure is unknown *ex ante* and will only be revealed *ex post* when consumption is known. In contrast to the "textbook model" of electricity reforms, the paper demonstrates through numerical simulations that in the current market context pure portfolios of contracts are incomplete risk management instruments compared to physical hedging. The latter is critical to overcome the asset-light retailer's curse.

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1. Introduction

The "ideal textbook" model of competitive decentralized electricity markets required the vertical separation of generation, retail as well as network services (transmission and distribution). According to the theoretical premises of the Austrian school which considerably influenced promoters of electricity liberalization (Littlechild, 2002),¹ introducing competition at the retail level is thought to imply the emergence and development of "entrepreneurs". Those firms are considered innovative and risk takers. In the context of retail electricity markets, asset-light retailers who neither own generating nor distribution assets were expected to offer innovative retail contracts with attractive prices to electricity consumers. Those retailers were expected to stimulate a fierce competition in the retailing segment of the value chain (Hunt, 2002; Hunt and Schuttleworth, 1997). In sharp contrast to this theoretical vision, asset light retail entry has never eventuated as expected. Asset-light retailers bankrupted, left the market, were taken over, or evolved towards an upstream integration in all the retail markets opened to competition (UK, New Zealand, Australia, France, etc.). Even in the UK, presented as a benchmark for electricity deregulation (Thomas, 2006), twenty new entrants left the retail market since 2000 (Oxera, 2008). At their climax between 1999 and 2001, the total market shares of

the new entrants into retail was less than 2% in the UK (Ofgem, 2007) despite high levels of net switching.² These market results give credit to the skeptical views of Joskow (2000) who recommended to provide a Basic Electricity Service (BES) that enables residential consumers to buy electricity in competitive wholesale markets at the spot price given the lack of value added of retail competition above the BES. Littlechild (2000) considered this vision is flawed in several respects because it fails to acknowledge the benefits of price competition and services innovation at the retail level. With a different perspective, Defeuilley (2008) shed some light on the limitations of the Austrian analysis of competition as an entrepreneurial-driven process.

We adopt a different perspective. By studying the risk management constraints of a retailer, this paper explains why the asset light organizational model is not sustainable in decentralized electricity markets. We argue that in contrast to physical assets, purely contractual portfolios are not efficient risk management devices³ for hedging uncertain delivery obligations of retailers. That is, the paper aims at demonstrating the critical necessity to manage electricity market risks through a combination of contractual and physical assets.

Comparing the determinants, costs, and benefits of different institutional arrangements has been a strong focus in the last three decades of the New Institutional Economics framework

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¹ As Defeuilley (2008) mentioned, this influence is stressed by S. Littlechild himself: "[Kirzner] writings in this area [nature of competition and entrepreneurship] were influential in the development of my own thinking about privatization, competition and regulation of the utilities. Subsequently, the regulation of the British electricity industry reflected his and other Austrian ideas" (Littlechild, 2002).

² 40% of net switching for the residential segment in the UK in 2007 (Ofgem, 2007).

³ Risk management embodies the process and the tools used for evaluating, measuring and managing the market risks within a retailer's portfolio of contracts and plants. The value of energy trades change over time as market conditions and underlying price variables change. In electricity markets, effective risk management depends not only upon proper portfolio analysis tools but also on a solid forecasting of forward prices.

and more specifically of the literature on Transaction Costs Economics (Coase, 1960; Williamson, 1985; Joskow, 1985; Shelanski and Klein, 1995; Coeurderoy et al., 1997; Whinston, 2003a, b). However, the originality of our paper is to compare vertical arrangements through the analytical lens of risk management (rather than transaction costs economics) taking the new perspective of an electricity retailer specific's intermediation function.

The paper is organized as follows: in Section 2 we put forward the market risks faced by a retailer. Section 3 demonstrates the limits of pure contractual hedging in liberalized electricity markets. Section 4 is devoted to comparing quantitatively the risk profiles of different portfolios of hedging. The last section concludes.

2. The market risks faced by retailers

By sourcing electricity for resale to final consumers, retailers are market intermediaries (Spulber, 1999). As market intermediaries, retailers have the contractual responsibility to balance on a real time basis their upstream and downstream portfolios of electricity. This real-time matching function exposes them to quantity and price risks.

An electricity retailer is specifically exposed to a quantity risk over a short term horizon (from a few days, a few hours, to real time risk exposure) due to unanticipated load variations, (e.g. related to the imperfect predictability of weather conditions).⁴ As demand for electricity is of stochastic nature, very inelastic, and characterized by strong short term variability and supply is rigid on the short term, spot prices are volatile (Stoft, 2002; Geman, 2005). Since electricity is not economically storable, all imbalances will have to be settled on the spot market at unforeseeable prices.⁵ This non-storability exacerbates the consequences arising from the classical matching uncertainty problem between any market intermediary's sourcing (downstream) and selling (upstream) portfolios (Bailey, 1998; Gehrig, 1993; Hackett, 1992; Spulber, 1999). Furthermore, the positive correlation between price and demand in electricity wholesale markets (Stoft, 2002; Chao et al., 2008), is worsening the financial costs of any under-contracted positions settlement on the spot market. This load/price positive correlation is seen as an important incentive for contractual hedging (Mackay and Moeller, 2007). Finally, any change on the number of a retailer's customers (loss/gain of market shares in newly liberalized retail segments) will generate vertical imbalances forcing the retailer to sell or buy any over or under-contracted position at uncertain prices. These structural imbalances put retailers' margins under threat.

Consequently, quantity risks systematically translate into price risks. The price risk is generated by the discrepancies between the selling price of electricity on the retail market (generally a fixed price) and the price of the complementary spot transactions to offset the structural disequilibria between a retailer sourcing and selling portfolios. To minimize quantity risk and price risk, retailers will aim at contractually hedging the main proportion of their aggregated load requirements through the purchase of hourly electricity blocks with a minimum physical capacity of 1 MW. Each individual demand being stochastic, retailers will define their contractual level of procurement based upon the imperfect segmentation method known as load profiling.

⁴ Weather uncertainty can be theoretically mitigated through weather derivatives. However, due to their speculative and illiquid features, difficulty of pricing, and lack of liquidity, weather derivatives are very seldom used by electricity retailers (Geman, 2005).

⁵ For further details on the links between the storage's level and price volatility of a commodity, please refer to Geman (2005) and Working (1949).

3. The expected role of long-term contracts and their structural limits for managing market risks

In the ideal theoretical paradigm of liberalized electricity markets, financial contracts⁶ (forward and futures) were predicted to be efficient instruments for managing quantity and price risks and assumed to be perfect substitutes to physical assets (Chao and Huntington, 1998; Hunt, 2002). These expectations have not been reached. In all electricity markets, forward and futures cover less than 50% of the total demand (Anderson et al., 2007; Chao et al., 2008). Meanwhile, upstream vertical integration has been maintained or has arisen in most of the markets (Cornwall Energy and EEE Ltd., 2008; Kuhn and Machado, 2004). In this section, we examine the structural limits of contractual hedging within liberalized electricity markets. These limits stems from contractual parties' misalignment of interests regarding price and quantity provisions.⁷

We first analyze the origins of price provisions' misalignment. Spot price fluctuations have opposite effects on retailers and generators profits as any increase in the spot price will affect positively the revenue of the producer to the detriment of the retailer.⁸ As the price risk's profiles of retailers and producers are negatively correlated, long-term fixed price sourcing contracts should, in principle, credibly align long term hedging needs of both parties, and safeguard their economic interests for the best of the contract's performance.⁹ However, in a setting of fixed price contracts, the ex post distribution of risks across the parties depends on the duration and magnitude of the periods during which the spot price will be above/below the contractual fixed price, which in the electricity sector is not foreseeable given the proven incapacity of current price forecasting models to capture real electricity price volatility within a very uncertain market environment (Szkuta et al., 1999; Nogales et al., 2002; Lora et al., 2002; Geman, 2005).

As sustainable periods of spot prices below the contract fixed price may induce profitable new entries into the retail market, retailers with significant level of sourcing through fixed-price contracts are exposed to a risk of price-squeeze.¹⁰ Given the low level of entry costs into the retail segment (Ofgem, 2007); low spot prices will represent strategic opportunities for potential new entrants to corner market shares from any retailer locked into high sourcing fixed price contract. Therefore, any fixed price contract gives rise to an opportunity cost for retailers.¹¹ When contracting, retailers have no guarantee ex ante that spot market sourcing will be more costly than contractual sourcing. The effectiveness of any hedging strategy is revealed only ex post, when demand is settled on the spot market. A retailer could always diminish its retail prices to match the competitors' prices and protect its market shares but will then face retail margin's reduction. In such setting, another option for retailers would be to

⁶ For the purpose of this paper, it is not necessary to distinguish between financial and physical contracts since potential physical delivery is not changing anything to our conclusion.

⁷ Or, the main role of long term contract is precisely to align parties' interests to ensure the contract execution's strong compliance (Masten 1996; Brousseau and Glachant, 2002).

⁸ Conversely, any spot price decrease will have opposite effects.

⁹ Moreover, by aggregating numerous customer loads, retailers would theoretically be able to lock in the major parts of their expected demand through sourcing contracts which would match the profile and risk features of their downstream portfolio at prices not tied to the volatile spot price.

¹⁰ For an example of price squeeze, see TXU Europe bankruptcy in 2001 on the UK market (Power in Europe, December 2004).

¹¹ Sourcing contracts indexed to the spot price should theoretically eliminate the aforementioned opportunity cost for retailers. However, in practice, a residual price risk remains due to the smoothing effect embedded in those spot indexed contracts.

renew on their contractual engagements, giving rise to a classical hold-up problem that leave generators with stranded long term investments (Klein et al., 1978). Anticipating this risk of opportunism, generators would require a higher contractual premium, making contracts more expensive for retailers.¹² The aforementioned ex ante uncertainty on a fair contractual risk sharing ex post across the parties hinders the incentives for a fixed price long term contract. Absent long term alignment of parties' interests, such contract is not "self enforcing" (Klein, 2000).

Provision's misalignments for quantity preferences are also a source of contractual problems and high maladaptation costs (Williamson, 1985; Saussier and Yvrande-Billon, 2008). Indeed, retailers prefer to contract on flexible quantities to match their variable load and demand swings whereas generators prefer to secure their revenues through fixed quantities but with contracts that follow their supply availability patterns (i.e. including technical maintenance and/or fuel shortage clauses). Retailers would not accept such availability clauses unless they have concluded load curtailing contracts downstream (i.e. interruptible contract).¹³ These quantity and availability clauses' misalignments contribute to a structural lack of matching between capacity and load and to high contractual premia for conceding contractual preferences.¹⁴

In the absence of any mutually beneficial price/quantity contractual mix to maximize long term revenues of both parties, the limits of symmetric fixed (or indexed) price contract make asymmetric contracts such as call options¹⁵ potentially more suitable for electricity retailers. Indeed, by giving the right to buy electricity at the strike price (Hull, 2005), call options enable retailers to mitigate their quantity risk (Boroumand, 2008 and Section 5 of this paper). With the structural limits of contractual hedging in mind, we now turn to the risk management benefits of a portfolio strategy based upon physical assets.

4. The need for physical hedging

We demonstrate that a retailer cannot reproduce the risk-reducing benefits of physical hedging by pure contractual portfolios. For this purpose, we compare the risk profiles of different portfolios of hedging with the traditional Value at Risk (VaR) indicator. The Value at Risk (VaR) is an aggregated measure of the total risk of a portfolio of contracts and assets. The VaR summarizes the expected maximum loss (worst loss) of a portfolio over a target horizon (one year in this paper) within a given confidence interval (generally 95%). Thus, VaR is measured in monetary units, Euros in our paper.¹⁶ As the maximum loss of a portfolio, the VaR(95%) is a negative number. Therefore, maximizing the VaR is equivalent to minimizing the portfolio's loss. We rely on the Value-at-Risk because it is a good measure of the downside risk of a portfolio and is for example used as preferred

criteria for market risk in the Basel II agreement. The Value-at-Risk for the 95% confidence interval (VaR(95%)) that we use in the remainder of the paper is the one hundred fiftieth lowest of the 3000 payoffs.

4.1. Payoff of the assets and contracts within a portfolio

A retailer is assumed to have concluded a retail contract (the retail contract is given ex ante and is therefore not a portfolio's parameter of choice) with its customers that imply stochastic demand \tilde{V}_t for $t = 1 : T$. The demand distribution is known to the retailer and the uncertainty about the actual demand \tilde{V}_t is completely resolved in time t .

To fulfill its retail commitments the retailer can buy electricity on the spot market at the ex ante uncertain spot market price \tilde{P}_t .¹⁷ The spot market price distribution is known by the retailer. To reduce its risk from buying an uncertain amount of electricity at an uncertain price, the retailer can conclude financial contracts and/or acquire physical generation assets. All contracts (including the retail contract and the physical assets generation volumes) are settled on the spot market that is assumed to be perfectly liquid. Thus, the payoff streams depend on a given number of spot market realizations (one year, i.e., 8760 h). For example, an annual baseload forward contract implies buying the agreed volume of electricity at the contractual price for 8760 h.

In Table 1 five different contracts/assets – namely a retail contract, a forward contract, a power plant, a call option on the spot price and a put option on the spot price¹⁸ given the spot price – are introduced. If for example, the electricity spot price (\tilde{P}_t) is above the strike price of the options (X) there is a positive payoff of the call option, while the payoff of the put option is zero. The payoff of the power plant, depends on the installed capacity of the plant (V_{plant}) and its marginal cost (mc) and only the payoff of the retail contract depends on the stochastic demand \tilde{V}_t . By subtracting the expected value ($E(\cdot)$) from the gross payoff all contracts/assets are assumed to have zero expected value. That is, we assume that in a perfect market (no market power, no transaction costs, full transparency, etc.) arbitrage would not allow for the existence of systematic profits. Without this postulate, the method for the evaluation of contracts and assets would drive our results. Indeed, the net loss calculated for each portfolio would be strongly determined by the valuation method of the assets or contracts within each portfolio.

4.2. Methodology of numerical simulations

To simulate the payoffs some assumptions on the distribution of the electricity spot price and retail volume have to be made. We rely on real data of the French electricity market from 2006 and 2007. The hourly prices are obtained from the French electricity exchange Powernext and the corresponding loads are obtained from the network operator RTE. Electricity prices depend non-linearly on the total load (see Fig. 1). Thus, load and prices are strongly (although not perfectly) correlated (46% in the sample period) and load increases have a stronger impact on prices than load decreases. To obtain realistic simulations we sort the observed price-load combinations by load. Then, the central points (medians) of 3000 windows of 8760 neighboring observations are drawn from a truncated normal distribution. The mean of this distribution is 8760, representing the central point of the 2 years data. The variance of the central points is 8760/4.

¹² The perceived asset light retailer's counterparty risk of default (which differs from the risk of opportunistic behavior) also contributes to high contractual premia. Electricity retailing is a financial rather than physical activity. As a retailer has no tangible assets (the portfolio of customers is an intangible asset), this represents a source of financial instability for contractual counterparties.

¹³ Interruptible contracts are equivalent to a callable forward. In such contractual framework, the retailer simultaneously (and virtually) sells a forward contract to its clients and buy a call option from them.

¹⁴ Wolak (2007) analyzes the benefit for a generator to accept a lower output price in exchange of flexible output.

¹⁵ A call option is a contract that gives its purchaser the right (but not the obligation) to buy the underlying commodity at a certain price, the strike (noted X in Section 5), on or before an agreed date, the maturity of the option (Geman, 2005).

¹⁶ For further details please refer to Jorion (2000) "Value at risk: The New Benchmark for Managing Financial Risk" Mc Graw Hill, second edition.

¹⁷ We ignore balancing markets. This can be justified by the fact that most of the adjustments of retailers take place in the day ahead market.

¹⁸ A put option on the spot price, gives the retailer the right to sell electricity on the spot market at a given price.

Table 1
Payoffs of different contracts/assets given the spot price (\tilde{P}_t).

Contract	Payoff
Retail contract	$\pi_{retail,t} = -\tilde{P}_t \times \tilde{V}_t + E(\tilde{P}_t \times \tilde{V}_t)$.
Forward	$\pi_{forward,t} = V_{forward} \times \tilde{P}_t - E(V_{forward} \times \tilde{P}_t)$.
Power plant	$\pi_{plant,t} = V_{plant} \times \max(\tilde{P}_t - mc, 0) - E(V_{plant} \times \max(\tilde{P}_t - mc, 0))$.
Call option on spot	$\pi_{call,t} = V_{call} \times \max(\tilde{P}_t - X, 0) - E(V_{call} \times \max(\tilde{P}_t - X, 0))$.
Put option on spot	$\pi_{put,t} = V_{put} \times \max(X - \tilde{P}_t, 0) - E(V_{put} \times \max(X - \tilde{P}_t, 0))$.

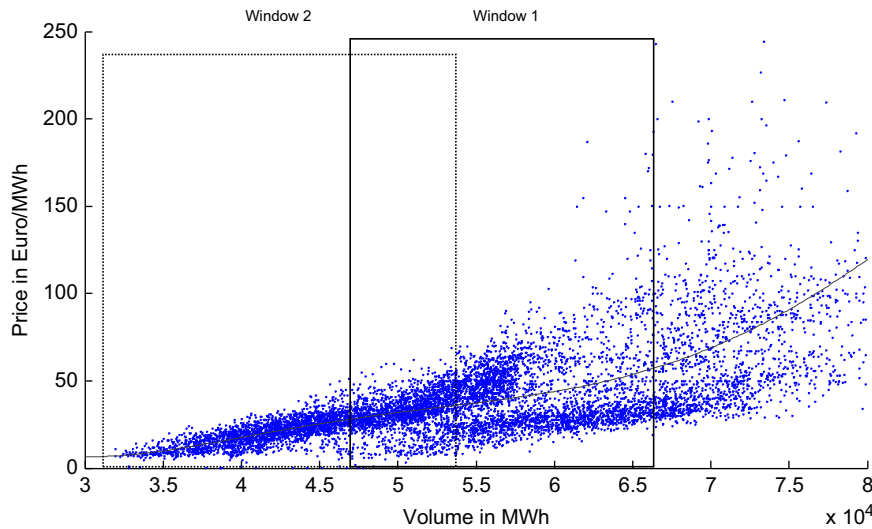


Fig. 1. French prices and volumes in 2007.

The distribution is truncated below 8760/2 and above 17520–8760/2 to fit the data sample. Note that, due to the normal distribution, windows with a median load closer to that of the observed sample are more likely than windows with a median very different from that of the real data. Finally, from each of the 3000 windows we draw randomly with replacement 8760 hourly price–load combinations. Consequently, in expectation the median of the observed data (load) is equal to that of the simulated data. Due to the non-normal (joint) distribution of the observed data, the mean of the simulated load is slightly lower (54 instead of 55 GW) than that of the observed loads in 2006–2007. The mean price of the simulated data is slightly lower than that of the observed data (43 instead of 45 Euro/MWh) and the median of the simulated prices is higher than the observed data (39 instead of 38 Euro/MWh). The variance of the mean (median) price across the 3000 simulations is 29 (20).

The marginal generation cost of the power plant is set to the median of the simulated spot prices $mc = 39.0$ Euro/MWh, thus representing a peak load power plant. The strike price of the options is set to the expectation value of the spot price $X = E(\tilde{P}_t) = 43.0$ Euro/MWh.¹⁹

¹⁹ This is done to make call options and power plants distinguishable as they are equivalent according to Table 1 if $X = mc$. The intuition of setting the marginal cost to the median price is that thus, the power plant will run exactly 50% of the times. The intuition of setting the strike price to the mean price is that the option is “at the money” in this case.

4.3. The risk minimization

We can calculate the cumulated annual payoffs of the 8760 hourly price/volume combinations for all 3000 simulations given the portfolio ($V_{forward}, V_{plant}, V_{call}$ and V_{put}):

$$\begin{aligned} \pi^i = & \sum_{t=1}^{8760} [\pi_{retail,t}(\tilde{P}_t^i, \tilde{V}_t^i)] + [V_{forward} \times \pi_{forward,t}(\tilde{P}_t^i)] \\ & + [V_{plant} \times \pi_{plant,t}(\tilde{P}_t^i, mc)] + [V_{call} \times \pi_{call,t}(\tilde{P}_t^i, X)] \\ & + [V_{put} \times \pi_{put,t}(\tilde{P}_t^i, X)]. \end{aligned}$$

Thus, π^i is the annual payoff of the i th price and volume simulation given the portfolio defined by $V_{forward}, V_{plant}, V_{call}$ and V_{put} .

Using an optimization routine, the portfolio that produce the lowest VaR(95%) can be identified. We use the “fmincon” routine in Matlab. As the routine does not necessarily converges for this non-linear problem (especially for the three and four assets case), we rerun the optimization for each case with 100 different randomly drawn starting values. The result of the best run can be considered sufficiently close to the global optimum, as all results tend to be within a fairly narrow range.

The objective is to find the portfolio consisting of one 1 MWh baseload retail contract and a linear combination of financial contracts as well as physical assets that reduces the retailers risk. Thus, the factors for the other contracts/assets are also measured in MWh. If the retailer, for example, sold two retail contracts and

Table 2
Portfolios containing one retail contract that maximize the VaR(95%).

#	Used assets	Retail	$V_{forward}$	V_{plant}	V_{call}	V_{put}	VaR(95%)
1	All contracts	1	-0.04	0.26	1.24	-0.27	-2088
2	Without options	1	0.09	1.33	-	-	-2131
3	Only options	1	-	-	1.47	-0.28	-2092
4	Only forward	1	0.98	-	-	-	-12,942
5	Only power plant	1	-	1.46	-	-	-2201

he would like to hedge this deal with only forward contracts (compare #4 in Table 2), he would have to buy (2×0.98 MWh) 1.96 MWh forwards. Any imbalance between the electricity sold and purchased (or produced) is settled in the spot market. Therefore, it is not necessary to have equality between the quantity sold downstream and the sourced one upstream. The volume of power plant contracts is constrained to be positive, while call option, put option and forward contracts could be both bought and sold at the market (i.e., negative quantities are allowed). In five different scenarios we constrain the volume of certain contract types to zero. Thus, the (non-)substitutability of these contracts for hedging a retailers risk can be assessed.

The VaR(95%) of the considered one MWh baseload contract with zero expectation is -97,852 (see Table 5 in the Appendix), i.e., the probability of the retailer to lose more than 100,000 Euro in one year (or more than 10 Euro on average per hour) with this contract is almost 5%. The optimal portfolio if all assets are allowed (portfolio #1) produces a VaR(95%) of -2088. Portfolio #1 consists in selling 0.04 MWh of forward, generating 0.26 MWh with the plant, buying 1.24 MWh on a call option, and selling 0.27 MWh with the put option. The VaR of #1 is thus 98% lower than that of the retail contract without any hedge.²⁰

Without plants or forwards a VaR(95%) very close to that of the unconstrained optimal portfolio (#1) can be attained if options are allowed (#3). If options cannot be chosen, the risk management characteristics of #3 can be reproduced without options if power plants and forward contracts are allowed (#2). With only forward contracts allowed (#4), the VaR(95%) is more than six times bigger than if both, power plants and forward contracts are the available portfolio choices (#2). Consequently, if options are no choice for retailers (because for example, nobody is willing to sell them as a counterparty), then power plants – whose payoffs feature option like characteristics – will help retailers to reduce their risk exposure.

If power plants with different marginal costs can be included in the portfolio, the selection decision equals the choice of hedging an underlying with options with different strike prices. If, for example, a low cost technology with marginal cost being equal to the 25% percentile of the electricity price and a high cost technology with marginal cost being equal to the 75% percentile are introduced, the VaR can be further reduced.

In our example the optimal portfolio (#6 in Table 3) that consists of 0.62 of the normal power plant, 0 of the cheap power plant, 0.59 of the expensive power plant and 0.3 of the forward contract can reduce the VaR(95%) to 2112. This implies a slight improvement with respect to the optimal portfolio for the normal power plant and the forward contract (VaR(95%)=-2131). By allowing only power plants it can be demonstrated that adding a power plant with different payoff characteristics might reduce the VaR of the portfolio. Going for example from #8 ($V_{plant,25}$ and $V_{plant,75}$, VaR=-2199) or #5 ($V_{plant,50}$, VaR=-2201) to #7

Table 3
Portfolios containing one retail contract and different power plants that maximize the VaR(95%).

#	Used assets	$V_{forward}$	$V_{plant,50}$	$V_{plant,25}$	$V_{plant,75}$	VaR(95%)
6	Forward and 3 plants	0.30	0.62	0.00	0.59	-2112
7	3 plants	-	1.17	0.22	0.03	-2141
8	$V_{plant,25}$ and $V_{plant,75}$	-	-	0.76	0.75	-2199
9	Forward and $V_{plant,75}$	0.05	-	-	1.09	-2183

Table 4
Portfolios for the stylized example containing one retail contract that maximize the VaR(95%).

Used assets	Retail	$V_{forward}$	V_{plant}	VaR(95%)
Constant demand				
Only forward	1	1		0
Only power plant	1		1	-4.77
Forward and power plant	1	1	0	0
Stochastic demand not correlated to the price				
Only forward	1	1.01		-2.56
Only power plant	1		1.18	-5.80
Forward and power plant	1	0.81	0.37	-2.05
Demand perfectly correlated to the price				
Only forward	1	1.01		-3.66
Only power plant	1		1.55	-2.89
Forward and power plant	1	0.46	1.08	-0.81

(all three power plant types, VaR=-2141) reduces the VaR(95%) by 3%.

In the above exercise we have shown, that forward contracts are not sufficient to hedge the supply obligations of a retailer. We demonstrated on the example of the French market, that either power plant shares or option contracts on the spot market are necessary to optimally reduce the risk of the portfolio. To understand why this option-like payoff structure is required we proceed with a stylized example. We assume a sinusoid price curve $p(x) = 30 + 15 \times \sin x$ and three different types of retail consumption: constant demand ($q(x) = 40$) stochastic demand $q(x) = 30 + \varepsilon(x)$ and demand correlated to the price $q(x) = 40 + 20 \times \sin x$. The payoffs of a retail contract, a forward contract and a power plant are calculated according to the approach described above.²¹ Finally, three different types of portfolios are considered: (1) the combination of one retail contract and the optimal number of forward contracts, (2) the combination of one retail contract and the optimal number of power plant shares, and (3) the combination of one retail contract, the optimal number of power plant shares and the optimal number of forward contracts.

Assuming demand being constant, a retail contract might be completely hedged by exactly one forward contract (see Table 4). This is obvious, as the payoffs of the forward contract exactly mirror those of the retail contract (see Table 1 and Fig. 2).

With stochastic demand (Fig. 3), a combination of forwards and plant assets forms the optimal portfolio. In cases with non-excessive volatility, forward contracts alone are responsible for the major part of the risk reduction.

²⁰ This level of risk reduction can be approached with very different combinations of assets, as the four assets imply one degree of freedom.

²¹ As a reminder: the payoff of the assets is computed according to the corresponding formulation in Table 1. Thereby, the marginal cost of the power plant is set at the median spot price and the expectation value of each payoff series is normalized to zero.

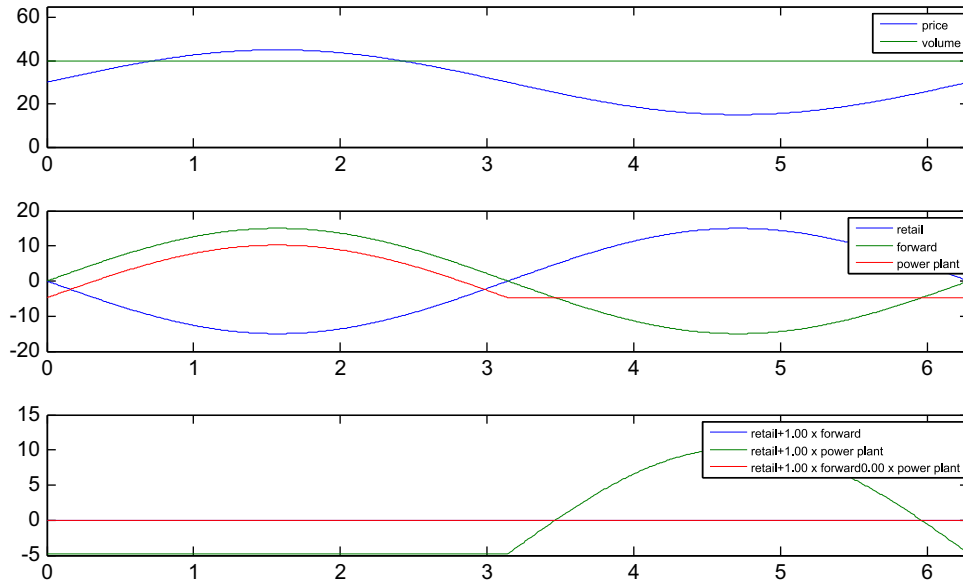


Fig. 2. Optimal hedging decision if retail volume is constant.

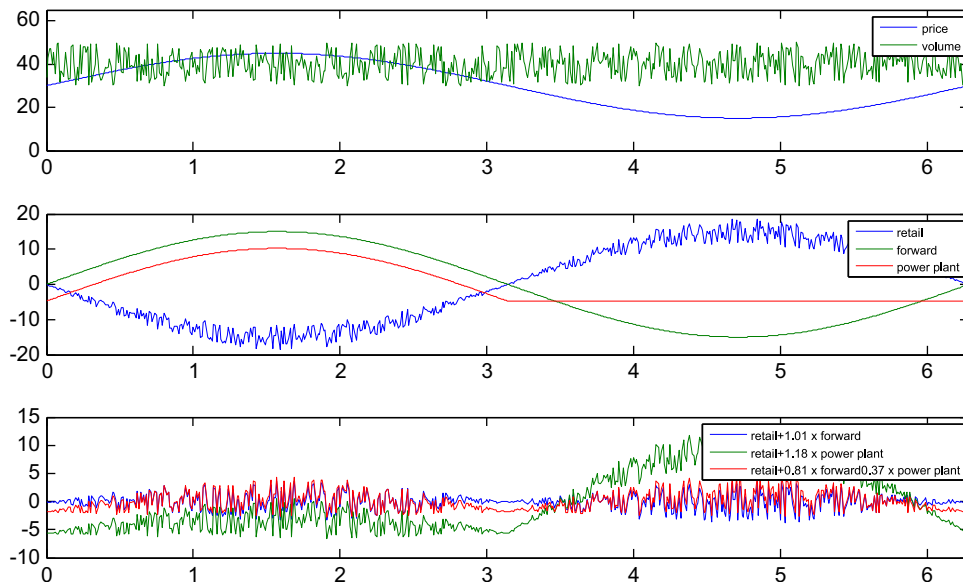


Fig. 3. Optimal hedging decision if retail volume is stochastic and uncorrelated to the wholesale price.

When price is assumed to be correlated to demand (Fig. 4) again, power plants and forward contracts are needed for optimal risk reduction. In this case power plant shares are responsible for the major part of the risk reduction.

Due to the correlation of retail quantities and spot prices retailer's profits have "flat hills and deep valleys" (see Fig. 4). That is, in periods of high wholesale prices their customers will demand more electricity. Thus, losses in periods where wholesale prices are above retail prices are over proportional. In periods of low wholesale prices the retail customers demand less electricity so that a retailer's gain from the positive retail-wholesale price differential is under proportional. This payoff-structure of retail contracts is almost perfectly mirrored by call options and peak generation assets. Thus, those assets are essential for hedging a retailer's joint price and volume risk. This explains why forward contracts alone are not sufficient for hedging a retail commitment (#4 in Table 2).

Through the presented analysis we provide evidence, that a retailer can hedge the market risks originating from a standard retail contract by either a combination of forwards and options on the spot price or by a combination of forwards and physical assets. In all observed electricity markets, however, liquid derivatives on the spot market are absent given the irrelevance of conventional financial models (such as the Black-Scholes pricing model) to price electricity options (Geman, 2005; Hull, 2005). Thus, the only real choice for a retailer is to hedge its retail obligations through physical assets. These, however, might help to significantly reduce a retailer's risk exposure. In our example the VaR(95%) with physical assets decreases by more than 80% compared to a situation where only forward contracts are allowed. Consequently, as long as derivative markets are not sufficiently liquid, retailers will strive to vertically integrate to better hedge their risk exposure. This, on the other hand implies a vicious cycle. The more retailers are vertically integrated the less

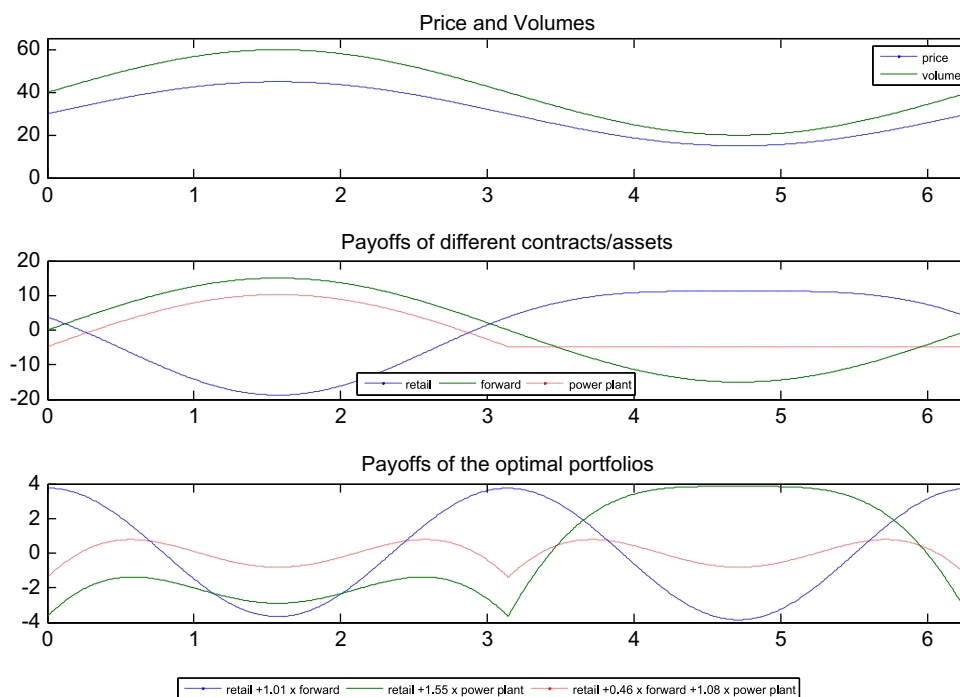


Fig. 4. Stylized examples of the necessity of option-like assets in retail portfolios.

likely is the development of a liquid contract market, thus forcing non-integrated retailers to leave the market or to move towards physical integration.

Different strategies to exit this vicious cycle might be proposed. By legislative barriers for vertical integration one might boost the demand for certain derivatives. This demand might translate into premiums that make it profitable for banks and generators to provide the demanded derivatives. In the course of time, the number of emitters might increase and drive the premiums down. Another approach would be to reduce the (regulatory) pressure on retail competition allowing for higher margins and thus giving a financial cushion that reduces the risk aversion in the operations. One easily adjusted parameter would, for example, be contract length that is regulated in certain markets. This might allow retailers to maintain potentially risky retail business without vertical integration. But in this case it is unclear whether having a series of oligopolies (retail oligopoly and generation oligopoly) is superior to having an oligopoly of vertically integrated companies.²² If the described policies are temporal (otherwise they would produce continued welfare losses) it is, however, unclear whether the liquidity in the derivatives markets would be self-sustaining or collapse back to the above outlined vicious cycle.

5. Conclusion

Our paper demonstrates that physical hedging, supported to some degree by forward contracting and spot transactions²³ is an efficient and sustainable approach to risk management in decentralized electricity markets. In contrast to the theoretical premises, financial contracts are imperfect substitutes to vertical integration in

²² The inelasticity of demand might limit the typical welfare losses from having a series of oligopolies while on the other hand from a customer's perspective the potentially higher prices due to reduced regulation might offset the potential gains of vertical unbundling.

²³ Being structurally shortly hedged leaves opportunity for residual contracting options opportunities in volatile electricity markets.

Table 5

Key characteristics of the payoffs of the considered assets.

	Variance	VaR(95%)	Correlation with retail
Retail contract without hedge	2,384,760,363	-97,852	1
$V_{forward}$	195,054,443	-79,179	-0.992
$V_{plant,25}$	668,204,401	-64,835	-0.998
$V_{plant,50}$	102,804,456	-48,858	-0.999
$V_{plant,75}$	7,871,146	-31,393	-0.993
V_{call}	7,879,490	-42,200	-0.998
V_{put}	2,557,274	-26,045	0.917

Table 6

Characteristics of the observed and simulated data.

	Observed data	Simulation
Mean price	45.1	43.0
Median price	37.9	39.0
Mean load	54,593	53,949
Median load	53,778	53,794
Variance price	1870	1056
Variance load	126,726,050	1,548,842

Table 7

Characteristics of the simulated data—variances.

Variance of the median price	20.20
Variance of the mean price	28.60
Variance of the median load	10,825,948
Variance of the mean load	14,512,156

the current market environment. The failure of asset-light electricity retailers is indicative of the intrinsic incapacity of this organizational model to manage efficiently the combination of sourcing and market risks.

Appendix

See Tables 5–7.

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