Vertical Structure and Forward Contract in Electricity Market

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Abstract

The pro-competitive effects of forward contracts in electricity market cannot be regarded alone without examining the market structure. In this paper, we show that under retail competition, spot market demand uncertainty and risk aversion, partially or fully integrated electricity generators and retailers have less incentives to be involved in trading electricity under forward contracts. Therefore, the effect of market power mitigation of forward contracts is countered by this vertical relationship between retailers and generators since it provides a natural hedging device as a substitute of forward contracts to the retailers. Both analytic framework and numerical simulation suggest that the optimal quantity of forward sales decreases and spot price increases with the degree of vertical control of retailers over generators’ assets. We thus conclude that the retailers’ ownership over generators’ profits could give rise to generators exercising market power in electricity spot market.

Keywords: L13, L42, L94

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1 Introduction

Electricity industry had been featured with integrated monopolies for many years and substantial market power from electricity generators. In general, a pivotal generator, that has the capacity to fulfill the last unit of demand, would have a strong incentive to raise wholesale price largely above a competitive level when he faces an inelastic demand given the fact that electricity is non-storable good. Therefore, competitive concerns have been particularly raised to competition authorities and governmental regulators for electricity market. Since the beginning of 90s, in order to create a competitive electricity market and mitigate pivotal generators’ market power, encouraged by a general trend towards deregulation and separating generation from the former integrated electricity industry, electricity reform has been underway in a number of countries. Following by the experience of privatization of national incumbent in the UK\textsuperscript{1}, liberalization and regulation of the electricity industry is under debate in both Europe and the US.

Two diverged tendencies can represent the ongoing vigorous reform in electricity market. The first tendency has focused on reconstructing electricity market. For example, dominant incumbent generators are being required to divest some of his generation plants to new entrants; electricity retailing and generation are being separated from transmission and distribution, that gives entry possibility to small players in both upstream and downstream market. The second tendency is based on the design of market rules for electricity industry. For instance, competition authorities intend to mitigate market power in wholesale electricity market by compelling firms to fulfill forward contract obligation with retailers; generators are obliged to trade electricity in a day-ahead market by submitting a supply function\textsuperscript{2} given each wholesale price realized. Furthermore in some countries, retail price regulation is being loosened in order to create vigorous competition downstream.\textsuperscript{3}

\textsuperscript{1}The Central Electricity Generating Board (CEGB) before market restructuring in England and Wales owned the vast majority of the electricity generation and the transmission system. The new structure was introduced on 31 March 1990 and CEGB’s assets were transferred to four successor companies: the fossil-fueled power stations were divided between National Power and PowerGen; his nuclear generation plants were transferred to Nuclear Electric; the transmission system was taken over by The National Grid Company. In addition, the business of the initial 12 Area Boards was transferred to the 12 Regional Electricity Companies (RECs). That signifies the whole electricity industry in England and Wales is open to competition.

\textsuperscript{2}Generators, in principal, bid their offers of electricity supply according to each price given in a day ahead market. That illustrates a curve of supply function of generators. From a theoretical point of view, Klemperer and Meyer (1989) characterize supply function equilibria (SFE) under demand uncertainty in which they show there exist multiple equilibria and the outcomes are bounded by the competitive outcome and Cournot outcome. Numerous applications of SFE can be found in work of Green and Newbery (1992), Green (1996), Rudkevich (1999), Baldick and Kahn (2000), and etc.

\textsuperscript{3}Littlechild (2002) analyzes the benefits of removing retail price control and introducing retail
seems natural that the global competitive effects could not be judged solely by making a rule which compels generators to commit to trade part of capacity in forward market or by the appearance of market structure.

It is common recognition that an electricity industry, which satisfies competitive standard, includes a separate transmission and distribution, privately owned and competing generation and all or part of the retail market open to competition. However it is not yet clear that such reform could bring more competition in electricity market and eventually benefit final consumers. It is especially not clear whether a vertically integrated market structure or a merger between generation and retailing would raise competitive concerns in electricity market. To be more precise, how ownership taken by retailers in generation assets influences forward trading remains still unstudied. As a result, we study in this paper the effects of a vertical integration between generation and retailing firms on forward trading when electricity retailing is open to competition.

The two main issues to study here are forward contracts and vertical integration. Before the pro-competitive effects of forward trading were well noticed, almost all competition authorities had been cautious about trading electricity under forward contracts which could possibly give rise to market power exercised by pivotal generators in electricity market for their consideration. They are concerned about forward contracts for two reasons: first, they considered that forward contracts could give rise to collusion among generators; second, forward contract might impede entry. However along with liberalization process in the 90s, it has been proven beneficial from a welfare perspective that generators in restructured electricity markets cover a large part of their sales in the contract market. On the other hand, the impacts of vertical integration in electricity market between generation and retailing remains still undetermined. Theories on industrial organization suggest that vertical integration gains efficiency for vertically integrated firms and eliminates the problem of double marginalization (Tirole, 1988 Chapter 4; Mathewson and Winter, 1986), but at the same time it raises the risks of foreclosure if the market is very concentrated. However in electricity market, the benefit of efficiency gain cannot be achieved since electricity has to be pooled in wholesale market where the wholesale price is realized by equalizing the supply and the demand on each hourly basis. Therefore, we incorporate two other motives for electricity retailers and generators to be vertically integrated particularly in electricity market, which are strategic moves and risk hedging. We study a situation where to some extent a retailer owns some generator’s assets competition in electricity market, including improving service quality, stimulating competition in generation, making wholesale market more liquid, etc.
but he is not involved in generator’s daily bidding behaviour. This happens commonly in merger and acquisition cases in electricity industry. We model a Cournot competition with conjectural variation between two strategic and risk-averse generators. Risk-averse retailers and generators maximize their mean-variance utilities. After liberalization of retail electricity market, retailers are threatened by potential entry.

As a principal result, we find that vertically integrated generators and retailers will be less engaged in trading electricity under forward contracts if the degree of risk aversion of generators is below a certain level. Since vertically integrated retailers have the ability to internalize part of generation profits as well as demand uncertainty in spot market, vertical integration provides a structural hedging device for retailers, and therefore presents as a substitute to forward contracts. When the quantity of forward trading decreases, generators are more willing to exercise market power in spot market. Consequently, realized spot prices increase and the effect of market power mitigation from forward trading is diminished. As a secondary result, we find that the coefficient of risk aversion of generators and the parameter of conjectural variation play interesting role in determining the optimal quantity of forward sales. If there is a Bertrand competition in forward market, the optimal level of forward trading does not depend on generators’ degree of risk aversion. However, to have the result of forward trading decreasing with the degree of vertical integration, a sufficient but not necessary condition is that generators’ risk aversion remains below a certain level. Finally, we collect data from electricity spot market in France, Germany and Nord Pool and use the calculated spot price variances to perform a numerical simulation. The results support former theoretical predictions.

The rest of the paper is organized as following: section 2 reviews the main contributions from related literature studies; section 3 presents a theoretical model; section 4 gives a numerical simulation; section 5 concludes.

2 Literature review

Numerous literature have been contributed to answer the question whether generators have incentives to trade forward in electricity market and whether forward contract enhances competition in electricity market in both theoretical and empirical aspects. Before the 90s, the incentives of hedging and arbitrage opportunities played an important role, such that most of the literature on forward markets was developed within the framework of perfect competition. Depart from this motive, Allaz and Vila (1993) derive a Cournot duopoly model in the case of certainty and
non-existence of arbitrage opportunity, in which they show forward contracts give Cournot players a first mover advantage but when they all do so, they end up in a prison dilemma. Therefore the wholesale price drops for a purely strategic reason, even in the absence of demand uncertainty. Especially when the number of forward trading periods becomes large, the output level approaches to the competitive benchmark. They conclude that selling forward contracts puts each generator into a prison dilemma, and then limit generators’ unilateral market power to raise wholesale prices. This result is largely supported by some empirical work. Le Coq and Orzen (2006) examine this theoretical result in a controlled laboratory environment and find competition-enhancing effect of a forward market as the main comparative-static predictions. Bushnell (2007) extends the number of firms to \( N \) in order to assess the competitive impacts of creation of forward market and the ones of firm concentration. He finds that in the case of constant marginal cost, the competitive impact of firm concentration is far greater than with the existence of a single forward market relative to a single spot market. Bushnell, Mansur and Saravia (2007) regard vertical integration and long-term contract as substitutes to each other. Their model indicates that firms with vertical relationships with retailers have less incentive to raise wholesale prices when retail prices are determined beforehand.

Besides Cournot model, Meyer and Klemperer (1989) model an oligopoly facing uncertain demand where each generator submits a supply function including both price and quantity as his supply strategy. Although it is very appealing to adopt supply function equilibria to model generators’ bidding behaviour, it suffers often from the problem of multiple equilibria. Wolak (2000, 2007) develops a multi-unit auction model with step-supply function under the assumption of expected profit-maximizing bidding behaviour to quantify unilateral power and cost functions. He finds that forward contract obligation decreases average production costs and significantly mitigates market power in electricity market.

Meanwhile, Allez and Vila’s framework has been largely extended by adding retail competition, or by releasing the assumptions of risk-neutrality from retailers and no uncertainty in spot market. Powell (1999) models a linear demand with an additive normally distributed error and risk-averse retailers with mean-variance utilities. He finds that spot prices will be above competitive level if generators collude, and the more risk-averse the retailers the larger the degree of hedging and the futures-spot price premium. Green (2003) thus concludes that retail competition makes retailers reluctant to sign forward contracts and generators sell less electricity in the forward market if retailers face competition than if the retailers are regulated monopolies. Gans and Wolak (2007) empirically quantify the effects of a passive
acquisition case AGL-LYA between an electric generator and a retailer in Australia in 2004\(^4\). The analysis indicates a raise in wholesale prices in National Electricity Market as a consequence of the change of ownership.

As for the literature on vertical integration, there are several motives that could explain vertical integration: efficiency gains and reducing purchasing costs, eliminating double marginalization and reducing free riding problem. However, the reason that electricity is a special commodity is that these benefits do not seem possible to be achieved since electricity is traded either in spot market where an independent system operator (ISO) matches supply and demand or in forward market by long-term contracts. Thus all retailers have to buy electricity from a common wholesale market. Hart and Tirole (1990), Rey and Tirole (2007) demonstrate the anti-competitive harm that lead to foreclosure from vertical integration, which comes from the potential softening of downstream price competition or bargaining effects. O’Brien and Salop (2000) illustrate how acquisitions can lead to anti-competitive effects in merger cases. In accordance with pro-competitive effects of vertical commitments, Bonacina and Creti (2010) demonstrated that these effects come at a price of monopolization of forward market under a Stackelberg-like market structures.

Having gone through recent related literature, the theoretical framework that analyzes the impacts on forward trading when generation and retailing are vertically integrated in electricity market has not been studied before. Our analyses fill out this blank in the field of the literature and inherit from Gans and Wolak’s (2007) empirical work on a specific passive acquisition case where an electricity retailer acquires generation assets. We further incorporate retail competition and conjectural variation in the model and loosen the assumption on no-arbitrage opportunity between spot market and forward market. Compared to the former work, the model of this paper captures the trend of electricity market reform. The model settings are developed on the basis of Powell (1993) and Green (2003) but differ from the former work in various aspects. Both former models focus on the effects of trading forward when retailers face retail competition, however the vertical relationships between generators and retailers as well as generators’ risk aversion have never been taken into account.

The paper is contributed to the identification of the important role of a verti-

\(^4\)In 2003, the largest energy retailers Australia Gas Light Company (AGL) intended to acquire a stake as part of a consortium in the largest base-load generator in the state of Victoria Loy Yang A power station (LYA). On April 1, 2004 AGL took control of a 35% stake of LYA despite that the Australian Competition and Consumer Commission (ACCC) challenged the acquisition at the first place. See Gans and Wolak (2007).
cally separated market structure while a forward market is created for the purpose of limiting electricity generators’ ability to exercise market power under retail competition. Our findings analytically support Gans and Wolak’s (2007) empirical findings that a retailer’s acquisition of generation assets could raise spot prices. Additionally, our analysis suggests a sufficient but not necessary condition that the degree of generators’ risk aversion is below a boundary can insure the above claim to be true. Our analysis is also consistent with Bushnell Mansur and Saravia’s (2007) suggestion that vertical integration and vertical contract work as substitutes to each other. However instead of assuming retail prices as given, we model a liberalized retail market. We further distinguish the impacts on electricity competition of vertical contracts from the ones of vertical integration. That is to say, forward contracts limit the possibility of exercising market power from generators in spot market, whereas vertical integration does not. Finally, we perform a numerical simulation by assuming that the value of linear demand function is given. The results show that electricity price may increase significantly with the degree of vertical integration in this market. Overall, these discussions have strong policy implications and raise the question whether after liberalization of retail market vertical integration affects forward market and enhances the ability of the combined entity to exercise unilateral market power and to what extent vertical integration between generators and retailers affects forward trading in electricity market.

3 The model

To study the impacts of vertical market structure on forward contract trading, we adopt a standard duopoly model in spot markets, which incorporates the demand uncertainty in spot market and the variation of vertical integration between generators and retailers. Some settings in this model inherit from Powell (1999) and Green (2003). As in the former work, we model a duopolistic competition upstream where two strategic generators, denoted by \(i\) and \(j\), compete in quantities. For the downstream electricity market, we assume a liberalized retail market downstream in order to accommodate tendencies toward retail liberalization in electricity markets across countries. Although in some countries electricity retailing still remains under price regulation\(^5\), the trend for electricity retail liberalization has been introduced

\(^5\)The cost-based regulation on electricity retail prices is still largely applied in many countries. Regulated retail prices are designed to cover production and transmission costs plus some taxes. This would give incumbents little incentive to lower their purchase costs. Another form of regulation, so-called yardstick regulation, which was introduced for small consumers in 2002 in the UK, allows a retailer to charge a price equal to the average cost of all the other retailers in the industry. See Green (2003).
in many countries gradually, for instance in the UK, New Zealand, Australia etc.\textsuperscript{6}.

Generators and retailers meet in two wholesale markets in order to trade electricity: one is spot market where electricity is traded for short-term or immediate delivery; the other one is contract market where generators commit to sell (or buy) part of their capacities under a form of forward contracts and retailers submit their forward purchase demand. It is worth mentioning that we consider here both physical contracts and financial contracts, which means that in the contracts period generators could possibly be in either short or long positions. Thus the quantity of forward sales from electricity generators could also possibly be negative. The only source of uncertainty in this model is the realized short-term spot price, $P_s$. We assume there is a random shock to electricity demand influencing on spot prices with mean 0 and variance $\sigma^2$, such that the realized spot price is $P(Q) = P(Q) + \varepsilon$. Both generators and retailers are risk-averse. Their utilities are modelled with a mean-variance form.

In terms of vertical structure, the essential setting of this model is that the retailers, competing to each other in prices, could be to some extent vertically integrated with one of the generators. In many countries, vertically integrated electricity supply chain is still very common in spite of the prevailing market restructuring in electricity market. For instance in France, EDF remains as regulated monopolist in retail market and owns most of generation plants. In Spain, the merger case between leading operator Endesa and main generator Iberdrola calls Spanish government and regulators’ attention.\textsuperscript{7} Also this is the case in the UK, some large generation firms in England and Wales market are vertically integrated with downstream retailing firms. In order to capture such market structure, the parameter $\alpha$ denotes the degree of vertical integration of retailers over one of the generators, varying from 0 to 1. It can also be interpreted as the percentage of shares in generation assets held by retailing company. Following Gans and Wolak (2007), we claim that this vertical integration is a passive one, which means that the vertically integrated retailer can have a share in generator’s profit but cannot be involved in generator’s day-to-day bidding either contract trading activities in wholesale market.

The timing of the model is as following:

\textsuperscript{6}Joskow and Tirole (2006) suggest that creating retail competition in electricity market need load profiling of customers to be measure on a real time basis. Besides that, consumers may not react to the real time prices of the spot market because of transaction and monitoring costs, and constraints of physical attribute of their current distribution network.

\textsuperscript{7}See decision of Spanish National Energy Commission (2008): RESOLUTION SOBRE PROPUESTAS DE ARCHIVO (EXPEDIENTES 2600/05 CNE/EMPRESAS SECTOR, 2771/07 ENDESA, 2772/07 ACECA Y 2773/07 IBERDROLA).
Generators and retailers trade electricity under forward contracts. The spot price uncertainty is revealed and generators compete in spot market. The retailers realize profits by serving final consumers.

The two generators are identical with constant marginal cost $c$. At the first stage, generator $i$ and $j$ are willing to sell $q_i^f$ and $q_j^f$ MW electricity under forward contract and a representative retailer $r$, chooses his optimal proportion of forward purchase $s_r$ in his total sales, taking account for the degree of ownership over generation profits (profits from upstream market are zero if they are completely separated). One of the key features of this model is that the short-term price uncertainty is revealed after generators and retailers signing forward contract, which leaves generators behave strategically in spot market only at the second stage. We further assume that the volume of electricity traded under forward contracts in equilibrium will only have an impact on expected spot prices, and thus on forward premiums as well, but not on the variance of spot prices. This implies that $\frac{\partial \sigma^2}{\partial q_i^f} = \frac{\partial \sigma^2}{\partial q_j^f} = 0$. As demand shocks are exogenous from forward trading decision, this can be explained by sudden climate or temperature changes. So the assumption above could be well justified.

Before moving to the second stage, it is worth mentioning that the total generation capacity exceeds the total quantity of electricity traded under forward contracts, so that trade in spot market is always needed. Additionally, we assume that as bottom line electricity generation can cover the total demand when spot prices drop to the level of generators’ marginal costs. At the second stage, generators face a downwards-sloping linear demand curve, $P_s(Q) = a - b(q_i + q_j)$, where $q_i$ and $q_j$ are the quantities produced by generator $i$ and $j$ respectively.

At the last stage, retailers serve final consumers by competing in prices. Under retail competition, retailers face competition from potential entrants who have access to buy electricity from spot market. Since we focus on competition issues in the short run, we assume that the final demand does not vary at a given point in time. Moreover since electricity transmission and capacity constraints are not the main issues here, possibilities of transmission congestion and generation expansions are excluded.
### 3.1 Spot market

We start with spot market to solve generators’ problem backward. By the time of spot market opening, the demand shock is revealed to generators. Therefore competition in spot market is a classic Cournot game. Given generation capacities reserved for forward trading, Generators maximize their profits equal to the revenues made in spot market subtracted by production costs. So generator $i$’s profits are equal to:

$$\pi_i^G = (a - b(q_i + q_j))(q_i - q_i^f) - cq_i \tag{1}$$

Differentiating this profit function with respect to $q_i$ gives us the response function of generator $i$:

$$q_i = a - bq_j + bq_i^f - c \frac{2}{2b} \tag{2}$$

Similarly, the best response from generator $j$ given generator $i$’s output level $q_i$ is equal to:

$$q_j = a - bq_i + bq_j^f - c \frac{2}{2b} \tag{3}$$

Solving the two equations above, we can obtain the outputs of firm $i$ and $j$ as a function of their forward sales, such that:

$$q_i = a + 2bq_i^f - bq_j^f - c \frac{3}{3b} \tag{4}$$

$$q_j = a + 2bq_j^f - bq_i^f - c \frac{3}{3b} \tag{5}$$

And the realized spot price is given by:

$$P_s = a - b(q_i^f + q_j^f) + 2c \frac{3}{3} \tag{6}$$

Notice that both firms’ outputs increase with their own forward sales, but decrease with his rival’s forward sales and the realized wholesale price drops as forward sales increase.

### 3.2 Forward market

As the vertical integration of the retailers over generation companies is passive, generators’ objective functions in spot market are unaffected. Under spot demand uncertainty, firm $i$ and $j$ maximize their expected utilities which are given by a
mean-variance form:

\[
E[U^G_i] = E[\pi^G_i] - \frac{1}{2} \lambda^G \text{var}[\pi^G_i] \quad (7)
\]

where \( E[\pi^G_i] = (E[P_s] - c)q_i + (P_f - E[P_s])q_f^i \)

\( \text{var}[\pi^G_i] = (q_i - q_f^i)^2 \sigma^2 \)

\( \lambda^G \) denotes the degree of risk aversion of generators, which is identical to generators by assumption. Here, we do not impose the assumption of no arbitrage between spot market and forward market, such that the expected spot price \( E[P_s] \) is not necessarily equal to the forward price \( P_f \). There are two reasons for that: first, supply of forward contracts from generators and demand of forward purchase will be equalized in the contract market, which will yield forward price in equilibrium; second, the risks brought by demand shocks in spot market and retailers’ risk attitude should be reflected in forward premium, which is the difference between forward price and spot price. We can then rewrite the expected utility of firm \( i \) equal to:

\[
E[U^G_i] = \frac{(a - b q^f_i - b q^f_j - c)}{3} (a + 2b q^f_i - b q^f_j - c) \frac{3b}{3} + (P_f - E[P_s])q_f^i - \frac{1}{2} \lambda^G \sigma^2 (a - b q^f_i - b q^f_j - c)^2 \frac{9b^2}{9b^2} \quad (8)
\]

Each of the generators wishes to maximize his utility by setting his quantity of electricity sales committed to forward contracts, in response to his rival’s. In order to model the strategic moves of generators in forward market, accounting for the fact that rival’s response may not be complete in forward market, we capture the competitive imperfections in forward market by the notion of conjectural variation. It represents one firm’s belief in its rival’s reaction on forward trading in response to a change of its forward sales. Following this rationale, the first order condition is
given by:

\[
\frac{\partial E[U^G_i]}{\partial q^f_i} = \frac{2(a - bq^f_i - bq^f_j - c)}{9} - \frac{(a + 2bq^f_i - bq^f_j - c)}{9} \\
+ \frac{\partial((P_f - E[P_s]))}{\partial q^f_i} q^f_i + (P_f - E[P_s]) + \lambda_G \sigma^2 \frac{(a - bq^f_i - bq^f_j - c)}{9b} \\
+ \frac{\partial q_j}{\partial q_i} \left( - \frac{(a - bq^f_i - bq^f_j - c)}{9} - \frac{(a + 2bq^f_i - bq^f_j - c)}{9} \\
+ \frac{\partial(P_f - E[P_s])}{\partial q^f_i} q^f_i + \lambda_G \sigma^2 \frac{(a - bq^f_i - bq^f_j - c)}{9b} \right) \\
= 0
\]  

(9)

Solving the optimal level of forward sales is more complicated under the first order condition derived from generator’s utility function at the second stage. Following Green’s method, we denote the extent of conjectural variation \( \frac{\partial q_j}{\partial q_i} \) by \( \beta \in [-1, 0] \). The two extreme cases are Bertrand competition in forward market corresponded by \( \beta = -1 \), and Cournot competition when \( \beta = 0 \). Consequently, the conjectural variations capture all cases in the middle status when firms’ reactions in forward market are not complete. As a result, we deduct the forward price premium from equation (9):

\[
P_f - E[P_s] = \frac{q^f_i}{9} \left[ (4 + \beta)b + (1 + \beta)(\lambda_G \sigma^2 - \frac{9\partial(P_f - E[P_s])}{\partial q^f_i}) \\
- \frac{a - c - bq^f_j}{9} \left[ 1 - 2\beta + (1 + \beta)\frac{\lambda_G \sigma^2}{b} \right] \right]
\]  

(10)

And the reaction function of forward trading from firm \( i \) is given by:

\[
q^f_i = \frac{(1 - 2\beta + (1 + \beta)\frac{\lambda_G \sigma^2}{b})(a - c - bq^f_j) + 9(P_f - E[P_s])}{(4 + \beta)b + (1 + \beta)(\lambda_G \sigma^2 - \frac{9\partial(P_f - E[P_s])}{\partial q^f_i})}
\]  

(11)

Notice that the best response on forward sales from generator \( i \) is, not surprisingly, increasing with the expected forward premium and decreasing with the variation of forward premium resulted from a variation of forward sales. Now we turn into retail market in the next section.

3.3 Retail market

We model a liberalized retail market where \( N \) symmetric retailers compete downstream by setting uniform retail prices to all customers in electricity downstream.
market given end-user demand at one point in time\textsuperscript{8}. The amount of electricity supplied by each retailer is denoted by $V$. We then consider one representative retailer $r$ owns some shares in generation firm $i$’s profits. The degree of vertical integration of the retailer, $\alpha$, is interpreted as the retailer’s shares in generator’s profits in percentage, such that $0 \leq \alpha \leq 1$. So $\alpha = 0$ represents complete separation between retailers and generators, whereas $\alpha = 1$ indicates fully vertical integration. When electricity retailing is unregulated, the existing retail incumbents are free to set retail prices, $P_r$, but they are threatened by new entrants who can buy electricity in spot market and undercut their retail prices if incumbents’ prices are high. Supposing the new entrants will always have the access to instantaneously buy electricity in spot market and the existing retail incumbents have an additional advantage as they are protected by switching costs, as a consequence, electricity retail prices at equilibrium chosen by the incumbents would be equal to the expected spot market prices plus the average switching costs per unit of electricity demand.

The fact that the obligation for retailers to meet any level of final demand from consumers and facing potential competition from new entrants makes the retailers expose to more risks than generators since he has limited ability to raise retail prices when quantity of forward purchase is determined before the spot uncertainty realized. As a consequence, it is reasonable to assume that the retailers is at least as risk-averse as generators, namely $\lambda_R \geq \lambda_G$. That means a retailer is more eager to seek a device to hedge risks than a generator.

Retailers also have mean-variance utility. At the contract stage, a retailer $r$ maximizes his expected utility by choosing the optimal share of forward purchase in his total electricity sales to final consumers. We denote retailer $r$’s forward proportion by $s_r$ and his expected profit is given by the sum of revenues from serving final consumers, trading forwards and his share in generator $i$’s profits benefited from the vertically integrated structure. The objective function of the retailer $r$ is given by:

\begin{align}
E[\pi^R] &= (P_r - E[P_s])V + (E[P_s] - P_f)s_rV + \alpha \left( (E(P_s) - c)q_i + (P_f - E[P_s])q_i^f \right) \\
&\quad - \frac{1}{2} \lambda_R \sigma^2 \left( V - s_rV - \alpha(q_i - q_i^f) \right)^2 \\
&= \pi V + (E[P_s] - P_f)s_rV + \alpha \left( (E(P_s) - c)q_i + (P_f - E[P_s])q_i^f \right) \\
&\quad - \frac{1}{2} \lambda_R \sigma^2 \left( V - s_rV - \alpha(q_i - q_i^f) \right)^2
\end{align}

\textsuperscript{8}Although retail prices could differ from industrial customers and residential customers, it is not the main issue here. We adopt a uniform price for both industrial customers and small customers by simplification
where $P_r = E[P_s] + \pi$ and $\pi$ is the average switching costs per unit of electricity to final consumers. As a consequence, the vertical integrated retailer is not only able to internalize the additional profits earned from the generation assets, there is also a risk reduction effect from his ownership over generation plants. Retailer’s decision of forward purchase depends on the variance of his profits. As we can see from his objective function, vertical integration reduces the profit variance of the retailer. Differentiating the retailer’s utility function with respect to the share of forward trading gives us the expression of forward premium from the demand side:

$$P_f - E[P_s] = (V - s_r V - \alpha(q_i - q_f^i))\lambda R \sigma^2$$  \hspace{1cm} (13)$$

As we can see from equation (13) without loss of generality, the expected utility maximizing retailers would fully hedge his retail sales with forward contracts if he is not vertically integrated with generation and if there is no arbitrage opportunities between forward market and spot market (forward price will be equal to expected spot price). Moreover without vertical relationships with generators, the retailer would be willing to purchase forward contracts only if forward prices exceed expected spot prices when retail market is open to competition. This result is consistent with Green’s finding. The degree of retailers’ risk attitude is reflected in the forward premium. Equation (13) implies that a vertical relationship between retailing and generation provides a natural hedge to retailers against wholesale price risks. The retailer is facing a trade-off between lowering profit variance by trading forward and obtaining more generation profits by trading in spot market. On one hand, a lower level of forward trading raises retailer’s risks and brings less benefit to the vertically integrated retailer; on the other hand, more generator’s profits are internalized by the retailer since the spot price is increased and at the same time the retailer’s risks can also be reduced by vertically integrated market structure. The optimal level of forward purchase will counterbalance these two effects.

**Benchmark case of vertical separation: $\alpha = 0$**

Notice that $s_r$ in equation (13) will be solved endogenously in the model. If every retailer is vertically separated from generation, a symmetric structure implies that every retailer will trade electricity at the level of the industry average and the optimal proportion of forward purchase is linear in the forward premium. So we will have $s_0 = s_r$, where $s_0$ denotes the coverage of forward trading when retailers’ profits are independent from upstream generators’ performance. The aggregated forward demand is therefore $N s_0 V$ and equal to the supply of forward contracts $q_f^i + q_f^j$ at
the equilibrium, such that \( s_0V = \frac{q_i^f + q_j^f}{N} \). Keeping in mind that at equilibrium the total demand of forward contracts and the total supply of forward contracts must be equal, we implement the above results into the forward premium equation of retailers. We have:

\[
P_f - E[P_s] = (V - \frac{(q_i^f + q_j^f)}{N})\lambda_R\sigma^2
\]

(14)

By equalizing equation (14) with the forward premium equation (10) for generators from the supply side, we solve the optimal level of contract sales symmetrically for generator \( i \):

\[
q_{i0}^* = \frac{9\lambda_R\sigma^2V + (1 - 2\beta + \frac{\lambda_G\sigma^2}{b}(1 + \beta))(a - c) - 2(1 + \beta)\lambda_G\sigma^2 + 2\frac{\sigma^2}{N}\lambda_R\sigma^2}{b(5 - \beta) + 2(1 + \beta)\lambda_G\sigma^2 + 2\frac{\sigma^2}{N}\lambda_R\sigma^2}
\]

(15)

Notice that when generators and retailers are independent to each other, the level of forward trading at equilibrium is mainly depend on generators’ and retailers’ degree of risk aversion and the number of firms in retail market. The result implies that increasing the number of players in retail market could increase the optimal contract level. Therefore without vertical integration of retailers over generation, opening electricity retail market in order to introduce new entrants has desirable effects on competition.

**Case of vertical integration: 0 < \alpha \leq 1**

Now we consider the case where a retailer holds \( \alpha \) shares in generator \( i \)’s profits. As in the former case, the proportion of forward contracting in each retailer’s total sales is endogenous. We thus hold the contracting level of the \( N - 1 \) independent firms unchanged since their vertical structure remains the same as before, meaning that firms are not reacting strategically in the retail market. This may not be an innocent assumption when retail market is not purely competitive yet. However we retain it to simplify our model, as our goal here is not to model retailers’ behaviour. The vertically integrated retailer \( r \), however will adjust his forward contracting level given his vertical structure change. Then we can naturally think that the share of forward contracting of the vertically integrated retailer would differ from the average level of the rest of the industry. To reach the result at equilibrium, the parameter \( s_0 \) in the case of \( \alpha = 0 \), now represents the average proportion of forward contracting in retail sales of the rest of active retailers in the market excluding the vertically integrated retailer \( r \). We equalize forward demand and forward supply and obtain \( s_rV + (N - 1)s_0V = q_i^f + q_j^f \), such that \( s_rV = q_i^f + q_j^f - (N - 1)s_0V \). Implementing
this equation and equation (4) into the forward premium equation (13), we have:

\[ P_f - E[P_s] = [V + (N - 1)s_0V - \frac{\alpha}{3b}(a - c) - (1 - \frac{\alpha}{3})(q^f_i + q^f_j)] \lambda R \sigma^2 \quad (16) \]

Differentiation equation (16) with respect to \( q^f_i \) gives us:

\[
\frac{\partial (P_f - E[P_s])}{\partial q^f_i} = -(1 - \frac{\alpha}{3}) \lambda R \sigma^2
\]

Notice that the forward premium is reasonably decreasing with the quantity of forward sales. As the uncertainty decrease with the quantity of forward contracting, forward prices would converge to the expectation of the spot prices. By equalizing the two forward premium equations (10) and (16) and bearing in mind that the level of forward sales at optimum would be symmetric for two strategic generators, we solve for optimal level of sales under forward contracts for generator \( i \):

\[
q^f_i^* = \frac{9 \lambda R \sigma^2(V + (N - 1)s_0V) + (1 - 2\beta + \frac{\lambda G \sigma^2}{b}(1 + \beta) - \frac{3\alpha \lambda \rho \sigma^2}{b})(a - c)}{b(5 - \beta) + 2(1 + \beta)\lambda G \sigma^2 + 9(3 + \beta)(1 - \frac{\alpha}{3}) \lambda R \sigma^2}
\]

Thus following the above results, the total amount of forward sales in equilibrium is \( 2q^f_i^* \). Notice that at optimum, the quantity of electricity traded under forward contracts does not depend on forward prices directly, but on various factors that affect forward premium. Increasing the number of retailers in downstream market, reducing marginal production costs and increasing the demand sensitivity to prices in spot market could raise the optimal level of forward contracting at equilibrium, and thus decrease spot prices and mitigate generators market power. Those are consistent results with the case of vertical separation and in line with classical industrial economic theories. It is worth noticing that the spot price uncertainty is adjusted by retailers’ and generators’ degree of risk aversion.

One interesting result is that when the competition in forward market between generators is Bertrand competition, correspondingly \( \beta = -1 \), the optimal quantity of forward trading does not depend on the coefficient of risk aversion of generators.

**Proposition 1.** Under retail competition in electricity market, generators’ degree of risk aversion is a determinant to the optimal level of forward trading at the equilibrium if and only if the generators are not competing in price.

Following the above proposition, we write the optimal quantity of forward trading
when the parameter of conjectural parameter is $-1$ and we have:

$$q_i^* = \frac{9\lambda R\sigma^2(V + (N - 1)s_0V) + (1 - 2\beta - \frac{3\alpha\lambda R\sigma^2}{b})(a - c)}{b(5 - \beta + 9(3 + \beta)(1 - \frac{a}{3})\lambda R\sigma^2)}$$  \hspace{1cm} (19)

As shown above, the optimal level of forward trading is determined by the coefficient of risk aversion of retailers and the degree of vertical integration. Having said so, generators’ risk aversion is still a determinant to the effects of vertical integration on forward trading, regardless price or quantity competition between generators in forward market.

**Proposition 2.** When generators’ risk aversion and spot price uncertainty are not too large, we have:

$$\frac{\partial q_i^f}{\partial \alpha} < 0 \quad \text{and} \quad \frac{\partial^2 q_i^f}{\partial \alpha^2} < 0$$

A sufficient but not necessary condition is:

$$\lambda_G < \frac{2b}{\sigma^2}$$

**Proof.** After a few rearrangements, we obtain:

$$\frac{\partial q_i^f}{\partial \alpha} = \frac{-27\lambda R^2\sigma^4(3 + \beta)(\frac{a - c}{b} - (V + (N - 1)s_0V)) - 3\lambda R\sigma^2(a - c)(1 + \beta)^2(2 - \frac{\lambda \sigma^2}{b})}{(b(5 - \beta + 2(1 + \beta)\lambda G\sigma^2 + 9(3 + \beta)(1 - \frac{a}{3})\lambda R\sigma^2))^2}$$

The first term of the nominator is negative since $\frac{a - c}{b} \geq Q > V + (N - 1)sV$. That is to say, the total electricity supply at the maximum achieved by setting spot price equals to marginal cost should be larger than the total forward demand in retail market plus one retailer’s demand in spot market. This point is covered by assumption. Consequently, as long as $\frac{2\lambda G\sigma^2}{b} < 2$, the second term of the nominator is negative. Thus the result $\frac{\partial q_i^f}{\partial \alpha} < 0$ is assured.

Under the same condition, the second derivative equal to:

$$\frac{\partial^2 q_i^f}{\partial \alpha^2} = -\frac{6(\beta + 3)[27\lambda R^2\sigma^4(3 + \beta)(\frac{a - c}{b} - (V + (N - 1)sV)) + 3\lambda R\sigma^2(a - c)(1 + \beta)^2(2 - \frac{\lambda \sigma^2}{b})]}{(b(5 - \beta) + 2(1 + \beta)\lambda G\sigma^2 + 9(3 + \beta)(1 - \frac{a}{3})\lambda R\sigma^2)^2}$$

$$< 0 \quad \text{if} \quad \lambda_G < \frac{2b}{\sigma^2}$$

Thus, the impact on electricity forward trading resulted from a vertical inte-
Integration between a retailer and generator $i$ is decreasing and concave. That means that the vertical relationship between retailers and generators not only results in anti-competitive effects in electricity market, but reinforces these effects at an increasing rate. We conclude that a vertical integration between a generation firm and a retailing firm, even a passive one, could give rise to unilateral market power of generators in electricity wholesale market and its negative impacts increase more quickly as the degree of vertical integration becomes large.

4 Numerical simulation

In order to perform a numerical simulation of our model, we introduce a numerical simulation to show whether the effects of market power mitigation are countered by vertical integration between retailers and generators. Although some of the values used for the parameters are hypothetical, they are as close as possible to the reality.

We set the intercept of the inverse demand function, $a$, equal to 100. The slope of the inverse is $b = 2/3$. The marginal cost $c$ is 25, which can be interpreted as €25/MWh. This implies that without forward trading, the total output from those two generators is equal to 75/MWh and thus 37.5/MWh from each one of them. Without retailers’ and generators’ risk aversion, the realized spot price will be certain and equal to €50/MWh.

There are 4 main retailers downstream, such that $N = 4$. Table 1 summarizes the evolution of numbers of main retailers in some representative European countries. We keep our definition for main retailers to be consistent with European Commission’s. A retailer is considered to be a main retailer if he sells at least 5% of the total national electricity consumption. As we can see, the number of main retailers varies from 1 to 6 across different European countries in 2011. In countries like France, electricity retailing is still very concentrated with only one main retailer, whereas in the UK, there are 6 main retailers 2011. All in all, the numbers of main retailers in representative European countries have been stable from 2003 to 2011. Therefore setting the number of retailers $N = 4$ is fairly realistic. Each retailer’s sales is $V = 15$/MWh. As a result in the absence of forward contracts, the gap between total electricity generation and total retailers’ sales is $15$/MWh.\textsuperscript{10} This gap could be explained by two reasons: first, there is transmission loss of electricity that has to be accounted for; second, retail fringes and entrants could possibly take over.

\textsuperscript{9}To simplify the model, we adopt an uniform average value for marginal cost of generation plants.

\textsuperscript{10}Recall that in the absence of forward trading and vertical integration, the total generation of electricity would be 75MWh. The quantity purchased by retailers is equal to 60MWh.
Table 1: Number of main electricity retailers

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Source: Eurostat

Table 2: Summary of statistics of spot prices (in Euro)

<table>
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<th>France</th>
<th>Germany</th>
<th>Nord Pool</th>
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<tbody>
<tr>
<td>Average spot prices</td>
<td>46.21</td>
<td>42.74</td>
<td>30.26</td>
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<tr>
<td>Std. Dev.</td>
<td>11.80</td>
<td>11.18</td>
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some amount of electricity sales in downstream market.

We calculate the variances of spot prices on a hourly basis by using spot market data in France, Germany and Nord Pool market between January 1st and December 31st 2012. The data of spot prices in French and German market is collected from European Energy Exchange (EEX), released by European Power Exchange (EPEX spot market data). Data of Nordic countries is sourced from website Nord Pool Spot. All spot prices are hourly and in euro. We drop the highest 5% and the lowest 5% spot prices in each market in order to avoid the influence from abnormal prices. Table 2 summarizes the variances of spot prices of the year 2012 in French market, German market and Nord Pool Spot. The average spot price is the highest and the price is the most volatile in France, whereas the average is the lowest and the price is the least volatile in Nordic countries.

We start with the value of retailer’s degree of risk aversion equal to 0.2. Since 11Green finds that the coefficient of retailers’ risk aversion is equal to 0.178 by using a “grapes from wine” technique suggested by Grinold (1996). Therefore it is reasonable for to start with 0.2 as coefficient of risk aversion of retailers

11
Figure 1: Share of forward sales on degree of vertical integration (France)

Figure 2: Expected spot prices on degree of vertical integration (France)
the retailers are at least as risk-averse as generators by assumption, under Cournot competition in forward market, we first study the case when generators are equally risk-averse as retailers. Then we reduce generators’ risk aversion gradually by 25%, 50% and 75% with respect to the coefficient of risk aversion of retailers. Finally we need not do sensitivity tests on generators’ coefficient of risk aversion in the case of Bertrand competition in forward market since generators’ risk aversion does not play a role on forward trading here.

The initial coverage of forward contract for generators and retailers at equilibrium under vertical separation is determined by equalizing $q^f_i$ from equation (18) given $\alpha = 0$ to $q^f_0$ from equation (15). The initial coverage is not sensitive to the changes of spot price variances, however it is sensitive to conjectural variation. When $\beta = 0$ in the case where generators and retailers are equally risk-averse for instance, the starting value of the average coverage of forward trading in retailers’ total sales when $\alpha = 0$ is all around 140%, calculated with variances of spot prices in France, Germany and Nord Pool Spot12. Thus with coefficient of risk aversion equal to 0.2, risk-averse retailers will be over covering their retail sales, up to about 40% more of their total sales. As generators’ risk aversion goes down, the average coverage when $\alpha = 0$ decreases. As a contrast when $\beta = -1$, the average industry coverage under vertical separation between generators and retailers is about 60% for three countries13. Therefore, when $\beta = -1$ retailers tend to under cover their sales with forward contracts.

Figure 1 shows how the share of forward sales in total electricity output generated vary with the degree of vertical integration between generators and retailers by using French data. Figure 2 shows how expected spot prices vary on the same basis by using French spot price variance. Given the level of vertical integration between one generator and one retailer, generators’ risk aversion has a scale effects on forward trading. The more risk-averse the generators are, the higher level of forward sales and thus the lower spot prices achieve. All five situations unanimously suggests that the optimal forward trading decreases with the degree of vertical integration and expected spot prices increase with vertical integration. Specifically in the case of Bertrand competition in forward market where $\beta = -1$, vertical integration draws downs the share of forward sales rapidly, from 46.73% to 8.34% when the degree of vertical integration varies from 0 to 1. Under the same condition, the

12To be more precise, the initial coverage with the variance of French spot prices is equal to 141.04%. The one with German variance is equal to 140.99% and the one with Nord Pool variance is 140.37%

13The initial coverage for each retailers is equal to 57.65% calculated with French data, 57.89% calculated with German data and 61.14% calculated with data from Nord Pool Spot.
expected spot price increases from 40.78/MWh to 48.57/MWh, representing 19.10% of price increase. As a contrast when conjectural variation is 0, in the case of the most risk-averse generators, forward coverage of total generation goes down from 60.14% to 52.38% and expected price raises from 37.46/MWh to 39.31/MWh, representing 4.94% of price increase. In the case of the least risk-averse generators, forward contracts cover 50.00% of electricity generation capacity when generators and retailers are separated, while they cover only 35.81% of electricity trading if the retailer owns fully the generator’s assets. The expected spot price raises 8.05%, from 40/MWh to 43.22/MWh as the degree of vertical integration varies from 0 to 1. Consequently under Cournot competition in forward market, a higher coefficient of risk aversion of generators indicates a higher contracting level when generators and retailers are separated, but it also presents a faster pattern of decrease along with the variation of vertical integration.

Similarly, 3 and figure 5 illustrate the changes of optimal forward trading of total output in percentage with the degree of vertical integration, calculated with spot price variances from Germany and Nord Pool in 2012 respectively. Figure 4 and figure 6 show the variation of expect spot prices on vertical integration, calculated with German data and Nord Pool’s data. All analysis uniformly shows the same pattern on the change of forward trading and the change of expect spot prices on the basis of vertical integration. Consequently, the results of numerical simulation refine our conclusion of the qualitative model that vertical integration diminishes the pro-competitive effects of forward contracts in electricity market. As a result, the quantity of forward sales drops and the expected spot price increases after a retailer acquires shares in generation.

5 Conclusion

The model developed in this paper is to analyze the impact of vertical integration between retailers and generators on forward trading. When electricity retailing is open to competition, we show that a partially or a fully vertical integration between a generating firm and a retailing firm will decrease the optimal quantity of electricity traded under forward contracts if the degree of risk aversion of generators is not too high as a sufficient but not necessary condition. Therefore, vertical integration appears as a substitute to forward contracts for risk-averse electricity retailers to hedge spot risks. However as vertical integration cannot work as a device of market power mitigation of generators, the spot prices increase as a result of vertical integration. Therefore we conclude that vertical integration could give rise to generators
**Figure 3:** Share of forward sales on degree of vertical integration (Germany)

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**Figure 4:** Expected spot prices on degree of vertical integration (Germany)
Figure 5: Share of forward sales on degree of vertical integration (Nord Pool)

Figure 6: Expected spot prices on degree of vertical integration (Nord Pool)
to exercise market power in electricity spot market.

A numerical simulation in the following step confirms our theoretical results. As shown in section 4, the pro-competitive effects of forward contracts are countered by vertical integration between generators and retailers. The optimal quantities of forward trading are decreasing and the spot prices are increasing with the degree of vertical integration. All sensitivity analysis points to the same conclusion. Furthermore, under Cournot competition in forward market, generators with higher degree of risk aversion trade more electricity under forward contracts if generators are structurally separated from retailers. However higher risk aversion of generators brings more adverse effects if generators are integrated with retailers.

Based on our analysis, we suggest that mergers and acquisitions between generators and retailers need more scrutiny even if the retailers have no impacts on generators’ bidding behaviour in spot market, since a retailer passively taking ownership over generation could already give rise to market power in spot market.

As for limitations of the model, some assumptions adopted are crucial in order to obtain the above results. The results might be sensitive to downstream settings. For instance, the results might vary if retail prices are subject to different types of price regulation, or they might vary according to retailers’ reactions to the change of market structure. It might be also worth studying the competitive impacts on electricity market when retailers have a influence on generators’ bidding behaviour. These issues leave room for future research.
References


