Economics Letters 146 (2016) 135–139

Contents lists available at ScienceDirect

Economics Letters

journal homepage: www.elsevier.com/locate/ecolet

How does renewables competition affect forward contracting in electricity markets?

Robert A. Ritz *

Energy Policy Research Group (EPRG), Judge Business School & Faculty of Economics, University of Cambridge, United Kingdom

HIGHLIGHTS

- Renewables weaken the incentive of conventional electricity generators to sell forward.
- This forward-contracting effect reduces the intensity of competition among incumbents.
- More renewable energy raises the wholesale price when its capacity utilization is low.
- Renewables may undermine the role of forward contracting in mitigating market power.

ARTICLE INFO

Article history:
Received 21 March 2016
Received in revised form
4 July 2016
Accepted 15 July 2016
Available online 2 August 2016

JEL classification:
L13
L94
Q21
Q41

Keywords:
Electricity markets
Renewable energy
Forward contracting

ABSTRACT

Higher renewables penetration reduces the incentive of conventional electricity generators to sell forward production. This can undermine the role of forward contracting in mitigating market power. More renewable energy *raises* wholesale electricity prices in states of the world where its capacity utilization is low due to intermittency.

1. Introduction

Renewables such as solar and wind already account for up to 30% of power generation in the UK, Germany and parts of the US (Pollitt and Anaya, forthcoming), and global decarbonization objectives will require further large-scale investment. Due to near-zero marginal costs, renewables come with a "merit-order effect" of displacing conventional generators (Green and Léautier, 2015; Liski and Vehvilainen, 2015).

The literature on wholesale electricity markets emphasizes how forward contracting can mitigate market power (e.g., Wolak, 2000; Ausubel and Cramton, 2010). Such commitments can take the form of forward contracting (Allaz and Vila, 1993) or retail sales (Bushnell et al., 2008).[1] In practice, power generators indeed sell forward a significant fraction of production (Anderson et al., 2007).

This paper examines the interaction between renewables competition and forward contracting. The model generalizes (Allaz and Vila, 1993) to (i) incorporate the intermittent nature of renewables production, and (ii) allow for $n > 2$ strategic players, with cost heterogeneity to represent different generation technologies.

2. Model

Consider a wholesale electricity market with a set $N = \{1, 2, \ldots, n\}$ of $n \geq 2$ "incumbent" electricity generators.

* Correspondence to: Cambridge Judge Business School, Trumpington Street, Cambridge CB2 1AG, United Kingdom.
E-mail address: rar36@cam.ac.uk.

[1] This paper takes the same approach as this literature in that it examines the *strategic* incentive for forward contracting rather than the hedging motive driven by risk aversion.

http://dx.doi.org/10.1016/j.econlet.2016.07.024

Renewables are installed with capacity R, with zero marginal costs.[2] Assume that the n firms are "active" (i.e., profitable); as will become clear, this holds as long as renewables capacity is "not too large", $R < \bar{R}$.

There are $M \geq 2$ states of the world, reflecting the intermittency of renewables production. State m occurs with probability $\delta_m \in (0, 1)$ where $\sum_{k=1}^{M} \delta_k \equiv 1$. In state m, the rate of capacity utilization of renewables is $\gamma_m \in (0, 1]$, ordered as $\gamma_1 > \gamma_2 > \cdots > \gamma_M$. Firm $i \in N$ sells x_i^m units at marginal cost c_i, so total conventional output $X_m \equiv \sum_{i \in N} x_i^m$.

Electricity buyers form a linear demand curve $p(Q) = \alpha - \beta Q$, where Q is consumption and $(\alpha, \beta) > 0$. There is market clearing in each state of the world, so prices are state-contingent: in state m, total output satisfies $Q_m = X_m + \gamma_m R$, and electricity trades at a price p_m.

The timing of the game is as follows. In Stage 1, each incumbent chooses its forward commitment y_i. Following Allaz and Vila (1993), Bushnell (2007), Fowlie (2009) and others, the contract market is assumed to be competitive with no arbitrage profits; as noted by Allaz and Vila (1993), this would be the case, e.g., in the presence of two Bertrand speculators.[3] Then the state of the world γ_m is revealed. In Stage 2, each incumbent chooses its output x_i^m. Incumbents each maximize profits while interacting strategically; renewables production is non-strategic. Firms' choices are assumed to be observable and there is no discounting. The game is solved for the subgame-perfect Nash equilibrium.

3. Results

The main question is, what is the equilibrium impact of more renewables capacity R? This could arise because of renewables subsidies or due to technological progress which reduces their investment costs.

First-order conditions

In Stage 2, the state of the world m is known. Firm i's problem is to:

$$\max_{x_i^m} \left\{ (x_i^m - y_i) p_m - c_i x_i^m \right\}$$

where y_i is its forward commitment made in Stage 1, and demand $p_m = \alpha - \beta(X_m + \gamma_m R)$. The firm here only makes revenues on its uncommitted units $(x_i^m - y_i)$. The first-order condition is:

$$\begin{aligned} 0 &= (p_m - c_i) - \beta(x_i^m - y_i) \\ &= [\alpha - \beta(X_m + \gamma_m R) - c_i] - \beta(x_i^m - y_i). \end{aligned} \quad (1)$$

These n first-order conditions define incumbents' optimal output choices as a function of contracts. Let $\mathbf{Y} = (y_1, y_2, \ldots, y_n)$ denote forward positions, leading to outputs $x_i^m = x_i(\mathbf{Y}; \gamma_m)$ for each $i \in N$, and thus $X_m = X(\mathbf{Y}; \gamma_m)$ and $p_m = p(\mathbf{Y}; \gamma_m)$ for each state m.

In Stage 1, the state of the world is not yet known, so firm i maximizes its expected profits:

$$\max_{y_i} E\pi_i = \sum_{k=1}^{M} \delta_k \left\{ (p_k - c_i) x_i^k + (p^f - p_k) y_i \right\}.$$

The first term reflects spot-market profits and the second term represents forward-market profits at price p^f. With a competitive forward market, the latter is zero since $p^f = \sum_{k=1}^{M} \delta_k p_k$ by the no-arbitrage condition.

Thus firm i's problem boils down to:

$$\max_{y_i} E\pi_i = \sum_{k=1}^{M} \delta_k \left[p(\mathbf{Y}; \gamma_k) - c_i \right] x_i(\mathbf{Y}; \gamma_k),$$

which makes explicit the dependencies on the contract position arising in Stage 2. The first-order condition is:

$$\begin{aligned} 0 = \sum_{k=1}^{M} \delta_k \bigg\{ &[p(\mathbf{Y}; \gamma_k) - c_i] \frac{dx_i(\mathbf{Y}; \gamma_k)}{dy_i} \\ &- \beta x_i(\mathbf{Y}; \gamma_k) \frac{dX(\mathbf{Y}; \gamma_k)}{dy_i} \bigg\}. \end{aligned} \quad (2)$$

This reflects how firm i's forward commitment y_i affects its own subsequent production x_i^m as well as total output X^m in each of the M states.

Lemma 1. *In state m, the incumbent firms' output responses in Stage 2 satisfy:*

$$\frac{dX(\mathbf{Y}; \gamma_k)}{dy_i} = \frac{1}{(n+1)} > 0 \quad \text{and} \quad \frac{dx_i(\mathbf{Y}; \gamma_m)}{dy_i} = \frac{n}{(n+1)} > 0.$$

Proof. Summing (1) over all n firms gives:

$$0 = n[\alpha - \beta(X(\mathbf{Y}; \gamma_m) + \gamma_m R)] - \sum_{i \in N} c_i - \beta[X(\mathbf{Y}; \gamma_m) - Y].$$

Solving this for aggregate output gives:

$$\begin{aligned} X(\mathbf{Y}; \gamma_m) &= \frac{n(\alpha - \beta\gamma_m R) - \sum_{i \in N} c_i + \beta Y}{\beta(n+1)} \Longrightarrow \frac{dX(\mathbf{Y}; \gamma_m)}{dy_i} \\ &= \frac{dX(\mathbf{Y}; \gamma_m)}{dY} = \frac{1}{(n+1)} \end{aligned} \quad (3)$$

since $Y \equiv \sum_{i \in N} y_i$, and so $dY/dy_i = 1$. Rearranging (1) shows that for firm i:

$$\begin{aligned} x_i(\mathbf{Y}; \gamma_m) &= y_i + \frac{(\alpha - c_i)}{\beta} - [X(\mathbf{Y}; \gamma_m) + \gamma_m R] \\ &\Longrightarrow \frac{dx_i(\mathbf{Y}; \gamma_m)}{dy_i} = 1 - \frac{dX(\mathbf{Y}; \gamma_m)}{dy_i}, \end{aligned}$$

which using (3) confirms that $dx_i(\mathbf{Y}; \gamma_m)/dy_i = n/(n+1)$. ■

Lemma 1 shows that the pro-competitive effect of forward contracting (Allaz and Vila, 1993) survives under the presence of renewables. This reflects that competition in Stage 2 is in *strategic substitutes*: if firm i raises its output, then it is optimal for its rivals to cut back (and so $dx_i/dy_i > dX/dy_i > 0$).

A key observation is that these output responses are *state-independent*: they do not vary with renewables utilization γ_m, which only has an impact on the levels of prices and quantities.[4]

2 For simplicity, renewables are grouped into a single capacity figure.

3 Forward markets can be more competitive than spot markets due to the participation of financial players like banks and commodity traders (who do not own physical assets). In several major European systems, e.g., Germany and the Nordics, forward markets are highly liquid with traded volumes being 3–6 times larger than underlying consumption (ECA, 2015). The Nordic financial electricity market has 400 participants and the Top 5 players' combined market share is only ∼25% (NordREG, 2010). By contrast, wholesale spot markets are often still dominated by a small number of large players.

4 This is a feature of the linear-quadratic model setup.