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Electricity Market Mergers with Endogenous Forward Contracting

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by

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Abstract

We analyze the effects of electricity market mergers in an environment where firms endogenously choose their level of forward contracts prior to competing in the wholesale market. We apply our model to Alberta's wholesale electricity market. Firms have an incentive to reduce their forward contract coverage in the more concentrated post-merger equilibrium. We demonstrate that endogenous forward contracting magnifies the price increasing impacts of mergers, resulting in larger reductions in consumer surplus. Current market screening procedures used to analyze electricity mergers consider firms' pre-existing forward commitments. We illustrate that ignoring the endogenous nature of firms' forward commitments can yield biased conclusions regarding the impacts of market structure changes such as mergers. In particular, we show that the price effects of mergers can be largely underestimated when forward contract quantities are held at pre-merger levels. Whether the profits of the merged firm are greater with fixed or endogenous forward quantities is ambiguous.

Keywords: Electricity, Mergers, Forward Contracts, Market Power, Regulation
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1 Introduction

Worldwide, the electricity industry has been undergoing considerable consolidation through large-scale mergers and acquisitions.[1] In the United States, recent examples of high profile electricity market merger cases include Exelon and Constellation (MPSC, 2012) and Exelon and Public Service Enterprise Group (PSEG) (FERC, 2005) valued at $8 and $16 billion, respectively. Analyses of mergers and market structure changes in the electricity industry present distinct challenges for regulatory authorities. While there is strong potential for market power, conventional market concentration measures used to assess market power are poorly suited for electricity markets (Borenstein et al., 1999; Bushnell, 2005, 2007).

A prominent issue that has arisen in merger and market power analyses in electricity markets is the effect of firms' fixed-price forward commitments on firm behavior. Forward contracts result in a firm committing to supply output at a fixed price in advance of the spot market. Such contracts can reflect retail commitments for vertically integrated utilities (Bushnell et al., 2008), competitive arrangements between generators and distribution utilities or retailers (Crew and Kleindorfer, 2002; Loxley and Salant, 2004), or regulatory requirements imposed on dominant generators (Frutos and Fabra, 2012).

It is well-established that the incentives of firms to exercise market power in wholesale spot markets depend critically on the quantity of electricity that firms have contracted in advance at fixed prices (Wolak, 2000, 2007; Bushnell et al., 2008). A firm that withholds a unit of output in order to exercise market power and raise the spot market price will realize increased revenues only on the portion of its output that will earn the spot market price, and is not previously committed under fixed prices. For this reason, the level of forward contracting has been a central issue in several recent electricity merger cases. For example, in the Exelon and Constellation merger analysis, the assumed level of forward contracts in the post-merger equilibrium had large implications on the predicted wholesale market impacts of the merger (MPSC, 2011, 2012). Experts raised concerns that the merged firm will have an incentive to reduce its forward contracts post-merger, elevating concerns over market power execution (see MPSC, 2012, pg. 47).[2] Recent changes to the U.S. Federal Energy Regulatory Commission's (FERC) horizontal market power screens that include pivotal supplier tests have been viewed as improvements to the use of concentration measures in part because it accounts for firms' existing forward commitments (Bushnell, 2005; FERC 2012, 2015).[3] However, the use of pre-existing forward commitments abstracts from changes in firms' incentives to sign new forward contracts in the presence of a merger.

In response to these concerns, this paper develops a model to analyze the effect of mergers on firms' incentives to forward contract. Further, we investigate the impact of endogenous forward contracting on post-merger wholesale market outcomes. Our model is an extension of the broad literature that investigates endogenous forward contracting in oligopoly markets. In particular, we build on the seminal contribution of Allaz and Vila (1993), which investigates the impact of endogenous forward contracting

[1]For example, in 2012 in the United States, 107 Gigawatts (GW) of generation capacity was exchanged via mergers and acquisitions, representing 10% of aggregate capacity nationwide (EIA, 2013). See Moss (2008) and Federico (2011) for a survey of recent electricity market merger cases in United States and Europe, respectively.

[2]Similarly, in the proposed merger of Exelon and PSEG (FERC, 2005), the importance of forward contracts in the post-merger environment was emphasized in several equilibrium simulation studies (Morris and Oska, 2008; McRae and Wolak, 2009). The estimated merger price effects depended critically on the merged firm's post-merger forward commitments.

[3]A supplier passes the pivotal supplier test if its uncommitted capacity is less than the difference between the annual peak wholesale demand and uncommitted installed capacity of all other suppliers. A firms' uncommitted capacity reflects its installed nameplate generation capacity, net of its native load obligations and long-term supply commitments (FERC, 2015).

on competition in oligopolistic markets when firms are risk-neutral, compete via Cournot, and forward contract for strategic reasons. In this model, firms unilaterally forward contract to pre-commit to a larger wholesale market output, inducing their rivals to reduce their output. The authors find that forward contracting increases competition because all firms attempt to exploit the pre-commitment effect.[4]

Other studies have looked at how forward contracting is affected by market structure. Bushnell (2007) investigates the relationship between market structure and the degree of forward contracting using a two-stage model with strategic forward contracting and Cournot spot market competition. Firms are risk-neutral and have symmetric linear marginal cost functions. The author shows that the proportion of market quantity that is forward contracted increases in the number of firms, and that forward contracts magnify the effect of concentration.[5] Miller (2013) extends this analysis by considering the welfare effects of mergers when firms have symmetric constant marginal costs. The author finds that the welfare losses from mergers are mitigated by exogenous forward contracting, but that when the market is highly concentrated, welfare losses can be increased in the presence of endogenous forward contracting.

While the insights of these papers regarding the relationship between forward markets and market power are important, their lessons for merger analysis are incomplete. Results that are based on changing the number of symmetric firms with linear and increasing marginal cost curves do not capture the possibility that a merger simultaneously reduces the number of firms and creates a new firm with a different (lower) marginal cost curve. Likewise, a limitation of analysis of a Cournot model that assumes constant marginal costs is that it is subject to what is sometimes referred to as the "merger paradox" – mergers other than near mergers to monopoly tend not to be profitable (see Salant et al, 1983). Perry and Porter (1985) argue that in such a model, mergers do not make sense conceptually because firms bring no assets into the merger. The authors develop a framework in which a firm's marginal cost depends on its capital stock; merging firms combine their capital stock, reducing marginal costs. This framework is adapted by McAfee and Williams (1992) to analyze the welfare effects of horizontal mergers.[6]

In this article, we combine these various areas of the literature to investigate how mergers affect firms' incentives to forward contract and illustrate the impact this has on wholesale market competition. In particular, we use the two-stage forward contracting and Cournot competition model of Allaz and Vila (1993) and Bushnell (2007), in which risk-neutral firms compete via Cournot competition and forward contract for strategic reasons, and adopt the capital stock interpretation of marginal cost established by Perry and Porter (1985). By considering an asymmetric environment where firms' cost depend on their level of capital stock, we avoid the "merger paradox". This allows us investigate the relationship between endogenous forward contracts and the estimated effects of mergers. We illustrate our results empirically using data from Alberta's wholesale electricity market for 2013.

We find that firms reduce the proportion of their wholesale market output that is covered by forward contracts in the post-merger equilibrium. This is driven primarily by a reduction in the strategic effect

[4] The competition-enhancing role of forward markets has been found to be sensitive to certain assumptions in the model. Hughes and Kao (1997) emphasize the importance of public knowledge of forward contracts. Mahenc and Salanie (2004) demonstrate that under price competition forward markets may allow firms to soften competition, while Liski and Montero (2006) and Green and Le Coq (2006) illustrate that forward contracts can facilitate collusion in a infinitely repeated context.

[5] Newbery (2009) extends Bushnell's analysis to consider firms with asymmetric constant marginal cost and develops a residual supplier index to assess market power in electricity markets.

[6] A discussion of Cournot models employing such cost functions and their usefulness in merger simulation can be found in Werden and Froeb (2008). A recent example employing this framework in a merger simulation is Greenfield et al. (2015).

of forward contracting. That is, a firm's rivals reduce their wholesale market output by less due to an increase in its forward contracted output in the more concentrated post-merger equilibrium. We show that endogenous forward contracting elevates the price effects of a merger because of firms' incentives to reduce their forward contracted quantities compared to a setting where forward contract quantities are held constant. The reduction in consumer surplus is magnified in the presence of endogenous forward contracting. As well, we find that while endogenous forward contracting yields larger price effects, the merging firms' profits may be larger in the post-merger equilibrium if their forward contract quantities are held constant. Holding forward contract quantities fixed at pre-merger levels commits the merged firm to a larger level of wholesale output, forcing rivals to reduce their wholesale production. This implies that endogenous forward contracting has the potential to erode the merging firms' profits.

Our results illustrate that the price effects of mergers are dampened in regions where firms' forward contracts are held constant post-merger due to regulatory requirements or mandated supply contracts.[7] Further, our results demonstrate that merger analyses that take firms' forward positions (either in MWs or as a percentage of output) as given can understate the wholesale market price effects of mergers in electricity markets. This can lead to biased conclusions regarding the impacts of mergers on market competition. These results provide support for the claims of expert testimony in recent electricity market mergers cases which raise concerns over firms' incentives to alter their forward contracts post-merger (e.g., MPSC, 2011, 2012). Further, these results raise concerns over the use of pre-existing forward commitments in FERC's market power screening tests to analyze the price effects of proposed mergers.

We develop and explain these results as follows. Section 2 reviews the key elements of our model, characterizes the equilibrium outcome of our two-stage forward contracting model, and investigates the effects of a merger on forward contracting in the general asymmetric environment. Section 3 considers the symmetric oligopoly equilibrium and illustrates the effects of a merger on forward contracting incentives and wholesale market outcomes when symmetric firms merge. Section 4 uses an empirical model in the context of Alberta's electricity market to illustrate the impacts of endogenous forward contracting in the presence of a merger with asymmetric firms. Section 5 concludes and discusses directions for further research. The Appendix provides the proofs of all formal conclusions.

2 Model

In our model, $N \geq 3$ firms compete to supply a homogeneous product (electricity). In the first stage of the model, firms simultaneously choose the quantities q_i^f to sell in the forward market at a price P^f. In the second stage, given the quantities of all firms in the forward market, firms choose their spot market quantities q_i simultaneously.[8] Market demand in the spot market is linear and is modeled as $P(Q) = a - bQ$ where $Q = \sum_{i=1}^{N} q_i$. Firm i's total cost function is given by $C_i(q_i) = q_i^2/2k_i$, where k_i represents firm i's capital stock for each $i = 1, 2, .., N$.

Following Allaz and Vila (1993) and Bushnell (2007), we assume that all participants are risk-neutral

[7]Exogenous long-run forward commitments can reflect regulatory mandated fixed-price contracts or requirements linked with the divestment of generation assets from large incumbent suppliers (Bushnell, 2007; Frutos and Fabra, 2012).

[8]Bushnell et al. (2008) illustrate that Cournot-Nash equilibria approximate observed behavior well in electricity markets once firms' forward commitments are taken into account.

and firms' forward positions are public knowledge.[9] Further, we assume that forward and spot market prices are efficiently arbitraged, so that forward prices equal expected spot market prices. Our solution concept is Subgame Perfect Nash Equilibrium, and we solve the model using backward induction.

2.1 Second Stage: Spot Market

Consider the second stage spot market where firm i's forward quantity q_i^f has already been committed at price P^f. The second stage spot market profit function for firm i is given by:

$$\pi_i(q_i, q_{-i}) = P(Q)(q_i - q_i^f) - C_i(q_i) + P^f q_i^f = \left(a - b\sum_{j=1}^{N} q_j\right)(q_i - q_i^f) - \frac{q_i^2}{2k_i} + P^f q_i^f. \quad (1)$$

Firm i sells $q_i - q_i^f$ units of output at the spot market price; if this term is positive (negative), firm i is a net seller (buyer) of electricity in the wholesale market. The remaining output q_i^f receives the price P^f, which is taken as given in the second stage. As a result, the firm has less incentive to withhold output to exercise market power when q_i^f is large, since the benefit of increasing the spot market price is only realized on output sold in the spot market and not subject to a fixed forward price.

For a given level of forward contracting, assuming an interior solution, firm i's payoff maximizing production level is defined by:[10]

$$\frac{\partial \pi_i(q_i, q_{-i})}{\partial q_i} = P(Q) + P'(Q)(q_i - q_i^f) - C_i'(q_i) = a - b\sum_{j=1}^{N} q_j - b(q_i - q_i^f) - \frac{q_i}{k_i} = 0. \quad (2)$$

From condition (2), marginal revenue converges to wholesale market price ($P(Q)$) as a firm's forward contracted quantity (q_i^f) converges to its spot market output (q_i) and so, firm i's behavior converges to that of a perfectly competitive producer.

Lemma 1 summarizes the equilibrium spot market aggregate output, market-clearing price, and each firm's optimal quantity for a given level of forward contracting.

Lemma 1. *For a given level of forward contracting, the optimal solution in the spot market entails:*

$$Q = \frac{a\,B + b\,\sum_{i=1}^{N} \beta_i q_i^f}{b(1+B)}, \quad (3)$$

$$P = \frac{a - b\,\sum_{i=1}^{N} \beta_i q_i^f}{1+B}, \quad \textit{and} \quad (4)$$

$$q_i = \frac{a}{b}\frac{\beta_i}{1+B} - \beta_i \frac{\sum_{j=1}^{N} \beta_j q_j^f}{1+B} + \beta_i q_i^f \quad (5)$$

where $\beta_i = \frac{bk_i}{bk_i+1}$ *for all* $i = 1, 2, ..., N$ *and* $B = \sum_{i=1}^{N} \beta_i$.

Lemma 2 summarizes the impact of a change in a firm's forward commitment on spot market outcomes.

[9] For example, the relative transparency of forward contracts in electricity markets can arise because of regulatory oversight (Bushnell, 2007).

[10] Throughout the theoretical analysis we focus on interior solutions. In equilibrium, the interior solutions are verified. In the empirical analysis in Section 4, we have verified that the addition of non-negativity forward contracting and spot market output constraints does not impact the estimated equilibrium outcomes.

Lemma 2. *An increase in firm i's forward contracted quantity: (i) increases firm i's spot market quantity* (q_i)*, (ii) decreases firm j's spot market quantity* (q_j) *for all* $i \neq j$*, (iii) increases total output* Q*, and (iv) decreases the spot price* $P(Q)$*.*

The results in Lemma 2 parallels the findings in the previous literature that forward contracts are pro-competitive in the spot market (e.g., Allaz and Vila, 1993; Bushnell, 2007). An increase in firm i's forward commitment results in an increase in firm i's output and a decrease in its opponents' output q_j for all $j \neq i$. By forward contracting, firm i is making a credible commitment to increase its spot market quantity and so, other firms reduce their spot market output. An increase in a firm's forward commitment level results in a net increase in total output and a reduction in the spot-market price because all firms have an incentive to exploit the pre-commitment effect of forward contracting.

2.2 First Stage: Forward Contracts

In this section, we analyze firms' incentives to forward contract. In the first stage, firms simultaneously choose quantities to sell under forward contracts, assuming that the subsequent spot market will follow the second stage Nash Equilibria derived in the previous section. Similar to Allaz and Vila (1993), we assume that there are no arbitrage opportunities, so that the forward price equals the spot price.

Let $q_i(q_i^f, q_{-i}^f)$ be firm i's second stage Nash Equilibrium spot market quantity given the forward positions of all firms from the first stage, where q_{-i}^f denotes the forward contracted output of all firms other than i. Firm i's first stage profit function can be written as:

$$\pi_i(q_i^f, q_{-i}^f) = P(Q(q_1^f, ..., q_N^f))q_i(q_i^f, q_{-i}^f) - C_i(q_i(q_i^f, q_{-i}^f)). \tag{6}$$

Assuming an interior solution, Firm i's payoff maximizing forward contracting quantity is:

$$\frac{\partial \pi_i(q_i^f, q_{-i}^f)}{\partial q_i^f} = P(Q)\frac{\partial q_i}{\partial q_i^f} + q_i P'(Q)\sum_{j=1}^{N}\frac{\partial q_j}{\partial q_i^f} - C_i'(q_i(q_i^f, q_{-i}^f))\frac{\partial q_i}{\partial q_i^f} = 0. \tag{7}$$

(7) can be rewritten as:

$$\frac{\partial q_i}{\partial q_i^f}[P(Q) + (q_i - q_i^f)P'(Q) - C_i'(q_i)] + q_i P'(Q)\sum_{j\neq i}\frac{\partial q_j}{\partial q_i^f} + q_i^f P'(Q)\frac{\partial q_i}{\partial q_i^f} = 0. \tag{8}$$

Recognizing that $P(Q)+(q_i-q_i^f)P'(Q)-C_i'(q_i) = 0$ holds in any equilibrium from (2) in the subsequent spot market, (8) simplifies to:

$$q_i P'(Q)\sum_{j\neq i}\frac{\partial q_j}{\partial q_i^f} + q_i^f P'(Q)\frac{\partial q_i}{\partial q_i^f} = 0. \tag{9}$$

Equation (9) reflects a firm's direct and strategic incentives for forward contracting, given how firms will respond in the spot market (recall Lemma 2). The first term reflects the strategic effect of forward contracting. An increase in q_i^f reduces its opponents' spot market quantities q_j for all $j \neq i$. The second term reflects the direct effect of increasing q_i^f. An increase in forward contracting increases firm i's spot market quantity, reducing the spot price and lowering revenue earned on the q_i^f forward units traded.

After solving for the partial derivatives of each firm's spot market quantity (q_j) with respect to firm i's forward quantity (q_i^f), Lemma 3 characterizes firm i's optimal forward contracting quantity, as a function of its opponents forward contracting quantities.

Lemma 3. *A firm i's optimal forward contracting quantity q_i^f, as a function of every other firm's forward contracting quantity q_{-i}^f, solves:*

$$q_i(q_i^f, q_{-i}^f) \sum_{j \neq i} \left(-\frac{\beta_j}{1+B} \right) + q_i^f \left(1 - \frac{\beta_i}{1+B} \right) = 0, \tag{10}$$

where firm i's equilibrium spot market output $q_i(q_i^f, q_{-i}^f)$ is defined in condition (5).

Condition (10) reflects the balance between firm i's offsetting strategic and direct incentives to forward contract. Conditions (3) - (5) and (10) characterize the equilibrium of this two-stage forward contracting and spot market competition model.[11] In equilibrium, the proportion of output that is forward contracted for firm i is represented by:

$$\frac{q_i^f}{q_i} = \frac{\sum_{j \neq i} \beta_j}{1 + \sum_{j \neq i} \beta_j}. \tag{11}$$

Several comparative statics results immediately follow from (11). First, in our model firm i's forward contract coverage ($\frac{q_i^f}{q_i}$) depends only on the sum of the β_j terms for all $j \neq i$, where $\beta_j = \frac{bk_j}{bk_j+1}$ depends only on b and k_j. It follows that a firms' forward contracting ratio is independent of its own capital stock. k_i enters firm i's strategic and direct effect terms symmetrically and so, k_i cancels out in the ratio. Second, a firm's forward contracting ratio is increasing in the sum of the rival β_j terms. As a result, it follows that a firm's forward contracting ratio is increasing in the demand slope parameter b and the capacity of any rival j (k_j). Third, the addition of a new rival firm will cause an increase in the sum of the rival β_j terms, and therefore an increase in a firm's forward contracting ratio.

To understand the intuition of these results, the expression in (11) is the ratio of the strategic effect (the effect of firm i's forward contract quantity on its rivals' spot quantities) over the direct effect (the effect of firm i's forward quantity on its own spot quantity). An increase in rival firm j's capital stock (k_j), which reduces the slope of its marginal cost curve, increases the sensitivity of firm j's spot market quantity to firm i's forward quantity by rotating j's second stage spot market best response function. This increased strategic effect exceeds the effect of an increase of firm j's capital stock on firm i's direct effect, implying that as k_j increases, firm i has a greater incentive to use forward contracting strategically. Alternatively, a reduction in the number of firms reduces the strategic effect of forward contracting. The impact of reducing N on the strategic effect dominates the impact on the direct effect, resulting in an overall decrease in firms' forward contracted ratio. Our findings bring together prior results in the literature. In particular, our findings regarding the impacts of changes in the capital stock (k) are consistent with Breitmoser (2013), who shows in an Allaz-Vila duopoly model with linear marginal cost that increasing the slopes of the firms' marginal cost curves reduces competition by weakening the degree of strategic substitution between firms' quantities. Likewise, the effect of changes in N in our model follows the findings in Bushnell's (2007) symmetric oligopoly model that firms' forward contract coverage is increasing in N.

Equation (11) can also be used to determine the effect of a merger on firms' forward contracting ratios, allowing us to state Proposition 1.

[11] A firm's profit function is strictly concave in its own strategy. This ensures that there exists a unique equilibrium level of forward contracts and spot market production for each firm. See the Proofs of Lemmas 1 and 3 for a formal derivation.

Proposition 1. *After the merger, all firms reduce the proportion of output sold forward.*

A merger represents a simultaneous reduction in the number of firms and an increase in the merging firm's capital stock. From the comparative statics discussed above, these effects have counteracting impacts on a firm's forward contracted ratio. Proposition 1 illustrates that while the increase in the merging firm's capital stock places upward pressure on the non-merging firms' forward contract coverage, the reduced strategic incentive to forward contract as the number of firms increases dominates this effect, resulting in a reduction in the non-merging firms' forward contracting ratio. For the merging firm, the higher market concentration reduces its strategic incentive for forward contracting. The reduction in the strategic forward contracting incentive decreases the merged firm's forward contracted ratio.

A reduction in the proportion of output sold forward has the potential to elevate the price effects of mergers because forward contracts are pro-competitive in our modeling framework. In particular, the price-effects of a merger may be magnified in the presence of endogenous forward contracting compared to an environment where firms' forward commitments are fixed pre- and post-merger. Due to the complexity of the analysis, we rely on empirical methods to illustrate these results in the asymmetric environment.

3 Mergers in a Symmetric Oligopoly

In this section, we provide analytical solutions for the symmetric oligopoly equilibrium and consider the impacts of a merger, accounting for the endogenous nature of forward contracts. Assume initially that the industry is a symmetric oligopoly with $k_1 = k_2 = ...k_N = k$. Lemma 4 provides the equilibrium spot market price and forward and spot market quantities.

Lemma 4. *In a symmetric market, the following conditions characterize the equilibrium of our forward contracting and spot market competition model:*

$$q = \frac{(N + \frac{1}{bk})\frac{a}{b}}{(N + \frac{1}{bk})^2 + (1 + \frac{1}{bk})}, \tag{12}$$

$$P(Q) = \frac{(N + \frac{1}{bk})\frac{a}{bk} + (1 + \frac{1}{bk})}{(N + \frac{1}{bk})^2 + (1 + \frac{1}{bk})}, \text{ and} \tag{13}$$

$$q^f = \frac{(N-1)\frac{a}{b}}{(N + \frac{1}{bk})^2 + (1 + \frac{1}{bk})}. \tag{14}$$

For this symmetric equilibrium, the ratio of output that is forward contracted is represented by:

$$\frac{q^f}{q} = \frac{(N-1)}{N + \frac{1}{bk}}. \tag{15}$$

Forward contract coverage increases with the number of firms and the level of capital stock (k).[12]

Next, we consider the impacts of a merger. The subscripts M and NM denote the merged and non-merged firms, respectively. The capital stock of the merged firm becomes $k_M = 2k$, so that the merged firm's marginal cost becomes $\frac{q_M}{k_M}$. Using the solutions from the general asymmetric model in (5) and (10),

[12]In a symmetric model, Bushnell (2007) illustrates that the percentage of output that is forward contracted increases quickly as N expands. Unlike the current study, Bushnell does not consider the impacts of forward contracts on mergers.

we can derive the post-merger spot market and forward market quantities for the merged firm (q_M, q_M^f) and for each non-merging firm (q_{NM}, q_{NM}^f).

In the post-merger equilibrium, the percentage of spot market output that is forward contracted for the merged and non-merged firm is represented by:

$$\frac{q_M^f}{q_M} = \frac{(N-2)\beta_{NM}}{1+(N-2)\beta_{NM}}, \text{and} \tag{16}$$

$$\frac{q_{NM}^f}{q_{NM}} = \frac{\beta_M + (N-3)\beta_{NM}}{1+\beta_M+(N-3)\beta_{NM}}. \tag{17}$$

where $\beta_M = \frac{bk_M}{bk_M+1}$ and $\beta_{NM} = \frac{bk}{bk+1}$.

From Proposition 1 we know that in the post-merger equilibrium, all firms reduce the proportion of output sold forward. As discussed in detail in the asymmetric environment, the reduced forward contracting coverage is driven by the reduction in the strategic effect in the more concentrated market. This dominates the impact of increasing the merged firms' capital stock parameter which elevates all non-merging firms' strategic incentive to forward contract. For the symmetric model, Proposition 2 describes the effects of the merger on spot market outcomes and consumer surplus.

Proposition 2. *In the post-merger equilibrium, aggregate output decreases, spot market price increases, and consumer surplus decreases. In addition, these merger effects are magnified in the presence of endogenous forward contracting compared to a setting where forward contract quantities are held fixed at pre-merger levels.*

From Proposition 2, in the symmetric model if we held forward commitments (in MWs) constant at pre-merger levels, the price effects of mergers would be dampened relative to the case of endogenous contracting. This occurs because in the endogenous environment the reduced strategic incentive of forward contracting results in a lower forward contract coverage for all firms. This magnifies the reduction in wholesale market output in the more concentrated post-merger equilibrium. Proposition 2 illustrates that it is essential to consider the nature of firms' forward commitments when analyzing the impact of mergers and market structure changes. Further, these results imply that if a merger occurs in a region with exogenous forward contracts (e.g., due to regulatory restrictions or long-term supply commitments), the price-increasing impacts of the merger will be lower than one in which forward contracts are endogenous.

Proposition 3 considers the merged firm's profits when forward contracts are endogenous compared to a setting where its forward commitments are held at pre-merger levels.

Proposition 3. *The merged firm's profits are strictly higher when forward contract quantities are fixed at pre-merger levels than with endogenous forward contracting if N is sufficiently sufficiently large, holding parameters bk constant.*

Proposition 3 demonstrates that the impact of endogenous forward contracting on the merging firm's profit is ambiguous. Because the merger reduces the merged firm's forward contract position, holding the merged firm to forward contracted quantities at pre-merger levels commits the merged firm to a higher level of spot market output than would result under endogenous forward contracts. However, doing so dampens the price effects of the merger (e.g., see Proposition 2). Recall that a higher level of forward contracting by the merged firm has a strategic effect of reducing its rivals output in the spot market, holding all else constant. The magnitude of this strategic effect is increasing in the number of firms in the industry, relative to the price effect of endogenizing forward positions, which falls as N increases. Therefore, for a sufficiently large N, the strategic benefit of holding forward contracted quantities fixed at pre-merger levels (in MWs) results in a higher profit for the merged firm compared to a setting where forward contracts are endogenous. While endogenous forward contracting elevates the impact of the merger on spot market prices, it has the potential to erode the merged firm's profits.

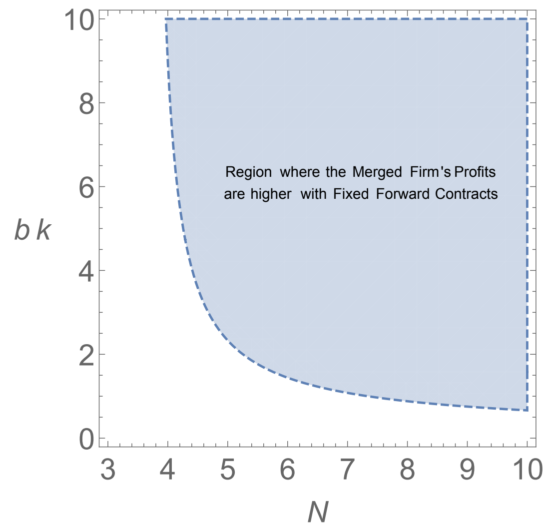

Figure 1: Merged Firm's Profits - Endogenous versus Fixed Forward Contracts

Figure 1 demonstrates the region in which the merged firms' profits are higher holding forward contracted quantities at pre-merger levels compared to endogenous forward contracts, for any given level on the parameters bk.[13] In the following section, we fit the asymmetric model to data from the wholesale electricity market in Alberta to further investigate the impacts of endogenous forward contracting in the presence of a merger.

4 Empirical Analysis

We apply the asymmetric model to Alberta's electricity market to illustrate the effects of mergers and market structure changes on firms' forward contracting incentives and market outcomes. Alberta's electricity market provides us with an ideal empirical setting to apply our theoretical model.[14] First, firms compete in a single hourly wholesale (spot) market to supply electricity. Second, the market is relatively concentrated with the five largest firms having offer control of 70% of dispatchable thermal generation capacity (MSA, 2013), and there are limited regulatory mechanisms to restrict firms' abilities to exercise market power in wholesale electricity markets. In particular, there are no bid (offer) mitigation mechanisms to limit firms' abilities to bid above (estimated) marginal cost. In addition, the province's Market Surveillance Administrator has stated in guidelines that the unilateral exercise of market power is per-

[13] The strategic effect of forward contracting is increasing in $b\,k$. Therefore, the critical value on N where the merged firm's profits are higher when forward quantities are held at pre-merger levels identified in Proposition 3 is decreasing in $b\,k$.

[14] For a detailed review of Alberta's electricity market see Olmstead and Ayres (2014) and Brown and Olmstead (2016).

mitted (MSA, 2011). This feature makes Alberta a natural laboratory for analyzing incentives for market power. Third, firms sign fixed-priced forward contracts prior to wholesale market competition (MSA, 2010). Forward contracts may take the form of direct sales agreements (or bilateral agreements), often between a generator and retailer, or as standardized products traded through the Natural Gas Exchange (NGX) and over the counter (OTC) brokers.

Our study employs available data from the Alberta Electric System Operator (AESO) from January 1 to December 31, 2013. The data set includes observed hourly price and quantity offers for all generation firms in Alberta, import supply, import transmission capacity, market-level demand, generation asset-specific characteristics and the identity and ownership of generation assets. As well, we gather hourly Alberta, British Columbia, and Saskatchewan weather data from Environment Canada: Weather Information. Table 1 presents summary statistics and market concentration measures in Alberta during our period of study. The dispatchable thermal generation capacity is concentrated within the largest five firms, with a competitive fringe that contains over twenty-five smaller firms.[15] The hourly market-clearing price has a high degree of price volatility with a maximum at the wholesale market price-cap of $999.99/MWh. Imports from neighboring provinces are limited as a portion of total market demand.

Table 1: Firm Characteristics and Summary Statistics, 2013

Panel A: Market Shares of Dispatchable Thermal Generation Capacity

Firm	Capacity (MW)	Market Share
ATCO	1,376	10.9%
Capital Power	1,456	11.6%
ENMAX	1,872	14.9%
TransAlta	1,800	14.3%
TransCanada	2,533	20.1%
Fringe	3,558	28.2%

Panel B: Summary Statistics

Measure	Units	Mean	Std Dev.	Min	Max
Price	$/MWh	80.44	175.13	0	999.99
Market Demand	MW	8144	730	6,595	10,325
Imports	MW	290	227	0	843
Fringe Output	MW	2,554	278	1,467	3,282

Notes: Dispatchable generation capacity contains all production capacity except for non-dispatchable wind capacity which represents 10.1% of aggregate capacity (MSA, 2013). The sample size $T = 8,760$.

The purpose of our empirical analysis is to simulate the effects of hypothetical mergers among the five largest firms for 2013, assuming that firms compete according to the Cournot model with endogenous forward contracts described above, and to compare these merger effects to those predicted under alternative assumptions regarding forward contract positions. Our analysis proceeds in the following steps. First, we estimate a residual demand function to be served by the five incumbents, net of price-responsive imports and supply from a competitive fringe that consists of over twenty-five small firms. Second, given our residual demand function and our theoretical model of endogenous forward quantities and spot market

[15] In Alberta, generation capacity primarily takes the form of thermal (dispatchable) fossil-fuel technologies: 47.2% coal, 36.9% natural gas, 7.2% Wind, 6.2% Hydro, and 2.4% Other (Brown and Olmstead, 2016).

production, we estimate firm-specific capital stocks to minimize the sum of squared deviations of the structurally estimated firm-level spot market output from the observed firm-level spot market quantities. We then use the model to illustrate the impacts of mergers in the presence of endogenous forward contracting and compare these results to a setting where forward contracts are held fixed in terms of a percentage of output or in MWs of forward quantities at pre-merger levels.

4.1 Residual Demand

We estimate the residual demand for electricity faced by the five large incumbent suppliers ($Q_t^{RD}(p_t)$) as the price-inelastic short-run market demand ($\overline{Q}_t$) minus price-responsive supply from fringe producers ($Q^f(p_t)$). Fringe producers represent imports from neighboring provinces Saskatchewan (SK) and British Columbia (BC) and the supply of the competitive fringe within Alberta.[16] By empirically estimating a linear fringe supply function, we get hourly estimates on the demand intercept a_t and a residual demand slope parameter b that we can take to our model. For each period t, we estimate the following price-responsive fringe supply function that includes both imports and production from the competitive fringe:

$$\begin{aligned} Q_t^f = \beta_0 + \beta_1 p_t + \beta_2 p_t^{NG} + \beta_3 \mathrm{Weekday_t} + \beta_4 \mathrm{ImpCapacity_{SK,t}} + \beta_5 \mathrm{ImpCapacity_{BC,t}} + \beta_6\, \mathrm{QWIND_t} \\ + \sum_{j \in \{AB,BC,SK\}} \alpha_j\, \mathrm{h(Temp_{jt})} + \sum_{h=1}^{24} \omega_{hj} \mathrm{Hour_{ht}} + \sum_{m=1}^{12} \gamma_{mj} \mathrm{Month_{mt}} + \epsilon_t \qquad (18) \end{aligned}$$

where p_t is the electricity market prices, p_t^{NG} is the natural gas price, $\mathrm{QWIND_t}$ is the level of wind production, $\mathrm{ImpCapacity_{jt}}$ reflects the amount of import transmission capacity (in MWs) from neighboring province $j \in \{SK, BC\}$, $\mathrm{h(temp_{jt})}$ is a non-linear function of temperature variables in province $j \in \{AB, BC, SK\}$, $\mathrm{Weekday_t}$ is an indicator for weekdays, and $\mathrm{Hour_{ht}}$ and $\mathrm{Month_{mt}}$ are indicator variables for each hour and month in our sample, respectively. Month fixed-effects, natural gas prices, and wind production covariates control for cost-related shocks.[17] Hourly, weekday, transmission capacity limits, and temperature covariates control for the relative prices in neighboring provinces which drives import decisions.[18] The price of electricity is endogenous to the amount of fringe output; therefore we employ an instrumental variables approach using the hourly day-ahead market demand forecast as the excluded instrument. Ignoring the endogeneity of price would lead to attenuation bias, reducing the estimated price-responsiveness of fringe supply. Day-ahead forecasted market demand is a valid instrument because wholesale electricity demand is perfectly price-inelastic. Most consumers in Alberta face largely fixed retail rates that vary at most monthly, shielding them from hourly wholesale price fluctuations. Further,

[16] Similar approaches to estimate residual demand have been used in Bushnell (2007) and Bushnell et al. (2008), for example.

[17] Natural gas prices reflect the hourly natural gas price from Alberta's Natural Gas Exchange (NGX). Because regional gas prices may be endogenous to local supply and demand conditions, we also used monthly natural gas prices from Henry Hub (converted to Canadian Dollars using Bank of Canada exchange rates) which provide a broader reflection of the natural gas market in North America. The Henry Hub and NGX natural gas prices are strongly correlated ($\rho = 0.94$) during our sample. The residual demand estimation results are unaffected by the use of Henry Hub prices in place of NGX prices.

[18] The temperature variables used in the analysis for AB, BC, and SK are modeled as quadratics for hourly cooling degrees (hourly mean degrees above 65^o F) and hourly heating degrees (hourly mean degrees below 65^o F). The cities considered in AB, BC, and SK are Calgary, Edmonton, Vancouver, and Saskatoon, respectively. This data is accessed through Environment Canada: Weather Information. The results of the analysis are robust to the consideration of alternative large cities in each province and higher degree polynomials on the temperature variables.

forecasted demand only impacts fringe production through its impact on the market price.[19]

Table A1 in the Appendix provides detailed results of the competitive supply function estimation. The estimated fringe supply function yields an average elasticity of fringe supply equal to 0.165. This corresponds to the degree of price-elasticity of fringe supply found in other regions such as California (Puller, 2007) and PJM and New England (Bushnell et al., 2008).

4.2 Capital Stock

Using observed market outcomes, the estimated residual demand function, and equilibrium conditions on firm behavior, we estimate the firm-specific capital stock k_i for each $i = 1, 2, 3, 4, 5$. In particular, we observe each firm's hourly production decisions $\widehat{q}_{it}$ for all $t = 1, 2, ..., T$ and $i = 1, 2, 3, 4, 5$. Further, the two-stage forward contracting and output decision model result in an endogenous hourly production level $q_{it}(\mathbf{k})$ that depends on each firm's capital stock $\mathbf{k} = \{k_1, k_2, ..., k_5\}$ for all $t = 1, 2, ..., T$ and $i = 1, 2, 3, 4, 5$. We estimate each firm's capital stock parameter to minimize the squared differences of the observed firm-specific output and the structurally estimated firm-specific output determined by the equilibrium conditions in our theoretical two-stage model:[20,21]

$$\min_{\mathbf{k}} \sum_{t=1}^{T} \sum_{i=1}^{5} \left(\widehat{q}_{it} - q_{it}(\mathbf{k})\right)^2 . \tag{19}$$

The nonlinear least squares formulation translates our problem into a Mathematical Program with Equilibrium Constraints (MPEC). This is a bilevel optimization problem where the lower-level takes the form of our two-stage forward contracting and production decisions model and the upper-level reflects a nonlinear least squares programming problem across all periods t. This yields an estimate on the implied firm-specific capital stock, given observed production behavior and our structurally estimated output. We rely on recent advances in computational approaches and algorithms to solve our large-scale bilevel optimization problem. In particular, we transform our MPEC into a nonlinear program and rely on traditional nonlinear programming methods to solve our bilevel least squares optimization (Ferris et al., 2005, 2009). This allows us to simultaneously solve the lower-level forward contracting and production decision model, while implicitly estimating the firm-specific capital stock using observed behavior.

Formally, using our hourly estimates on residual demand parameters a_t and b, we aim to minimize condition (19), with the constraints that the oligopoly firms make their output decisions according to (5) and firms make their forward contracting decisions according to (10) for each $i = 1, 2, 3, 4, 5$ and $t = 1, 2, ..., T$. The MPEC can be written as the following nonlinear program:

$$\begin{aligned} \underset{\mathbf{k},\, q_{it},\, q_{it}^f\ \forall\, i,t}{\text{minimize}} \quad & \textstyle\sum_{t=1}^{T} \sum_{i=1}^{5} \left(\widehat{q}_{it} - q_{it}(\mathbf{k})\right)^2 \\ \text{subject to} \quad & \end{aligned} \tag{20}$$

[19] We estimate the model using an IV approach with Newey-West heteroskedasatic and autocorrelation robust standard errors with 24 lags. The Kleibergen-Paap F-Statistic 27.83 (> 10) strongly rejects the null hypothesis that our instrument is weak. For detailed output of the fringe supply function estimation results, see Table A1 in the Appendix.

[20] The time-varying process that is used for identification in this optimization problem is associated with the time-specific variation resulting from the estimation of the residual demand function.

[21] We are estimating capital stock parameters, under the structural assumption that firms' production decisions can be approximated by a Cournot-Nash equilibrium after a stage of endogenous forward contracting. Bushnell et al. (2008) find that a Cournot-Nash equilibrium approximates observed behavior well once firms' forward commitments are considered.

$$q_{it} = \frac{a_t}{b}\frac{\beta_i}{1+B} - \beta_i \frac{\sum_{j=1}^{N} \beta_j q_{jt}^f}{1+B} + \beta_i q_{it}^f; \tag{21}$$

$$q_{it} \sum_{j \neq i} \left(-\frac{\beta_j \beta_i}{1+B} \right) + q_{it}^f \left(\beta_i - \frac{\beta_i^2}{1+B} \right) = 0; \tag{22}$$

for all $i = 1, 2, 3, 4, 5$ and $t = 1, 2, ..., T$ (where $T = 8,760$). To implement this large-scale bilevel optimization, we use the Nonlinear Programming with Equilibrium Constraints (NLPEC) solver in GAMS (Ferris et al., 2009) on the external NEOS server (Czyzyk et al., 1998).

4.3 Results

In this section, we discuss the key findings of our analysis. We illustrate the quality-of-fit of the bilevel Cournot model to observed market outcomes. Then, we use these results to simulate various mergers, illustrating the importance of forward commitments.

4.3.1 Comparison of Actual and Estimated Market Outcomes

Before proceeding to simulating the effects of various market structure changes on spot market outcomes, we review the output from the bilevel optimization program for the existing market structure. Table 2 presents mean and standard deviation for the observed and estimated firm-specific wholesale market quantities and market-clearing prices for the year 2013.

Table 2: Actual vs. Estimated Market Outcomes

	Estimated		Observed	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Price	93.44	13.78	80.44	175.13
q_{ATCO}	535.05	78.93	539.88	103.17
q_{CP}	1056.5	155.86	1073.07	174.09
q_{ENMAX}	1141.72	168.4	1144.86	241.86
q_{TA}	990.63	146.14	1009.84	143.13
q_{TC}	1513.45	223.27	1532.17	312.14

Notes: All quantity values are in MW and price is in \$/MWh.

Table 2 illustrates that average observed and estimated wholesale market quantities are closely matched. Our model overestimates average market price. In addition, estimated prices exhibit less variability than actual prices, which hit both the minimum and maximum caps over the year. The higher variability in observed wholesale market price reflects idiosyncratic variation in market conditions such as generation unit outages and transmission and generation capacity constraints.[22]

Table 3 presents the firm-specific estimates for the capital stock parameter and the percentage of output that is forward contracted. The ranking of the capital stock parameter (k) is consistent with the observed market capacities reported in Table 1. Capital Power, ENMAX, and TransAlta have similar

[22]Brown and Eckert (2016) consider a more robust cost function which includes capacity constraints, expected unit outages, and non-linearities to investigate the impacts of mergers and market structure changes. While this improves the fit in the Cournot spot market, the authors do not formally model the endogenous nature of forward contracts.

Table 3: Estimated Capacity and Percentage Forward Commitments

Firm	k	Forward Contract (%)
ATCO	7.41	76.51
Capital Power	21.50	75.18
ENMAX	25.23	75.02
TransAlta	19.01	75.32
TransCanada	53.90	74.44

capital stocks, while TransCanada has the largest and ATCO the smallest. The model yields limited heterogeneity across firms in terms of the estimated percentage of spot market output that is forward contracted, with all firms having percentages between 74 and 77 percent.[23]

4.3.2 Merger Simulation

Having fit our theoretical model to the observed environment in Alberta, we simulate the effects of all possible two-firm mergers involving the five large firms. In the context of our model, a merger represents a transfer of a firm's capital stock to another firm. To simulate the post-merger equilibrium for each firm and hour in our sample, we combine the merging firms' capital stocks and use the equilibrium spot market output and forward contracted quantities decisions defined in (5) and (10), respectively.[24]

To understand the impact of endogenous forward contracting on wholesale market outcomes in the presence of a merger, we undertake two additional simulations that fix the level of forward contracted quantities. First, we simulate the post-merger wholesale market outcomes holding the forward quantities of the merging firms (in MWs) constant. This environment reflects a setting where forward commitments are exogenous. For example, the merging firms have exogenous forward retail commitments or long-term supply contracts that they are required to serve (Bushnell et al., 2008). Second, we simulate the post-merger wholesale market outcomes holding the percentage of output forward contracted constant. This setting can reflect an environment where firms are required to forward contract a fixed percentage of their wholesale market output.[25]

Table 4 illustrates the percentage change in average wholesale market price and total surplus (welfare) for each of the ten possible two firm mergers.[26] Because market demand is assumed to be perfectly price-inelastic, changes in total surplus reflect changes in the cost of electricity production due to redistribution of output across the firms. When forward contracts are endogenous the simulated price effects of the mergers are potentially dramatic. The simulated mergers lead to price increases of 5% to 35% depending on the merger and assumptions regarding forward position.[27] In contrast, the effect on total surplus

[23] The estimated forward contract coverage is consistent with the amount observed in practice. Wolfram (1999), Wolak (2007), and Sweeting (2007) observe forward contract coverage as a percentage of output from 73% to 103%.

[24] More formally, to implement this numerical program we use the Linear Programming solver CPLEX in GAMS (Ferris et al., 2009) to solve the two-stage equilibrium for all firms in our sample using the primal simplex method.

[25] Regulators have imposed or advocated for the imposition of requirements on firms' forward contracting quantities to alleviate concerns over market power (Harvey and Hogan, 2000; Frutos and Fabra, 2012).

[26] The results are presented as unweighted averages. Weighting hours by market demand has little impact on estimated price effects, estimated weighted and unweighted average prices differ by less than $2/MWh for all mergers.

[27] In the recent Exelon and Constellation merger analysis, numerical simulations of wholesale market competition found that under certain circumstances wholesale prices could rise by as much as 25% due to the merger (MPSC, 2012, pg. 46).

Table 4: Merger Effects: Percentage Changes in Price and Total Surplus

	Change in Price (%)			Change in Total Surplus (%)		
Merger	Endog.	Fixed (%)	Fixed (MW)	Endog.	Fixed (%)	Fixed (MW)
ATCO-CP	14.92	6.11	5.60	-0.04	0.08	0.04
ATCO-ENMAX	15.56	6.40	5.77	-0.08	0.06	0.04
ATCO-TA	14.38	5.86	5.45	-0.02	0.09	0.04
ATCO-TC	17.66	7.02	6.07	-0.26	-0.02	0.11
CP-ENMAX	27.35	14.26	10.66	-0.57	-0.25	-0.13
CP-TA	24.69	12.53	9.64	-0.38	-0.13	-0.09
CP-TC	32.50	17.85	12.31	-1.05	-0.63	-0.17
ENMAX-TA	26.04	13.54	10.13	-0.48	-0.20	-0.11
ENMAX-TC	34.69	19.66	13.25	-1.24	-0.78	-0.24
TA-TC	30.76	16.46	11.56	-0.91	-0.52	-0.12

is limited, with percentage changes of less than a percent in most cases. While the change in total surplus is limited, these mergers result in large distributional changes across consumer and producer surplus. These results are arising in part because the residual demand faced by the top five firms is highly price-inelastic.[28] Our high degree of residual demand price-inelasticity is consistent with studies of other jurisdictions, including PJM and New England (Bushnell et al., 2008).

The price effects of the mergers in Table 4 are substantially larger when the forward positions are endogenous. As shown in Proposition 2, the price effects of mergers are magnified when forward contracts are endogenous because firms have an incentive to reduce their forward contract coverage. This commits the firms' to a lower level of output in the Cournot wholesale market, holding all else constant. We find that the percentage increase in price from the merger is in general between two and three times larger with endogenous forward positions than when forward committed MW are held constant. The setting where firms are required to hold forward contracts as a percentage of output constant is the intermediate case in terms of price effects. This arises because the higher concentration reduces firms' output levels in the Cournot framework and so, the forward contracted quantities decrease even though the percentage of forward contracts are held constant. In our simulations, firms' forward contract coverage decreases from an average of 75.30% pre-merger to 69.54% post-merger for the merging firm and 70.62% for the non-merging firms in the post-merger equilibrium.

In light of the large price effects in Table 4, it is illustrative to consider how these transactions might have been handled using traditional antitrust screens based on concentration measures. Our discussion is at most suggestive, as we do not engage in a detailed market definition exercise.[29] Taking the market to be wholesale electricity from generators located in Alberta (including nondispatchable generation such as wind), and using generation capacity to compute market shares, we can compute for each merger the combined market shares of the merging parties, along with the pre- and post-merger Herfindahl-Hirschman Index (HHI) statistics. Table 5 presents these concentration measures for each merger. Using the US Horizontal Merger Guidelines (United States Department of Justice, 2010), only three of the merger simulations would be considered even moderately concentrated with an HHI exceeding 1500, although

[28]The estimated fringe supply function in Section 4.1 yields an average residual demand elasticity of -0.27 in our sample.

[29]See MSA(2012) for an extended discussion of geographic market definition issues in Alberta's wholesale electricity market, and issues arising regarding concentration statistics and market shares.

Table 5: Merging Firms' Market Shares and HHI Statistics, by Merger

Merger	Merged Firms' Market Share	HHI	Change in HHI
ATCO - CP	21.29	1306.13	225.24
ATCO - ENMAX	24.74	1373.87	292.98
ATCO - TA	25.29	1384.81	303.92
ATCO - TC	27.91	1436.14	355.25
CP - ENMAX	26.38	1422.84	341.95
CP - TA	26.93	1435.61	354.72
CP - TC	29.55	1495.52	414.63
ENMAX - TA	30.38	1542.29	461.40
ENMAX - TC	33.00	1620.22	539.33
TA - TC	33.55	1640.36	559.46

Notes: Change in HHI represents the change in the HHI due to the merger.

the increases in HHI would all exceed the 100 or 200 point thresholds identified in those guidelines. The combined market share of the merging firms in all cases fall below the 35% safe harbour threshold given in the Canadian Merger Enforcement Guidelines (Competition Bureau, 2011), suggesting that the Commissioner would be unlikely to challenge the merger.[30] The combined market share of the merging firms all fail the FERC's wholesale market share threshold of 20% (FERC, 2012). Of course, these concentration measures will be sensitive to the precise market definition and construction of market shares.[31] However, the results highlight the well known observation that traditional concentration measures can be poorly suited for identifying market power in electricity markets.

Table 6: Percentage Changes in Combined Profit of Merging Firms

Merger	Endog.	Fixed (%)	Fixed (MW)
ATCO - CP	6.10	-1.84	4.74
ATCO - ENMAX	6.02	-1.43	5.12
ATCO - TA	6.15	-2.10	4.45
ATCO - TC	5.51	1.14	6.93
CP - ENMAX	6.69	-2.62	7.10
CP - TA	6.77	-3.09	6.50
CP - TC	6.46	0.19	9.11
ENMAX - TA	6.72	-2.86	6.87
ENMAX - TC	6.37	0.34	9.28
TA - TC	6.50	0.15	8.96

We can also use the model to assess the change in variable profits of the merging firms that arise from the merger.[32] For each merger, Table 6 presents the percentage change in the combined profits of the merged firms after the merger. Interestingly, while all mergers increase the merging firm's profits assuming endogenous forward contracting, this is not the case when forward contract percentages are fixed. On the other hand, for many cases, the estimated increase in profit for the merging firms is greatest under the assumption that firms' forward contracted quantities (in MWs) are held fixed at pre-merger

[30]The majority of the mergers do not violate the provisions in Alberta's *Fair, Efficient and Open Competition Regulation* (Alta Reg 159/2009) that prevents a firm from holding offer control greater than 30% of Alberta Maximum Capability.

[31]Reasons that our approach could lead to underestimating market power are detailed in MSA (2011).

[32]The mergers may also impact firms' fixed costs. We focus our analysis on wholesale market profits.

levels. Hence, the effect of endogenous forward contracting on the incentive to merge is ambiguous. Committing the merged firm to forward sales equal to the sum of the firms' forward MWs pre-merger results in a higher market share of the total wholesale market output for the merging firm than under endogenous contracting. This credible forward commitment can result in higher profits compared to the endogenous forward contracting environment, as was demonstrated in Proposition 3 for the symmetric model. As an example, in the case of a merger between CP and TC, under endogenous forward contracting the market share of output of the merging firms falls from 32% to 23%. Assuming that firms' forward market-contracted MWs remain constant post-merger, the merged firms' market share of wholesale output declines only to 29%. Therefore, while endogenous forward contracting yields the largest price effect from the merger, there can be a strategic benefit of holding forward contracted quantities fixed at pre-merger levels for the merging firms. This effectively commits them to a larger market output, forcing rivals to smaller outputs.

5 Conclusion

We have developed a model of electricity market mergers with endogenous forward contracting. We found that mergers reduce firms' incentives to forward contract in the post-merger environment. This is primarily driven by the lower strategic effect of forward contracting in the post-merger equilibrium. The reduction in forward contracting elevates the price effects of mergers, magnifying the reduction in consumer surplus compared to an environment where forward contracted quantities are held at pre-merger levels. Whether the profits of the merged firm are higher when forward contract quantities can be adjusted post-merger compared to when they are fixed at pre-merger levels is ambiguous, and depends on the number of firms in the market. Our results illustrate that the price effects of mergers are dampened when firms' forward commitments are held constant post-merger due to regulatory restrictions or mandated supply contracts.

Our formal analysis lends considerable support to concerns in recent merger cases that firms may reduce their level of fixed-price forward contracts in the post-merger equilibrium. Using data from Alberta's wholesale electricity market, we demonstrate that a merger simulation can largely underestimate the price effects of proposed mergers if forward commitments are held constant at pre-merger levels. Further our empirical analysis supports the finding that while endogenous forward contracting can elevate wholesale prices, it can potentially erode the merged firm's profits. Holding forward contracts at pre-merger levels (in MWs) can commit the merged firm to a higher level of production in the post-merger wholesale markets, driving their rivals to a lower level of output.

Market screening policies and oligopoly simulation models currently used by antitrust authorities such as the FERC and the Department of Justice can be useful instruments to investigate the competitive impacts of proposed electricity market mergers. However, a more detailed consideration of firms' forward commitments when analyzing electricity market structure changes such as mergers is necessary. Abstracting from the endogenous nature of fixed-price forward contracts can lead regulators and antitrust authorities to biased conclusions regarding the competitive impacts of proposed mergers.

In concluding, we discuss several extensions of our analysis that merit further investigation. First, we focused on a setting where firms signed forward contracts solely for strategic reasons. Generation firms may also forward contract for risk-hedgng reasons. This can potentially reduce firms' incentives to decrease their level of forward contracting in the post-merger environment.[33] A formal analysis that considers both strategic and risk-hedging forward contracting incentives in the presence of a merger warrants formal investigation. Second, we focused on a setting with asymmetric linear marginal cost. A more robust characterization of firms' marginal cost functions with capacity constraints can improve the quality of fit of oligopoly simulation models in electricity markets.[34] However, the key conclusions drawn above seem likely persist in the context of this more robust cost function.

Third, similar to Bushnell (2007), we assumed that firms undergo a single round of forward contracting prior to wholesale Cournot competition. However, several studies find that repeated interaction and multiple stages of forward contracting may erode the competitive effects of forward contracting by facilitating collusion (e.g., Liski and Montero (2006); Green and Le Coq (2006)). Such anticompetitive behavior through the use of forward contracts can potentially be enhanced in the post-merger equilibrium.

Fourth, alternative market structure changes such as partial mergers, generation unit divestitures, and asset acquisitions merits further investigation.[35,36] These types of market structure changes can also impact firms incentives to adjust their level of forward contracts. We anticipate these market structure changes will exhibit similar findings to those illustrated in our current analysis, but the details of the analysis remain to be determined.

[33] van Eijkel and Moraga-Gonzalez (2013) find that strategic and risk-hedging reasons for forward contracting create opposing predictions regarding the effect of an increase in the number of firms on firms' incentives to sign forward contracts. The authors find that risk-hedging increases firms' incentives to sign forward contracts as the number of firms decrease.

[34] Brown and Eckert (2016) illustrate the improved fit of the Cournot model in Alberta's electricity market using a non-linear cost function with capacity constraints. However, the authors do not formally model the endogenous nature of firms' forward contracting decisions.

[35] For example, in Alberta, certain generating units are under long-term contracts called Power Purchase Arrangements which give the buyer of the contract offer control over the asset. In 2020, the expiry of these contracts will return offer control of the generating asset to the owner, leading to a sizable change in the market structure (MSA, 2011).

[36] Virtual divestitures of generation assets have been used in European electricity markets to reduce market concentration (Frutos and Fabra, 2012).

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Appendix

Proof of Lemma 1: (2) can be rewritten as:

$$a - bQ + bq_i^f = \frac{bq_i}{\beta_i}. \tag{23}$$

Multiplying both sides of (23) by β_i and summing across all firms yields:

$$B(a - bQ) + b\sum \beta_i q_i^f = bQ. \tag{24}$$

(3) and (4) follows from (24) given $P(Q) = a - bQ$. (5) follows from (3) and (23).

Using (2), because b and k_i are positive constants, each firm's profit function is strictly concave in q_i:

$$\frac{\partial^2 \pi_i(q_i, q_{-i})}{\partial q_i^2} = -2b - \frac{1}{k_i} < 0. \quad \blacksquare$$

Proof of Lemma 2: Using (3) - (5) and that $\beta_i > 0 \; \forall \; i = 1, 2, ..., N$, the following inequalities hold:

$$\frac{\partial q_i}{\partial q_i^f} = \beta_i - \frac{\beta_i^2}{1+B} \stackrel{s}{=} 1 + B - \beta_i = 1 + \sum_{j \neq i} \beta_j > 0;$$

$$\frac{\partial q_j}{\partial q_i^f} = \frac{-\beta_i \beta_j}{1+B} < 0; \quad \frac{\partial Q}{\partial q_i^f} = \frac{\beta_i}{1+B} > 0; \quad \text{and} \quad \frac{\partial P}{\partial q_i^f} = \frac{-b\beta_i}{1+B} < 0. \quad \blacksquare$$

Proof of Lemma 3: Using the marginal effects of forward contracting on spot market quantities identified in Lemma 2, (10) follows from (9).

Using (7) and from Lemma 2 $\frac{\partial q_i}{\partial q_i^f}$ and $\frac{\partial q_j}{\partial q_i^f}$ are independent of q_i^f for all $i, j = 1, 2, ..., N$ with $i \neq j$:

$$\frac{\partial^2 \pi_i(q_i^f, q_{-i}^f)}{\partial {q_i^f}^2} = P'(Q)\frac{\partial q_i}{\partial q_i^f} + q_i P''(Q) \sum_{j=1}^{N} \frac{\partial q_j}{\partial q_i^f} + P'(Q)\frac{\partial q_i}{\partial q_i^f} \sum_{j=1}^{N} \frac{\partial q_j}{\partial q_i^f} - C_i''(\cdot)\left(\frac{\partial q_i}{\partial q_i^f}\right)^2. \tag{25}$$

Since $P'(Q) = -b < 0$, $P''(Q) = 0$, $C_i''(\cdot) = \frac{1}{k_i} > 0$, and from Lemma 2 $\frac{\partial q_i}{\partial q_i^f} > 0$ and $\sum_{j=1}^N \frac{\partial q_j}{\partial q_i^f} = \frac{\partial Q}{\partial q_i^f} > 0$, (25) simplifies and satisfies the following inequality:

$$\frac{\partial q_i}{\partial q_i^f}\left[P'(Q) + P'(Q)\frac{\partial Q}{\partial q_i^f} - C_i''(\cdot)\frac{\partial q_i}{\partial q_i^f}\right] < 0. \quad \blacksquare \tag{26}$$

Proof of Proposition 1: It is without loss of generality to assume that firms 1 and 2 merge resulting in capital stock $k_M = k_1 + k_2$. Define $\beta_M = \frac{bk_M}{bk_M+1}$ and $\beta_j = \frac{bk_j}{bk_j+1} \; \forall \; j \geq 3$. Using (11), the difference between firm 1 and the merged firm's proportion of forward contracted output satisfies:

$$\frac{q_1^f}{q_1} - \frac{q_M^f}{q_M} = \frac{\sum_{j=2}^N \beta_j}{1 + \sum_{j=2}^N \beta_j} - \frac{\sum_{j=3}^N \beta_j}{1 + \sum_{j=3}^N \beta_j} \; > \; 0$$

$$\Rightarrow \left(\sum_{j=2}^{N} \beta_j\right)\left(1 + \sum_{j=3}^{N} \beta_j\right) - \left(\sum_{j=3}^{N} \beta_j\right)\left(\sum_{j=2}^{N} \beta_j\right) = \left(\sum_{j=2}^{N} \beta_j\right) \; > \; 0.$$

Similar intuition follows for firm 2. Next, we illustrate that the non-merging firms reduce the proportion of output that is forward contracted. It is without loss of generality to focus on the non-merging firm 3. Denote ${q_3^f}'$ and q_3' to be firm 3's post-merger forward and spot market output, respectively. Using (11) and that $\beta_1 + \beta_2 - \beta_M > 0$:

$$\frac{q_3^f}{q_3} - \frac{q_3^{f\prime}}{q_3^\prime} = \frac{\sum_{j\neq 3}\beta_j}{1+\sum_{j\neq 3}\beta_j} - \frac{\beta_M + \sum_{j=4}^N \beta_j}{1+\beta_M+\sum_{j=4}^N\beta_j} \;>\; 0$$

$$\Rightarrow \left(\sum_{j\neq 3}\beta_j\right)\left(1+\beta_M+\sum_{j=4}^N\beta_j\right) - \left(\beta_M+\sum_{j=4}^N\beta_j\right)\left(1+\sum_{j\neq 3}\beta_j\right) \;>\; 0$$

$$\Rightarrow \left(\sum_{j\neq 3}\beta_j\right) - \beta_M - \sum_{j=4}^N\beta_j = \beta_1+\beta_2-\beta_M \;>\; 0. \quad \blacksquare$$

Proof of Lemma 4: Using (10) and that $\beta_i = \beta$ for all $i = 1, 2, ..., N$ and $B = N\beta$:

$$\left[\frac{a}{b}\frac{\beta}{1+B} - \frac{\beta^2 N\, q_f}{1+B} + \beta q^f\right]\left(\frac{-\beta^2}{1+B}\right) + q^f\left(\beta - \frac{\beta^2}{1+B}\right) = 0$$

$$\Rightarrow\; q^f\left(\frac{\beta}{1+B}\right)\left[\frac{\beta^3}{1+B}N(N-1) - \beta^2(N-1) + 1 - B - \beta\right] = \beta^3\frac{a}{b}\left(\frac{N-1}{(1+B)^2}\right).$$

$$\Rightarrow\; q^f = \frac{\frac{(N-1)}{1+B}\beta^2\frac{a}{b}}{(1+B)-\beta+(N-1)\beta^2(\frac{\beta N}{1+B}-1)} \;=\; \frac{\frac{(N-1)}{1+NB}\beta^2\frac{a}{b}}{1+(N-1)\beta-\frac{(N-1)\beta^2}{1+N\beta}}$$

$$= \frac{(N-1)\frac{a}{b}}{(1+(N-1)\beta)(1+N\beta)-(N-1)} \;=\; \frac{(N-1)\frac{a}{b}}{\frac{\left(\frac{1+Nbk}{1+bk}\right)\left(\frac{1+(N+1)bk}{1+bk}\right)}{\left(\frac{bk}{1+bk}\right)^2}-(N-1)} \tag{27}$$

$$= \frac{(N-1)\frac{a}{b}}{\left(N+\frac{1}{bk}\right)\left(N+1+\frac{1}{bk}\right)-(N-1)} = \frac{(N-1)\frac{a}{b}}{\left(N+\frac{1}{bk}\right)^2+N+\frac{1}{bk}-(N-1)}. \tag{28}$$

(14) follows from (28).

Using (14) and recognizing that $B = N\beta$ in this symmetric setting, (5) is simplified to:

$$q_i \;=\; \frac{a}{b}\frac{\beta}{1+B} + q^f\beta\left[1-\frac{\beta N}{1+B}\right] \;=\; \frac{a}{b}\frac{\beta}{1+B} + q^f\frac{\beta}{1+B}$$

$$= \frac{a}{b}\frac{\beta}{1+B} + q^f\frac{\beta}{1+B} = \frac{a}{b}\frac{\beta}{1+N\beta}\left[\frac{\left(N+\frac{1}{bk}\right)^2+N+\frac{1}{bk}}{\left(N+\frac{1}{bk}\right)^2+(1+\frac{1}{bk})}\right]$$

$$= \frac{a}{b}\frac{1}{\frac{1}{\beta}+N}\left[\frac{\left(N+\frac{1}{bk}\right)^2+N+\frac{1}{bk}}{\left(N+\frac{1}{bk}\right)^2+(1+\frac{1}{bk})}\right] \;=\; \frac{a}{b}\frac{1}{\frac{1+bk}{bk}+N}\left[\frac{\left(N+\frac{1}{bk}\right)\left(N+\frac{1}{bk}+1\right)}{\left(N+\frac{1}{bk}\right)^2+(1+\frac{1}{bk})}\right]. \tag{29}$$

(12) follows from (29). Recognizing that $P(Q) = a - bNq$, (13) follows from (12). $\blacksquare$

Proof of Proposition 2: First, we illustrate that the spot market prices increase post-merger, holding forward contracting quantities at pre-merger levels. Define q^f_{Pre} to be the symmetric pre-merger forward contracting level. Using (4) and that $B = N\beta_{NM}$ and $B_M = \beta_M + (N-2)\beta_{NM}$, the spot market prices pre- and post-merger, holding forward contracting quantities at pre-merger levels, equals:

$$P^{Pre} \;=\; \left(\frac{1}{1+B}\right)\left(a - bq^f_{Pre}B\right) \quad \text{and} \quad P^{Post} \;=\; \left(\frac{1}{1+B_M}\right)\left(a - bq^f_{Pre}(\beta_M + B_M)\right). \tag{30}$$

Using (30) and that $B = N\beta_{NM}$, $B_M = \beta_M + (N-2)\beta_{NM}$, $\beta_{NM} = \frac{bk}{bk+1}$, and $\beta_M = \frac{2bk}{2bk+1}$:

$$\begin{aligned} P^{Post} - P^{Pre} = \left(\frac{1}{1+B_M}\right)\left(a - bq^f_{Pre}(\beta_M + B_M)\right) - \left(\frac{1}{1+B}\right)\left(a - bq^f_{Pre}B\right) &> 0 \\ \Rightarrow \quad a(B - B_M) - bq^f_{Pre}\left[(1+B)(\beta_M + B_M) - B(1+B_M)\right] &> 0 \\ \Rightarrow \quad a(2\beta_{NM} - \beta_M) - bq^f_{Pre}\left[2(\beta_M - \beta_{NM}) + N\beta_{NM}\beta_M\right] &> 0 \\ \Rightarrow \quad a\left(\frac{2(bk)^2}{(bk+1)(2bk+1)}\right) - bq^f_{Pre}\left[\frac{2bk}{(2bk+1)(bk+1)} + \frac{2N(bk)^2}{(bk+1)(2bk+1)}\right] &> 0. \end{aligned} \tag{31}$$

Using (14), (31) simplifies:

$$\begin{aligned} a\,bk - b\left(\frac{(N-1)\frac{a}{b}}{\left(N+\frac{1}{bk}\right)^2 + \left(1+\frac{1}{bk}\right)}\right)(1+NbK) &> 0 \\ \Rightarrow \quad N + 2 + Nbk + \frac{1}{bk} + bk &> 0. \end{aligned} \tag{32}$$

Because spot market prices are decreasing in total output Q, $P^{Post} - P^{Pre} > 0$ implies that total output decreases post-merger, holding forward contracting quantities at pre-merger levels.

Second, we illustrate that total output post-merger is lower with endogenous forward contracts (Q^{Post}_{Endog}) compared to total output holding forward contracting quantities at pre-merger levels (Q^{Post}_{Fixed}). Using (3) and $B_M = \beta_M + (N-2)\beta_{NM}$, $Q^{Post}_{Endog} < Q^{Post}_{Fixed}$ if:

$$\begin{aligned} \frac{a}{b}\frac{1}{1+B_M} + \frac{\beta_M q^f_M + (N-2)\beta_{NM}q^f_{NM}}{1+B_M} &< \frac{a}{b}\frac{1}{1+B_M} + \frac{\left[\beta_M + (N-2)\beta_{NM}\right]q^f_{Pre}}{1+B_M} \\ \Rightarrow \quad \beta_M q^f_M + (N-2)\beta_{NM}q^f_{NM} &< \left[\beta_M + (N-2)\beta_{NM}\right]q^f_{Pre}. \end{aligned} \tag{33}$$

Using (10) and $B_M = \beta_M + (N-2)\beta_{NM}$, in the post-merger equilibrium the merged firms' forward contract quantity satisfies:

$$q^f_M\beta_M\left(1 - \frac{\beta_M}{1+B_M}\right) = q_M\left(\frac{\beta_M\beta_{NM}(N-2)}{1+B_M}\right) \quad \Rightarrow \quad q^f_M(1 + B_M - \beta_M) = q_M\beta_M(N-2). \tag{34}$$

Using (5) and that $B_M = \beta_M + (N-2)\beta_{NM}$ and $\sum_{j\neq M} q^f_j = (N-2)q^f_{NM}$, the merged firms' spot market quantity satisfies:

$$\begin{aligned} q_M &= \left(\frac{\beta_M}{1+B_M}\right)\left[\frac{a}{b} - \beta_{NM}\sum_{j\neq M} q^f_j - \beta_M q^f_M + (1+B_M)q^f_M\right] \\ &= \left(\frac{\beta_M}{1+B_M}\right)\left[\frac{a}{b} - \beta_{NM}(N-2)q^f_{NM} + q^f_M(1+(N-2)\beta_{NM})\right]. \end{aligned} \tag{35}$$

Using (35), (34) simplifies:

$$q^f_M = \frac{\beta_{NM}\beta_M(N-2)\left(\frac{a}{b} - \beta_{NM}(N-2)q^f_{NM}\right)}{\left(1+(N-2)\beta_{NM}\right)\left(1+\beta_M+(N-2)\beta_{NM} - (N-2)\beta_{NM}\beta_M\right)}. \tag{36}$$

Using (10) and $B_M = \beta_M + (N-2)\beta_{NM}$, in the post-merger equilibrium a non-merging firm's forward contract quantity satisfies:

$$q^f_{NM}\left(1-\frac{\beta_{NM}}{1+B_M}\right)=q_{NM}\left(\frac{\beta_{NM}(N-3)+\beta_M}{1+B_M}\right)\;\Rightarrow\; q^f_{NM}(1+B_M-\beta_{NM})=q_{NM}\left(\beta_{NM}(N-3)+\beta_M\right). \tag{37}$$

Using (5) and that $B_M = \beta_M + (N-2)\beta_{NM}$ and $q^f_j = q^f_{NM}$ for all $j \neq M$, a non-merging firm's spot market quantity satisfies:

$$\begin{aligned} q_{NM} &= \left(\frac{\beta_{NM}}{1+B_M}\right)\left[\frac{a}{b}-\beta_{NM}\sum_{j\neq M} q^f_j - \beta_M q^f_M + (1+B_M)q^f_{NM}\right] \\ &= \left(\frac{\beta_{NM}}{1+B_M}\right)\left[\frac{a}{b}-\beta_M q^f_M + q^f_{NM}(1+\beta_M)\right]. \end{aligned} \tag{38}$$

Using (38), (37) simplifies:

$$q^f_{NM} = \frac{\beta_{NM}\left((N-3)\beta_{NM}+\beta_M\right)\left(\frac{a}{b}-\beta_M q^f_M\right)}{\left(1+(N-3)\beta_{NM}+\beta_M\right)\left(1+\beta_M+(N-2)\beta_{NM}\right)-\left((N-3)\beta_{NM}+\beta_M\right)\beta_{NM}(1+\beta_M)}. \tag{39}$$

Using (36) and (39), the post-merger forward contract quantities satisfy:

$$q^f_{NM} = \frac{\frac{a}{b}D(H-\beta_M G)}{HE-(N-2)\beta_M\beta_{NM}GD} \quad\text{and}\quad q^f_M = \frac{\frac{a}{b}G(E-\beta_{NM}(N-2)D)}{HE-(N-2)\beta_M\beta_{NM}GD},\ \text{where} \tag{40}$$

$$\begin{aligned} &D \equiv \beta_{NM}\left((N-3)\beta_{NM}+\beta_M\right); \\ &E \equiv \left(1+(N-3)\beta_{NM}+\beta_M\right)\left(1+(N-2)\beta_{NM}+\beta_M\right)-\left((N-3)\beta_{NM}+\beta_M\right)\beta_{NM}(1+\beta_M); \\ &G \equiv \beta_{NM}\beta_M(N-2);\ \text{and} \\ &H \equiv \left(1+(N-2)\beta_{NM}\right)\left(1+\beta_M+(N-2)\beta_{NM}-(N-2)\beta_{NM}\beta_M\right). \end{aligned} \tag{41}$$

Using (27) and (41), (33) can be rewritten as:

$$\frac{(N-2)\beta_{NM}DH+\beta_M GE-2(N-2)\beta_M\beta_{NM}DG}{HE-(N-2)\beta_M\beta_{NM}GD} < \frac{(N-1)\left(\beta_M+(N-2)\beta_{NM}\right)}{\left(1+(N-1)\beta_{NM}\right)\left(1+N\beta_{NM}\right)-(N-1)}. \tag{42}$$

Using (41), that $\beta_{NM} = \frac{bk}{1+bk}$ and $\beta_M = \frac{2bk}{1+2bk}$, and using *Mathematica* to simplify the algebraic expression, (42) can be rewritten as:

$$\begin{aligned} &\frac{2bk(1+bk(3+N+2Nbk))}{(1+3bk+2(bk)^2)^3}\Bigg\{2+bk\Bigg[6+7N+bk\Bigg(2+19N+7N^2+4(bk)^3\left[N^2+N-2\right] \\ &\qquad + 2(bk)^2\left[2N^3+N^2+9N-8\right]+2(bk)\left[N^3+8N^2+4N-1\right]\Bigg)\Bigg]\Bigg\} > 0. \end{aligned} \tag{43}$$

(43) holds for all $N \geq 3$. Hence, $Q^{Post}_{Endog} < Q^{Post}_{Fixed}$. This implies that the price increasing impact of mergers is magnified in the endogenous forward contracting environment.

Third, because consumers' demand is perfectly price-inelastic, price increases strictly reduce consumer surplus. The price effects illustrated above imply that consumer surplus is lower post-merger and the reduction in consumer surplus is larger when forward quantities are endogenous. ■

Proof of Proposition 3: Using (4) - (6), the merged firm's profit with endogenous forward contracts:

$$\pi_M(q_M^f, q_{NM}^f) \;=\; \left[\frac{a - b\left(\beta_M q_M^f + (N-2)\beta_{NM} q_{NM}^f\right)}{1 + B_M}\right] q_M - \frac{(q_M)^2}{2k_M} \tag{44}$$

where $k_M = 2k$, $B_M = (N-2)\beta_{NM} + \beta_M$, and

$$q_M \;=\; \frac{a}{b}\left(\frac{\beta_M}{1+B_M}\right) - \beta_M\left[\frac{(N-2)\beta_{NM} q_{NM}^f + \beta_M q_M^f}{1+B_M}\right] + \beta_M q_M^f.$$

Using (4) - (6), the merged firm's profit with fixed pre-merger forward contracts:

$$\pi_M(\overline{q}^f) \;=\; \left[\frac{a - b\left(2\beta_M \overline{q}^f + (N-2)\beta_{NM}\overline{q}^f\right)}{1 + B_M}\right] q_M - \frac{(q_M)^2}{2k_M} \tag{45}$$

$$\text{where} \quad q_M \;=\; \frac{a}{b}\left(\frac{\beta_M}{1+B_M}\right) - \beta_M\left[\frac{(N-2)\beta_{NM}\overline{q}^f + 2\beta_M \overline{q}^f}{1+B_M}\right] + 2\beta_M \overline{q}^f.$$

Using $\overline{q}^f$, q_{NM}^f, and q_M^f defined in (14) and (40) and (44), (45), and *Mathematica* to simplify the following expression:

$$\begin{aligned}
&\pi_M(\overline{q}^f) - \pi_M(q_M^f, q_{NM}^f) \;>\; 0 \\
\Leftrightarrow\quad & 1 - N + bk(17 - 9N - 6N^2) + (bk)^2(112 + 4N - 68N^2 - 15N^3) + (bk)^3(398 + 268N - 237N^2 \\
& -170N^3 - 20N^4) - (bk)^4(-870 - 1206N + 171N^2 + 674N^3 + 214N^4 + 15N^5) \\
& + (bk)^5(1244 + 2738N + 928N^2 - 1227N^3 - 830N^4 - 145N^5 - 6N^6) + (bk)^7(1125 + 2923N \\
& + 4281N^2 + 1088N^3 - 2005N^4 - 1011N^5 - 133N^6 - 4N^7) + 16(bk)^{12}(4 - 8N + 13N^2 - 5N^3 \\
& - 5N^4 + 10N^5 - 6N^6 + N^7) - (bk)^6(-1269 - 3621N - 3125N^2 + 854N^3 + 1668N^4 + 512N^5 \\
& + 48N^6 + N^7) + (bk)^8(932 + 1846N + 2741N^2 + 2576N^3 - 827N^4 - 1416N^5 - 231N^6 + 6N^7 + N^8) \\
& + 4(bk)^{11}(44 - 20N + 151N^2 - 166N^3 + 182N^4 - 66N^5 - 2N^6 - 10N^7 + 3N^8) \\
& + 4(bk)^{10}(76 + 188N - 48N^2 + 250N^3 + 25N^4 - 89N^6 - 2N^7 + 4N^8) \\
& + (bk)^9(688 + 924N + 1333N^2 + 1296N^3 + 709N^4 - 976N^5 - 405N^6 + 28N^7 + 7N^8) \;>\; 0.
\end{aligned} \tag{46}$$

For a given $bk > 0$, inequality (46) holds for a sufficiently large value on N. ■

Table A1: Hourly Fringe Supply Function IV Estimation

	First Stage	Second Stage
	p_t	Q_t^f
p_t	—	5.92***
		(1.45)
p_t^{NG}	46.96**	-213.84
	(21.90)	(162.41)
$ImportCap_{BC}$	-0.247***	1.73***
	(0.035)	(0.44)
$ImportCap_{SK}$	-0.0017	-0.44
	(0.17)	(1.09)
Q_{WIND}	-0.133***	0.84***
	(0.017)	(0.22)
$Q^D_{DayAhead}$	0.065***	—
	(0.015)	
Constant	-344.88**	1030.33**
	(144.39)	(520.45)
Kleibergen-Paap Wald F-Stat	27.83***	—
Sample Size	8,760	8,760
Province Temperature Covariates	Y	Y
Hour-Weekday-Month Covariates	Y	Y

Notes: The regressions are estimated using two-stage least squares with Heteroskedasatic and Autocorrelation (HAC) robust standard errors (in parentheses) with 24 lags. The sixteen temperature variables contain second-order polynomials of heating degree days (HDD) and cooling degree days (CDD) for cities in Alberta (Edmonton and Calgary), British Columbia (Vancouver), and Saskatchewan (Saskatoon). ***, **, and * indicate statistically significant coefficients at the 1%, 5%, and 10% percent levels, respectively. The heteroskedastic robust Kleibergen-Paap Wald F-Stat strongly rejects the null hypothesis that our excluded instrument is weak.

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