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An Examination of Frank Wolak's Model of Market Power and its Application to the New Zealand Electricity Market

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Abstract

We appraise the theoretical basis and the consequent empirical work of Frank Wolak in his study of the New Zealand Electricity Market in a report to the New Zealand Commerce Commission released in March 2009. The report found no multilateral actions, but concluded there was evidence of unilateral market power. We find that the theoretical and empirical methodologies employed to reach this position do not substantiate it, and that the building blocks of this study provide no blue-print for study of market power in any electricity market.

JEL Classification code: L41, L13

Keywords: electricity markets, market power

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1 Introduction

In March 2009 the report "An Assessment of the Performance of the New Zealand Wholesale Electricity Market" conducted for the New Zealand competition authority was released.[1] It was the culmination of a 3-year investigation by Professor Wolak, and it reported that, while there was no evidence of collusion in the New Zealand wholesale electricity market, there was evidence of unilateral market power.[2] In reaching this conclusion Professor Wolak drew on methodology authored by him (Wolak (2003a and 2003b)) and empirical work that relied on that methodology. It is our purpose to explain why Professor Wolak's methodology is applicable in only very limited circumstances that are typically not present in electricity markets, and that the empirical element of the study was flawed.

2 Market power in electricity markets: Wolak's theory of 2003

In Wolak (2003a and 2003b) the market power assessment of generators uses the residual demand facing each generator defined in the conventional way for generator i as

$$DR_i(p, \varepsilon, \omega_j, j \neq i) = D(p, \varepsilon) - \sum_{j \neq i} Q_j(p, mc_j, \omega_j) \tag{1}$$

where $D(p, \varepsilon)$ and $Q_j(p, mc_j, \omega_j)$ are aggregate demand and firm j's supply taken as given in the choice of output by generator i, ε encapsulates aggregate demand shocks, ω_j represents idiosyncratic and common factors that affect supply from the j^{th} generator, and mc_j is marginal cost. This approach presumes the existence of a Cournot market equilibrium. It allows the residual demand curve to be uncertain and to shift unpredictably between the time the generator makes an offer and when its offer is dispatched under the uniform price auction used in many electricity markets.[3] This volatility in demand results in each generator submitting a set of offers to the dispatcher. The set is constructed as the Cournot price/quantity pairs that are implied for the set of possible residual demands. It represents the generator's offer function for dispatch.[4]

The offer function is constructed for every trading period: half hourly in the New Zealand spot market (NZEM). Wolak (2003b) uses recorded generator offer functions for California and an assumed known marginal cost, independent of demand, to calculate the Lerner condition as

[1]See the New Zealand Commerce Commission (2009) at http://www.comcom.govt.nz/index.aspx (March 2010). A companion paper, Wolak (2009a), was made available in seminar presentations prior to the Commission's release of the report.

[2]See the summary of the Commission (2009, p.6).

[3]Uniform-price-auctions (UPAs) are used in at least the institutional electricity markets of the CAISO, PJM, ERCOT and NYISO (see http://www.ferc.gov/industries/electric/indus-act/rto.asp), and the Australian electricity market (NEM) (see http://epress.anu.edu.au/cs/mobile_devices/ch11s03.html). The NZEM is described at http://www.electricity.commission.govt.nz, All accessed 28 May 2010.The UPA dispatch process results in a single market-clearing price.

[4]The offer curve has to be submitted 2 hours in advance of dispatch in NZEM. It is designed to accommodate variations in demand that arise in the half-hour dispatch period. If fluctuations in marginal cost were in prospect during this period – as may arise from network outages for example—the offer curve could be constructed in a way that reflected possible marginal cost scenarios – as for demand: but the result may not be a well defined offer function particularly if residual demand is affected by variations in marginal cost.

an indicator of unilateral market power. Evans and Guthrie (2009) have pointed out that this approach ignores the effect on short-run marginal cost of fuel uncertainty and storage, and that this may materially affect results.

The New Zealand study follows the reasoning of Wolak (2003b, repeated in 2009a, s.3). Given the residual demand for company i, $(DR_i(p))$[5] and the Learner condition $(p_i - mc_i)/p_i = -1/\varepsilon_i(p_i)$ ($\varepsilon_i(p_i)$ being the elasticity of demand), Wolak writes

$$p_i = mc_i + \frac{p_i}{-\varepsilon_i(p_i)} = mc_i + 100\eta_i(p_i) \tag{2}$$

where

$$\eta_i(p_i) = -\frac{1}{100}\frac{DR_i(p_i)}{\partial DR_i(p_i)/\partial p_i} = \frac{1}{100}\frac{p_i}{(-\varepsilon_i(p_i))} \tag{3}$$

is termed by Wolak an inverse semi-elasticity. Based on Equations (2) and (3) Wolak argues that the higher is the observed inverse semi-elasticity the more the firm is actually exercising market power. He then argues that a positive association in the data between price and the inverse semi-elasticity of demand indicates the use of market power in the New Zealand electricity market. We consider these two arguments separately.

3 A Relatively High inverse semi-elasticity does not indicate the exercise of unilateral market power

Wolak correctly claims (2009a, p. 30) that

> "This magnitude [level of the semi-elasticity] gives the \$/MWh increase in the market-clearing price associated with a one percent reduction in the amount of output sold by the supplier."

Wolak incorrectly claims (2009a, p. 29) that the

> "... simplified model of expected profit-maximizing offer behavior [as in (2)] implies that higher market-clearing prices should be associated with higher values of the inverse semi-elasticity"

We make this point by means of the following Proposition assuming a linear demand function—which Wolak (2009b) finds to be a reasonable approximation in the New Zealand market.[6,7] The inverse semi-elasticity for the i^{th} generator's linear residual demand function is for any p_i, $\eta_i(p_i) = \frac{a_i - b_i p_i}{100 b_i}$ and

Pa) Unilateral profit maximisation yields the offer price $p_i^* = \frac{a_i + b_i mc_i}{2b_i}$ and inverse semi-elasticity $\eta_i^*(p_i^*) = \frac{a_i - b_i mc_i}{200 b_i}$;

Pb) Price equals marginal cost yields the offer price $p_i^{**} = mc_i$ and inverse semi-elasticity $\eta_i^{**}(mc_i) = \frac{a_i - b_i mc_i}{100 b_i} = 2\eta_i^*$; and

[5] The shocks to residual demand are suppressed.

[6] The supply and demand functions of electricity spot markets are typically step functions as only a finite number of price-quantity generator offers and demand bids are permitted. Residual demand functions reflect the step of both demand and other suppliers. The assumption of a linear demand function is suggested by Wolak's (2009a, 31) discussion, where he describes his method for estimating the slope of the residual demand function. The comment that his "inverse semi-elasticities are not sensitive to the choice of the price window used to compute them" suggests that the residual demand curve is approximately linear. The constant elasticity demand curve yields quite unrealistic results and will not be considered.

[7] The Proposition is established in Appendix 6.1.

Pc) Price equal to some convex combination of the Cournot profit maximising price (p_i^*) and marginal cost {i.e. $p_i^\lambda = mc_i + \lambda(p_i^* - mc_i)$ for $\lambda\varepsilon[0,1]$} yields the offer price $p_i^\lambda = mc_i + \frac{100\lambda}{2-\lambda}\eta_i^\lambda$, and the inverse semi-elasticity $\eta_i^\lambda(mc_i) = \frac{(2-\lambda)(a_i - b_i mc_i)}{200b_i}$.

The inverse semi-elasticity of the linear demand function implies that higher prices are associated with a lower inverse semi-elasticity. In fact, η_i^λ of Pc) is declining in λ—that is, as pricing approaches unilateral profit maximisation against the residual demand curve the inverse semi-elasticity falls in magnitude. Further, when price is chosen equal to marginal cost this inverse semi-elasticity is twice the magnitude it would be if the firm maximised profits by setting marginal revenue to marginal cost. Thus, an observed high level of the inverse semi-elasticity does not indicate whether market power is actually being exercised.[8]

Wolak's error is to interpret the effect on profit of a unit reduction in output—i.e. the level of the inverse semi-elasticity—as showing whether or not the firm is actually exercising unilateral market power. But as the Proposition shows, the payoff from such a reduction—as given by the inverse semi-elasticity—can be higher when unilateral market power is not being exercised.

Although the pricing formulae of the Proposition have analogous forms to Wolak's equations (2) and (3), only Pa) is consistent with it. In Pb), for example, price equal marginal cost can be true in both (2) and Pb) only if $\eta_i^*(mc_i) = 0$ which requires $mc_i = a_i/b_i$ which there is no reason to expect. The seeming inconsistency arises because the behaviour differs across these alternatives. The pricing formula of (2) and (3) are valid under the assumption that repeatedly over an indefinite period in each and every period offers are determined by firms that know their marginal cost and the set of feasible residual demand functions, and that for each and every period choose price quantity pairs that equate marginal revenue to marginal cost. Where this assumption is violated and firms price at a lower level than Wolak assumes, the magnitude of their inverse semi-elasticities will be higher rather than lower, at least for one set of demand functions.[9]

4 The Empirical Work

Wolak presents various data in his study of market power. His main conclusion is that offer prices and concomitant inverse semi-elasticities are positively correlated and that this indicates the utilisation of market power by the four major generators in the New Zealand market.

We start by considering his analysis of his system (2) and (3) which we re-express as:

$$p_i = mc_i(\nu) + \beta_i^* \eta_i(\nu) + \vartheta_i \tag{4}$$

where ν is a vector of the shocks depicted in (1) and, presumably, $\beta_i^* = 100$, pursuant to hypothesis (2).[10] Wolak estimates, by means of ordinary least squares, the equation

$$p_i^\# = mc_i^\# + \beta_i^\# \eta_i^\# + \vartheta_i^\# \tag{5}$$

[8] Wolak (2009, s.3) does recognise the effect of hedge arrangements on the ability of firms to exercise unilateral market power in the short run, and modifies his analysis by measuring residual demand as that demand remaining after meeting hedge commitments. We do not consider this issue, for it does not affect our general results.

[9] Generation in the NZEM utilises a variety of fuels including approximately 55%-65% by quantum of hydro. Limited storage and variation of inflows to storage across time and space for both water and gas mean that the cost structures of generators differ and vary relatively and unpredictably over time. In this situation affiliated actions are unlikely. Indeed, Wolak finds no affiliated actions in the New Zealand market (see the Commission (2009,p. 6)). Thus one would not expect a higher than Cournot price to be set.

[10] Wolak gives no reason for estimating the regression equation. He does refer to Reiss and Wolak (2007) in a claim to the effect that regression produces a prediction equation.

where # denotes variable estimate and ϑ the error term of the respective equations. The price variable is the offer price corresponding to the quantum of dispatched generation. Linear regression will produce the best—in a least squares sense—linear approximation to a function expressing the expected value of price conditional on the explanatory variables. There are two levels of issues. The first concern is that (4) represents a structural equation and it remains to be seen whether it will be consistently estimated by its conditional expectation. It will be so estimable if $E(\vartheta_i|mc_i, \eta_i) = 0$ (equivalently, $E(p_i|mc_i, \eta_i) = mc_i + \beta_i^* \eta_i$) which requires that the error term and the explanatory variables are uncorrelated at every observation. The second layer of issues arises because the variables in (4) are unobserved and must be estimated: in particular marginal cost and the inverse semi elasticity require calculation. Estimation then can only be applied to (5) and the properties of these estimates evaluated. It is well known that as (4) and (5) differ by measurement error that $E(p_i^{\#}|mc_i^{\#}, \eta_i^{\#}) \neq E(p_i|mc_i, \eta_i)$. Before considering this issue further, we delve further into the nature of marginal cost and its association with residual demand.

If marginal cost is volatile and correlated across generators then marginal cost and the inverse semi-elasticity must be correlated because the residual demand curve embodies decisions taken by competing generators based upon the marginal costs that they face. Where there is correlation among the mc_i $i \neq j = 1, \ldots, n$, correlation between mc_i and η_i would arise, let alone between measured $mc_i^{\#}$ and $\eta_i^{\#}$. The existence of spot markets for fuel, and fluctuations in fuel supplies—such as occurs in New Zealand as a result of fluctuation in water inflows to dams and gas supplies and contracts—impart common shocks to the marginal costs of all gas and hydro generation plants as the marginal cost of, particularly gas, generation increases, over the range of gas generation.

4.1 Positive correlation between price and the inverse semi-elasticity does not imply market power

To consider the effect of correlation among generators' marginal costs consider a duopoly of generators with marginal cost functions $mc_i(q) = c_i q$ $i = 1, 2$. In Appendix 6.2 it is shown that if these firms offer in at marginal cost

$$\eta_1^{**} = \frac{(c_2)^2 Q}{100(c_1+c_2)} \text{ and } p^{**} = \frac{Q}{1/c_1 + 1/c_2}$$

where Q is perfectly inelastic demand. Higher (lower) marginal cost of generator 2 produces a higher (lower) market clearing price and higher (lower) inverse semi-elasticity. In consequence, p and η_1^{**} are positively correlated. Further, suppose that marginal costs are influenced by a volatile nonnegative common factor, φ, such that $mc_i(q) = \varphi c_i q$ for $i = 1, 2$. Fluctuations in the common factor yield positive correlations among p, η_1^{**} and η_2^{**}. Because these correlations arise under marginal cost pricing it cannot be that positive correlations among prices and inverse semi-elasticities imply unilateral market power is being exercised: in contrast to Wolak's (2009a, pp. 32–33) claim. This conclusion does not rest on mis-measurement of the variables.

4.2 The regression model

We examine the regression model taking as the null hypothesis that firms do set prices according to Cournot, demand is linear and uncertain. While various specifications are possible, we take demand to be $DR_i = a_i + \xi_i - b_i p_i$ where the shock, ξ_i, is white noise and potentially correlated with mc_i: in this case the inverse semi-elasticity is $\eta_i = (a_i + \xi_i - b_i p_i)/100 b_i$. We consider separately the cases where marginal cost and η are measured with error and when they not.[11]

[11] Evans and Guthrie (2009) demonstrate one source of error that results from the fact that the marginal cost of stored fuel, water and gas, is often higher than the spot market reports. In his regressions Wolak seeks to control

When marginal cost and the inverse semi-elasticity are measured accurately the regression model may be written $y_i = p_i - mc_i = \beta_i^* \eta_i + \vartheta_i$, using (4). For this equation, ordinary least squares estimates the parameter

$$\beta_i = \frac{cov(y_i, \eta_i)}{var(\eta_i)} = \frac{cov(p_i - mc_i, \eta_i)}{var(\eta_i)} = \frac{cov(\beta_i^* \eta_i + \vartheta_i, \eta_i)}{var(\eta_i)} = \beta_i^* + \frac{cov(\vartheta_i, \eta_i)}{var(\eta_i)}.$$

This parameter will equal β_i^* if the final covariance in this expression is zero, which it would be if (2) held exactly in the data, or alternatively where the error term exists and is uncorrelated with the inverse semi-elasticity. Since there is no reason to suppose (2) would hold exactly the more interesting case arises where there is no measurement error and yet the error term exists. In this circumstance it is likely that the error term will be correlated with the inverse semi-elasticity because common shocks are likely to affect y_i and η_i in ways that do not preserve the linear relationship (2). For example, common marginal cost shocks may affect both residual demand[12] (and thereby η_i) in various ways not encapsulated by (2). In this case β_i is not the structural coefficient β_i^*, and so it is not identified and consistently estimated by means of ordinary least squares.

When marginal cost and/or the inverse semi-elasticity are measured with error the difficulty of estimating a structural relationship is enhanced. Although Wolak estimates marginal cost utilising gas-price information provided by generators to construct a counterfactual electricity price series for aspects of his analysis—see Wolak (2009b, para. 388)—in his regression he approximates variations in marginal cost by means of time-specific dummy variables. If marginal cost and the inverse semi-elasticity are measured with error then they will be stochastic. If marginal cost were known, the effect of measurement error in the explanatory variable, η_i, in isolation from other statistical issues, generally will be to truncate the estimated coefficient on it. Although η_i is measured by approximation, suppose that it is measured accurately, but that $mc_i^{\#} = mc_i + \upsilon_i$ where υ_i is measurement error.[13] In this case

$$\beta_i = \frac{cov(y_i, \eta_i)}{var(\eta_i)} = \frac{cov(p_i - mc_i - \upsilon_i, \eta_i)}{var(\eta_i)} = \beta_i^* + \frac{cov(\vartheta_i, \eta_i)}{var(\eta_i)} - \frac{cov(\upsilon_i, \eta_i)}{var(\eta_i)}$$

which shows that measurement error in marginal cost will potentially materially affect the estimation of the slope coefficient in (4). There must be measurement error arising from the unobserved valuation of stored fuel and its correlation across generators in the electricity market. Hence, ordinary least squares applied to (5) yields biased and inconsistent estimates of the slope coefficient in (4), which we have argued is unidentified in any event.

4.3 Regression findings

In this section we consider the results of the Wolak regressions. The first point is that Wolak (2009a) does not report goodness of fit statistics that might shed light on whether (2) holds as a tautology. Certainly, the graphs of the NZEM system-wide prices and inverse semi-elasticities do not support the notion of a tautology (see Figures 4.5, 4.6 and 4.8 (Wolak (2009a, 70-71)). We report Wolak's regression estimates of β in (5). In proposition Pc) the firm sets price at

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for marginal cost by replacing marginal cost in (5) with dummy variables.

[12]For example, the analysis suggests that marginal cost may be positively correlated with the residual demand shifter ξ_i, as higher system wide marginal cost yields, *ceteris paribus*, reductions in offered supply from all generators.

[13]The dummy variables used in the regressions cannot capture well variations in marginal cost that occur continuously with considerable variation. In one of the two specifications Wolak uses the same intra-day profile is assumed. Since there can be expected to be more intra-day variation in relatively high demand days; the specification will under- (over-) estimate marginal cost in high (low) demand days.

Table 1: Spot-market regression results

	Table 5.1		Table 5.2	
	$\hat{\beta}$	$\hat{\lambda}$	$\hat{\beta}$	$\hat{\lambda}$
Firm A	0.46	0.009	0.67	0.013
Firm B	0.56	0.011	0.73	0.015
Firm C	1.41	0.028	1.16	0.023
Firm D	3.81	0.073	4.54	0.087

Source: Wolak (2009a, p. 74).

a level between marginal cost and the profit maximising price as $p_i^\lambda = mc_i + \lambda(p_i^* - mc_i)$ for $\lambda\varepsilon[0,1]$ which results in the offer price $p_i^\lambda = mc_i + \frac{100\lambda}{2-\lambda}\eta_i^\lambda$. We utilise this relationsip and report estimates of $\lambda_i = \left(\frac{2\beta_i}{100+\beta_i}\right)$ recovered from the estimates of β. For these estimates of λ to retain their interpretation as the extent to which pricing is above marginal cost one requires that (4) is identified and $(p_i^\lambda, mc_i, \eta_i^\lambda)$ measured without error.

The results are reported in Table 1 for two different specifications of the dummy variables included in the regression to control for variations in marginal cost.The estimated βs are orders of magnitude below the 100 implied by Wolak's methodology, and the concomitant $\hat{\lambda}$s indicate that pricing is not far different from pricing at marginal cost, Firm C (D), for example, would appear to be pricing at 3% (7%) of the inverse semi-elasticity over marginal cost in the sample period. We report in Appendix 6.3 the Wolak (2009, 73) equation estimates after adjusting for generation committed under forward contracts. These estimates are higher than those reported in Table 1 but far lower than those that would be consistent with his hypothesis.

Were (2) and its stochastic counterpart (4) identified, and price, marginal cost and the inverse semi-elasticity accurately measured these regression results would falsify Wolak's hypothesis that the price mark-up over marginal cost be 100 times the inverse semi-elasticity. They imply it is just 3-8% of this level. However, we consider that Wolak's regression model is not identified under ordinary least squares and that even if it were that there is such measurement error that the regression estimates are simply not informative about the utilisation of unilateral market power in the New Zealand electricity spot market.

The slope coefficients of the regression do indicate a positive association between price and the inverse semi-elasticity. However this too is uninformative, for as we have explained in Section 4.1, positive correlation between price and the inverse semi-elasticity conveys no information about the use of unilateral market power, for it can occur when generators are not unilaterally exercising market power at all and are instead behaving perfectly competitively.

5 Concluding comments

In his conclusion Wolak (2009a) includes the following statements

> "The three lines of empirical inquiry presented in this paper are broadly consistent with the implications of expected profit-maximizing offer behavior by the four large suppliers in response to the extent of competition they face from other suppliers on a half-hourly basis. This conclusion does not depend on any assumptions about the functional form of aggregate demand in the market or any model of strategic interaction among firms. Because of the data-rich multiunit auction environment that we study, ex post half-hourly measures of the ability of a supplier to exercise market power using the offers submitted by all suppliers and the level of system demand can be computed without either of these assumptions."

"We find that each of the four large suppliers submits a higher half-hourly offer price when it has a higher half-hourly unilateral ability to exercise market power [inverse semi-elasticity]. The half-hourly offer price increases predicted by the parameter estimates from our econometric model for typical changes in the half-hourly ability of each supplier to exercise market power are economically significant in the sense that the implied offer price increases can be in the range of \$10/MWh to \$20/MWh during peak periods of the day."

and

"Taken together, the empirical results in this paper demonstrate that although prices in a multi-unit auction wholesale electricity market depend on supply and demand conditions, actual supply conditions depend on the offer curves submitted by market participants to the wholesale market. These offer curves are direct result of the unilateral expected profit-maximizing actions of suppliers given factors that they are unable to control such as the level of demand at all locations in the New Zealand, amount of water inflows to hydroelectric generation units and the price of fossil fuels and other inputs consumed to produce electricity."

The first cannot be right in that it eschews Wolak's use of Cournot equilibria, and some model is required to interpret the results. It does admit the possibility of a linear (stochastic) demand function for Wolak's results. The second statement contains the erroneous claim that positive correlation between the inverse semi-elasticity and the offer price implies that unilateral market power is being exercised. We have provided examples where the reverse is true. Further, we have shown Wolak's regression model (4) is not identified and confounded with measurement error. Given this, it might have been expected that Wolak explain the reason for and basis of his application of regression analysis. The third statement is unremarkable.

A Appendix

A.1 Firm behaviour under linear demand

The i^{th} firm facing a linear residual demand, and which has constant marginal cost, has inverse semi-elasticity for any p_i

$$\eta_i(p_i) = \frac{-1}{100}\frac{DR(p_i)}{\partial DR(p_i)/\partial p_i} = \frac{a_i - b_i p_i}{100 b_i}$$

and under unilateral profit maximisation will choose a price offer that maximises

$$\pi_i(p_i) = (p_i - mc_i)(a_i - b_i p_i) = -mc_i a_i + (a_i + b_i mc_i)p_i - b_i p_i^2.$$

It produces the optimal price $p_i^* = \frac{a_i + b_i mc_i}{2b_i}$ and the inverse semi-elasticity $\eta_i^*(p_i^*) = \frac{a_i - b_i mc_i}{200 b_i}$.

Setting price equal to marginal cost yields $p_i^{**} = mc_i$ (by definition) and (by subsitution of mc for p) the inverse semi-elasticity $\eta_i^{**}(mc_i) = \frac{a_i - b_i mc_i}{100 b_i}$.

Setting price as $p_i^\lambda = mc_i + \lambda(p_i^* - mc_i)$ for $\lambda \varepsilon [0,1]$ yields

$$p_i^\lambda = mc_i + \lambda(\frac{a_i + b_i mc_i}{2b} - mc_i) = mc_i + \lambda(\frac{a_i - b_i mc_i}{2b_i})$$

and

$$\eta_i^\lambda = \frac{a_i - b_i p_i^\lambda}{100 b_i} = \frac{a_i - b_i(mc_i + \lambda(p_i^* - mc_i)}{100 b_i} = \frac{(2-\lambda)(a_i - b_i mc_i)}{200 b_i}$$

Eliminating $(a_i - b_i mc_i)/2b_i$ utilising the expressions for p_i^λ and η_i^λ yields $p_i^\lambda = mc_i + \left(\frac{100\lambda}{2-\lambda}\right)\eta_i^\lambda$.

A.2 Duopoly

Assume firm i has marginal cost function $mc_i(q) = c_i q$ for $i = 1, 2$, where c_1 and c_2 are positive constants. Each firm offers to generate electricity at marginal cost yielding the supply schedules $q_i = p/c_i$ for $i = 1, 2$. Firm 1's residual demand function is $DR_1(p) = Q - p/c_2$, where Q is aggregate demand at $p = 0$. Its inverse semi-elasticity is $\eta_i(p) = (c_2 Q - p)/100$ and when its supply function is evaluated at the actual level of generation the market price is $p^{**} = \frac{Q}{1/c_1 + 1/c_2}$. The firm's inverse semi-elasticity is $\eta_1^{**} = \frac{(c_2)^2 Q}{100(c_1 + c_2)}$.

A.3 Regression results: Net of forward commitment

Table 2: Spot-market regression results

	Table 5.1		Table 5.2	
	$\hat{\beta}$	$\hat{\lambda}$	$\hat{\beta}$	$\hat{\lambda}$
Firm A	5.08	0.0966	7.27	0.135
Firm B	4.02	0.0773	3.39	0.0655
Firm C	4.31	0.0826	3.38	0.0654
Firm D	21.6	0.3557	22.86	0.3721

Source: Wolak (2009a, p. 74).

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