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Information and Transparency in Wholesale Electricity Markets: Evidence from Alberta

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by

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Abstract

We examine the role of information transparency in Alberta's wholesale electricity market. Using data on firms' bidding behavior, we analyze whether firms utilize information revealed in near real-time through the Historical Trading Report (HTR), which is released 10 minutes after each hour and contains a complete (de-identified) list of every firms' bids into the wholesale market from the previous hour. We demonstrate that firms are often able to identify the offers of specific rivals by offer patterns adopted by those firms. For one of these firms, these patterns are associated with higher offer prices. This is consistent with allegations by Alberta's Market Surveillance Administrator that firms may be utilizing unique bidding patterns to reveal their identities to their rivals to elevate market prices. We show that certain firms respond to rival offer changes with a lag consistent with responding to information revealed through the HTR, and that they respond differently to different firms, suggesting that they are able to infer identification.

Keywords: Electricity, Market Power, Information, Regulation, Antitrust
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1 Introduction

A fundamental question in competition and regulatory policy is the role of information and data transparency. Two general and opposing views suggest that increased market transparency either (1) enhances competition by promoting consumer search and allowing firms to respond efficiently to market events or (2) facilitates coordination by enhancing communication and allows firms to more swiftly and accurately detect cheating.[1] The role of information and transparency is particularly important in restructured electricity markets. On one hand, these markets face substantial uncertainty due to unexpected generation unit outages, intermittent supply from renewables, and demand uncertainty. On the other hand, firms interact repeatedly in often concentrated markets, raising concerns over firms' abilities to utilize information to elevate prices.

We add to the limited evidence regarding the effects of information and transparency on electricity markets by examining the case of Alberta's wholesale electricity market. In this market, firms submit hourly offer curves made up of price-quantity pairs that reflect the price at which they are willing to supply a specified quantity of electricity. Firms can adjust their offers up to two hours before an hour, allowing them to respond quickly to the disclosure of new information. Until recently, at the end of each hour a list of all price-quantity offers were released publicly in a report known as the Historical Trading Report (HTR). The identity of the firms and assets corresponding to the offers were removed in the HTR.

In August 2013, Alberta's Market Surveillance Administrator (MSA) issued a report alleging that "the participating oligopolists have used offer information made available through the Historical Trading Report in near real-time to achieve sharply higher wholesale market prices..."(MSA 2013, p.iii). The MSA supported this conclusion with examples of ten days between August 2011 and April 2013, in which they argued that firms were using the HTR to coordinate. These examples involved claims that firms were "tagging" offers on these days, by bidding using particular patterns (not documented by the MSA) that revealed their identities through the HTR and could be used to send signals to rivals. Following this report and a subsequent hearing, in May 2017 the Alberta Utilities Commission (AUC) ordered that the HTR no longer be published (AUC, 2017b).

Our paper proceeds in the following stages. First, we document patterns observed in wholesale electricity offer prices and quantities by individual firms that may have revealed their identities to rivals. We investigate to what extent these offer patterns allow firms to identify particular rivals' bids. More specifically, does a careful examination of the data support the allegation that "tagging" can potentially allow rivals to identify a firm's bids from the HTR? Second, we establish econometric models to investigate whether firms utilize information provided in the HTR when submitting their price-quantity offers. In these analyses, we allow firms to respond differently to different rivals; this provides insights into whether firms are able to identify a particular rival's offer behavior through information disclosed in the de-identified HTR.

[1] See Kuhn and Vives (1994), von der Fehr (2013), and Holmberg and Wolak (2016) for a related discussion.

We demonstrate that firms are often able to identify, with a high degree of accuracy, the offers of specific rivals in the HTR by the offer patterns adopted by those firms. We also demonstrate that for one firm its unique offer pattern ended abruptly upon the announcement of the MSA's concerns, and that for another firm there is a strong relationship between the incidence of its unique offer pattern and the price level of its offers. Our econometric results provide evidence suggesting that two large firms respond to information disclosed in the HTR when they submit their price-quantity offers. In particular, for one of these firms, there is evidence it responds differently to changes in offer behavior of particular rivals disclosed in the de-identified HTR.

This paper will proceed as follows. Section 2 discusses the related literature. Section 3 provides a general overview of the wholesale electricity market in Alberta and the allegations of the MSA. The data used in our analysis are described in Section 4. In Section 5, we consider the MSA's (2013) claim that firms "tag" offers and whether this conduct allows firms to accurately identify the firms submitting particular offers. Section 6 details our econometric methodology used to evaluate whether and how information disclosed through the HTR impacts firms' price and quantity offer behavior. Results are presented in Section 7. Section 8 concludes.

2 Related Literature

An important debate in electricity market design concerns the role of information transparency. Existing theoretical literature suggests that increased transparency enhances competition in a static setting with non-cooperative firms. For example, Holmberg and Wolak (2016) consider a one-shot static duopoly multi-unit auction game in which firms have private information on production costs.[2] In this setting, the authors find that markups are lower when the firms receive signals that are more highly correlated. The authors conclude that increased transparency and public information on cost variables are expected to increase the degree of competition.

The argument that increased public information increases competition relies on an assumption of non-cooperative behaviour. Holmberg and Wolak (2016, p.4) note that "there is a risk that increased transparency...can facilitate tacit collusion in a repeated game." von der Fehr (2013) argues that increased market transparency facilitates firms' abilities to detect cheating by rivals on a collusive strategy. As well, in the presence of multiple equilibria, market transparency may allow firms to coordinate on particular static equilibria.[3] A similar coordination issue arises in theoretical models of collusion in electricity markets. For example, in Fabra (2003) and Dechenaux and Kovenock (2007) collusion in electricity markets involves firms playing asymmetric roles, either setting the market price or offering at low prices to reduce their rivals' incentive to deviate.

These arguments have impacted recent policy decisions. In 2013, the European Commission introduced regulations to increase market transparency and the publication of data in European

[2]See also Kuhn and Vives (1994) and Vives (2011).

[3]See Bolle (1992), Fabra et al. (2006), and Crawford et al. (2007) for examples of electricity market models with multiple equilibria. The potential that communication could allow firms to coordinate on the most profitable equilibrium is discussed in the Alberta context in Baziliauskas et al. (2011).

electricity markets. These regulations require the disclosure of generation unit outages, asset-level production data, and detailed reporting on all wholesale energy market transactions (EU, 2013).[4] Similarly, in 2012, the Federal Energy Regulatory Commission (FERC) issued a Notice of Inquiry that required increased transparency and data reporting in the Natural Gas markets (FERC, 2012). The United States Department of Justice (2012) raised concerns that the increased transparency can facilitate coordination and market power execution. In 2015, FERC terminated the proceeding and chose not to increase information disclosure requirements (FERC, 2015).

Empirical studies of possible coordination in electricity markets are limited. Fabra and Toro (2005) test whether pricing in the Spanish wholesale electricity market is consistent with switching to and from collusive and competitive (price-war) regimes. The authors then investigate the triggers of price wars. Macatangay (2002) considers whether bidding behaviour of the two largest electricity firms in England and Wales differs from that of other market participants, and whether their offer behaviour is consistent with collusion. The author concludes that the two largest firms behave statistically differently from other firms, and that their offers are inter-dependent in a way unobserved in other firms. In both studies the role of transparency is not directly addressed.

Beyond electricity markets, our analysis is related to the literature examining the dynamic responses of the prices of firms to those of rivals, and whether such response patterns are consistent with non-cooperative or coordinated behaviour. Particularly relevant to the current study are papers using high frequency pricing data to identify price leadership. Examples include Seaton and Waterson (2013) for grocery prices, Atkinson (2009), Andreoli-Versbach and Franck (2015) and Lewis (2012) for retail gasoline, and Marshall et al. (2008) for price announcements in vitamins.

Finally, our paper is related to the literature documenting pricing patterns that may be associated with coordination in other industries. Borenstein (1998) discusses the alleged use of fare basis codes and footnote designators by airlines to communicate through the Airline Tariff Publishing Company. Christie and Schultz (1994, 1999) examine the use of "odd-eighth" quotes in Nasdaq. Lewis (2015) examines gasoline pricing in the U.S., and finds that prices are higher and more rigid in locations that frequently end prices with 5 and 9; this is taken to suggest that these endings may be used to establish focal prices. Abrantes-Metz et al. (2011) consider the distribution of the second digit of the Libor rate. The authors identify deviations in this distribution from that predicted by Benford's law and observed in other settings, and suggest that rate manipulation or collusion is one possible answer. Other agencies and authors have attempted to identify coordination through prices that are highly uniform or rigid (e.g., see Abrantes-Metz et al. (2006)).

3 Background

In this section, we outline the key features of Alberta's wholesale electricity market. We then discuss the allegations of the MSA regarding the HTR and the subsequent decision by the Alberta

[4] von der Fehr (2013) raises concerns that the European Commission's regulations provide too much information. The author argues that this information may facilitate coordinated behavior or market power execution.

Utilities Commission (AUC) to stop publishing the HTR.

3.1 Alberta's Wholesale Electricity Market

Alberta's wholesale electricity market consists of a single hourly uniform-price procurement auction. Generators submit offers to supply electricity to the spot market. Firms are restricted to offer prices between $0 and $999.99/MWh, and must offer all available capacity from their generating units. A firm may submit up to seven price-quantity blocks for each generating asset. Each such block represents the price at which the firm is willing to supply the specified amount of electricity. These bids must be submitted before 12:00 PM the day before the spot market clears.

Throughout each hour, the system operator calls upon firms to supply electricity in order of their offers until sufficient supply is dispatched to meet market demand. The marginal bidder represents the last bidder called upon to supply electricity. This bid sets the system marginal price (SMP) at any point in the hour. The hourly pool price that is paid to all generation units dispatched within an hour equals the time-weighted average of the SMPs set throughout the hour.

During our period of study, Alberta's electricity market operated as an energy-only design where firms relied solely on revenues from the wholesale spot market (and ancillary service markets) to recover both variable and fixed costs.[5] Alberta explicitly permits certain forms of unilateral market power execution with the objective of allowing firms to earn rents in the wholesale market to cover fixed costs of capacity investment (MSA, 2011). There are no limitations to the extent that a firm can bid above marginal cost.

Production capacity was concentrated with the five largest firms during the sample period, while a competitive fringe of over thirty firms owned the remaining capacity. In 2010, the firm-specific shares of dispatchable (non-wind) generation capacity were 12%, 10%, 16%, 16%, and 21% for ATCO, Capital Power (CP), ENMAX, TransAlta (TA), and TransCanada (TC), respectively.[6] These shares experienced some change over our sample period; most notably, by 2016 TransAlta's share of capacity had fallen to 10%, while the capacity share of the competitive fringe had increased from 23% to 31%. In Alberta, the dominant production technologies are coal and natural gas. For example, in 2015 coal, natural gas, wind, and hydro represented 44%, 39%, 9%, and 6% of generation capacity, respectively (AUC, 2017a).[7]

3.2 Historical Trading Report

In Alberta's wholesale electricity market, generators have access to substantial near real-time information on the price and quantity bids of their rivals. The market price and the current generation of each individual asset is published in real-time on the Alberta Electric System Operator's (AESO's) website, which also provides real-time information on imports from neighboring

[5]In November 2016, the Alberta government announced that the market will be transitioning from an energy-only to a capacity market design. For additional details, see AESO (2016).

[6]Source: Alberta MSA.

[7]For further detail on Alberta's electricity market, see Olmstead and Ayres (2014) and Brown and Olmstead (2017).

provinces and notifications regarding important market events such as generation outages.

In addition, until recently the AESO published the Historical Trading Report (HTR) approximately 10 minutes after the end of each hour. The HTR provided a comprehensive list of every firms' offered price and quantities in that hour, giving firms a detailed picture of the prices and quantities offered by their competitors. Due to regulatory restrictions, the HTR did not publish the explicit identities of the firms or assets associated with each offer block. Firms' identities are revealed with a sixty day delay.[8]

While firms must submit their bids in advance of the spot market, firms can make an unlimited number of adjustments (restatements) to their price-quantity bids up to two hours before the clearing of the wholesale market (AESO, 2014).[9] This near real-time information provides firms with the opportunity to adjust their offers quickly based on information disclosed in the HTR.

In 2013, the Alberta Market Surveillance Administrator (MSA) released a report that raised concerns over the ability of firms to coordinate and utilize information in the HTR to achieve substantial price increases that would have not arisen in the absence of the HTR (MSA, 2013). While the HTR is de-identified, "sophisticated market participants can decode the report with a high degree of certainty and therefore know the price and volume their counterparts were prepared to sell at" (MSA, 2013, pg. 6). In this report, the MSA raised concerns that the HTR could provide firms with the opportunity to send signals via the HTR in order to coordinate on high spot market prices.

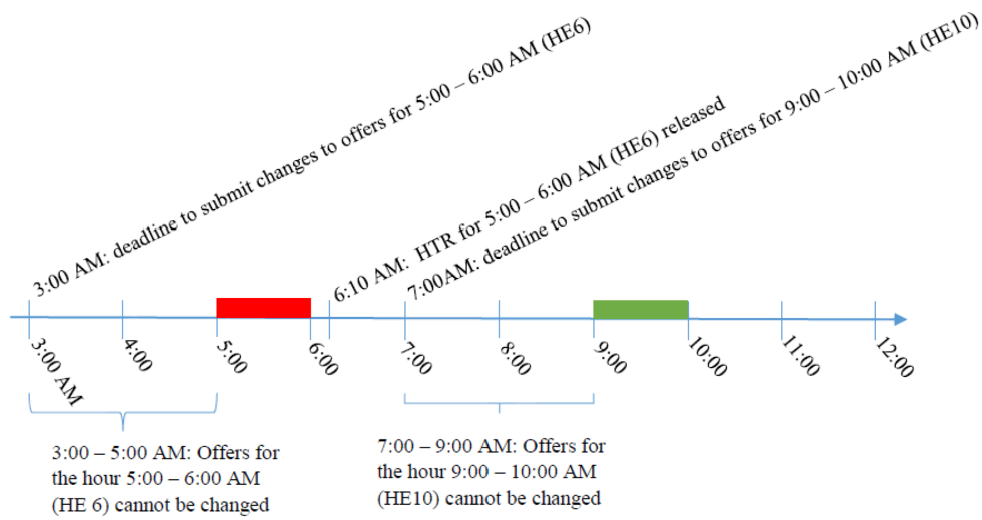


Figure 1: Offer Information and Timing

[8]For additional discussion of the HTR, see AUC (2017b).

[9]The MWhs of an offer block, but not price, can also be adjusted after the two hour limit if accompanied with an acceptable operating reason, such as physical constraints or safety. In our following discussion of adjustment timing, we will assume that no such acceptable operating reason is present.

Figure 1 presents an example of the timing of the HTR and how it affects firms' abilities to respond to rivals' offers. Consider first the offers submitted by firms for the hour running from 5:00 to 6:00 AM (denoted using AESO's terminology as Hour Ending 6 or HE6); this hour is highlighted in red. Because offer prices may only be changed up to two hours before the hour, the latest that offer prices for HE6 can be changed is 3:00 AM (the start of HE4). At approximately 6:10 AM, ten minutes after the end of the hour, the price-quantity offers submitted for HE6 are revealed through the HTR, with identifying information removed. Because offers for an hour cannot be changed less than two hours in advance, the information revealed at 6:10 AM regarding HE6 cannot be incorporated into the offers for HE7 (which has already begun), HE8 (which starts 50 minutes later) or HE9 (which starts 110 minutes later). The earliest hour for which offers can be restated to incorporate information learned at 6:10 AM about bidding in HE6 is HE10, which starts at 9:00 AM (highlighted in green in Figure 1). More generally, since the offers from HE t are revealed ten minutes after the end of that hour, the earliest hour for which bids can be adjusted to reflect information disclosed in those offers is HE $t + 4$.

Due to these concerns, the MSA recommended to the AESO that the HTR be replaced by one that does not provide detailed price-quantity offers, but instead aggregates offers into pre-specified price bands (MSA, 2013). The proposed revision to the HTR was contested by firms, and in December 2015 the MSA filed an application for the AUC to hold a hearing on the matter.

In May 2017, the AUC majority concluded that "the MSA has established, on a balance of probabilities, that in certain market conditions, the publication of the HTR has facilitated the enhancement of market power which, in turn, has resulted in market prices that do not reflect a competitive market outcome... The majority is also satisfied that the data provided in the HTR could potentially be used by market participants for signaling to facilitate coordinated behavior. However, it finds that, on balance, the evidence in this proceeding does not support a finding that the HTR facilitated coordinated behavior in any specific instance" (AUC, 2017b, pg. 40). The AUC ordered that the HTR cease to be published; publication of the HTR ended on May 23, 2017.

An important aspect of the AUC hearing (and the economic evidence presented) was a greater focus on the unilateral effects of the HTR, with less attention being given to its ability to facilitate coordination. For example, an economic expert for ENMAX focused on unilateral effects, arguing that the MSA's evidence presented in the hearing does not address "why and whether the HTR makes the coordinated exercise of market power more likely. Instead the possibility is mentioned only in passing" (Church 2016a, p. 26). The MSA's submitted report in the hearing made no reference to firms use of bid tagging to reveal their identifies via the HTR (MSA 2015).

Further, the empirical evidence submitted in the hearing gave no consideration to pricing patterns or communication through the HTR. Instead, the evidence consisted largely of counterfactual analyses in which observed wholesale prices were compared to spot market prices that would have occurred if the initial offer curve (without restatements) was employed (e.g., Church 2016b, MSA 2016). One problem with these counterfactuals is that by assuming away offer restatements that occurred after the release of the HTR, the authors are assuming that the firms would employ the same initial offer curve that they would if they knew that they could not adjust their offer curve in response to new information.

Finally, in a report submitted by the AESO, Wolak (2014) analyzes the offer curves of several firms, and concludes that they are consistent with unilateral profit maximization. However, there was no discussion of pricing patterns or "tagging" of offers. Further, it is worth noting that if communication is being employed to coordinate on a specific static equilibrium in a multiple equilibrium setting, one would expect firms to be playing unilateral best responses to rivals.

4 Data

Our primary data source consists of price and quantity offers reported in the HTR from September 2009 to June 2013, and provided to us by the Alberta MSA. For each hour, our data set reports the initial offer price and quantity of each block submitted by noon the day before the hour, and the final (restated) price and quantity of each block. The HTR data provided to us are enhanced beyond what is available to the firms immediately after each hour, as the data provided by the MSA identify the firm and asset offering each price-quantity block. These data allow us to identify changes to a firm's offer curve that are made after noon on the day before the hour.

Our description and econometric analyses below focus primarily on the time period between January 1, 2011 to June 30, 2013. This is driven by two factors. First, this is the time period where the primary concerns were raised by the MSA regarding firms use of information disclosed in the HTR (AUC, 2017b). The second is data availability. In our subsequent econometric analyses, several covariates are only available starting November 27, 2011.

Because our data set on prices and quantities reported through the HTR ends before the release of the MSA report on the HTR, we supplement the data with offer price and quantity data reported through the AESO's Merit Order Snapshot up to December 2016, which is released with a 90 day lag. In contrast to the HTR, this data set is publicly released with asset identification. However, it reports only the final price-quantity submission for each block and hour. Therefore, in contrast to the HTR data, it cannot be used to identify adjustments to offers made leading up to an hour.

Finally, our econometric analysis utilizes publicly available hourly data from the AESO on import capacity from neighboring provinces British Columbia and Saskatchewan, observed and forecasted wind production and market-level demand, and the SMP. Summary statistics for these market-level hourly variables are provided in Panel A of Table A1 in the Appendix.

5 Patterns in Offers Behaviour and Identifying Rivals

In this section, we investigate whether firms submit price-quantity offers using patterns that would allow their rivals to identify their offers, and which could potentially be used to communicate with other firms. We begin by documenting observable patterns by specific firms and the circumstances in which these patterns are employed. We then examine the accuracy with which each firm can identify rival offers from the HTR, assuming that these offer patterns were known.[10]

5.1 Observed Offer Patterns

A difficulty with searching for non-random behaviour consistent with signaling is that economic theory provides limited guidance on how firms might communicate through public information, resulting in a large number of potential methods. This problem is exacerbated in Alberta's wholesale electricity market because of the abundance of high frequency information. Even focusing on the HTR, there are numerous possibilities. A firm might send a message or signal its identity through price endings or particular digits within its price offers. Messages might be sent through block sizes (the quantity offered at a particular price). In addition, firms may communicate through complicated patterns of prices and block sizes within an offer curve, or over time across hours.

Due to the wide range of possible signaling behaviour, we do not attempt to develop a methodology to systematically identify non-random offer patterns. Rather, our approach is to consider non-random patterns in block sizes and price endings, and to document specific patterns that have been observed in the offer data. In order to concentrate on strategic behaviour, we focus offers with prices exceeding $100/MWh; marginal cost of production for even the most expensive assets during our sample are less than $100/MWh.[11]

One way in which the identity of a firm could be revealed is if certain assets tend to be offered in specific block sizes. This could represent deliberate signaling, but could also be the result of physical characteristics and constraints of the unit (e.g., a unit with a capacity of 43 MW may frequently offer blocks of 43 MWhs). To consider this possibility, Table 1 presents the most frequently used block sizes of each large firm, focusing attention on prices above $100 for the period of January 2011 to June 2013. The percentage frequency within the firm's portfolio is in parentheses, and the firm's share of all offers of that size is in bold.

Table 1 reveals that firms may be able to identify the ownership of certain price-quantity pairs in the HTR with a high degree of accuracy based on block sizes. For example, ATCO (CP) submits an offer with a block size equal to 46 (51) MWhs for 6.2 (9.3) percent of its high priced offers; these offers constitute 89.1 (92.3) percent of all block size offers that are equal to 46 (51) MWhs.

Information also could be conveyed through offer price endings, which are unlikely to affect the ranking of assets in the merit order. Table 2 presents the most frequently used price endings of each large firm for prices above $100 for the period of January 2011 to June 2013. TransCanada is the only large firm whose most used ending is not .00. As with block sizes, several firms have

[10]While the HTR does not provide firm or asset-level identities on firms' offers in real-time, this information is made available at a sixty day delay. This delayed disclosure of identities can allow firms to verify their beliefs about rivals' offer price patterns ex-post.

[11]Regulatory authorities in Alberta were concerned with firms utilizing information from the HTR to coordinate on an outcome where certain firms "price out" their units at high price levels to create a high price offer ledge below which the market level offer curve is very steep in order to elevate the spot market price (MSA, 2013).

Table 1: Most Frequently used Block Sizes (MWhs) by Firm, Price Offers $\in (100.00, 999.99)$

Rank	ATCO	CP	ENMAX	TA	TC
1st	46 (6.2)	50 (13.7)	40 (15.4)	40 (12.3)	25 (11.3)
	89.1	**42.3**	**28.4**	**31.8**	**47.0**
2nd	28 (6.1)	51 (9.3)	4 (11.5)	80 (6.1)	35 (8.7)
	89.0	**92.3**	**54.5**	**79.0**	**19.9**
3rd	47 (6.0)	35 (8.6)	5 (6.1)	230 (4.4)	18 (7.5)
	85.4	**22.5**	**10.0**	**100.0**	**53.11**
4th	35 (4.8)	27 (7.1)	30 (5.2)	60 (2.4)	53 (7.0)
	22.5	**59.1**	**15.9**	**42.5**	**59.5**
5th	40 (4.8)	70 (6.7)	41 (5.1))	270 (2.4)	21 (6.8)
	22.1	**70.7**	**63.5**	**100.0**	**74.9**

Notes: The first number is the block size, followed in parentheses by the frequency the specified block size arises in the firm's offer curve. The percentage of occurrences of this block size belonging to the firm in question is in bold.

at least one ending where they are the majority user. Further, for certain price endings, firms are able to identify the ownership of a price-quantity pair in the HTR with a high degree of accuracy. For example, ATCO (TA) submits price endings of .25 and .75 (.92 and .24) for 9.2 and 6.7 (19.9 and 18.3) percent of its high priced offers; these offers constitute 82.2 and 82.6 (93.66 and 89.9) percent of all observed price endings that are equal to .25 and .75 (.92 and .24), respectively.

Table 2: Most Frequently used Price Offer Endings by Firm, Price Offer $\in (100.00, 999.99)$

Rank	ATCO	CP	ENMAX	TA	TC
1st	.00 (43.3)	.00 (70.1)	.00 (61.6)	.00 (25.2)	.51 (4.5)
	24.5	**14.2**	**13.8**	**8.0**	**75.4**
2nd	.25 (9.2)	.50 (4.4)	.44 (3.0)	.99 (22.0)	.52 (4.5)
	82.2	**16.3**	**40.4**	**17.9**	**74.1**
3rd	.75 (6.7)	.99 (3.2)	.99 (2.9)	.92 (19.9)	.53 (4.3)
	82.6	**1.49**	**1.7**	**93.66**	**77.5**
4th	.99 (6.5)	.01 (2.1)	.18 (2.6)	.24 (18.3)	.54 (3.9)
	9.4	**19.7**	**42.2**	**89.9**	**66.0**
5th	.50 (6.4)	.98 (1.7)	.45 (1.6)	.15 (1.2)	.84 (3.9)
	66.5	**1.5**	**28.7**	**27.4**	**79.4**

Notes: The first number is the price ending, followed in parentheses by the frequency the specified price ending arises in the firm's offer curve. The percentage of occurrences of this price ending belonging to the firm in question is in bold.

In Table 2, it is possible that a price ending may be common for a firm simply because it often offers a particular price. For example, one of ATCO's most frequent price endings is .25. However, 96 percent of all of ATCO's usages of an ending of .25 are with prices of 992.25 or 994.25. This raises a further possibility that firms may use a small number of specific price levels with sufficient frequency to reveal their identity. Indeed, over the period January 2011 to June 2013, 59% of TransAlta's offers above \$100 use one of three distinct prices 999.24, 999.92, or 999.99. For two of these prices, TransAlta accounts for over 99% of all instances of that price. However, the usage of only a small number of prices is much less prevalent for the other major firms. For ATCO, Capital Power, TransCanada, and ENMAX, the percentage of offered blocks with prices above

$100 accounted for by their five most frequently used prices are only 35%, 10%, 5%, and 18%, respectively. For this reason, we do not pursue the use of specific price levels further.

5.2 Other Offer Patterns

The complexity of firms' offers, with multiple price and quantity pairs stated for every hour and asset, allow for sophisticated signaling methods. While we do not attempt an exhaustive search for all such patterns in our data, we document certain patterns observed in the offers of two large firms that could allow rivals to identify their offer curves with a high degree of accuracy.

5.2.1 TransCanada

Our first example involves offer price endings of TransCanada over the period of May 2010 to August 2013. Table 3 presents TransCanada's price ending pattern over this period.

Table 3: TransCanada Price Ending Pattern, May 2010 to August 2013

Day of Month	Price Endings
1, 8, 15, 22, 29	0.06, 0.15, 0.24, 0.33, 0.42, 0.51, 0.60
2, 9, 16, 23, 30	0.07, 0.16, 0.25, 0.34, 0.43, 0.52, 0.61
3, 10, 17, 24, 31	0.08, 0.17, 0.26, 0.35, 0.44, 0.53, 0.62
4, 11, 18 , 25	0.09, 0.18, 0.27, 0.36, 0.45, 0.54, 0.63
5, 12, 19, 26	0.19, 0.28, 0.37, 0.46, 0.55, 0.64, 0.73
6, 13, 20, 27	0.29, 0.38, 0.47, 0.56, 0.65, 0.74, 0.83
7, 14, 21, 28	0.39, 0.48, 0.57, 0.66, 0.75, 0.84, 0.93

This pattern can be described as follows. On the first day of the month, all non-zero price endings are 0.06, or are 0.06 plus some multiple of 0.09. On the second day of the month, price endings used are increased 0.01 from the previous day. This continues until the 5th day of the month, at which point price endings increase 0.1 from the previous day, so that all price endings are 0.19 or 0.19 plus multiples of 0.09. Similar increases are used on day 6 and 7; on Day 8 of the month, the 7-day pattern of price endings begins again, and repeats throughout the month.

Figure 2 illustrates the cyclical nature of TransCanada's price endings, along with the use of 0.09 increments, for the period January to June 2012. Considering TransCanada's final restatement price-quantity offers in the HTR data from January 2011 to June 2013, we find 86.5% of all TransCanada's offers above $100 fit this pattern. We find no evidence that the usage of TransCanada's pattern is significantly correlated with demand or other market-level variables.

To identify the start and end dates of this pattern, we employ prices from the merit order data from January 2010 to December 2016. Investigation of this data demonstrates that the cyclical pattern in price endings began in May 2010 and ended in August 2013. These dates coincide with two events. On April 27, 2010, the Alberta MSA released a report which detailed their view that the unilateral exercise of market power is permissible in Alberta's spot market (MSA, 2010), a view that was entrenched through the "Offer Behaviour Enforcement Guidelines"

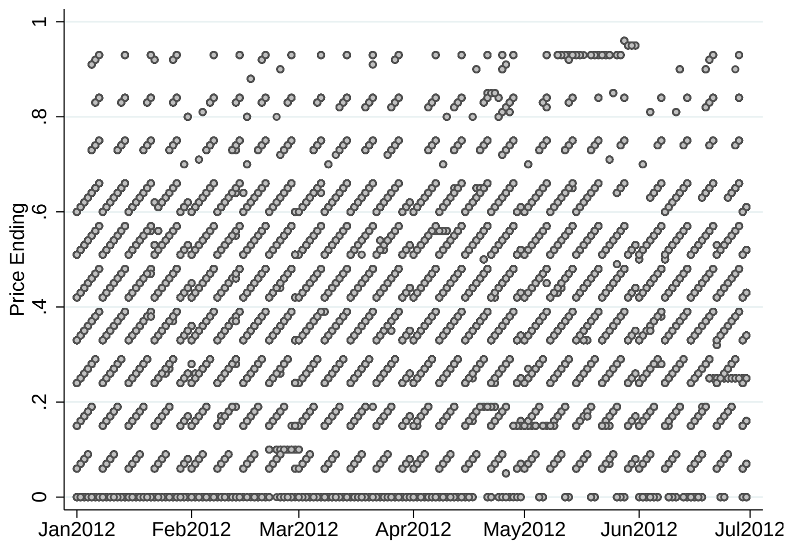


Figure 2: TransCanada's Daily Price Endings: January - June 2012

published in January 2011 (MSA, 2011). The latter date corresponds approximately to the release of the MSA's report on concerns regarding the HTR on August 7th, 2013 (MSA, 2013). Figure 3 presents TransCanada's offer behavior between January 2010 to December 2013 for HE12, with vertical lines corresponding to the publication of the MSA's (2010) and (2013) reports.[12] Offer data for subsequent years indicate no return to TransCanada's cyclical price ending pattern.

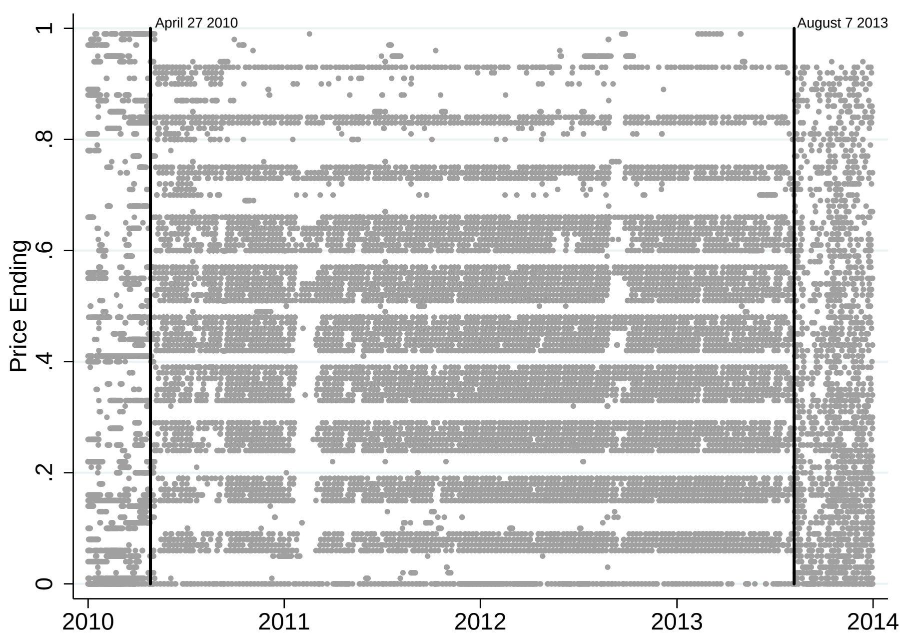


Figure 3: Transcanada's Daily Price Endings: Jan. 2010 - Dec. 2013, HE12

[12]We focus on a single hour for illustrative purposes. The results are robust to the consideration of other hours.

5.2.2 Capital Power

A distinct pattern has been observed in the offer curves of Capital Power for certain hours. To illustrate, Table 4 presents Capital Power's initial offer curve and its final (restated) offer curve for HE14 on February 19, 2013. For illustrative purposes, only blocks with final prices above $100 are reported. The final offer curve submitted by Capital Power exhibits a sequence of blocks at high prices ($936 to $942), with each offer price ending in .00 and being exactly $1/MWh higher than the previous offer. All of these offers are restatements from the initial offer curve, under which all but one of the blocks were being offered at prices below $30/MWh. In this example, the restated price-quantity blocks in the sequence are from large coal units SD5 and SD6.

Table 4: Capital Power Initial and Final Offer Curves, February 19 2013, HE14

Asset	Initial Price	Final Price	Initial Quantity	Final Quantity
ENC1	77.10	325.00	0	43
ENC1	510.00	510.00	43	0
ENC2	976.00	840.00	70	70
ENC2	976.50	841.00	27	27
ENC3	910.00	910.00	70	0
ENC3	912.30	912.30	27	0
SD5	9.02	936.00	20	80
SD5	15.90	937.00	53	20
SD5	26.23	938.00	53	53
SD5	26.27	939.00	50	50
SD6	9.78	940.00	67	70
SD6	15.85	941.00	20	70
SD6	980.00	942.00	0	60
SD6	999.98	999.99	0	7

More generally, we define Capital Power's pricing pattern as a sequence of at least four offer blocks with prices separated by $1/MWh. This offer pattern systematically arises in settings where Capital Power prices up several large units from initially low prices to high priced offers. In contrast to TransCanada's pattern, which is employed for the majority of offers in all hours, Capital Power appears to be more selective in the use of this pattern. For example, from the period November 2011 to June 2013, this pattern is observed in 10% of hours. Employing the longer time series available in the merit order data, it is observed that Capital Power's use of this pattern is concentrated in the period between July 2011 to July 2014. Figure 4 illustrates the fraction of hours each month in which this pattern was observed in Capital Power's offer curve.

On average, Capital Power's offer prices are higher when it is employing its unique offer pattern. Figure 5 presents the cumulative distribution function of Capital Power's MWh-weighted offer prices after its final restatement for peak hours ($8 \leq HE \leq 20$) for the period July 2011 to June 2013, dividing hours into ones in which the pattern is and is not employed. Peak hours in which Capital Power employs its unique offer pattern are associated with a higher frequency of high

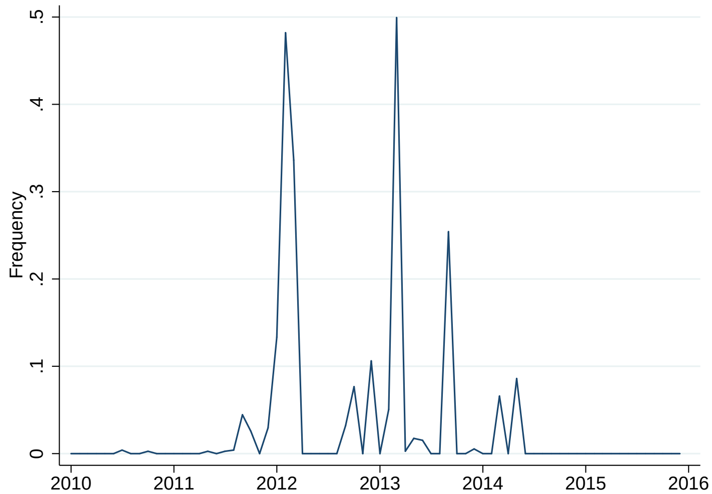


Figure 4: Capital Power: Frequency of Hours Per Month Exhibiting Pricing Pattern

prices. For example, we find that in peak hours without Capital Power's unique offer pattern, over 75% of Capital Power's MWhs are offered at prices below $800. Alternatively, in peak hours when its unique offer pattern is employed, this percentage falls to roughly 45%.

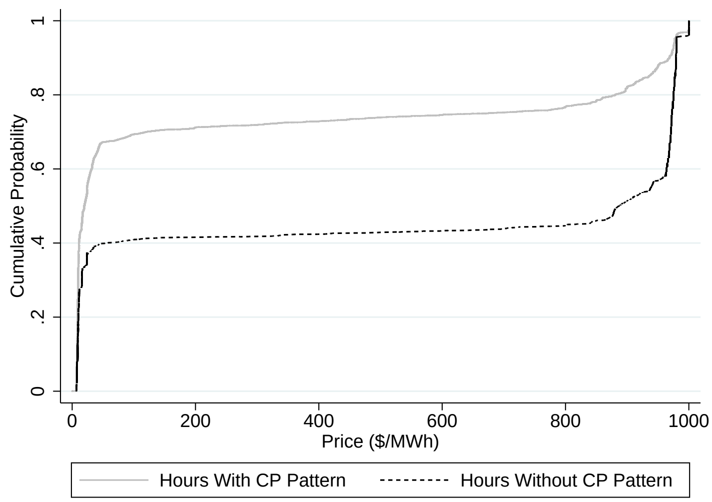


Figure 5: CDF of MWh-Weighted Peak Prices With and Without Capital Power's Offer Pattern

A final question is whether Capital Power is more likely to use its pattern on days in which the exercise of market power is more likely. Figure 6 plots the distribution of market-level hourly demand during peak hours on days with and without Capital Power's offer price pattern. Capital Power is more likely to utilize its unique offer pattern on days with higher peak demand. However, market supply cushion (which equals available market supply minus demand) is only 2% lower in hours where Capital Power employs its unique offer pattern. Average peak wholesale market prices are 6% higher in hours where Capital Power employs its unique offer pattern.[13] These statistics

[13]This price effect is magnified when Capital Power's pricing pattern involves "pricing out" large coal assets.

provide some evidence that Capital Power's pattern is associated with a greater likelihood of market power execution and higher observed market prices.

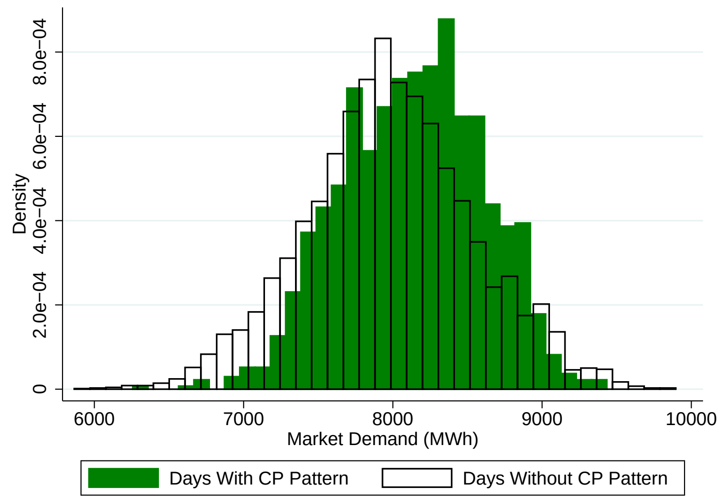


Figure 6: Distribution of Demand by Days With and Without Capital Power's Offer Pattern

5.3 Predicting Identities from Offer Price Patterns

We now investigate if firms are able to accurately identify their rival's price-quantity offers based on the patterns in TransCanada and Capital Power's offers as described above. Specifically, we compute the frequencies with which each firm would have been correct if it assumed that an offer block fitting the pattern of one of these firms was submitted by that firm, and if it assumed that an offer block not fitting the pattern was submitted by a different firm. These frequencies are computed for each rival firm removing its own offers from the HTR. These frequencies are reported in Tables 5 and 6 for the period January 2011 to June 2013. As an example, Table 5 indicates that if ATCO predicted that a non-ATCO block in the HTR that fit TransCanada's pattern was offered by TransCanada, it would be correct in 87% of cases.

Table 5 demonstrates that TransCanada's pricing pattern allows rival firms to identify its offers in the HTR with a high degree of accuracy. This arises because TransCanada systematically follows the defined pricing pattern and other firms do not submit price-quantity pairs that could be interpreted as following TransCanada's pattern.

Table 6 demonstrates that rival firms have a high degree of accuracy in determining if a price-quantity pair that does not follow Capital Power's pricing pattern is not associated with Capital Power. ATCO has a high degree of accuracy that an offer pair was submitted by Capital Power after observing Capital Power's pricing pattern in the HTR report. The other large rival firms would experience much less accuracy if they assumed that an offer block fitting Capital Power's

Average peak prices are 44% higher in these hours. It is plausible that firms are able to both observe if certain price-quantity pairs in the HTR follow Capital Power's pattern, and whether these units are large coal assets.

Table 5: Bayesian Probabilities on Price Offers $\in (100.00, 999.99)$ by TC Pricing Pattern

	ATCO's Probabilities			CP's Probabilities	
	TC Pattern	Not TC Pattern		TC Pattern	Not TC Pattern
Firm is TC	**87.05**	2.15	Firm is TC	**82.11**	1.84
Firm is not TC	12.95	**97.85**	Firm is not TC	17.89	**98.16**
	ENMAX's Probabilities			TA's Probabilities	
	TC Pattern	Not TC Pattern		TC Pattern	Not TC Pattern
Firm is TC	**83.61**	1.89	Firm is TC	**84.57**	1.90
Firm is not TC	16.39	**98.11**	Firm is not TC	15.43	**98.10**

pricing pattern came from Capital Power. This arises because ATCO often submits offers with price endings of .00 that are within \$1/MWh of Capital Power's offers exhibiting its pattern. These offers can be incorrectly interpreted as following Capital Power's pricing pattern.

Table 6: Bayesian Probabilities on Price Offers $\in (100.00, 999.99)$ by CP Pricing Pattern

	ATCO's Probabilities			TC's Probabilities	
	CP Pattern	Not CP Pattern		CP Pattern	Not CP Pattern
Firm is CP	**79.62**	14.89	Firm is CP	**33.52**	12.03
Firm is not CP	20.38	**85.11**	Firm is not CP	66.48	**87.97**
	ENMAX's Probabilities			TA's Probabilities	
	CP Pattern	Not CP Pattern		CP Pattern	Not CP Pattern
Firm is CP	**36.32**	14.21	Firm is CP	**33.94**	12.37
Firm is not CP	63.68	**85.79**	Firm is not CP	66.06	**87.63**

6 Econometric Model

6.1 Summary of Empirical Methodology

The discussion above has demonstrated the use of pricing patterns by certain firms that would allow rivals to identify the firm in the HTR with a high degree of accuracy, and that could potentially be used to signal information to rivals. Our focus in the remainder of the paper is on whether rivals act on information in the HTR. More specifically, we are interested in two distinct questions: do firms respond to changes in the market offer curve as described in the HTR, and do they respond differently to changes by different firms (suggesting that they are making use of the ability to distinguish individual firms in the HTR)?

One possibility would be to use the hourly pricing-quantity offer data in the AESO's Merit Order Snapshot that is released with a sixty day lag, and reports the final offer prices and quantities for all blocks after all restatements. However, this data set does not allow us to answer our key questions of interest because it does not provide sufficient information on the timing of changes in firms' price-quantity offers. For example, an observed change between hour t and $t+1$ in a firm's final offers could simply reflect the fact that the firm changed its initial offers between these two hours, and it did not undertake any offer restatements in response to information disclosed near real-time in the HTR.

To properly examine whether firms respond to offer curve changes of firms with a four hour lag, and whether they respond differently to different rivals, one would like to control for or net out price changes that are specified well in advance, and focus on 'last minute' offer changes. The ideal data set would contain the initial offer submissions for each asset and hour (as of noon the previous day), as well as the precise timing and magnitudes of all changes made to those offers in the hours approaching the trading hour. Unfortunately, such data are not publicly available.[14]

To partially address this concern, we employ the HTR data obtained from the MSA, which contains for each block the initial and final (restated) offer price and quantity. These data allow us to isolate changes in a firm's final offer curve from hour t to $t+1$ that were not present in its initial offers for those hours. While this approach does not perfectly identify offer changes that are made after the revelation of the HTR, it does allow us to eliminate offer changes that were submitted the previous day, and to focus on restatements that occurred in the last twenty-four hours.

Our empirical analysis below considers two specific questions. First, we look at when firms change the number of MWhs they are offering at high prices (above $100/MWh), and whether that decision is associated with lagged changes in the number of high priced MWhs being offered by rivals. Next, we investigate the price level decisions made on MWhs that have been recently 'priced up', and how those prices are associated with lagged prices set by rivals. In both analyses, we allow firms to respond asymmetrically to different rivals.

We focus on the behavior of three large strategic rivals (ATCO, TransCanada, and Capital Power) because they were the focus of the MSA's concerns regarding strategic use of the HTR (AUC, 2017b), and because the remaining large firms in Alberta (ENMAX and TransAlta) had few high priced offers during our sample period. We are restricted to consider the period of November 27, 2011 to June 30, 2013 due to data limitations on wind production and demand data.[15] Our analysis focuses on peak demand hours HE9 - HE20 (8:00 AM - 8:00 PM) when firms are most likely to utilize information in the HTR to exercise market power.[16] Table A1 in the Appendix presents summary statistics for the variables utilized in the subsequent econometric analyses.

In the remainder of this section, we summarize our econometric models for the timing of offer curve changes, and for the determination of offer prices on bids that are 'priced up'.

6.2 MWhs Priced Up

Our first econometric model analyzes the probability that a firm restates the number of its MWhs "priced up" above $100/MWh and how this relates to lagged changes in its rivals' offer

[14]As noted earlier, data of this nature was employed by the MSA and firms in the AUC proceeding (AUC, 2017b).

[15]This time period coincides with the time period when the MSA was concerned firms were utilizing information disclosed in the HTR to elevate market prices (AUC, 2017b).

[16]Brown and Olmstead (2017) analyze Alberta's wholesale electricity market for the period 2008 to 2014, and find that firms exercise a sizable amount of market power in peak hours, and limited market power in off-peak hours.

behavior. To address this question, we consider instances in which the number of MWhs a firm is offering above \$100 changes from hour t to $t+1$ in its final restated prices, but not in its initial submission for those hours. That is, we define:

$$\Delta MW_{it}^{100} = (MWRESTATE_{it}^{100} - MWRESTATE_{it-1}^{100}) - (MWPREV_{it}^{100} - MWPREV_{it-1}^{100})$$

where $MWPREV_{it}^{100}$ and $MWRESTATE_{it}^{100}$ are the number of MWhs priced above \$100 by firm i in hour t in its initial and final offers, respectively. ΔMW_{it}^{100} represents the change in the number of MWhs priced above \$100 in the final restated offers between hours t and $t-1$, less the change that would have already occurred in the initial submission. Intuitively, ΔMW_{it}^{100} captures changes in the number of high priced MWhs offered by a firm since noon the previous day that were not already observed in the previous hour. In the subsequent discussion, we will refer to these occurrences as *recent high priced offer restatements*. Similarly, we define $\Delta MWRivals_{it}^{100} = \sum_{j \neq i} \Delta MW_{jt}^{100}$ to be the corresponding change in the number of high priced MWhs of all of firm i's strategic rivals.

We employ a qualitative dependent variable approach because of the high prevalence of zeros in ΔMW_{it}^{100}. We define I_{it} to be an indicator variable that equals 1 if firm i undertakes a sudden high priced offer restatement in hour t that was larger than 10 MWhs (i.e., $|\Delta MW_{it}^{100} > 10|$), and zero otherwise. Likewise, we identify all hours where a firm's rivals changed their MWhs priced above \$100 by more than 100 MWhs (i.e., $|\Delta MWRivals_{it}^{100}| > 100$). These observations identify hours in which a firm's rivals have suddenly increased or decreased a sizable number of MWhs being offered at high prices via offer restatements. For each such hour, we identify whether this change was followed by a sudden change in high priced MWhs by firm i that was larger than 10 MWhs (i.e., $|\Delta MW_{it}^{100}| > 10$). In our econometric analysis, the probability of I_{it} equal to one will depend on the timing of rival offer curve changes, as well as market-level control variables.

The precise 10 MWh and 100 MWh thresholds were chosen through an examination of the distribution of the changes in own and rival high priced MWhs. In particular, we want to rule out small changes in a firm's offer curve that reflect small idiosyncratic adjustments to available capacity. For the strategic firms in our sample, we observe a small cluster of MWh changes less than 10 MWhs. In the subsequent econometric results sections, we carry out numerous robustness checks that change the high price threshold of \$100/MWh, as well as the rival and own quantity threshold changes of 100 MWhs and 10 MWhs.

We utilize a probit analysis to model the timing of recent high priced offer restatements. For each hour t and firm $i \in \{ATCO, TC, CP\}$, we estimate the following:

$$I_{i,t} \; = \; \beta_{0,i} + \sum_{j=1}^{6} \beta_{1,i,j} \, DRival_{i,t-j}^{100} + \sum_{j=1}^{24} \beta_{2,i,j} \, I_{i,t-j} + \gamma_i \, Z_t + \delta_t + \epsilon_{i,t}$$

where $DRival_{i,t-j}^{100}$ is an indicator dummy that equals 1 if firm i's rivals undertook a recent high priced offer restatement that exceeded 100 MWhs in hour $t-j$ (i.e., $|\Delta MWRivals_{i,t-j}^{100}| > 100$), $I_{i,t-j}$ represents firm i's lagged dependent variable, Z_t is a vector of covariates, δ_t is a vector of time-specific dummies for each hour, day of the week, and year-month, and $\epsilon_{i,t}$ is the residual term. We include six lags of firm i's rival's sudden high priced restatements to investigate whether the timing of a firm's response to rival's sudden offer curve changes is consistent with the responding to information disclosed in the HTR.[17]

We include 24 lagged values of each firm's own recent high priced restatements that exceed 10 MWhs to control for the large degree of rigidity observed in a firm's offer curve.[18] The time-specific dummies (δ_t) control for variation and systematic market changes that occur at the hourly level, day of week, or within a particular year-month of our sample.

We include several control variables (Z_t) to control for unanticipated market changes that may drive a firm to undertake a recent high priced offer curve restatement, independent of changes in their rivals' lagged offer behavior. First, we utilize observed and day-ahead forecasts on wind:

$$|\Delta Wind_t| = |Wind_t^{Observed} - Wind_{t-1}^{Observed} - (Wind_t^{Forecast} - Wind_{t-1}^{Forecast})|$$

which represents the absolute value of the changes in the MWhs of wind generation between hours t and $t-1$ that was not already expected to arise. Second, we utilize observed and day-ahead forecasted demand to construct $|\Delta Demand_t|$, which measures the absolute value of the changes in demand between hours t and $t-1$ that was not already expected to arise:

$$|\Delta Demand_t| = |Demand_t^{Observed} - Demand_{t-1}^{Observed} - (Demand_t^{Forecast} - Demand_{t-1}^{Forecast})|.$$

Third, we use information on transmission capacity from neighboring provinces to construct $|\Delta ImportCapacity_t^j|$ which represents the absolute value of the hourly changes in available transmission capacity from province $j \in$ {Saskatchewan, British Columbia} $= \{SK, BC\}$. Summary statistics for wind output, demand, and imports are given in Panel A of Table A1 of the Appendix.

In addition to the symmetric model, we investigate if firms have asymmetric responses to sudden high priced offer restatements of particular large rivals. For each hour t and firm $i \in \{ATCO, TC, CP\}$, we estimate the following asymmetric probit model:

$$I_{i,t} = \beta_{0,i} + \sum_{j=1}^{6} \beta_{1,i,j}\, DRival_{i,t-j}^{100} + \sum_{j=1}^{24} \beta_{2,i,j}\, I_{i,t-j} + \sum_{\substack{k \in K \\ k \neq i}} \sum_{j=1}^{6} \beta_{3,i,j}^{k}\, Dk_{i,t-j}^{100} \times DRival_{i,t-j}^{100} + \gamma_i\, Z_t + \delta_t + \epsilon_{i,t}$$

where $K = \{ATCO, TC, CP\}$ denotes the set of large rivals and $D\,k_{i,t-j}^{100}$ (i.e., $DATCO_{i,t-j}^{100}$, $DTC_{i,t-j}^{100}$, $DCP_{i,t-j}^{100}$) equals 1 if rival k ($k \neq i$) has undertaken a recent high priced offer restatement that exceeded 10 MWhs in hour $t-j$. The interaction $Dk_{i,t-j}^{100} \times DRival_{i,t-j}^{100}$ allows firm i's lagged response to its rivals' sudden high priced offer restatements to vary by particular large strategic rivals in the set K. This allows us to investigate if firms respond differently to different rivals'

[17] We also included lagged rival offer behavior beyond six lags. These coefficients were statistically insignificant.

[18] See De Jong and Woutersen (2011) for a detailed proof of the validity of probit models with lagged dependent variables in the absence of unit roots. We reject the presence of unit roots in our analysis.

recent high priced restatements.

In each model specification, we construct the generalized residuals from our estimated probit specification and test for the presence of serial correlation.[19] Serial correlation is rejected in all specifications. To consider heteroskedasticity, we estimated heterogeneous probit models, which estimates a heteroskedastic variance equation as a function of model covariates (Williams, 2010). However, similar to recent findings in the literature that raise concerns over the robustness of heterogeneous choice models (e.g., Keele and Park, 2006; Williams, 2009, 2010), we find that the heterogeneous probit models are sensitive to model specification and/or exhibit convergence issues. In order to ensure that our econometric results are not impacted by the presence of heteroskedasticity, we estimate the symmetric and asymmetric model specifications using a linear probability model with heteroskedastic robust standard errors (see details below).

6.3 Price Levels

The second part of our econometric analysis considers hours where a large strategic firm undertakes a sudden high priced offer restatement (above \$100/MWh) that exceeds 10 MWhs and investigate how the prices it chooses is related to their rivals' offer behavior (observable at a four hour lag based on information from the HTR).

For each firm $i \in \{ATCO, TC, CP\}$ and hour t, we compute the MWh-weighted average price on their final (restatement) bids above \$100 ($\overline{P}_{i,t}^{REST100}$). For hours t where firm i undertakes a high priced offer restatement between hours $t-1$ and t, we estimate the following linear regression:

$$\overline{P}_{i,t}^{REST100} = \alpha_{0i} + \alpha_{1i}\ln(PRival_{i,t-4}^{25,REST100}) + \alpha_{2i}\ln(PRival_{i,t-4}^{50,REST100}) + \alpha_{3i}\ln(PRival_{i,t-4}^{75,REST100})$$

$$+ \alpha_{4i}MWRival_{i,t-4}^{\leq 100} + \alpha_{5i}MWRival_{i,t-4}^{>100} + \tau_i W_t + \mu_i \delta_t + v_{i,t}$$

where, in period $t-4$, $PRival_{i,t-4}^{25,REST100}$, $PRival_{i,t-4}^{50,REST100}$, and $PRival_{i,t-4}^{75,REST100}$ are the 25th, 50th, and 75 percentile (MWh-weighted) offer prices of firm i's rivals above \$100, $MWRival_{i,t-4}^{\leq 100}$ is the MWhs offered by firm i's rivals at prices below \$100, $MWRival_{i,t-4}^{>100}$ is the MWhs offered at prices above \$100 by firm i's rivals, and, in period t, W_t is a vector of controls, δ_t is a vector of time-specific dummies for each hour, day of the week, and year-month in our sample, and $v_{i,t}$ reflects the residual term.

The rival offer behavior variables capture both the distribution of rivals' high priced offers and number of MWhs priced above and below \$100/MWh at a four hour lag. This specification allows firms to respond differently to the quantity of high priced MWhs compared to MWhs priced below \$100/MWh. Ideally, we would include multiple lagged values of the rival offer behavior variables as in the previous section; this is prevented by the observence of a high degree of collinearity in rival offer behavior across hours. We utilize rival offer behavior variables at a four hour lag reflecting

[19]See Gourieroux et al. (1985) and Gourieroux et al. (1987) for a detailed discussion of generalized residuals and their use in testing for serial correlation in a probit model.

the disclosure of this information via the HTR. We employ a linear-log functional form to control for the skewed distribution observed in the rivals' MWh-weighted offer price percentiles.[20]

The price level of a firm's sudden high priced restatements can be affected by factors other than lagged rival offer behavior observed via the HTR. The vector of covariates W_t includes market-level factors such as day-ahead demand forecast, day-ahead wind forecasts, and import capacity from neighboring province $j \in \{BC, SK\}$ in hour t.[21] The time covariates (δ_t) control for systematic factors that vary at the hourly level, day of week, or within a year-month.

We also investigate if firm i's sudden high priced restatement decision varies asymmetrically with the distribution of particular large rivals' lagged offer behavior. For hours t where firm i undertakes a sudden high priced offer restatement that exceeds 10 MWhs between hours $t-1$ and t, we estimate the following linear regression:

$$\begin{aligned}
\overline{P}_{i,t}^{REST100} = {} & \psi_{0i} + \psi_{1i}\ln(PRival_{i,t-4}^{25,REST100}) + \psi_{2i}\ln(PRival_{i,t-4}^{50,REST100}) + \psi_{3i}\ln(PRival_{i,t-4}^{75,REST100}) \\
& + \sum_{\substack{k\in K \\ k\neq i}} \left\{ \psi_{4ik}\ln(P\,k_{i,t-4}^{25,REST100}) \right\} + \psi_{5i} MW Rival_{i,t-4}^{\leq 100} + \psi_{6i} MW Rival_{i,t-4}^{>100} \\
& + \sum_{\substack{k\in K \\ k\neq i}} \left\{ \psi_{7ik} MW k_{i,t-4}^{\leq 100} + \psi_{8i} MW k_{i,t-4}^{>100} \right\} + \tau_i W_t + \mu_i \delta_t + v_{i,t}
\end{aligned}$$

where $K = \{ATCO, TC, CP\}$ is the set of large strategic rivals, and in period $t-4$, $P\,k_{i,t-4}^{25,REST100}$ is the 25th percentile (MWh-weighted) restated offer prices of firm i's rival k above \$100, $MW k_{i,t-4}^{\leq 100}$ is the MWhs offered by firm i's rival k at prices less than \$100, and $MW k_{i,t-4}^{>100}$ is the MWhs offered at prices above \$100 by firm i's rival k for each $k \in K = \{ATCO, TC, CP\}$ with $k \neq i$.

Ideally, we would control for the 25th, 50th, and 75th percentiles of the (MWh-weighted) offer prices of firm i's large strategic rivals' bids above \$100. However, there is substantial multi-collinearity in the distribution of an individual firm's offer percentiles.[22] Therefore, we control for the 25th percentile (MWh-weighted) offer prices above \$100 of firm i's large strategic rivals in the asymmetric model. This specification is based on the findings of the symmetric model (detailed below) which only finds a statistically significant response to the changes in the distribution of rivals' offer behavior at the 25th percentile. If firms respond only to the distribution of rival offers and not the price offers of specific firms, then we would expect the 25th percentile prices above \$100 of specific rivals to have insignificant coefficients.

Finally, in addition to controlling for the total rival MWhs offered below and above \$100, we control for the MWhs offered by each large strategic rival; again, for each rival we include separately

[20]The results detailed below hold in other model specifications such as linear-linear or log-log. Box-Cox tests demonstrate that linear-log provides the best statistical fit.

[21]We also control for observed hourly demand and wind. The results are robust to this alternative specification.

[22]The observed multi-collinearity is driven by the limited number of offers above \$100 that an individual firm makes in any given hour. Consequently, it is often the case that the 50th and 75th percentiles are equal.

the number of MWh offered at prices below $100 and at prices above $100. This allows us to test if firms are responding to offer information of specific rivals based on offered quantities disclosed in the HTR.

7 Results

7.1 Timing of Offer Curve Changes

In this subsection we present the estimation results from our probit model of the timing of offer curve changes. We first present descriptive evidence of the relationship between the timing of sudden high priced offer restatements, and the price restatements of rival firms. Define Lag_{it} to be the number of hours between a high priced offer restatement of firm i's rivals and the earliest subsequent offer restatement made by firm i. We restrict attention to values of Lag_{it} of no more than eight hours.

Figure 7: Response Lag to Rival Changes in MWhs Priced Up: Symmetric Response

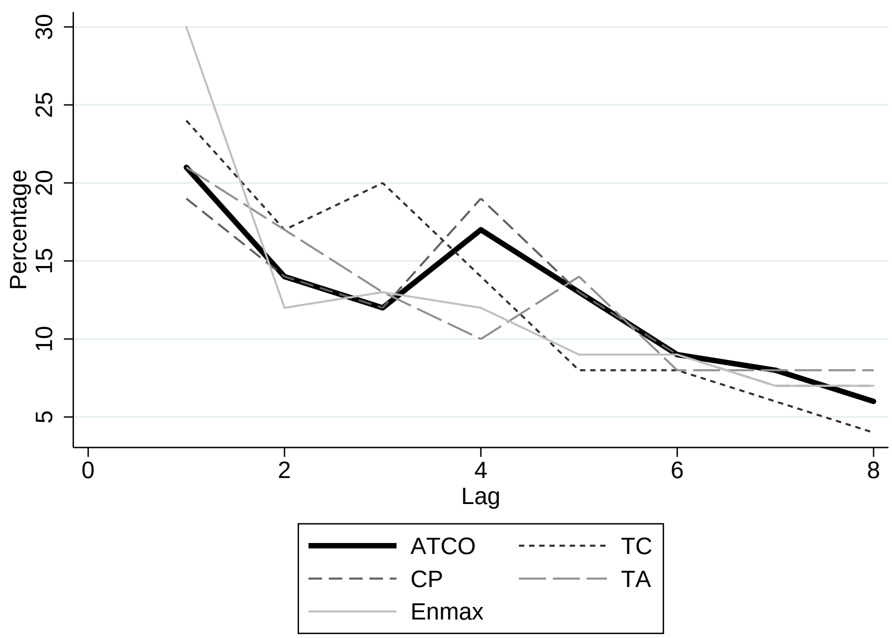


Figure 7 presents for each firm the percentage of lagged responses of one hour, two hours, etc., up to eight hours for the period of November 27, 2011 to June 30, 2013. For all five major firms, when its rivals unexpectedly change their MWhs priced above $100 and the firm follows with a change in the next eight hours, the most frequent lag length is one hour; this is likely capturing some other change in the market which induces a response by multiple firms. For ATCO and Capital Power, the second most common lag length is four hours, consistent with responding to information revealed through the HTR. Notably, the other three firms do not exhibit a spike at four hours; TransCanada's spike at three hours is consistent with responding to other public information such as the SMP or changes in asset-level available capacity that is made available at a three hour lag by the AESO.

To examine whether firms respond asymmetrically to recent high priced offer restatements by other major rivals, we consider the three firms identified by the MSA as behaving strategically through the HTR: ATCO, TransCanada, and Capital Power. Figure 8 plots the lag times between recent high priced offer restatements of rivals and of the firm in question, dividing rival changes into those that involved the other two strategic firms and those that did not.

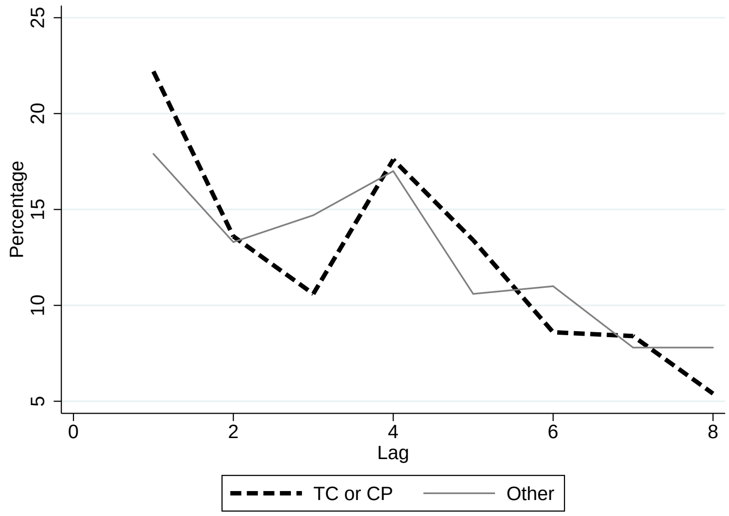
As is evident in Figures 8a, 8b, and 8c, ATCO's lag timing exhibits a spike at four hours for rival changes involving TransCanada and/or Capital Power, and changes involving Other firms. In contrast, the four hour spike in Capital Power's response time is only evident in responses to the other strategic rivals, ATCO and TransCanada. Likewise, TransCanada's three hour spike is only apparent following rival changes involving either ATCO or Capital Power. These figures provide initial evidence that following a sudden large change in a rival's MWhs offered above \$100, two of the three firms (ATCO and Capital Power) exhibit a spike in changes to their high priced MWhs four hours later, with one of the firms only exhibiting the spike following changes involving the other two large rivals. These responses are broadly consistent with firms responding to information provided in the HTR, and identifying rival-specific offer behavior. However, these figures do not control for other factors that may induce a firm to undertake a high priced offer restatement.

Table 7 presents the results of our symmetric and asymmetric probit models which consider the timing of changes in firms' MWhs priced up detailed in Section 6.2. First, we focus on the symmetric model. As in Figure 7, we find that ATCO and CP have positive and statistically significant four hour lagged responses to their rivals' recent large high priced offer curve restatements. This is consistent with responding to information revealed through the HTR. These effects are also economically significant. For example, if ATCO and CP's rivals had a large unexpected high priced restatement four hours ago, the probability that they undertake a sudden high priced offer restatement increases by 2.5% and 2.2%, respectively, holding all other variables at their means. These marginal effects represent 20.7% and 35.5% of the average values of the dependent variable (which are 12.1% and 6.2% from Table A1 Panel B) for ATCO and CP, respectively.

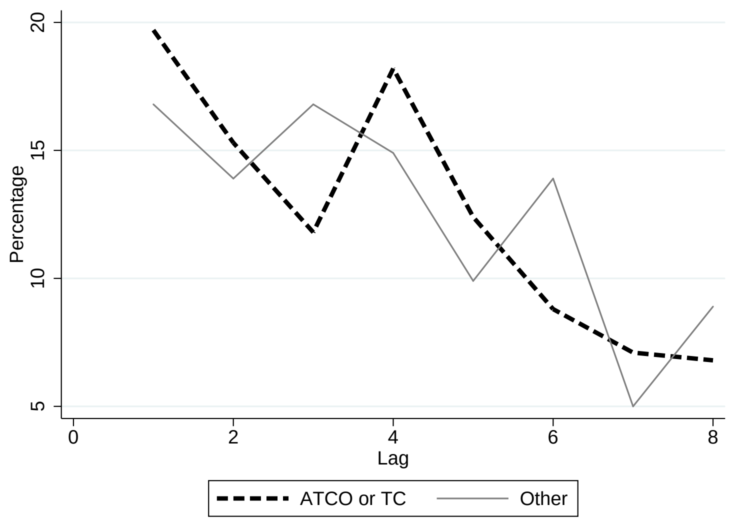
ATCO also has positive and statistical significant coefficients at a five and six hour lag suggesting a delayed response to information provided in the HTR. The statistical significance for ATCO at a one hour lag is likely capturing other changes in the market that impact multiple firm's offer restatement behavior. Consistent with Figure 7, we find marginal statistical significance of a three hour lag for TransCanada.

Second, we discuss the results for the asymmetric model specification. Define the set of firms that does not include ATCO, Capital Power, or TransCanada as Other. With the exception of the third lag for TransCanada, the non-interacted recent high priced restatement covariates (i.e., $\text{DRival}^{100}_{t-j}$ for $j = 1, ..., 6$) are statistically insignificant. Intuitively, this suggests that if a firm's rivals undertake a sudden high priced restatement that exceeds 100 MWhs and these high priced

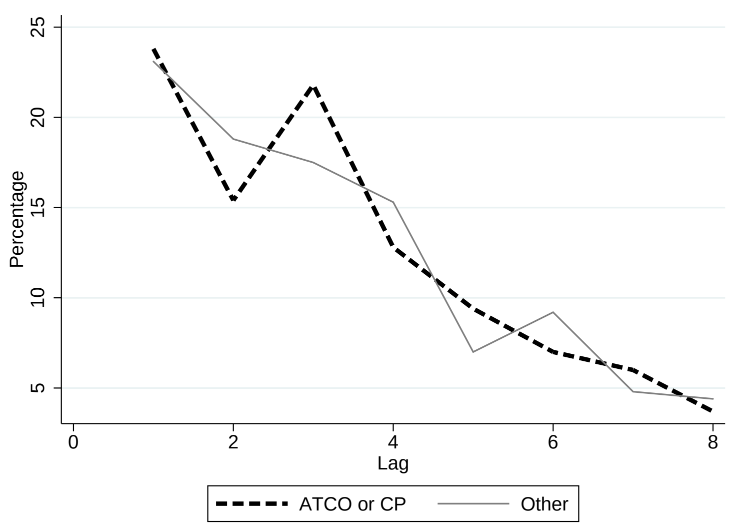
Figure 8: Response Lag to Rival Changes in MWhs Priced Up: Asymmetric Response



(a) Response lag: ATCO



(b) Response lag: CP



(c) Response lag: TC

Table 7: Probit Regressions with Lagged Symmetric and Asymmetric Responses

	ATCO Symmetric	ATCO Asymmetric	CP Symmetric	CP Asymmetric	TC Symmetric	TC Asymmetric
$DRival^{100}_{t-1}$	0.1782***	0.0885	-0.0025	0.0544	0.1421**	0.1463
	(0.0597)	(0.0961)	(0.0790)	(0.1318)	(0.0670)	(0.0915)
$DRival^{100}_{t-2}$	0.0018	-0.1044	0.0677	0.0783	-0.1006	-0.0248
	(0.0604)	(0.0919)	(0.0766)	(0.1193)	(0.0671)	(0.0870)
$DRival^{100}_{t-3}$	0.0315	-0.0267	-0.0114	0.0426	0.1383**	0.1338*
	(0.0593)	(0.0861)	(0.0771)	(0.1146)	(0.0627)	(0.0809)
$DRival^{100}_{t-4}$	0.1287**	0.0348	0.2619***	0.1422	0.0545	0.1206
	(0.0589)	(0.0848)	(0.0726)	(0.1121)	(0.0654)	(0.0829)
$DRival^{100}_{t-5}$	0.1278**	-0.0164	0.0122	0.0004	-0.1153*	-0.0701
	(0.0590)	(0.0837)	(0.0781)	(0.1130)	(0.0695)	(0.0866)
$DRival^{100}_{t-6}$	0.1020*	-0.0093	-0.0206	-0.0662	0.0114	0.0284
	(0.0597)	(0.0833)	(0.0800)	(0.1168)	(0.0680)	(0.0848)
$DTC^{100}_{t-1} \times DRival^{100}_{t-1}$		0.1349		-0.0045		
		(0.1103)		(0.1477)		
$DTC^{100}_{t-2} \times DRival^{100}_{t-2}$		0.1247		0.0471		
		(0.1096)		(0.1400)		
$DTC^{100}_{t-3} \times DRival^{100}_{t-3}$		0.0873		-0.1434		
		(0.1062)		(0.1387)		
$DTC^{100}_{t-4} \times DRival^{100}_{t-4}$		0.1295		0.0710		
		(0.1043)		(0.1295)		
$DTC^{100}_{t-5} \times DRival^{100}_{t-5}$		0.1749*		-0.1293		
		(0.1047)		(0.1392)		
$DTC^{100}_{t-6} \times DRival^{100}_{t-6}$		0.2012*		-0.0013		
		(0.1065)		(0.1447)		
$DCP^{100}_{t-1} \times DRival^{100}_{t-1}$		0.0535				-0.0630
		(0.1305)				(0.1345)
$DCP^{100}_{t-2} \times DRival^{100}_{t-2}$		0.1577				-0.1414
		(0.1300)				(0.1387)
$DCP^{100}_{t-3} \times DRival^{100}_{t-3}$		0.0546				-0.0210
		(0.1293)				(0.1274)
$DCP^{100}_{t-4} \times DRival^{100}_{t-4}$		0.1363				-0.0814
		(0.1243)				(0.1331)
$DCP^{100}_{t-5} \times DRival^{100}_{t-5}$		0.2840**				-0.0163
		(0.1247)				(0.1450)
$DCP^{100}_{t-6} \times DRival^{100}_{t-6}$		0.0605				-0.1051
		(0.1325)				(0.1463)
$DATCO^{100}_{t-1} \times DRival^{100}_{t-1}$				-0.1712		0.0613
				(0.1624)		(0.1279)
$DATCO^{100}_{t-2} \times DRival^{100}_{t-2}$				-0.1249		-0.1223
				(0.1592)		(0.1342)
$DATCO^{100}_{t-3} \times DRival^{100}_{t-3}$				0.0932		0.0438
				(0.1540)		(0.1216)
$DATCO^{100}_{t-4} \times DRival^{100}_{t-4}$				0.2937**		-0.1484
				(0.1404)		(0.1321)
$DATCO^{100}_{t-5} \times DRival^{100}_{t-5}$				0.2567*		-0.1551
				(0.1537)		(0.1464)
$DATCO^{100}_{t-6} \times DRival^{100}_{t-6}$				0.1518		0.0292
				(0.1644)		(0.1386)
$\lvert\Delta Demand_t\rvert$	0.0018**	0.0017**	-0.0021**	-0.0021**	0.0016**	0.0016**
	(0.0007)	(0.0007)	(0.0010)	(0.0010)	(0.0007)	(0.0007)
$\lvert\Delta Wind_t\rvert$	0.0005	0.0006	0.0003	0.0003	0.0003	0.0003
	(0.0005)	(0.0005)	(0.0007)	(0.0007)	(0.0005)	(0.0005)
$\lvert\Delta ImportCapacity^{BC}_t\rvert$	0.0009**	0.0009**	0.0017***	0.0017***	0.0002	0.0002
	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
$\lvert\Delta ImportCapacity^{SK}_t\rvert$	-0.0005	-0.0006	0.0018	0.0019	-0.0009	-0.0009
	(0.0022)	(0.0022)	(0.0025)	(0.0025)	(0.0022)	(0.0022)
Constant	-2.3806***	-2.2773***	-1.5542***	-1.5541***	-2.1520***	-2.1849***
	(0.3576)	(0.3569)	(0.1642)	(0.1650)	(0.3563)	(0.3591)
N	6,952	6,952	6,556	6,556	6,952	6,952
Pseudo R^2	0.065	0.069	0.179	0.183	0.079	0.080
χ^2	333.64	354.74	571.80	585.15	433.12	439.28

All regressions include 24 own lags and time controls for each year-month, hour, and day of week. Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Asymmetric Lagged Coefficients by Rival Firm

Firm i	ATCO			CP			TC		
Rival k	TC	CP	Other	ATCO	TC	Other	ATCO	CP	Other
Lag									
1	0.22***	0.14	0.09	-0.12	0.05	0.05	0.21*	0.08	0.15
2	0.02	0.05	-0.10	-0.05	0.13	0.08	-0.15	-0.17	-0.02
3	0.06	0.03	-0.03	0.14	-0.10	0.04	0.18	0.11	0.13*
4	0.16**	0.17*	0.04	0.44***	0.21***	0.14	-0.03	0.04	0.12
5	0.16*	0.27**	-0.02	0.26*	-0.13	-0.001	-0.22	-0.09	-0.07
6	0.19**	0.05	-0.01	0.09	-0.07	-0.07	0.06	-0.08	0.03

Notes. For each lag j, these numbers represent the summation of the coefficient on the covariate $\text{DRival}_{t-j}^{100}$ and the coefficient on the interaction term $\text{D}k_{t-1}^{100} \times \text{DRival}_{t-1}^{100}$ for rival $k \in \{ATCO, CP, TC\}$ with $k \neq i$. Statistical significance is represented by $^*(p < 0.10)$, $^{**}(p < 0.05)$, $^{***}(p < 0.01)$.

offer restatements do not include the other dominant firms ATCO, TransCanada, or Capital Power, then this has no impact on the likelihood that a firm will undertake an unexpected high priced restatement itself. That is, there is no evidence that ATCO, TransCanada, or Capital Power respond to unexpected high priced restatements by the Other Firms.

The coefficients on the interaction terms (e.g., $\text{DTC}_{t-4}^{100} \times \text{DRival}_{t-4}^{100}$) test if a firm responds differently to recent high priced restatements that exceed 10 MWhs for one of the dominant firms (ATCO, Capital Power, TransCanada) compared to the set of Other firms. For ATCO, there is some evidence to suggest that its response to sudden high priced restatements differs from its response to Other firms at the fifth and sixth lag for TransCanada and fifth lag for Capital Power. For Capital Power, the results demonstrate that it responds more strongly to ATCO in the fourth and fifth lag. There is no evidence that TransCanada responds differently to sudden high priced offer restatements of ATCO and CP compared to the Other firms. A joint Wald test that tests for the joint statistical significance of the interaction terms in each regression yields a p-value of 0.05, 0.33, and 0.91 for ATCO, Capital Power, and TransCanada, respectively. Consequently, we find that only ATCO has a statistically significant asymmetric response to recent high priced restatements of Capital Power and TransCanada compared to the Other firms.

In order to investigate the timing of a firm's response to sudden high priced offer restatements for different rivals, we need to consider the summation of the coefficients on the level ($\text{DRival}_{t-j}^{100}$) and interacted terms ($\text{D}k_{t-j}^{100} \times \text{DRival}_{t-j}^{100}$) and test if the summation of these coefficients are statistically different from zero. Table 8 presents the summed coefficients and their statistical significance for ATCO, Captial Power, and TransCanada for each of its rivals and Other firms.[23] Both ATCO and Capital Power have positive and statistically significant responses to high priced offer restatements from their rivals that occurred four hours ago. In particular, Capital Power has a large positive and statistically significant response to four hour lagged sudden high priced

[23] These calculations estimate the effect of one rival undertaking a sudden high priced restatement. We observe hours where both of the large rivals undertake a high priced restatement. We calculated the joint effect of this simultaneous change. This increases the magnitude of the coefficients and generates similar statistical significance.

restatements made by ATCO. If ATCO undertakes a large unexpected high priced restatement four hours ago, the probability that Capital Power will undertake a sudden high priced offer restatement increases by 3.1%, holding all other variables at their means. More generally, with exception of ATCO's first lagged response for TransCanada, for both ATCO and Capital Power we find strong support for a lagged response that occurs at a four or more hour lag consistent with the timing of HTR information disclosure. We find limited statistical significance for TransCanada.

Lastly, using the results from Table 7, we discuss the impact of the covariates in the symmetric and asymmetric models. For ATCO and CP, changes in import capacity from British Columbia has a positive and statistically significant effect on the probability that a firm undertakes a sudden high priced restatement. For ATCO and TC, as expected, changes in demand between hours t and $t-1$ that was not already expected to arise has a positive and statistically significant impact on the probability that a firm undertakes a sudden high priced restatement.[24]

For both the symmetric and asymmetric model specifications, we also estimate linear probability models (LPM) with heteroskedastic robust standard errors. We utilize Durbin's Alternative test to test for the presence of serial correlation (Durbin, 1970). Serial correlation is rejected in all specifications. Tables A2 and A3 demonstrate that the LPMs generate similar qualitative conclusions as the probit specifications.[25,26]

Our econometric model of the timing of offer curve changes involves the use of certain parameters and thresholds. In particular, we considered individual changes to high priced offers of at least 10 MWhs, and changes to all rival high priced offers of at least 100 MWhs. Because these thresholds lack theoretical justification, we conducted numerous robustness checks varying these magnitudes. The models were re-estimated using 5 MWh and 20 MWh thresholds for own-firm offer curve changes, and 50 MWh and 150 MWh thresholds for rival changes. We also estimated specifications changing the price threshold for high priced offers to \$50/MWh and \$250/MWh.

While the precise significance of individual coefficients varies across specifications, the overall qualitative conclusions are robust. In particular, we continue to find a clear statistically significant peak in response with a four hour lag. In ATCO's asymmetric model, ATCO has a systematic statistically significant response to changes in TransCanada's offer behavior at a four hour lag. In addition, the statistically significant response to Capital Power's fourth and fifth lag largely persists across numerous specifications. For Capital Power's asymmetric model, the statistically significant response to ATCO's fourth and fifth lag systematically holds. The asymmetric response

[24] For CP, changes in $|\Delta Demand_t|$ have a negative and significant impact. This could be capturing a dynamic response to changes in demand overtime. For example, when we include lagged measures of $|\Delta Demand_t|$ this unexpected effect no longer holds for CP, while the positive and significance effect remains for ATCO and TC.

[25] The major critique of the LPM is that the model does not constrain predicted values to the set [0,1]. For ATCO and TransCanada, less than 2% predicted values fall outside the interval (0,1), while 17% and 19% of predicted values fall outside the interval (0,1) for Capital Power for the symmetric and asymmetric models, respectively.

[26] In addition to generating similar qualitative conclusions, the predicted values of the LPMs and probit models are highly correlated. For ATCO and TransCanada (Capital Power), the correlation between the fitted values of the LPM and probit models are approximately 0.97 (0.94) for the symmetric and asymmetric specifications.

to TransCanada's fourth and fifth lags are significant in numerous specifications.

To summarize, our econometric estimates broadly support the conjecture that certain firms respond to recent high priced restatements at a lag which is consistent with firms' abilities to respond to information disclosed in the HTR. There is evidence that ATCO and CP respond differently to sudden high priced offer restatements of certain rivals.[27]

7.2 Pricing Decisions

Table 9 presents the results of our symmetric and asymmetric pricing decision models. First, we focus on the symmetric model. We find evidence that when a firm undertakes a sudden high priced restatement, the price it sets is positively and significantly associated with the 25th percentile of rival prices above \$100. To interpret these magnitudes, assuming that the 25th percentile of rival prices above \$100 in an hour is set equal to its sample average (\$679 for ATCO, \$679 for CP, and \$753 for TC), we find that a \$1 increase in the 25th percentile of rival prices above \$100 increases ATCO, CP, and TC's price on its sudden high priced restated MWhs by \$0.18, \$0.14, and \$0.15, respectively. The observation that a firm's price on newly restated MWhs is related to the 25th percentile of rival prices, but not to higher percentiles, is consistent with the suggestion by the MSA that when firms price up assets they do so to undercut the lowest-priced 'high price' units as revealed in the HTR, making the lower prices above \$100 more relevant (MSA, 2013).

For each firm, we find that an increase in lagged rival MWhs results in a statistically significant reduction in the average price of a firm's high priced offer restatements. In the symmetric model, only ATCO responds differently to lagged rival MWhs priced above and below \$100, with a stronger response to lagged MWhs priced above \$100. As anticipated, increases in forecasted demand (wind) has a positive (negative) statistically significant effect of a firm's high priced offer restatement. Firms systematically respond to imports from British Columbia (the primary importer into Alberta) by lowering the level of its high priced offer restatements.

In the asymmetric model, we investigate if firms respond differently to lagged price-quantity offer decisions of particular rivals. This suggests that firms are responding to information on a particular rival(s) lagged offer behavior disclosed in the HTR. As discussed above, we only include the 25th percentile of particular large strategic rival's high priced offers due to multi-collinearity in the data. If firms respond only to the distribution of rival's high priced offers, and not the offers of specific firms, then we would expect the 25th percentile prices above \$100 of specific rivals to have insignificant coefficients.

Table 9 demonstrates that ATCO and TransCanada respond differently to the lagged high price offers of individual large rivals. In particular, our results yield a statistically significant and positive coefficient on the 25th percentile price of TransCanada's high priced offers in the ATCO

[27] The lower statistical significance in the asymmetric model could be driven in part by the positive correlation in high priced restatements across firms. The asymmetric model identifies off the differential timing of sudden high price offer restatements across the firms ATCO, Capital Power, TransCanada, and Other.

Table 9: Results: Price Regressions with Lagged Symmetric and Asymmetric Responses

	ATCO Symmetric	ATCO Asymmetric	CP Symmetric	CP Asymmetric	TC Symmetric	TC Asymmetric
$ln(PRival^{25,REST100}_{t-4})$	123.6400***	103.0730**	91.5644**	73.9256*	109.9178***	68.9573**
	(33.6157)	(41.9517)	(38.2524)	(44.2145)	(26.0738)	(30.9275)
$ln(PRival^{50,REST100}_{t-4})$	-135.8869	131.4081	-11.6336	7.4868	-116.3805	13.3751
	(92.2736)	(123.5435)	(142.8512)	(134.3841)	(135.3890)	(134.4494)
$ln(PRival^{75,REST100}_{t-4})$	3719.3789	1609.4497	-4756.4955	-6544.5140	2635.2965	6311.3283
	(4109.9716)	(3726.7944)	(3594.7665)	(4078.9300)	(2218.9347)	(5422.3293)
$ln(PTC^{25,REST100}_{t-4})$		54.3292***		26.0331		
		(20.3687)		(20.9251)		
$ln(PCP^{25,REST100}_{t-4})$		18.9960				58.2259***
		(30.5716)				(18.5374)
$ln(PATCO^{25,REST100}_{t-4})$				19.3381		-0.9650
				(21.7889)		(15.8980)
$MWRivals^{\leq 100}_{t-4}$	-0.1487***	-0.1915***	-0.2068***	-0.1188*	-0.2069***	-0.1070***
	(0.0427)	(0.0548)	(0.0445)	(0.0610)	(0.0314)	(0.0384)
$MWRivals^{>100}_{t-4}$	-0.2551***	-0.5651***	-0.2093**	-0.1829	-0.2439***	-0.1037
	(0.0635)	(0.0988)	(0.0881)	(0.1276)	(0.0514)	(0.0755)
$MWTC^{\leq 100}_{t-4}$		0.2442*		-0.0928		
		(0.1292)		(0.1192)		
$MWTC^{>100}_{t-4}$		0.6714***		-0.0647		
		(0.1563)		(0.1830)		
$MWCP^{\leq 100}_{t-4}$		-0.1754				-0.3753***
		(0.1354)				(0.0807)
$MWCP^{>100}_{t-4}$		0.2029				-0.2529**
		(0.1743)				(0.1152)
$MWATCO^{\leq 100}_{t-4}$				-0.3657		-0.7210***
				(0.2487)		(0.1562)
$MWATCO^{>100}_{t-4}$				0.2497		-0.6464***
				(0.3448)		(0.1850)
$ForecastedDemand_t$	0.1870***	0.2285***	0.1378*	0.1343*	0.1630***	0.1249**
	(0.0677)	(0.0728)	(0.0703)	(0.0696)	(0.0442)	(0.0492)
$ForecastedWind_t$	-0.2008***	-0.1608**	-0.1287*	-0.1432*	-0.2331***	-0.2576***
	(0.0681)	(0.0757)	(0.0709)	(0.0770)	(0.0444)	(0.0469)
$ImportCapacity^{SK}_t$	0.9758*	0.3214	-0.3885	-0.6275	0.5301**	0.3157
	(0.5124)	(0.6393)	(0.4616)	(0.4621)	(0.2290)	(0.2485)
$ImportCapacity^{BC}_t$	-0.1459*	-0.1860*	-0.3330***	-0.3594***	-0.2456***	-0.2439***
	(0.0822)	(0.0976)	(0.1166)	(0.1254)	(0.0761)	(0.0807)
Constant	-25587.9989	-13224.3834	34162.1593	45939.2067	-17452.7831	-43301.1945**
	(28443.4689)	(25830.8581)	(24738.4610)	(28013.8391)	(15382.5799)	(16799.4054)
Year-Month	Yes	Yes	Yes	Yes	Yes	Yes
Hour	Yes	Yes	Yes	Yes	Yes	Yes
Day of Week	Yes	Yes	Yes	Yes	Yes	Yes
N	463	323	310	303	814	660
R^2	0.407	0.543	0.348	0.362	0.303	0.372
F-Statistic	15.0039	15.8953	8.0631	6.9848	10.6895	11.4927

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

regression, and a significant positive coefficient on the 25th percentile price of Capital Power's high priced offers in the TransCanada regression. These results suggest that ATCO and TransCanada respond to the lagged high priced offering of those individual firms, even after controlling for the distribution of all rivals' high priced offers.

Table 10: Price Regressions: Asymmetric Responses to MWh Changes by Rival Firm

Firm i	ATCO			CP			TC		
Rival k	TC	CP	Other	ATCO	TC	Other	ATCO	CP	Other
Variable									
$MW_{t-4}^{\leq 100}$	0.05	-0.37***	-0.19***	-0.83***	-0.48***	-0.11***	-0.49**	-0.21**	-0.12*
$MW_{t-4}^{>100}$	0.11	-0.36**	-0.57***	-0.75***	-0.36***	-0.10	0.07	-0.25*	-0.18

Notes. For each firm $i \in \{ATCO, CP, TC\}$ and $j \in \{\leq 100, > 100\}$, the numbers for Other represent the coefficient on the covariate $MWRivals_{t-4}^{j}$. Otherwise, for each firm $i \in \{ATCO, CP, TC\}$ and $j \in \{\leq 100, > 100\}$, the numbers represent the summation of the coefficient on the covariate $MWRivals_{t-4}^{j}$ and MWk_{t-4}^{j} for rival $k \in \{ATCO, CP, TC\}$ with $k \neq i$. Statistical significance is represented by $^{*}(p < 0.10)$, $^{**}(p < 0.05)$, $^{***}(p < 0.01)$.

Looking next at the lagged rival MWhs offered above and below \$100, the coefficient on $MWRivals_{t-4}^{j}$ captures a firm's response to an increase in MWhs offered by other rival firms that are not in the set $K = \{ATCO, TC, CP\}$ for both $j \in \{\leq 100, > 100\}$. Similar to the symmetric model, for ATCO and TransCanada we continue to find a statistically significant negative effect. Only ATCO seems to respond differently to increases in MWhs above or below \$100 by the Other firms, with a stronger response to an increase in MWhs above \$100. The coefficients on the firm specific variables MWk_{t-4}^{j} tests if a firm responds differently to changes in the MWhs offered by one of the large strategic rivals in the set $K = \{ATCO, TC, CP\}$ compared changes in the MWhs offered by the set of Other firms for both $j \in \{\leq 100, > 100\}$. For TransCanada, these coefficients demonstrate that TransCanada responds by lowering the price on its high priced offer(s) more strongly when its large strategic rivals increase their lagged MWhs at all price levels compared to other. Alternatively, there is statistically significant evidence that ATCO responds less strongly to increases in TC's lagged MWhs compared to changes in the Other firms' MWhs.

In order to investigate how a firm responds to changes in lagged MWhs above and below \$100 for different large strategic rivals, we need to consider the summation of the coefficients on the terms $MWRivals_{t-4}^{j}$ and MWk_{t-4}^{j} for all large rivals $k \in \{ATCO, TC, CP\}$ and test if the summation of these coefficients are statistically significant. Table 10 presents the summed coefficients and their statistical significance for ATCO, Capital Power, and TransCanada for each of its rivals and the Other firms. ATCO has a negative and statistically significant response to changes in Capital Power and Other firms' lagged MWhs above and below \$100. There is a statistically significantly stronger response to MWh changes above \$100 for the Other firms. Capital Power has a negative and statistically significant response to changes in ATCO and TransCanada's MWhs offered above and below \$100. There is statistically significant evidence that TransCanada responds negatively to increases in MWhs offered by ATCO, Capital Power and Other below \$100.

As in the previous subsection, we conducted numerous robustness checks varying the high price threshold to \$50/MWh and \$150/MWh, own-firm offer curve change thresholds of 5 MWhs and 20 MWhs, and 50 MWh and 150 MWh thresholds for rival changes. For the symmetric price regressions, the qualitative results are unaffected. Firms continue to have a strong response to changes in rivals' 25th percentile high priced offers and strong negative responses to changes in rival's MWhs at all price levels at a four hour lag. In the asymmetric models, the statistically significant asymmetric responses observed in Capital Power and TransCanada's price regressions are systematically unaffected. For ATCO, we lose statistically significant evidence of an asymmetric response to TC's 25th percentile high priced offers in several of the specifications. However, the asymmetric statistically significant responses to changes in rival's lagged MWhs persist. When the high price threshold is increased to \$250/MWh, we find stronger evidence of asymmetry for Capital Power and less for ATCO. When the high price threshold is reduced to \$50/MWh, we find statistically significant coefficients on the 50th percentiles of rival prices. This is likely driven by the increased variation observed in the 50th percentile of rival prices due to the wider price range.

7.3 Role of Capital Power's Pricing Pattern

The analyses above did not consider whether the behavior of firms change with the use of pricing patterns by rivals, which might be expected if such patterns are being used not only to identify firms but also to communicate intended actions in specific circumstances. As documented in Section 5.2.1, the use of TransCanada's offer pattern persisted in nearly all hours until August 2013, coinciding with the publication of the MSA's (2013) report. We therefore focus on the offer pattern observed in the bids of Capital Power which only occurred in a subset of hours. In Section 5.2.2, we demonstrated that Capital Power's offer curve shifts up when it employs its unique offer pattern. We now investigate whether ATCO's or TransCanada's offer behavior (in terms of timing of offer changes and price levels) differ when Capital Power's pricing pattern is employed.

First, we reestimate the asymmetric probit model described in Section 6.2 for ATCO and TransCanada, including a dummy variable for whether CP's pattern was observed four hours ago ($CPTag_{t-4}$), and interacting this indicator variable with the dummy variable that equals 1 if CP has undertaken a high priced offer restatement that exceeded 10 MWhs four hours ago ($DCP^{100}_{t-4} \times DRival^{100}_{t-4}$).[28] This interaction variable allows us to test whether ATCO and TransCanada respond differently to Capital Power's high priced offer changes when its pricing pattern is employed. The detailed results are presented in Table A4 in the Appendix.

For both firms, we find that the coefficient on CP's pattern indicator is statistically insignificant suggesting that ATCO and TransCanada are not more or less likely to adjust their high-priced

[28] We are unable to include multiple lagged values on the CP's price pattern dummy ($CPTag_{t-4}$) because of the high correlation observed across hours. We included up to six lags on the interaction variable $DCP^{100}_{t-j} \times DRival^{100}_{t-j} \times CPTag_{t-j}$ for $j = 1, 2, 3, ..., 6$. Joint test systematically find no statistical significance among all six lags.

MWhs when CP employs its unique offer pattern. In addition, for both firms the interactions between CP's high priced restatements and whether its unique offer pattern was in effect are insignificant. Therefore, we do not find evidence that ATCO or TransCanada respond differently to Capital Power's high priced offer restatements when its unique offer pattern is in effect. All other results in the asymmetric model are robust.

Second, we re-estimated the asymmetric pricing regressions described in Section 6.3 for ATCO and TransCanada, including a dummy variable for whether Capital Power's tag was in place four hours ago ($CPTag_{t-4}$), and interacting this dummy variable with Capital Power's 25th percentile (MWh-weighted) restated offer prices above \$100 variable ($ln(PCP^{25,REST100}_{t-4})$) and Capital Power's MWhs offered below ($MWCP^{\leq 100}_{t-4}$) and above \$100 ($MWCP^{>100}_{t-4}$) at a four hour lag. These latter interactions allow us to investigate if ATCO and TransCanada responses to information on Capital Power's offer behavior differ depending on whether Capital Power employs its unique offer pattern. The detailed results are presented in Table A5 in the Appendix.

We find statistically significant evidence that both firms' high priced offer restatements differ when CP employs its unique bidding pattern at a four hour lag. When TransCanada undertakes a high priced offer restatement, it bids more aggressively when CP's pattern is employed. More specifically, TransCanada's high priced offer restatements are on average \$29.75 lower when CP's pattern is employed, holding the interacted covariates at their mean values. ATCO reduces the price it sets on its high priced offer restatements when Capital Power expands the amount of supply it offers at all price levels at a four hour lag when it employs its observed pricing pattern. In fact, this reflects ATCO's only statistically significant response to CP's lagged offer behavior suggesting that ATCO is only able to identify CP's offer behavior when the pattern is employed. The core results of the asymmetric model are robust to the inclusion of the CP pattern covariates.

8 Conclusion and Policy Implications

An important issue in electricity market design is whether increased information transparency results in more competitive behaviour or facilitates coordination. Motivated by recent regulatory attention, we have examined Alberta's wholesale electricity market and the publication of the Historical Trading Report (HTR), which disclosed near real-time information on firms' (de-identified) offer behavior. Our paper addresses whether firms submit offer prices and quantities in ways that can allow rivals to identify them through public information (the HTR), and whether firms respond to the behaviour of specific rivals in ways that can be attributed to the release of the HTR.

With regard to the first question, we document patterns in firms' hourly price-quantity offers that would allow firms to reveal their identities to rival firms with a high probability. In particular, we find that two large firms undertake unique offer patterns. While one of the firms appears to use this pattern consistently in nearly all hours, the second firm's pattern is associated with higher demand hours and higher offer prices for that firm. We find that firms are often able to identify their rivals by the offer patterns adopted by those firms with a high degree of accuracy.

Regarding the second question, we focus first on the timing of changes in the number of high priced MWhs. We find that two of the three large firms of interest are more likely to adjust the quantity of MWhs offered at high prices after their rivals have adjusted their offer behavior four hours ago. The timing of these changes is consistent with a response to information released in the HTR. Further, we find that firms respond differently to changes in the lagged offer behavior of particular large rivals at a four hour lag. This suggests that firms are utilizing information disclosed in the HTR to identify which of its rivals are submitting specific offers. This information could be conveyed if patterns in firms' offers reveal their identities.

We then consider the price levels that firms set when they are adjusting (restating) their initially low-priced offers to high prices (above $100). We find that when firms restate their offer prices to above $100, their prices are significantly associated with the four hour lagged 25th percentile prices of rivals. For two of the large firms of interest, we find asymmetric responses to the lagged prices and quantities of different rival firms. While this asymmetry could be the result of identifying information revealed through the HTR, it could at least partly be explained through other firm-specific public information.

Overall, our results suggest that restrictions to "anonymize" publicly released information may be ineffective, and that rivals do respond differently to the prices of different firms even when identities are withheld. This, combined with our finding that certain firms price in conspicuous ways that could be intended to convey information to rivals, suggests caution on the part of regulators when determining the degree of information to reveal in real-time. This has important policy implications as jurisdictions have moved to increase information disclosure in concentrated markets where firms interact repeatedly (e.g., in European electricity markets (EU, 2013)).[29]

Our paper suggests several directions for future research. First, our ability to identify restatements of offers is limited because public information only indicates whether changes to offers were made in the twenty-four hours leading up to an hour; whether these changes occurred in the last four hours is unobservable. Restatement data with more precise timing, which is in the possession of regulators, would allow a more finely tuned analysis of the timing of responses and the role of the HTR. As well, our analysis is reduced form. This allows us to identify associations between a firm's pricing and the lagged pricing of rivals, and to determine whether the lag structure and observed asymmetry is consistent with the use of information conveyed through the HTR. However, in the absence of a structural model, we are unable to address whether information contained in the HTR is being used to reduce the degree of competition in the market. A structural model that could be used for such analysis is the subject of future research.

[29]von der Fehr (2013) raises concerns regarding the degree of information disclosure in the recent policies implemented in the European electricity sector. Similar concerns that increased market transparency would facilitate coordination led regulators to reject a policy to increase information disclosure in the U.S. natural gas sector (United States Department of Justice, 2012; FERC, 2012, 2015).

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Table A1: Summary Statistics: November 27, 2011 - June 30, 2013, Peak Hours

Panel A: Observed Market-Level Hourly Variables

	Units	Mean	Std. Dev.	Min	Max
Pool Price	$/MWh	108.23	211.76	0	999.99
Demand	MWh	9,058	564	7,208	10,609
Imports - SK	MWh	82.07	55.44	0	169
Imports - BC	MWh	385.33	172.84	0	675
Import Capacity - SK	MW	144.93	33.35	0	169
Import Capacity - BC	MW	514.38	146.36	0	700
Wind	MWh	322.50	256.29	0	952.2

Panel B: MWh Regression Variables

	ATCO				Capital Power				TransCanada			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
$DATCO^{100}$	0.121	0.326	0	1	-	-	-	-	-	-	-	-
DCP^{100}	-	-	-	-	0.062	0.241	0	1	-	-	-	-
DTC^{100}	-	-	-	-	-	-	-	-	0.135	0.341	0	1
$DRival^{100}$	0.111	0.314	0	1	0.110	0.313	0	1	0.074	0.262	0	1

Panel C: Price Regression Variables

	ATCO				Capital Power				TransCanada			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
$\overline{P}^{REST,100}$	489.04	303.35	101.20	993.00	653.68	289.11	101.11	999.98	538.06	284.34	100.64	991.32
$PRival^{25,REST100}$	647.33	248.48	117.55	999.92	639.62	245.57	113.41	994.00	724.70	227.42	113.21	996.00
$PRival^{50,REST100}$	947.49	94.63	157.84	999.99	966.37	73.11	285.00	999.99	978.25	40.57	397.46	999.99
$PRival^{75,REST100}$	997.72	7.86	605.00	999.99	998.22	4.77	900.52	999.99	998.59	2.94	970.00	999.99
$MWRival^{\leq 100}$	7993	537	5943	9785	7866	547	6044	9324	7071	535	5198	8581
$MWRival^{>100}$	1,065	312	245	2071	1133	225	343	1881	1150	263	352	1938
$PATCO^{25,REST100}$	680.24	348.43	100.01	996.00	-	-	-	-	-	-	-	-
$PCP^{25,REST100}$	-	-	-	-	690.98	321.95	100.00	999.99	-	-	-	-
$PTC^{25,REST100}$	-	-	-	-	-	-	-	-	573.16	343.34	100.00	990.57
$MWATCO^{\leq 100}$	625	105	348	963	-	-	-	-	-	-	-	-
$MWATCO^{>100}$	251	97	0	557	-	-	-	-	-	-	-	-
$MWCP^{\leq 100}$	-	-	-	-	751	198	132	1036	-	-	-	-
$MWCP^{>100}$	-	-	-	-	183	179	0	658	-	-	-	-
$MWTC^{\leq 100}$	-	-	-	-	-	-	-	-	1546	246	588	1952
$MWTC^{>100}$	-	-	-	-	-	-	-	-	166	152	0	871

Notes. These summary statistics represent the sample period from November 27, 2011 to June 30, 2013 for peak hours HE9 to HE20 utilized in our econometric analyses. MW variables are rounded to the nearest integer in Panel C.

Table A2: Linear Regressions with Lagged Symmetric and Asymmetric Responses

	ATCO Symmetric	ATCO Asymmetric	CP Symmetric	CP Asymmetric	TC Symmetric	TC Asymmetric
$\text{DRival}_{t-1}^{100}$	0.0341***	0.0166	-0.0005	0.0055	0.0317**	0.0317
	(0.0127)	(0.0186)	(0.0092)	(0.0144)	(0.0161)	(0.0216)
$\text{DRival}_{t-2}^{100}$	0.0016	-0.0166	0.0062	0.0103	-0.0205	-0.0067
	(0.0114)	(0.0156)	(0.0087)	(0.0127)	(0.0136)	(0.0180)
$\text{DRival}_{t-3}^{100}$	0.0039	-0.0045	-0.0025	0.0045	0.0330**	0.0294
	(0.0116)	(0.0163)	(0.0084)	(0.0128)	(0.0148)	(0.0191)
$\text{DRival}_{t-4}^{100}$	0.0255**	0.0071	0.0291***	0.0054	0.0118	0.0254
	(0.0130)	(0.0174)	(0.0102)	(0.0138)	(0.0151)	(0.0189)
$\text{DRival}_{t-5}^{100}$	0.0263**	-0.0052	0.0018	-0.0022	-0.0222	-0.0128
	(0.0132)	(0.0174)	(0.0091)	(0.0131)	(0.0140)	(0.0172)
$\text{DRival}_{t-6}^{100}$	0.0188	-0.0032	-0.0048	-0.0070	-0.0015	0.0033
	(0.0128)	(0.0172)	(0.0089)	(0.0127)	(0.0143)	(0.0175)
$\text{DTC}_{t-1}^{100} \times \text{DRival}_{t-1}^{100}$		0.0284		0.0005		
		(0.0231)		(0.0172)		
$\text{DTC}_{t-2}^{100} \times \text{DRival}_{t-2}^{100}$		0.0212		0.0031		
		(0.0204)		(0.0161)		
$\text{DTC}_{t-3}^{100} \times \text{DRival}_{t-3}^{100}$		0.0140		-0.0168		
		(0.0211)		(0.0160)		
$\text{DTC}_{t-4}^{100} \times \text{DRival}_{t-4}^{100}$		0.0266		0.0224		
		(0.0239)		(0.0194)		
$\text{DTC}_{t-5}^{100} \times \text{DRival}_{t-5}^{100}$		0.0406*		-0.0109		
		(0.0245)		(0.0178)		
$\text{DTC}_{t-6}^{100} \times \text{DRival}_{t-6}^{100}$		0.0426*		-0.0043		
		(0.0236)		(0.0168)		
$\text{DCP}_{t-1}^{100} \times \text{DRival}_{t-1}^{100}$		0.0062				-0.0112
		(0.0275)				(0.0335)
$\text{DCP}_{t-2}^{100} \times \text{DRival}_{t-2}^{100}$		0.0293				-0.0277
		(0.0256)				(0.0286)
$\text{DCP}_{t-3}^{100} \times \text{DRival}_{t-3}^{100}$		0.0067				0.0070
		(0.0268)				(0.0327)
$\text{DCP}_{t-4}^{100} \times \text{DRival}_{t-4}^{100}$		0.0293				-0.0156
		(0.0317)				(0.0349)
$\text{DCP}_{t-5}^{100} \times \text{DRival}_{t-5}^{100}$		0.0684**				-0.0033
		(0.0333)				(0.0318)
$\text{DCP}_{t-6}^{100} \times \text{DRival}_{t-6}^{100}$		0.0091				-0.0226
		(0.0297)				(0.0316)
$\text{DATCO}_{t-1}^{100} \times \text{DRival}_{t-1}^{100}$				-0.0185		0.0130
				(0.0180)		(0.0314)
$\text{DATCO}_{t-2}^{100} \times \text{DRival}_{t-2}^{100}$				-0.0199		-0.0217
				(0.0172)		(0.0253)
$\text{DATCO}_{t-3}^{100} \times \text{DRival}_{t-3}^{100}$				0.0080		0.0068
				(0.0181)		(0.0301)
$\text{DATCO}_{t-4}^{100} \times \text{DRival}_{t-4}^{100}$				0.0513**		-0.0333
				(0.0239)		(0.0300)
$\text{DATCO}_{t-5}^{100} \times \text{DRival}_{t-5}^{100}$				0.0342		-0.0306
				(0.0217)		(0.0272)
$\text{DATCO}_{t-6}^{100} \times \text{DRival}_{t-6}^{100}$				0.0134		0.0026
				(0.0203)		(0.0299)
$\lvert\Delta Demand_t\rvert$	0.0004**	0.0003**	-0.0002**	-0.0002**	0.0003**	0.0003*
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)
$\lvert\Delta Wind_t\rvert$	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
$\lvert\Delta ImportCapacity_t^{BC}\rvert$	0.0002*	0.0002*	0.0003***	0.0003***	0.0000	0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
$\lvert\Delta ImportCapacity_t^{SK}\rvert$	-0.0001	-0.0001	0.0002	0.0002	-0.0002	-0.0002
	(0.0004)	(0.0004)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Constant	-0.0767*	-0.0581	-0.0059	-0.0051	-0.0451	-0.0503
	(0.0409)	(0.0414)	(0.0130)	(0.0133)	(0.0405)	(0.0403)
N	6,952	6,952	6,952	6,952	6,952	6,952
R^2	0.050	0.053	0.106	0.109	0.062	0.063

All regressions include 24 own lags and time controls for each year-month, hour, and day of week. Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A3: Asymmetric Lagged Coefficients by Rival Firm: Linear Regression

Firm i	ATCO			CP			TC		
Rival k	TC	CP	Other	ATCO	TC	Other	ATCO	CP	Other
Lag									
1	0.045***	0.023	0.017	-0.013	0.006	0.006	0.045*	0.021	0.032
2	0.005	0.013	-0.017	-0.009	0.013	0.010	-0.028	-0.034	-0.007
3	0.009	0.002	-0.005	0.013	-0.012	0.005	0.036	0.036	0.029
4	0.034**	0.036	0.007	0.057***	0.028*	0.005	-0.008	0.009	0.025
5	0.035*	0.063**	-0.005	0.032	-0.013	-0.002	-0.043	-0.016	-0.013
6	0.039**	0.006	-0.003	0.006	-0.011	-0.007	0.006	-0.019	0.003

Notes. For each lag j, these numbers represent the summation of the coefficient on the covariate $\text{DRival}_{t-j}^{100}$ and the coefficient on the interaction term $\text{D}k_{t-1}^{100} \times \text{DRival}_{t-1}^{100}$ for rival $k \in \{ATCO, CP, TC\}$ with $k \neq i$. Statistical significance is represented by $^{*}(p < 0.10)$, $^{**}(p < 0.05)$, $^{***}(p < 0.01)$.

Table A4: Probit Regressions with Lagged Asymmetric Responses and CP Pricing Pattern

	ATCO Asymmetric	TC Asymmetric
$\text{DRival}_{t-1}^{100}$	0.0885	0.1466
	(0.0961)	(0.0915)
$\text{DRival}_{t-2}^{100}$	-0.1045	-0.0247
	(0.0919)	(0.0870)
$\text{DRival}_{t-3}^{100}$	-0.0260	0.1340*
	(0.0862)	(0.0809)
$\text{DRival}_{t-4}^{100}$	0.0351	0.1204
	(0.0848)	(0.0829)
$\text{DRival}_{t-5}^{100}$	-0.0145	-0.0701
	(0.0837)	(0.0866)
$\text{DRival}_{t-6}^{100}$	-0.0079	0.0278
	(0.0833)	(0.0848)
$\text{DTC}_{t-1}^{100} \times \text{DRival}_{t-1}^{100}$	0.1341	
	(0.1103)	
$\text{DTC}_{t-2}^{100} \times \text{DRival}_{t-2}^{100}$	0.1245	
	(0.1097)	
$\text{DTC}_{t-3}^{100} \times \text{DRival}_{t-3}^{100}$	0.0890	
	(0.1062)	
$\text{DTC}_{t-4}^{100} \times \text{DRival}_{t-4}^{100}$	0.1308	
	(0.1043)	
$\text{DTC}_{t-5}^{100} \times \text{DRival}_{t-5}^{100}$	0.1747*	
	(0.1047)	
$\text{DTC}_{t-6}^{100} \times \text{DRival}_{t-6}^{100}$	0.2017*	
	(0.1066)	
$\text{DCP}_{t-1}^{100} \times \text{DRival}_{t-1}^{100}$	0.0530	-0.0626
	(0.1305)	(0.1345)
$\text{DCP}_{t-2}^{100} \times \text{DRival}_{t-2}^{100}$	0.1590	-0.1419
	(0.1301)	(0.1387)
$\text{DCP}_{t-3}^{100} \times \text{DRival}_{t-3}^{100}$	0.0529	-0.0212
	(0.1293)	(0.1275)
$\text{DCP}_{t-4}^{100} \times \text{DRival}_{t-4}^{100}$	0.1497	-0.0903
	(0.1321)	(0.1422)
$\text{DCP}_{t-5}^{100} \times \text{DRival}_{t-5}^{100}$	0.2844**	-0.0163
	(0.1247)	(0.1450)
$\text{DCP}_{t-6}^{100} \times \text{DRival}_{t-6}^{100}$	0.0614	-0.1048
	(0.1326)	(0.1463)
$\text{DATCO}_{t-1}^{100} \times \text{DRival}_{t-1}^{100}$		0.0609
		(0.1280)
$\text{DATCO}_{t-2}^{100} \times \text{DRival}_{t-2}^{100}$		-0.1225
		(0.1342)
$\text{DATCO}_{t-3}^{100} \times \text{DRival}_{t-3}^{100}$		0.0439
		(0.1216)
$\text{DATCO}_{t-4}^{100} \times \text{DRival}_{t-4}^{100}$		-0.1472
		(0.1322)
$\text{DATCO}_{t-5}^{100} \times \text{DRival}_{t-5}^{100}$		-0.1549
		(0.1464)
$\text{DATCO}_{t-6}^{100} \times \text{DRival}_{t-6}^{100}$		0.0298
		(0.1386)
$CPTAG_{t-4}$	-0.0505	0.0009
	(0.0843)	(0.0770)
$\text{DCP}_{t-4}^{100} \times \text{DRival}_{t-4}^{100} \times CPTAG_{t-4}$	-0.0863	0.0533
	(0.3030)	(0.2978)
$\lvert\Delta Demand_t\rvert$	0.0017**	0.0016**
	(0.0007)	(0.0007)
$\lvert\Delta Wind_t\rvert$	0.0006	0.0003
	(0.0005)	(0.0005)
$\lvert\Delta ImportCapacity_t^{BC}\rvert$	0.0009**	0.0002
	(0.0004)	(0.0005)
$\lvert\Delta ImportCapacity_t^{SK}\rvert$	-0.0006	-0.0010
	(0.0022)	(0.0022)
Constant	-2.2736***	-2.1850***
	(0.3569)	(0.3591)
N	6,952	6,952
Pseudo R^2	0.070	0.080
χ^2	355.3016	439.3126

All regressions include 24 own lags and time controls for each year-month, hour, and day of week. Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5: Price Regressions with Lagged Asymmetric Responses and CP's Pricing Pattern

	ATCO Asymmetric	TC Asymmetric
$ln(PRival_{t-4}^{25,REST100})$	87.4388**	61.7257**
	(41.8559)	(30.5998)
$ln(PRival_{t-4}^{50,REST100})$	84.8686	-25.0360
	(120.6823)	(136.1546)
$ln(PRival_{t-4}^{75,REST100})$	1067.0363	7684.7632
	(3645.3493)	(5477.4775)
$ln(PTC_{t-4}^{25,REST100})$	55.2428***	
	(20.3398)	
$ln(PCP_{t-4}^{25,REST100})$	27.9248	74.5776***
	(29.8231)	(19.0793)
$ln(PATCO_{t-4}^{25,REST100})$		-1.1939
		(15.8762)
$MWRivals_{t-4}^{\leq 100}$	-0.2187***	-0.1032***
	(0.0565)	(0.0384)
$MWRivals_{t-4}^{>100}$	-0.5636***	-0.1181
	(0.0997)	(0.0754)
$MWTC_{t-4}^{\leq 100}$	0.2188*	
	(0.1286)	
$MWTC_{t-4}^{>100}$	0.6290***	
	(0.1584)	
$MWCP_{t-4}^{\leq 100}$	-0.0755	-0.2865***
	(0.1423)	(0.0888)
$MWCP_{t-4}^{>100}$	0.1734	-0.2680**
	(0.1871)	(0.1206)
$MWATCO_{t-4}^{\leq 100}$		-0.6493***
		(0.1593)
$MWATCO_{t-4}^{>100}$		-0.5719***
		(0.1828)
$CPTag_{t-4}$	-2936.6164	1868.1232***
	(4456.3480)	(405.6839)
$ln(PCP_{t-4}^{25,REST100}) \times CPTag_{t-4}$	806.3786	-280.0912***
	(696.9624)	(72.2740)
$MWCP_{t-4}^{\leq 100} \times CPTag_{t-4}$	-2.8197***	-0.2266
	(0.6633)	(0.2683)
$MWCP_{t-4}^{>100} \times CPTag_{t-4}$	-2.2459***	0.3123
	(0.6805)	(0.2393)
$ForecastedDemand_t$	0.2517***	0.1386***
	(0.0752)	(0.0497)
$ForecastedWind_t$	-0.1607**	-0.2199***
	(0.0773)	(0.0479)
$ImportCapacity_t^{SK}$	0.3687	0.2518
	(0.6487)	(0.2523)
$ImportCapacity_t^{BC}$	-0.1713*	-0.2529***
	(0.0987)	(0.0796)
Constant	-9175.8090	-52827.2599***
	(25247.0288)	(17174.4817)
Year-Month	Yes	Yes
Hour	Yes	Yes
Day-of-Week	Yes	Yes
N	323	660
R^2	0.562	0.390
F-Statistic	16.0681	13.0349

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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