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MARKET EFFICIENCY ON THE MIDWEST INDEPENDENT TRANSMISSION SYSTEM OPERATOR ELECTRICITY EXCHANGE: An Inter-hub Analysis

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ABSTRACT

Midwest Independent Transmission System Operator, Inc. (MISO) coordinates the flow of electricity across a large portion of the Midwestern United States as well as one Canadian province. MISO also manages a wholesale electricity exchange within its geographic footprint. Previous research suggests that exchanges similar in design to MISO's may lead to wholesale electricity prices that are weak-form inefficient. We employ a simple strategy that relies solely on historical price information to examine the profits available to a speculator in Midwest ISO's forward market. We find that a speculator can earn economically and statistically significant profits by simultaneously buying (selling) forward electricity on the Minnesota hub and selling (buying) forward electricity on any other hub within the MISO footprint.

INTRODUCTION

A major shift in the federal government's stance toward regulation of the US electricity industry occurred in the mid-1990s. Historically, the federal government treated electricity organizations as natural monopolies since many of these organizations generated and transmitted power to end- users. In an effort to increase competition within the industry, the Federal Energy Regulatory Commission (FERC) passed FERC orders 888 and 889 in 1996. FERC orders 888 and 889 were designed to make the nation's transmissions systems more accessible to power producers. These orders led to the establishment of the Open Access Same-Time Information System (OASIS), which provides real-time information about transmission capacity and transmission price for wholesale electricity. FERC orders 888 and 889 also mandated that regional transmission organizations (RTOs) coordinate the flow of electricity within their geographic footprint. Midwest Independent Transmission System Operator, Inc. (MISO) became the nation's first RTO in December 2001. There are currently five regional electricity hubs within the MISO footprint: Cinergy (CI), Indiana (ID), Illinois (IL), Michigan (MI), and Minnesota (MN).

MISO gained approval from FERC to oversee an electronic exchange for trading wholesale electricity in 2005. Midwest ISO operates both a spot and forward market for wholesale electricity

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within each of its five regional hubs. Since location plays a role in the value of electricity, each hub is treated as its own, independent market. MISO obtains bids and offers for wholesale electricity and determines the market clearing price in the spot and forward markets for each hour of the day, on each hub. The market clearing price, which is known as the locational marginal price (LMP), represents “the cost of supplying the last incremental amount of energy at a particular node on the MISO grid” (Midwest ISO, 2009). Locational marginal prices are quoted in terms of dollars per megawatt hour ($/MWh) and are determined using a proprietary optimization equation.

The spot market is known as the real-time (RT) market. Market participants that trade in the RT market must submit their bids and offers no later than thirty minutes prior to the hour in which the electricity is to be delivered (Midwest ISO, 2009). Midwest ISO then uses the bottom of each hour to determine the real-time LMP for each hub. Midwest ISO calculates 120 RT locational marginal prices each day; 24 for each of its five regional hubs.

The forward market for electricity is referred to as the day-ahead (DA) market. Those who wish to trade on the day-ahead market must place bids or offers by 1100 EST on the day prior to delivery (Midwest ISO, 2009). Midwest ISO then posts 24 hourly day-ahead LMPs for each hub by 1600 EST on the day prior to delivery. Demand in excess of the megawatt hours contracted for in the day-ahead market is filled at the real-time LMP for any given hour the following day. In other words, market participants that underestimate demand when placing a bid in the day-ahead market for a specified hour must purchase electricity in the real-time market the next day at that given hour. Market participants who overestimate demand for electricity for a specific hour in the day-ahead market become sellers at the real-time LMP on that specific hour the following day.

PRIOR RESEARCH ON INEFFICIENCIES IN WHOLESALE ELECTRICITY MARKETS

In theory, the prices of fuel oil, natural gas, and electricity should be related for a few reasons. The power generated from fuel oil, electricity, and natural gas can be measured in the same basis, British thermal units (BTUs). Since all three forms of energy produce the same output (BTUs), a long-term relationship should exist between the prices for all three. Furthermore, oil and gas are often used as substitutes in the production of energy and electricity is often generated using natural gas.

Serletis and Herbert (1999) examine the price relationship between natural gas, fuel oil, and electricity in the Eastern United States. The authors first examine the correlations between the three price series and find that natural gas and fuel oil are highly correlated, but neither have a high correlation with electricity prices. Serletis and Herbert also report that electricity prices are mean-reverting, while fuel oil and natural gas are not. This implies that price shocks have a longer impact on fuel oil and natural gas prices as compared to electricity prices. The authors suggest that the disconnect between electricity prices and prices from the other two forms of energy may allow for arbitrage profits.

Borenstein, Bushnell, Knittel, and Wolfram (2001) find that large price differences existed between spot and forward electricity prices in the months immediately prior to the collapse of the California Power Exchange. The authors attribute this in part to the fact that the market was designed to be used only for hedging purposes. Trading on the California Power Exchange was restricted to entities that could produce and receive wholesale electricity. Borenstein *et al.* (2001) use a simple trading rule that assumes a speculator uses historical forward and spot price information to make buy and sell decisions. They report this rule leads to statistically and economically significant profits.

One major difference between the MISO electricity exchange and the market that Borenstein *et al.* (2001) examine is that the MISO exchange is designed to be used by both hedgers and speculators. Physically and financially settled contracts (known as virtual contracts) are available in both the day-ahead and real-time markets of the MISO exchange. Hadsell and Shawky (2007) examine the impact that the introduction of virtual contracts had on forward premiums on the New York Independent System Operator (NYISO) market. They find that forward premiums decreased in off-peak hours and increased during peak hours after virtual bidding was allowed on the NYISO exchange. Virtual bidding is also associated with lower volatility in real-time and day-ahead NYISO markets (Hadsell, 2007). These results suggest that allowing the trade of financially settled electricity contracts provides efficiency to the market. The existence of financially settled contracts may prevent the large discrepancies between spot and forward prices found on the California Power Exchange.

Borenstein, Bushnell, and Wolak (2002) model the determinants of electricity price changes over a two year period in California after deregulation and found that generation owners exert market power in the summer months. The authors argue that price inelasticity of supply and demand for electricity in the short run allows generation owners to exert a significant amount of market power with a relatively small market share. Borenstein *et al.* (2002) report that market power is a major factor in the price spikes observed in the summer months in California.

Banerjee and Noe (2006) argue that inefficiencies exist in wholesale electricity markets since the electricity industry is only partially deregulated. The authors note that while electricity exchanges themselves may be deregulated, utility companies that trade on these markets are not. Utility companies act as intermediates between power generation companies and end-use customers. The price that utility companies may charge to end-users is still highly regulated. This puts the average utility company in a serious bind, as they have little control of their cost or revenue structure. As a result, the authors state that no optimal hedging position for utility companies can be obtained by only using forward contracts.

This study uses the trading strategy employed by Borenstein *et al.* (2001) to examine the profits that can be achieved by simultaneously buying and selling forward electricity in a given hour across Midwest ISO's five regional hubs. We focus on the day-ahead contracts since most of the trading on the MISO exchange occurs in the forward market. Since risk-neutral speculators may enter the market via virtual contracts, the profits found by simultaneously trading electricity across hubs should not be economically significant.

DATA AND METHODOLOGY

Day-ahead locational marginal prices from June 1, 2006 to April 11, 2009 are obtained from MISO's website, *www.midwestiso.org*. During this time period the five regional electricity hubs within the MISO footprint during this time period were: Cinergy (CI), Illinois (IL), Michigan (MI), Minnesota (MN) and First Energy (FE). Since time plays an important role in the value of electricity, each hour of the day is treated as its own time series on each hub. Each hourly time series consists of 1046 observations. Thus, the sample consists of 1046 day-ahead observations for each hourly time series on each hub.

Borenstein *et al.* (2001) create a trading rule based on the pure expectations hypothesis. Their goal was to determine the profits available to a speculator who made trading decisions based on past real-time and day-ahead prices. Their rule can be expressed as follows (Borenstein, Busnell, Knittel and Wolfram, 2001):

$$RT_{i,t+1} - DA_{i,t} = \alpha + \beta TR + \varepsilon_t. \tag{1}$$

TR is an indicator variable that equals one if the real-time price for a given hour in the previous period is higher than the day-ahead price in the previous period. If *TR* equals one, market participants who use this rule will sell at the real-time price and buy at the day-ahead price the following period. If the real-time price was below the day-ahead price in the previous period, *TR* equals negative one.

Using similar logic, we can apply this rule to the price differences between two hubs for any hour of the day. The rule can then be re-specified as follows:

$$DA_{i,t} - DA_{j,t} = \alpha + \beta\ TR + \varepsilon_t. \tag{2}$$

In this case, *TR* equals one if yesterday's DA price for electricity for a given hour on hub *i* was greater than yesterday's DA price for electricity for the same hour on hub *j*. A speculator using this rule would buy electricity for that specific hour on hub *j* and sell an equal amount of electricity on hub *i*. If *TR* equals negative one, a speculator would sell electricity for a given hour on hub *j* and buy an equal amount on hub *i*. The coefficient associated with *TR* indicates the average dollar amount per megawatt hour that could be earned by implementing this rule. Equation (2) is estimated via OLS. Since there are five regional hubs, ten pairwise comparisons between hubs can be made for each hour of the day. Thus, equation (2) is estimated 240 times.

RESULTS

Table 1 shows the profit earned ($/MWh) when equation (2) is applied to the day-ahead market on the MISO exchange. Estimated t-statistics appear in italics. The coefficient on the indicator variable used in equation (2) is positive and statistically significant (5% level) in each of the 240 regressions. The profits, however, are not uniform across hours. For example, profits tend to be highest between 07:00 and 22:00. A speculator who employed this rule during these hours could earn in excess of $10 per megawatt hour depending on the hubs being utilized.

Although all of the pairwise comparisons produce positive and statistically significant results, many of the coefficients may not be economically significant. For example, the largest coefficient estimated buying and selling between the MI and CI hubs during the sample period is $1.88. In fact, many of the regressions produce average profits that are below $1. The Minnesota (MN) hub, however, produces surprisingly large profits when combined with any other hub on the MISO exchange.

When examining all 10 inter-hub comparisons, the highest average profit for any hour of the day always involves trading on the MN hub. The highest minimum average profit ($4.28) and highest maximum average profit ($11.29) for any of the 10 inter-hub comparisons occurs when equation (2) is applied to the Minnesota hub in conjunction with the other hubs on the MISO exchange. The profits earned by applying this rule to the MN hub in connection to other MISO hubs for any given hour represent 10-25% of the average price of day-ahead electricity for that specific hour. These profits appear to be economically significant since there are no fees associated with placing bids or offers on the exchange. Furthermore, the standard errors of the regression coefficients are small (typically between .2-.5) when the trading rule is applied to the MN hub. Therefore, a speculator who chooses to apply this rule on the exchange would likely focus on simultaneously buying and selling day-ahead electricity between the MN hub and the other four hubs on the exchange.

A fairly simple trading rule is found to produce economically and statistically significant results when using the Minnesota hub in connection with any other MISO hub to simultaneously buy and sell forward electricity. One possible explanation as to why average profits are high when applying equation (2) to the Minnesota hub is excessive hedging pressure. The MN hub is the northernmost hub in the MISO footprint. Because of this, extreme fluctuations in prices (especially in the winter months) could cause trading activity in this hub to be dominated by hedgers. Another possible explanation deals is the Minnesota hub contains Manitoba, the only Canadian province within the MISO footprint. Since all payments on the MISO exchange are made in US dollars, Canadian market participants within the MISO footprint have to deal with exchange rate risk. The profitability of the rule may also be attributable to the proprietary optimization strategy MISO employs to determine locational marginal prices.

Table 1
Inter-Hub Trading Rule Profits

The table below shows profits, in terms of dollars per megawatt hour ($/MWh), that are achieved from implementing equation (2) on the day-ahead market of the MISO exchange. Estimated t-statistics appear in italics.

Hour	*IL-CI*	*IL-MI*	*IL-MN*	*IL-FE*	*CI-MI*	*CI-MN*	*CI-FE*	*MI-MN*	*MI-FE*	*MN-FE*
0:00	1.56	1.58	7.16	2.69	0.95	9.04	2.01	9.00	2.01	7.80
	4.77	4.58	22.41	12.01	12.94	27.45	13.64	26.82	10.80	22.52
1:00	1.45	2.03	6.02	2.58	1.01	7.47	1.70	7.46	1.68	7.03
	4.23	5.34	23.11	13.69	10.11	26.08	15.45	24.08	10.86	25.04
2:00	1.32	1.97	5.33	2.27	0.97	6.57	1.65	6.76	1.56	6.07
	4.38	6.54	23.90	12.28	10.62	25.95	14.95	24.23	10.88	24.16
3:00	1.31	2.05	4.46	2.72	0.99	5.79	1.78	5.75	1.63	5.21
	3.96	6.86	22.35	14.06	11.74	23.52	16.24	20.89	11.93	21.65
4:00	1.32	2.31	4.28	2.69	1.12	5.59	1.80	5.66	1.68	5.30
	3.51	7.20	22.95	13.33	11.57	22.56	16.30	20.10	12.04	21.81
5:00	1.52	2.77	4.52	2.66	1.32	6.09	1.64	6.21	1.88	5.80
	3.26	6.72	23.87	11.81	9.61	22.23	15.38	18.79	12.29	22.47

contd. table 1

Hour	*IL-CI*	*IL-MI*	*IL-MN*	*IL-FE*	*CI-MI*	*CI-MN*	*CI-FE*	*MI-MN*	*MI-FE*	*MN-FE*
6:00	1.85	3.45	4.86	3.07	1.61	6.65	1.86	7.23	2.10	6.29
	3.41	6.04	21.36	10.94	8.01	19.07	13.12	16.77	8.90	19.30
7:00	2.17	2.79	4.44	2.81	1.34	5.57	1.62	5.90	1.84	5.37
	5.51	4.57	15.80	9.31	7.22	19.14	11.17	18.15	9.20	17.75
8:00	2.25	2.41	5.72	2.48	0.93	6.97	1.64	7.10	1.72	6.94
	6.96	4.06	12.66	8.12	5.02	17.07	10.40	18.19	8.32	16.77
9:00	2.09	2.44	8.03	2.83	0.67	9.02	1.51	9.33	1.61	8.73
	6.25	3.88	12.25	8.75	3.81	15.04	8.93	16.82	6.72	14.40
10:00	2.29	2.67	7.39	2.77	0.81	8.70	1.77	8.46	1.79	8.47
	6.36	4.10	12.61	7.98	4.24	16.02	9.87	16.48	6.69	15.35
11:00	2.21	2.16	7.87	2.75	0.99	9.00	1.87	9.12	1.83	8.98
	6.83	3.92	13.38	8.40	4.41	15.68	9.67	17.61	6.35	15.96
12:00	2.33	2.65	8.81	2.53	1.06	9.96	1.79	9.74	1.92	9.54
	7.74	5.17	14.27	7.79	4.73	16.46	8.46	17.75	6.68	15.94
13:00	2.50	3.03	8.53	2.98	1.22	9.67	1.89	9.52	1.98	9.53
	8.32	6.64	14.30	8.96	5.01	15.58	8.18	16.84	6.82	15.77
14:00	2.58	2.58	8.31	2.97	1.66	9.62	2.05	9.39	2.21	9.25
	9.16	6.43	13.70	9.19	7.06	15.26	8.76	16.29	7.00	14.92
15:00	2.86	2.63	8.57	3.33	1.23	9.96	2.25	9.75	2.14	9.66
	10.11	6.33	13.84	9.87	5.27	15.52	9.15	16.16	6.59	15.07
16:00	2.49	2.63	8.77	3.43	1.67	10.15	2.11	9.87	2.19	9.77
	8.10	5.89	13.94	9.92	5.51	15.23	8.05	15.99	6.26	15.00
17:00	3.51	3.06	8.05	3.90	1.88	9.75	2.02	9.31	1.94	9.58
	9.23	5.93	13.62	10.34	7.26	15.11	8.39	15.54	6.48	15.17
18:00	2.62	2.96	7.12	3.39	1.07	9.01	2.39	8.23	2.00	8.80
	7.50	6.69	12.83	10.73	4.13	15.19	10.59	15.15	7.02	14.74
19:00	2.87	2.09	9.27	2.85	1.52	10.79	2.44	9.79	2.40	10.51
	8.24	4.06	13.93	8.60	5.72	16.08	10.45	16.10	7.54	15.54
20:00	2.59	1.77	9.91	2.95	1.12	11.29	2.61	10.91	2.24	11.29
	8.18	3.79	14.52	9.98	5.11	17.11	11.79	18.47	7.58	17.25
21:00	2.19	1.76	8.20	3.02	1.04	9.46	2.23	8.93	1.89	9.08
	6.50	3.16	15.27	9.73	5.36	17.83	11.88	17.85	7.05	16.81
22:00	2.11	1.99	6.52	2.52	0.69	7.19	1.85	6.79	1.84	7.06
	9.20	5.70	13.15	10.87	4.04	15.18	10.91	15.93	8.42	14.84
23:00	1.59	1.79	7.50	2.48	0.93	8.79	1.85	9.06	2.40	7.58
	4.82	4.51	20.76	10.69	10.09	23.38	12.39	24.15	11.10	19.36

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