Impact Mitigation for Emergency Events: Their Effects on Day-ahead and Real-time Market Locational Based Marginal Pricing at the New York ISO

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ABSTRACT

This paper examines whether the forward premium (the difference between the forward and expected spot prices) was reduced by measures that have the potential to mitigate impacts from a sudden and unforeseen event. With regard to such measures, this paper focuses on the Price Response Load (PRL) programs and the Emergency Energy Transaction (EET) agreements that were concluded by the New York Independent System Operator (NYISO). If market participants understand these measures' potential to mitigate the impacts or if the measures actually reduce the volatility of Real-time Market Locational Based Marginal Pricing (RT^LBMP), then the forward premium should decrease. This is because market participants are relieved from aggressively hedging against emergency risks in advance in a Day-ahead (DA) market. By testing the existence of structural breaks in the relation between the DA-LBMP and the Integrated RT^LLBMP for all fifteen zones in the NYISO (including four neighbor zones), I found that the EET agreements and the PRL programs significantly reduced the forward premium. This effect is particularly pronounced in the west side of the state of New York.

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I. INTRODUCTION

Wholesale power markets have been growing rapidly throughout the world and issues related to pricing in these markets have been widely discussed. One of the features of wholesale power prices is that they are subject to sudden upward spikes. This feature is attributed to the nonstorability of electric power and the inelasticity of electricity demand to price changes. Even in a situation of sudden and unforeseen outages and/or shortfalls in electric power, the market is cleared without any buffer or demand response. For this reason, market-clearing prices are volatile and sometimes show large spurts.

The purpose of this paper is to examine how electricity pricing is affected by measures that can mitigate impacts from such sudden and unforeseen events. Specifically, this paper focuses on the forward premium (the difference between the forward and expected spot prices) at the New York Independent System Operator (NYISO) and examines how the forward premium was affected by the NYISO's Emergency Energy Transaction (EET) agreements and Price Response Load (PRL) programs.

An EET agreement makes markets prepared for a possible emergency situation by specifying the terms and conditions pursuant to when the markets provide emergency services to each other. The NYISO is uniquely situated in an area surrounded by other electricity markets: ISO New England; Pennsylvania, New Jersey, and Maryland Interconnection (PJM); Independent Electricity Market Operator (IMO); and Hydro-Quebec. This geographic advantage allows the NYISO to work cooperatively with its neighbors to mitigate any impact from an emergency event. Indeed, the NYISO has already concluded several bilateral EET agreements.

The PRL programs comprise three programs: the Emergency Demand

Response Program (EDRP), the Installed Capacity/Special Case Resources (ICAP/SCR) Program, and the Day-ahead Demand Response Program (DADRP). The EDRP is a short-notice program that encourages retail electricity consumers to voluntarily reduce their demand during specific times when the electric grid could be jeopardized. The ICAP/SCR Program is a contract-based program. Retail electricity consumers are paid to make a contract in which they provide their load reduction capacity in case of an emergency. The DADRP is a consumer-initiated bidding program. Retail electricity consumers can bid their load reduction capability into the DA market. The ICAP/SCR Program was first implemented in 2000 and became practically functional from the summer of 2001. The EDRP and DADRP were also implemented in the summer of 2001.

Their performances were later presented in the NYISO PRL Program Evaluation Final Report, ¹ and also the further effects from the programs were expected as follows.

If these [PRL] programs persist in the long run and as a result market participants come to expect that real-time LBMPs are likely to be lower and less variable, eventually this influence will be reflected in downward pressure on prices at which LSEs [Load Supply Entities] pay to hedge their load obligations, either through physical bilateral supply contracts or financial hedges. *("NYISO Price-Responsive Load Program Evaluation Final Report," page E-14)*

This suggests that the forward premium, which represents the compensation to market participants for bearing risks, can be decreased by PRL programs because these

¹ As compared to the EDRP or the ICAP/SCR Program, DADRP participants are very few in number. According to the survey results presented in the report, the most important reasons for its low popularity are a limited awareness of the DADRP and a lack of understanding of its benefits and risks.

programs have the potential to reduce the RT price volatility by making the electricity demand responsive to its higher price. This study is motivated by what that report expected, and examines whether the forward premium was reduced by the measures that have the potential to reduce RT price volatilities, i.e. by the PRL programs and EET agreements.

To examine this, I employ a multiple structural break test developed by Bai and Perron (1998). The results indicate that the forward premium decreased significantly at the time that is consistent with the PRL programs or the EET agreements. This suggests that these measures successfully led market participants to expect lower, less volatile RT prices. Thus, the market participants were relieved from aggressively hedging against emergency risks in the DA market, and consequently, the forward premium decreased. This result is especially pronounced in the west side of the state of New York.

The rest of this paper is structured as follows. Section II compares this research with previous studies. Section III discusses the model and methodology, and gives the criteria to assess whether the forward premium decreased with the measures. Section IV provides the empirical results. Section V presents the conclusion.

II. PREVIOUS STUDIES AND THIS STUDY

Among the rapidly growing literatures on electricity forward prices, Bessembinder and Lemmon (2002) and Longstaff and Wang (2004) accomplished remarkable researches. Bessembinder and Lemmon explicitly modeled the economic determinants of an equilibrium forward premium. Longstaff and Wang determined the time-varying forward premium with the data from the PJM. They used VAR forecasts to obtain the expected spot prices and GARCH forecasts to measure the time-varying risks, and found that the forward premium varied systematically through the sample period.

This study also examines the time variation in the forward premium through the sample period. However, this variation is not systematic. What is examined in this study is the variation caused by a random event: the EET agreements or the PRL programs. This variation is examined by a multiple structural break test. Paye and Timmermann (2003) suggested that a discrete change that affects the risk premium may cause a structural break in the return prediction model. In light of their implication, the time variation examined in this study can be considered to be complementary to the variation measured based on VAR forecasting. The sample span examined by Longstaff and Wang was 2 years and 5 months. If the span is expanded, the VAR parameters are likely to become unstable because of a possible random event. Hence, finding structural breaks in the forward premium in advance can improve VAR forecasting for expected spot prices and further helps in finding a systematic time-varying forward premium within a regime.

Saravia (2003) examined whether a discrete change exists in the forward premium with the data from the NYISO. Because of the purpose of her research, which is testing the effect of the NYISO's virtual bidding policy, she set the cut-off day of dummy variables at November 7, 2001, that is, the date when the policy was implemented. The results showed that the forward premium was different between the periods before and after this date. However, problems caused by the extensive use of prior information are very similar to those caused by data-mining, which is described in Zivot and Andrews (1992). Therefore, this paper does not use any prior information to select a cut-off day. Instead, I employ a multiple structural break test to investigate a structural change in the forward premium.

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III. MODEL AND METHODOLOGY

This section specifies a model and a hypothesis to examine whether the forward premium was reduced by the PRL programs and/or the EET agreements. I employ a framework of the market efficiency test and extend it to a form that allows structural breaks in the forward premium.

A forward price reflects not only the expected value of the spot price, but also risks and market participants' attitude toward these risks, i.e., the forward premium. Formally, this is described as follows.

$$DA_{st} = E_{t-1}[RT_{st}] + FP_{st-1}$$
(1)

where DA_{st} denotes the electricity forward price observed on day t - 1 for delivery during hour s of day t, RT_{st} denotes the electricity spot price for delivery during hour s of day t, $E_{t-1}[RT_{st}]$ denotes the expected value of RT_{st} that is formed at day t - 1, and *FP* denotes the forward premium. Without assuming risk-neutrality, the market efficiency is examined by the hypothesis b = 1, with the following specification:

$$RT_{st} = a + b * DA_{st} + \varepsilon_{st} \tag{2}$$

where $a \equiv -b * \overline{FP}$, and that ε_{st} denotes white noise. The coefficient b is an indicator to measure market efficiency. The constant term a captures the mean of the forward premia over the sample period, and can be positive or negative depending on the forward premium. For example, supposing that b > 0, if load suppliers are more eager to hedge against a risk from an upsurge in the price, then the constant term becomes negative. Equivalently, \overline{FP} itself becomes positive.²

This paper allows the mean of the forward premia to vary from one regime to another. The situation where there are m + 1 regimes (*m* breaks) is formally illustrated as follows:

$$RT_{st} = a_j + b * DA_{st} + \varepsilon_{st}$$
(3)

for j = 1,...,m+1, where $a_j \equiv -b * FP_j$. When the coefficient b is not subject to the variation, the constant term a_j changes from j = 1 to m+1 as the mean of the forward premia FP_j changes. These shifts in the mean of the forward premia reflect the shifts in risks and the hedging attitude within the sample period.

To examine whether the PRL programs and/or the EET agreements reduced the forward premium, I use estimates of the coefficients and structural break dates that are obtained with the method developed by Bai and Perron (1998). This method enables us to estimate the coefficients together with unknown break points within the context of a linear model. Specifically, with the method we obtain the estimates of the coefficients, \hat{a}_j (for j = 1, ..., m + 1) and \hat{b} , and the structural break dates, $\hat{T}_1, ..., \hat{T}_m$. (The details are given in Appendix A.) Among them, \hat{a}_j (for j = 1, ..., m + 1) and $\hat{T}_1, ..., \hat{T}_m$ are used to test the following hypotheses: Hypothesis (1) the estimated break dates $\hat{T}_1, ..., \hat{T}_m$ are related to the EET agreements or the PRL programs; Hypothesis (2) the shifting direction of the estimated coefficient \hat{a}_j is positive, which means that the forward premium FP_j itself becomes smaller.

If the estimated break date is consistent with the EET agreements or the PRL programs

² From the viewpoint of market efficiency, the constant term multiplied by -1 becomes the forward premium itself only when the market is efficient, i.e., b = 1.

and if the shifting direction of \hat{a}_j is positive, then I conclude that the EET agreements or the PRL programs significantly reduced the forward premium.

IV. EMPIRICS

IV. A. Data and Preliminary Analysis

Daily Locational Based Marginal Pricing (LBMP) in the Day-ahead (DA) and Real-time (RT) markets is analyzed for all fifteen zones in the NYISO (including four neighbor zones) over the period November 19, 1999 through November 17, 2004.³ The analyzed zones are West, Genesse, Central, Mohawk Valley, North, Capital, Hudson Valley, Millwood, Dunwoodie, New York City, Long Island, ISO New England, PJM, IMO, and Hydro-Quebec. All the data are available on the NYISO website. In the DA market, each zonal load is scheduled for each of the 24 hours of the following day (e.g., 0:00 through 0:59, 1:00 through 1:59, and so forth), and therefore, 24 settlement prices are determined for each zone. Hence, for each zone, there are 24 sets of daily DA-pricing data. Similarly, each zone has 24 sets of daily Integrated RT-pricing data. In the RT market, a contract is made every second if a match is available. Therefore, I used the Integrated RT-LBMP, which is the integrated price of all the clearing prices over the real-time contracts made in an hour.

Table 1 reports the summary statistics for selected time slots: 2:00, 5:00, 8:00, 11:00, 14:00, 17:00, 20:00, and 23:00. The table is split vertically into four super zones: West Super Zone (West to Mohawk Valley), East Super Zone (Capital to Dunwoodie), NYC-LongIL Zone (New York City and Long Island), and Neighbor Zone (Hydro-Quebec to PJM). As expected, in the both cases of DA and RT, the mean prices in the

³ If the RT price and/or DA price for a particular day were/was not available, I excluded that day from the data set. The excluded dates for the 2:00, 5:00, 14:00, and 17:00 time slots are reported in the Appendix B.

NYC-LongIL Zone are higher than those in the East Super Zone and much higher than those in the West Super Zone. This reflects the fact that the West Super Zone is the major electricity exporter in the state of New York. The mean prices in the Neighbor Zone are between those of the West and East Super Zones. For all the zones, the RT pricing is more volatile than the DA pricing. On observing the characteristics of the time slots, we find that the mean prices for the hour 17:00 are higher than those for the other time slots. The same characteristic was observed by Longstaff and Wang (2004) for PJM. As in the case of PJM, all the data sets here are covariance stationary.⁴

As a preliminary analysis, I calculated the forward premium by using the method of Longstaff and Wang (2004):

$$E[FP_{st-1}] = \frac{1}{T} \sum_{t=1}^{T} (DA_{st} - RT_{st}).$$
(4)

The unconditional expectation is taken over one year. Figure 1 shows how the mean of the forward premia varied through the sample period. The top panel is for the hour 2:00, and the bottom panel is for the hour 14:00. The bar at the left-end in each box shows the mean forward premium from Nov. 19, 1999 to Nov. 18, 2000. The bar at the second-left shows the mean forward premium from Nov. 19, 2000 to Nov. 18, 2001, and so forth. Interestingly, the mean forward premium tends to be lower. It is especially obvious that the West Super Zone experienced a large shift in the mean forward premium during the sample period. This suggests that there is, at least, one structural break in the forward premium. To obtain rigorous results, I invoke a multiple structural break test developed by Bai and Perron (1998) in the next section.

⁴ The results for the stationarity will be provided on request.

IV. B. Empirical Results

The empirical results from the Bai-Perron test are reported in Tables 2 and 3.⁵ Table 2 focuses on a specific time slot, and provides the detected break dates and their corresponding coefficients. Table 2 is split into I, II, III, and IV, and reports the results for the time slots 2:00, 11:00, 14:00, and 20:00, respectively. Table 3 instead focuses on a specific year, and provides the detected break dates for all the 24 time slots. Table 3 is split into i, ii, iii, and iv, and reports the results for the years 2000, 2001, 2002, and 2003/2004, respectively.

In Table 2, each top panel of the tables shows the break dates detected with a 5% or 10% significance level. A break date detected with a 5% significance level is indicated by bold characters. Detected break dates are categorized into Break Date A through M depending on the characteristics of each break (the characteristics will be described shortly). The panel at the bottom shows the values of the estimated coefficients \hat{a}_j (for j = 1, ..., m+1) and \hat{b} . The first row in the panel shows \hat{a}_1 . This is an estimated constant term for the period after the NYISO was launched, that is, November 19, 1999. The following rows, labeled as "**a** after Break Date XX," show \hat{a}_j (for j = 2, ..., m+1). These are the values of estimated constant terms for each period after the break date XX. If \hat{a}_j increases with j and if the corresponding dates of the breaks (in the top panel) matches with the EET agreements or the PRL programs, then we can conclude that the measures significantly reduced the forward premium. In other words, the premium that was paid from load suppliers to generators became lower. The last row in Table 2 shows the values of the stable coefficient \hat{b} . If the null hypothesis

⁵ When conducting the Bai-Perron test, I set the maximum break number as 5, allowed heterogeneity in the residuals, and assigned a value of .15 for the trimming criteria.

 $\hat{b} = 1$ is not rejected can we observe the corresponding \hat{a}_j as a forward premium itself with the unit of \$/MWh.⁶ In such a case, \hat{b} is underlined. Further, if the corresponding \hat{a}_j is significantly different from zero, \hat{a}_j too has been underlined. This implies that the forward premium had been a significant amount. In Table 3, the break dates refuting Hypothesis (2), i.e., \hat{a} decreased after the break, are underlined.

Among the categories A through M, Break Dates A, C, D, E, H, and I are consistent with the EET agreements or the PRL programs.⁷

IV. B. 1. The EET Agreement between the NYISO and ISO New England

Break Date *A* is consistent with the time when an EET agreement was concluded between the NYISO and ISO New England.⁸ This agreement became effective on August 14, 2000, and it was filed later on September 11, 2000. It states that the participants in the NYISO and ISO New England will provide emergency service to each other, subject to the specified rates, terms, and conditions. Break Date *A* appears in Table 2-I (2:00) and 2-II (11:00), showing either August 22, 2000 or September 6, 2000. In Table 3-i, the agreement-consistent dates are blocked by solid lines. The dates

 $^{^{6}}$ Note that since b is not subject to a structural break, any *a* divided by the corresponding *b* may also be considered as the forward premium itself.

⁷ Break date *B* indicates a PJM-specific break that occurred in mid-December 2000. Break date *L* indicates breaks that occurred around June 20, 2002. The detected zones and dates are consistent with the improvement in load pocket modeling within NYC, which was implemented on June 3, 2002, for the RT market and June 19, 2002, for the DA market. On observing the column "New York City" in Table 3-iii, we find that all the breaks that occurred in New York City during 2002 are consistent with the improvement in the modeling. Break date *M* indicates breaks that occurred due to the September 11 attacks. After this break the forward premium increased. Break Date *F* indicates breaks that occurred in early January 2003, and was mainly observed in New York City, Long Island, Hydro-Quebec, or IMO. Break date *G* indicates breaks that occurred in late 2003 or mid-January 2004, and was only observed in Hydro-Quebec or IMO. Break Date *K* indicates a break that was detected immediately after the August 14 blackout of 2003. It was observed only at the time slot 11:00.

⁸ Break Date J, which appears in Table 2-IV, seems to be consistent with the EET agreement with ISO New England. However, the confidence interval is too wide. Therefore, I categorized these breaks into Break Date J instead of A. In Table 3-i, the breaks categorized into Break Date J are all the seven dates that appeared in the time slots 20:00 and 21:00. The confidence intervals are not reported in this paper, but will be provided on request.

clustering around 12:00 noon are exclusively consistent with the date when the agreement became effective. On the other hand, the dates appearing at the off-peak hours are mainly consistent with the date when the agreement was filed.

Returning to Table 2-I and -II and observing the panel at the bottom of each table, we find that every constant term \hat{a} in the second row is larger than those in the first row. This supports the argument that the EET agreement with ISO New England significantly reduced the forward premium. Thus, it reduced the premium that had been paid from load suppliers to generators.

Additionally, we can provide an assessment of an earlier implementation of the EET agreement. That agreement became effective prior to its filing on submission of a waiver of the Commission's notice requirement. According to the waiver, the earlier implementation was required to address the increased potential for emergency transactions during the remainder of the summer season. As seen in Table 3-i, the practical implementation exclusively affected the forward premium on a peak-hour contract. This suggests that after the implementation, the market participants began to expect the RT prices of the peak-hour loads to become lower and/or less volatile. Therefore, the forward premium became smaller, and equivalently, the constant term \hat{a} became larger. In light of these results, we may conclude that the earlier implementation resulted in what the both ISOs had aimed for.

IV. B. 2. The Commencement of the PRL Programs

Break Date H is consistent with the period when the PRL programs were launched, i.e., the summer of 2001. The final draft for the programs was confirmed on May 3, 2001. In July, twenty-three demand reduction providers were qualified to bid in the DA market under the Day-ahead Demand Response Program (DADRP),⁹ and the events of both the Emergency Demand Response Program (EDRP) and the Installed Capacity/Special Case Resources (ICAP/SCR) Program occurred from August 7 to 10, 2001. Break Date H appears in Table 2-IV (20:00), showing August 8, 2001.¹⁰ The bottom panel shows that every constant term \hat{a} in the third row is larger than that in the previous row. In Table 3-ii, we observe that the dates related to the commencement of the programs, which are blocked by a solid line, mainly appear over the off-peak hours in the West Super Zone. Based on this fact, we can conclude that the commencement of the PRL programs significantly reduced the forward premium mainly on off-peak-hour contracts.

However, the DA contracts for delivery during peak hours generated the opposite results: the constant term \hat{a} decreased after the commencement of the PRL programs. This implies that the forward premium increased after the commencement of the programs. In Table 3-ii such break dates are blocked by a dotted line. We can observe that these appear over the peak hours. I assign Break Date D for such the break dates. In Table 2, Break Date D appears in the table for 11:00 and 14:00. Note that, despite the refutation of the Hypothesis (2), half of the underlined dates is not blocked in Table 3-ii. (The refutation has been identified with the underline.) This is because these refutations seem caused by the September 11 attacks.

Excluding the effects from the September 11 attacks, there appears to be a contradiction between the peak and off-peak hours regarding the effect of the commencement of the programs. However, this difference can be explained by the late

⁹ These new entries brought about a substantial increase in the total number of generators. Besides May 2001, which recorded 13 new entries, the movement of the number of generators is very sluggish.
¹⁰ Saravia (2003) tested the effects of the virtual bidding policy, which was implemented by the NYISO on November 7, 2001. With a priori information, she assumed that the break point is November 7, 2001, and used dummy variables to identify the pre- and post-policy situation. However, the result from the Bai-Perron test suggests that the break date is earlier than the time when the virtual bidding policy was implemented. Even the 90% confidence interval of the detected break date does not reach November 7,

response of the market participants' expectations to a brand new program. Since the constant term \hat{a} is related to the difference between the DA price and the RT price, it can become larger if the DA prices did not reflect an event that lowered the RT prices. For example, if market participants take time to learn about such an event, then the DA prices will remain at a high level until they learn of the decrease in the RT prices. Figure 2 provides a preliminary evidence for this. The bar on the left-hand side (right-hand side) shows the mean of the RT (DA) prices for delivery during the hour 11:00 in the West Super Zone. The line graph displays the difference between the means. The shaded bars indicate the period following Break Date D, that is, the commencement of the programs. The both means decreased after the commencement, but the mean of the RT prices decreased more than that of the DA prices. It implies that the market participants could not quickly assess the effects of the brand new programs on the RT prices, and therefore they could not fully incorporate the effects into their expectations and further into the DA prices. Therefore, the DA prices remained at a higher level comparing to the RT prices. Interestingly, Break Date D is mostly observed over the peak hours. This observation suggests that the peak hours were the most difficult hours for the market participants to assess the effect of the new programs. This is because the peak hours are the hours in which most irresistible price spikes are likely to occur. Hence, it is reasonable to explain the different results by the late response of the market participants' expectations to a brand new program.

Returning to the topic of Break Date *H* in Table 2-IV (20:00), we find that in the West Super Zone, none of the coefficients \hat{b} reject the hypothesis that $\hat{b} = 1$. This means that the corresponding \hat{a} is the forward premium itself. Among the values of \hat{a} , only the West Zone's \hat{a} corresponding to the period preceding the PRL programs is

2001.

significantly different from zero. This suggests that the premium, \$4.03/MWh, was paid by load suppliers to generators in the West Zone until the implementation of the PRL programs. This amount is very close to the amount that Saravia (2003) observed for the West Super Zone, which is \$3.97/MWh.¹¹

IV. B. 3. The Amelioration in the PRL Programs and Seam-issue Alliances

Break Dates *C, E,* and *I* are assigned for the breaks that occurred during the summer of 2002. During this period, the NYISO aggressively resolved seam issues with its neighbor markets,¹² and also dramatically boosted both the EDRP and the ICAP/SCR Program. Specifically, the NYISO concluded an EET agreement with the IMO on May 1, 2002, and later concluded the Interconnection agreement with Hydro-Quebec TransEnergy.¹³ The Interconnection agreement was originally planned to be effective from September 2002 but was actually signed on October 21, 2002. In the meantime, the number of participants in the EDRP and/or the ICAP/SCR Program increased dramatically. According to the NYISO PRL program evaluation report for 2002, enrollment in the programs increased from 427 in 2001 to 1785 in 2002. Two statewide exercises were held between the hours 13:00 and 18:00 on the days of July 30 and August 14, 2002. The average EDRP hourly curtailment recorded was 668 MW. This is 50% higher than the corresponding value in 2001.

Break Date E overlaps the time when the Interconnection agreement between

¹² Not only the EET agreements but also many seam issues were resolved during this period. In order to boost external transactions, the rules at NYISO/ISO New England/PJM were amended during this period. Moreover, in June 2002, IMO, ISO New England, and NYISO concluded an agreement to work cooperatively to harmonize market rules, eliminate seam issues, and develop larger markets. ¹³ TransEnergy is the transmission division of Hydro-Quebec and is responsible for operating the

¹¹ However, she has explained it as the forward premium that was paid until the implementation of the virtual bidding policy, i.e., November 7, 2001.

transmission system owned by Hydro-Quebec and for managing the reliability of the Quebec transmission system.

the NYISO and Hydro-Quebec TransEnergy became effective. This agreement establishes a structure and framework for functions related to the reliability of the operations of the interconnected electricity systems. One of the functions is to provide assistance to each other in an emergency. Later, this agreement progresses to High Voltage Direct Current (HVDC) Interconnections among the NYISO, Hydro-Quebec, and ISO New England. Break Date *E* appears in Table 2-II (11:00). The breaks occurred between September 3 and October 9, 2002. The zones observed are the West and East Super Zones. On observing the panel at the bottom, we find that every constant term \hat{a} in the row indexed as "*a* after Break Date E" is larger than that in the previous row. In Table 3-iii, we find that such breaks appear between 8:00 and 12:00 and over the West and East Super Zones. The break dates related to the EET agreement are indicated by the dark solid line in Table 3-iii. From these observations, we can conclude that the interconnection agreement with Hydro-Quebec TransEnergy significantly reduced the forward premium that had been included in the contracts for delivery during the hours 8:00 through 12:00 in the West and East Super Zones.

Break Date I is assigned for the breaks that occurred on July 17 or 28, 2002, and appears in Table 2-II (11:00) and 2-III (14:00). These dates are close to the first event of the EDRP and ICAP/SCR Program in 2002, or equivalently, the first event after the dramatic increase in enrollment. On observing the panel at the bottom, we find that every constant term \hat{a} in the fifth row is larger than that in the previous row. In Table 3-iii, we find that Break Date I clusters around the West Super Zone and the time slots 11:00 through 17:00. This suggests that the augmentation of the EDRP and ICAP/SCR Program made the market participants expect the RT prices to become lower and less volatile, and consequently, the forward premium became lower.

Break Date C is assigned for the breaks with the following conditions: (1) on

August 10, 11, or 12, 2002; (2) with a confidence interval wide enough to include Break Dates I and E.¹⁴ Break Date C appears in Table 2-I (2:00). In the panel at the bottom, we find that every constant term \hat{a} in the fourth row is larger than that in the previous row. In Table 3-iii, we find that Break Date C exclusively appears in the midnight time slot, that is, outside the event hours of the EDRP and ICAP/SCR Program. Taking these results into account, I conclude that the amelioration in both the PRL programs and the seam-issue alliances indirectly affected the market participants' expectations regarding the midnight RT prices.

IV. C. The Summary of the Results from the Bai-Perron Test

The overall result of the Bai-Perron test is reported in Table 4. The test detected 275 breaks throughout the time slots and zones. Among them, 156 breaks satisfied the hypotheses (1) and (2), that is, the break date is consistent with the PRL programs or the EET agreement, and also the coefficient changes to the positive direction. If Break Date *D*, which was explained as the late response of the market participants' expectations, is counted, the number of consistent breaks becomes 170. This constitutes 61.8% of all the detected break dates. On comparing the results from each super zone, we find that the higher percentage of the detected breaks in the West Super Zone matches with the measures. This finding agrees with the facts reported in the NYISO PRL program evaluation report: a higher percentage of the curtailment in the EDRP and ICAP/SCR Program was pledged in the West Super Zone, a majority of the DADRP participants are from the West Super Zone. From these results, we can conclude that the PRL programs and the EET agreements could reduce the forward premium,

¹⁴ The confidence intervals are not reported in this paper, but will be provided on request.

and their effects were especially prominent in the West Super Zone.

V. CONCLUSION

This paper examined whether the forward premium was reduced by the measures that have the potential to reduce RT price volatilities, i.e., the Price Response Load (PRL) programs and the Emergency Energy Transaction (EET) agreements. By testing the existence of structural breaks in the relationship between the Day-ahead Market Locational Based Marginal Pricing (DA-LBMP) and the Integrated Real-time-LBMP of all the fifteen zones in the NYISO (including four neighbor zones), I found that the following EET agreements and PRL programs significantly reduced the forward premium: the EET agreement concluded between the NYISO and ISO New England (effective on August 14, 2000), the Interconnection agreement between the NYISO and Hydro-Quebec TransEnergy (effective on October 21, 2002), the implementation of the PRL programs (summer 2001), and the augmentation of the Emergency Demand Response Program (EDRP) (early 2002). These results suggest that, because these measures successfully made market participants expect the Real-time pricing to be lower and less volatile, they were relieved from aggressively hedging against emergency risks in the DA market. Therefore, the forward premium that had been included in the DA contract decreased. These effects are especially pronounced in the west side of the state of New York.

APPENDIX A. Empirical Methodology

This appendix describes the methodology to estimate and test a linear model with multiple structural breaks, following Bai and Perron (1998), and formally provides criteria to assess the above hypotheses. The model for the estimate, for each time slot s, is as follows:

$$RT_{t} = a_{j} + b * DA_{t} + \varepsilon_{t} \quad (t = T_{j-1} + 1, \dots, T_{j})$$
(5)

for $j = 1, ..., m + 1.^{15}$ This is a set of multiple linear regressions with *m* breaks (*m* + 1 regimes). Break points, indicated by $T_1, ..., T_m$, are treated as unknowns and are estimated together with the coefficients.

The estimation is doublefold. At the first stage, we assume that the number of breaks, m, is given and estimate the coefficients and break points. This method is based on the least-squares principle. For each m-partition (T_1, \ldots, T_m) , denoted by $\{T_j\}$, the associated least-squares estimates of b and a_j are obtained by minimizing the sum of

the squared residuals:
$$\sum_{i=1}^{m+1} \sum_{t=T_{i-1}+1}^{T_i} \{RT_t - a_i - b * DA_t\}^2$$
. Let $\widehat{b}(\{T_j\})$ and $\widehat{a}(\{T_j\})$ denote the

obtained estimates. Substituting them in the objective function, we obtain the sum of the squared residuals for each *m*-partition, denoted as $S_T(T_1,...,T_m)$. Among all the partitions, the one that minimizes the sum of the squared residuals are considered to be the estimated break points $\hat{T}_1,...,\hat{T}_m$. Formally, these are described as follows:

¹⁵ Unlike the specification provided here, many market efficiency tests are conducted in a differential form. Thus, both the sides are substituted by the DA price observed on day t-2. One of the reasons for taking the difference is to avoid the problem of spurious regression (see Phillips (1986), Fama and French (1987), and Beck (1994)). However, all the data sets used in this paper are covariance stationary. Therefore, the difference is not taken in this paper.

$$\left(\hat{T}_1,\ldots,\hat{T}_m\right) = \underset{T_1,\ldots,T_m}{\arg\min} S_T\left(T_1,\ldots,T_m\right)$$
(6)

where the minimization is taken over all the partitions (T_1, \ldots, T_m) such that $T_i - T_{i-1} \ge q$. The break point estimators are the global minimizers of the objective function. The estimates of the parameters are the associated least-squares estimates at the estimated *m*-partition $\{\hat{T}_j\}$, i.e., $\hat{b} = \hat{b}(\{\hat{T}_j\})$ and $\hat{a} = \hat{a}(\{\hat{T}_j\})$.

At the second stage, we seek the number of break points, *m*, by testing the null hypothesis of *I* breaks against the alternative that an additional break exists. Practically, we test whether each I + I segment obtained in the first stage, T_1, \ldots, T_I , contains an additional break. If the overall minimal value of the sum of the squared residuals with an additional break is sufficiently smaller than that without the additional break, then we conclude that the model including the additional break is favorable. The test statistics is formally defined as follows:

$$F_T(l+1|l) = \left\{ S_T(\hat{T}_1, \dots, \hat{T}_l) - \min_{1 \le i \le l+1} \inf_{i \in \Lambda_{i,\eta}} S_T(\hat{T}_1, \dots, \hat{T}_{i-1}, i, \hat{T}_i, \dots, \hat{T}_l) \right\} \middle/ \hat{\sigma}^2$$
(7)

where $\Lambda_{i,\eta} = \{t; \hat{T}_{i-1} + (\hat{T}_i - \hat{T}_{i-1})\eta \le t \le \hat{T}_i - (\hat{T}_i - \hat{T}_{i-1})\eta\}$ and $\hat{\sigma}^2$ is a consistent estimate of σ^2 .

Through the two stages, we obtain estimates of the coefficients and the structural break dates: \hat{a}_j (for j = 1, ..., m + 1), \hat{b} , and $\hat{T}_1, ..., \hat{T}_m$. Among them, I used \hat{a}_j (for j = 1, ..., m + 1) and $\hat{T}_1, ..., \hat{T}_m$ to examine whether the EET agreements and/or the PRL programs significantly reduced the forward premium. Hypothesis (1) is examined with the estimated break dates $\hat{T}_1, ..., \hat{T}_m$, and Hypothesis (2) is examined

with the coefficient \hat{a}_j (for j = 1, ..., m + 1). If the estimated break date is consistent with the EET agreements or the PRL programs and if the shifting direction of \hat{a}_j is positive, then I conclude that the EET agreements or the PRL programs significantly reduced the forward premium.

APPENDIX B. The Excluded Data

In each time slot the listed dates are excluded from the analysis because the DA price and/or RT price are/is not available.

2:00	5:00	14:00	17:00
2000/4/2			
2001/4/1			
2002/4/7			
			2002/11/1
			2002/11/6
		2003/3/9	2003/3/9
		2003/3/10	2003/3/10
2003/4/6			
2003/4/30	2003/4/30	2003/4/30	2003/4/30
2003/5/1	2003/5/1	2003/5/1	2003/5/1
2003/5/2	2003/5/2	2003/5/2	2003/5/2
2003/5/3	2003/5/3	2003/5/3	2003/5/3
2003/5/4	2003/5/4	2003/5/4	2003/5/4
2003/6/13	2003/6/13	2003/6/13	2003/6/13
2003/6/14	2003/6/14	2003/6/14	2003/6/14
2003/8/15	2003/8/15	2003/8/15	2003/8/15
2003/10/16	2003/10/16	2003/10/16	2003/10/16
2003/10/17	2003/10/17	2003/10/17	2003/10/17
2003/10/18	2003/10/18	2003/10/18	2003/10/18
2003/10/19	2003/10/19	2003/10/19	2003/10/19
2003/10/20	2003/10/20	2003/10/20	2003/10/20
2003/10/21	2003/10/21	2003/10/21	2003/10/21
2003/10/22	2003/10/22	2003/10/22	2003/10/22
2003/10/23	2003/10/23	2003/10/23	2003/10/23
2003/10/24	2003/10/24	2003/10/24	2003/10/24
2004/1/1	2004/1/1	2004/1/1	2004/1/1
2004/1/2	2004/1/2	2004/1/2	2004/1/2
2004/1/3	2004/1/3	2004/1/3	2004/1/3
2004/1/4	2004/1/4	2004/1/4	2004/1/4
2004/4/4			
2005/1/28		2005/1/28	
2005/1/29		2005/1/29	
2005/1/30		2005/1/30	
2005/1/31		2005/1/31	

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Table	1:	Summary	V Statistics
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Table 1	: Summary Statistics															
		West	Genesse	Central	North	Mohawk	Capital	Hudson	Millwood	Dunwoodie	New York	Long Island	Hydro	ISO New England	IMO	PJM
2:00	Day-Ahead Price					valley		Valley			City		Quebec	Eligialiu		
	Mean	24.87	25.68	26.08	26.99	26.65	28.60	28.66	28.59	29.00	31.82	35.58	26.65	28.70	24.74	22.28
	s.d.	9.14	9.63	9.77	10.22	10.13	10.76	10.55	10.60	10.76	11.94	12.35	10.13	10.82	9.07	8.57
	Real-Time Price															
	Mean	23.60	24.82	24.46	25.45	24.94	28.44	26.91	27.17	27.60	30.44	33.18	25.32	27.59	21.61	14.14
	s.d.	17.65	18.29	18.10	18.89	18.54	20.37	19.44	19.77	19.95	22.41	24.88	46.23	32.82	38.14	72.30
5:00	Day-Ahead Price															
	Mean	27.84	28.71	29.11	29.60	30.07	31.66	31.77	31.69	32.09	34.91	38.20	29.46	31.58	27.45	25.90
	s.d.	10.71	11.23	11.25	11.51	11.68	12.05	11.87	11.93	12.12	12.92	12.15	11.35	11.98	10.39	10.45
	Real-Time Price															
	Mean	26.30	27.60	27.24	27.74	28.29	31.42	30.01	30.36	30.76	33.54	38.61	28.80	30.59	25.14	20.26
	s.d.	22.08	22.28	22.10	22.48	22.84	24.08	23.62	23.80	24.07	25.34	25.00	41.99	24.39	21.29	60.49
8:00	Day-Ahead Price							.=								
	Mean	38.80	40.46	41.38	42.52	41.11	47.10	47.29	47.20	47.88	54.54	52.37	41.33	47.26	38.29	39.93
	s.d.	14.55	15.50	15.55	16.21	16.16	17.37	16.68	16.86	17.16	20.30	17.34	15.92	17.32	14.24	15.35
	Real-Time Price	20 52	20 54	20.44	20.42	20.24	40.04	45.24	40.07	47.00	54.00	54.04	20.40	47.40	07 47	20.40
	Wean	30.53	38.54	38.44	39.43	38.31	40.91	45.34	40.37	47.08	54.89	54.04	39.12	47.40	37.17	30.40 52.65
11.00	S.u.	19.20	21.10	20.75	22.09	22.00	30.39	29.90	30.22	30.07	41.70	30.62	45.14	50.55	30.90	52.05
11.00	Day-Alleau Flice	44.04	40.05	44.04	44.00	45 70	F4 07	50.00	50.50	52.40	C2 01	01.10	44.44	50.07	44.00	40.44
	Mean	41.84	43.05	44.01	44.09	45.73	51.97	52.60	52.59	53.40	03.01	01.13	44.14	52.27	41.03	43.41
	S.u. Roal Timo Prico	10.51	10.91	10.91	17.00	17.50	25.00	23.52	23.09	24.27	20.11	25.50	10.02	24.95	15.60	17.75
	Mean	30.87	42 10	41.08	41.66	12 04	51 26	50 43	52.28	53.02	63 75	64 42	11 56	50.67	30.23	30.00
	Niean be	22 42	23 43	23 10	23 56	23.03	35.01	31.82	34.09	34.48	47 11	37.24	23 57	39.58	26 78	47 31
14.00	Dav-Ahead Price	22.72	20.40	20.10	20.00	20.00	55.01	01.02	54.05	34.40	47.11	57.24	20.07	09.00	20.70	77.51
14.00	Mean	41 19	42 86	43 83	44 81	43 12	52 32	53 12	53 17	54 00	64 48	63 26	43 18	52 68	40.34	42 95
	sd	26.26	26.64	26.51	27.26	26.34	48 48	42 74	42.88	43 41	44 97	40.67	25 78	46 44	25.44	31 11
	Real-Time Price	_00	20.0	20.01		2010 1			.2.00				20.10			•
	Mean	38.55	40.30	40.21	41.07	39.80	49.75	51.10	54.07	54.79	66.25	66.24	38.92	51.03	38.19	37.15
	s.d.	34.43	35.48	35.54	36.77	36.03	51.51	53.50	59.90	59.40	74.38	60.69	48.29	58.83	35.74	61.41
17:00	Day-Ahead Price															
	Mean	46.90	48.92	49.95	49.49	51.28	57.46	58.74	58.93	59.88	69.05	72.97	49.57	57.97	46.12	48.77
	s.d.	21.61	22.56	22.66	22.98	23.58	32.64	32.94	33.80	34.30	37.45	42.19	22.68	33.23	21.19	23.36
	Real-Time Price															
	Mean	44.83	47.18	47.13	46.75	48.21	56.99	57.59	60.66	61.60	74.28	77.23	42.97	56.40	44.13	45.31
	s.d.	39.31	41.24	40.97	41.54	42.41	50.51	50.42	55.28	55.50	75.63	56.37	69.09	54.72	46.41	61.57
20:00	Day-Ahead Price															
	Mean	42.60	44.47	45.42	46.67	45.08	51.88	52.21	52.15	52.85	59.19	65.09	45.19	51.96	41.94	44.05
	s.d.	14.52	15.43	15.47	16.24	16.15	17.53	16.83	17.01	17.30	20.95	25.40	15.83	17.46	14.21	15.31
	Real-Time Price															
	Mean	41.73	43.77	43.78	44.95	43.69	51.58	51.23	53.26	54.05	63.60	72.01	42.48	51.48	40.91	39.86
	s.d.	34.08	34.46	34.10	35.48	34.79	36.75	36.98	43.99	44.47	64.06	49.00	34.41	44.78	38.19	58.54
23:00	Day-Ahead Price						ac		ac							ac
	Mean	33.05	34.36	35.07	35.61	36.31	38.56	38.98	38.77	39.21	45.06	46.33	35.14	38.12	32.24	30.79
	s.d.	10.50	11.31	11.49	11.82	12.04	12.57	12.59	12.77	13.02	14.95	14.27	12.09	12.80	10.63	10.77
	Real-Time Price	00.07	00.07	00 70	04.40	04.00	05.07	04.40	04 57	05.40	40.00	40.00	00.70	04.00	00.07	00.55
	Mean	29.34	30.97	30.73	31.13	31.82	35.37	34.16	34.57	35.13	42.08	42.63	30.79	34.90	26.87	22.55
	\$.d.	24.96	25.27	25.29	25.81	26.27	27.75	21.23	27.42	27.87	33.46	30.62	36.52	39.79	36.38	70.02

Table 2-I Detected Break Dates by Time Slot (Time Slot 2:00)

Table 2 shows the results brought by the multiple structural break test, due toBai and Perron (1998), through the sample period 11/19/1999 to 11/17/2004. Table 2-I shows the results for Time Slot 2:00; 2-II for 11:00; 2-III for 14:00; and 2-IV for 20:00. Each top panel shows the detected structural-break dates detes on the time slot. The break detected with 5% significant level is indicated by bold characters. Each bottom panel shows the *a* and *b* of this equation: [Real Time Price] = $a + b^*$ [Day Ahead Price]. The *a* is subject to a structural break. *a*'s sequential move is described from the first row to the second-last row on the bottom panel. The last row shows **b**, which is not subject to a structural break. The <u>underlined *a*</u> indicates that the *a* rejected the hypothesis, a = 0, at 10% significant level, and therefore the <u>-a is forward premium itself (unit: \$/MWHr)</u>. The <u>underlined *b* indicates that the *b* did not reject the null hypothesis, b = 1, at the 10% significant level.</u>

	West	Genesse	Central	North	Mohawk Valley	Capital	Hudson Valley	Millwood	Dunwoodie	New York City	Long Island	Hydro Quebec	ISO New England	IMO	PJM
Break Date A	09/06/2000	09/06/2000	09/06/2000	09/06/2000	09/06/2000	none	none	09/06/2000	09/06/2000	09/06/2000	09/06/2000	none	09/06/2000	none	none
Break Date L	07/02/2002	none	none	none	none	none	none	none	none	06/19/2002	none	none	none	none	none
Break Date C	none	08/11/2002	08/11/2002	08/11/2002	08/11/2002	none	none	none	08/10/2002	none	none	none	none	none	none
Break Date G	none	none	none	none	none	none	none	none	none	none	none	none	none	10/04/2003	none
a after 11/19/1999 s.e.	-2.87 1.15	-3.45 1.16	-2.86 1.16	-3.06 1.16	-3.21 1.19	0.50 1.17	0.53 1.15	-1.84 1.30	-1.56 1.33	-3.89 1.50	-4.06 1.80	-1.59 2.99	1.87 2.36	5.62 2.58	-2.38 4.73
a after Break Date A s.e.	1.49 1.17	1.63 1.16	1.85 1.17	1.57 1.18	1.78 1.20			4.07 1.30	3.41 1.30	3.58 1.38	6.67 1.70		8.87 2.39		
a after Break Date L s.e.	4.41 1.35									8.25 1.70					
a after Break Date C s.e.		4.41 1.41	4.75 1.40	4.66 1.41	4.80 1.44				5.81 1.55						
a after Break Date G s.e.														12.12 3.44	
b s.e.	0.86 0.04	0.89 0.04	0.85 0.04	0.85 0.04	0.86 0.04	<u>0.98</u> 0.04	0.92 0.04	0.84 0.04	0.82 0.04	0.81 0.04	0.79 0.04	<u>1.01</u> 0.10	0.69 0.07	0.59 0.10	<u>0.74</u> 0.20

Table 2-II continue (Time Slot 11:00)

	West	Genesse	Central	North	Mohawk Valley	Capital	Hudson Valley	Millwood	Dunwoodie	New York City	Long Island	Hydro Quebec	ISO New England	IMO	PJM
Break Date A	08/22/2000	08/22/2000	08/22/2000	08/22/2000	08/22/2000	none	none	none	none	none	08/24/2000	08/22/2000	none	08/22/2000	none
Break Date B	none	12/17/2000													
Break Date D	none	05/20/2001	05/20/2001	05/20/2001	05/20/2001	08/13/2001	none	none	none	none	none	05/21/2001	none	none	none
Break Date M	none	09/13/2001	none	none	none	none									
Break Date I	none	07/17/2002	none	none	none										
Break Date E	09/03/2002	09/03/2002	09/03/2002	09/03/2002	09/03/2002	10/09/2002	09/14/2002	10/09/2002	10/09/2002	none	none	none	none	none	none
Break Date F	none	01/08/2003	01/15/2003	none	none	01/08/2003	none								
Break Date K	none	08/24/2003	08/24/2003	none	none	none	none	none	none						
a after 11/19/1999 s.e.	8.17 1.50	9.25 1.55	9.37 1.55	10.73 1.56	9.90 1.59	27.53 2.06	19.97 1.69	20.81 1.77	21.24 1.79	16.66 2.42	20.67 2.64	10.73 1.59	22.80 2.04	8.35 1.93	-0.35 3.23
a after Break Date A s.e.	14.18 1.33	21.89 1.88	20.89 1.89	23.82 1.93	22.72 1.95						32.96 2.63	23.18 1.97		14.24 1.70	
a after Break Date B s.e.															15.65 3.00
a after Break Date D s.e.		13.39 1.40	13.12 1.41	15.10 1.45	14.33 1.46	20.37 2.00						14.24 1.47			
a after Break Date M s.e.											20.45 2.15				
a after Break Date I s.e.												27.15 1.89			
a after Break Date E s.e.	21.35 1.61	24.26 1.77	23.51 1.77	27.35 1.85	25.96 1.85	32.18 2.15	26.25 2.02	35.77 2.56	36.76 2.58						
a after Break Date F s.e.										26.87 3.29	31.79 2.61			20.76 2.17	
a after Break Date K s.e.								24.91 2.33	25.85 2.35						
b s.e.	0.56 0.03	0.53 0.03	0.53 0.03	0.47 0.03	0.50 0.03	0.45 0.03	0.53 0.03	0.53 0.03	0.52 0.03	0.69 0.04	0.61 0.03	0.47 0.03	0.53 0.04	0.57 0.04	0.62 0.06

Table 2-III continue (Time Slot 14:00)

	West	Genesse	Central	North	Mohawk Valley	Capital	Hudson Valley	Millwood	Dunwoodie	New York City	Long Island	Hydro Quebec	ISO New England	IMO	PJM
Break Date B	none	12/17/2000													
Break Date D	none	none	none	none	none	08/08/2001	none								
Break Date M	none	09/10/2001	none	none	none	none	none								
Break Date L	none	06/20/2002	none	none	none										
Break Date I	07/20/2002	07/28/2002	07/28/2002	07/28/2002	07/28/2002	07/28/2002	none								
Break Date F	none	02/10/2003	01/14/2003	none	none	none	none	none							
a after 11/19/1999 s.e.	19.49 1.50	20.37 1.55	20.00 1.58	21.13 1.59	20.55 1.62	41.93 2.39	34.20 1.94	34.71 2.17	33.21 2.31	43.23 3.68	33.26 2.48	18.77 2.22	36.16 2.04	19.34 1.49	4.36 3.45
a after Break Date B s.e.															23.98 2.55
a after Break Date D s.e.						26.41 2.85									
a after Break Date M s.e.										28.48 3.79					
a after Break Date L s.e.												31.09 2.78			
a after Break Date I s.e.	30.66 1.81	32.42 1.93	31.55 1.96	34.20 2.02	33.22 2.04	44.66 2.23									
a after Break Date F s.e.									41.49 2.95	47.47 4.02					
b s.e.	0.34 0.03	0.34 0.03	0.34 0.03	0.30 0.03	0.33 0.03	0.18 0.02	0.32 0.03	0.36 0.03	0.35 0.03	0.40 0.04	0.52 0.03	0.33 0.04	0.28 0.03	0.47 0.03	0.41 0.05

Table 2-IV continue (Time Slot 20:00)

	West	Genesse	Central	North	Mohawk Valley	Capital	Hudson Valley	Millwood	Dunwoodie	New York City	Long Island	Hydro Quebec	ISO New England	IMO	PJM
Break Date J	none	none	none	08/21/2000	none	none	none	none	none	none	none	none	none	none	none
Break Date H	08/08/2001	08/08/2001	08/08/2001	08/08/2001	08/08/2001	none	none	none	none	none	none	none	none	none	none
a after 11/19/1999 s.e.	<u>-4.03</u> 2.32	-3.18 2.28	-2.68 2.30	-0.30 2.42	-2.61 2.34	9.21 2.49	2.74 2.58	2.72 3.10	3.03 3.12	-1.00 4.23	25.67 2.95	2.22 2.24	7.21 3.13	<u>-4.47</u> 2.57	-4.87 4.05
a after Break Date J s.e.				-1.23 2.87											
a after Break Date H s.e.	0.72 2.41	1.43 2.40	1.79 2.42	3.75 2.51	2.16 2.48										
b s.e.	<u>1.00</u> 0.05	<u>0.99</u> 0.05	<u>0.96</u> 0.05	<u>0.92</u> 0.05	<u>0.95</u> 0.05	0.82 0.05	<u>0.93</u> 0.05	<u>0.97</u> 0.06	<u>0.97</u> 0.06	<u>1.09</u> 0.07	0.71 0.04	0.89 0.05	0.85 0.06	<u>1.08</u> 0.06	<u>1.02</u> 0.09

Table 3-i Detected Break Dates by Year for All the Time Slots (Year 2000)

Table 3 also shows the results brought by the multiple structural break test, due toBai and Perron (1998), through the sample period 11/19/1999 to 11/17/2004, but provides the other angle from Table 2. Not just for some selected time slots, Table 3 shows all the detected break dates. The table is split into i through vi by year. Breaks occurred in 2000 is reported in Table i; 2001 in Table ii; 2002 in Table iii; 2003 and 2004 in Table iv. In each table a break date detected with 5% significant level is indicated by bold characters. Otherwise, 10%. Underline indicates that the constant term decreased at the break date, meaning forward premium increased. In 2004 two breaks are detected, both of which are in IMO. To save space, they are reported within Table 3-iv with Italic figures. Each table has a note at the bottom.

Time Slot	West	Genesse	Central	North	Mohawk Valley	Capital	Hudson Valley	Millwood	Dunwoodi e	New York City	Long Island	Hydro Quebec	ISO New England	IMO	PJM
0															
1										09/06	09/06				
2	09/06	09/06	09/06	09/06	09/06			09/06	09/06	09/06	09/06		09/06		
3										09/06	09/08				
4										08/30	09/08				12/13
5											09/06				
6															
7															
8															
9	08/18	08/18	08/18	08/22	08/22			08/18	08/18	08/18	08/18			08/18	
10	08/15	08/15	08/15	08/15	08/15					08/31	08/31	08/22			
11	08/22	08/22	08/22	08/22	08/22						08/24	08/22		08/22	12/17
12	08/22	08/22	08/22	08/22	08/22										
13	08/22	08/22	08/22		08/22										12/17
14															12/17
15															
16															
17															
18	-					08/16									
19	08/21	09/06													
20				<u>08/21</u>											
21	08/22	08/22	<u>08/22</u>	08/22	08/22									08/22	
22	09/26	09/26	09/26	09/26	09/26										
23															

The blocked dates in Table 3-i are corresponding to Break Date A in the Table 2.

Table 3-ii continue (Year 2001)

Time Slot	West	Genesse	Central	North	Mohawk Valley	Capital	Hudson Valley	Millwood	Dunwoodi e	New York City	Long Island	Hydro Quebec	ISO New England	IMO	PJM
0	06/19	06/19	06/19	06/19	06/19							06/17			
1	06/05	06/05	06/05	06/05	06/05										
2															
3												01/20			
4			07/03	07/03	06/05							01/20			
5	-	-													
6	06/03										01/09				
7			_		-										
8			ļ	<u>05/05</u>											
9											<u>09/13</u>				
10						<u>09/24</u>						07/08			02/15
11		05/20	05/20	05/20	05/20	<u>08/13</u>					<u>09/13</u>	05/21	1		
12		<u>09/10</u>	09/10		<u>09/10</u>	<u>09/10</u>									
13	<u>09/10</u>	<u>05/19</u>	<u>05/19</u>				<u>09/10</u>	<u>09/10</u>		<u>08/21</u>					
14						<u>08/08</u>				<u>09/10</u>					
15						<u>09/09</u>								07/08	
16										_					
17										ļ	<u>08/31</u>	l			
18						<u>05/13</u>			<u>05/12</u>		<u>09/10</u>				
19	08/07	08/07													07/22
20	08/08	08/08	08/08	08/08	08/08										
21	07/03	07/03	07/03	07/03	07/03									07/03	07/03
22											<u>09/10</u>		<u>04/07</u>		
23															

In Table 3-ii, the dates blocked by a solid line are corresponding to Break Date H in the Table 2. Similarly, the dates blocked by a dotted line are Break Date D. The most of the underlined but unblocked dates are consistent with the September 11 attacks.

Table 3-iii continue (Year 2002)

Time Slot	West	Genesse	Central	North	Mohawk Valley	Capital	Hudson Valley	Millwood	Dunwood ie	New York City	Long Island	Hydro Quebec	ISO New England	IMO	PJM
0						08/11	08/11	06/12	06/12	06/11	06/24				
1						 I									
2	07/02	08/11	08/11	08/11	08/11				08/10	06/19					
3	08/12			08/12						06/21					
4															
5															
6	<u>12/19</u>					<u>12/19</u>	<u>12/19</u>				<u>02/06</u>				
7								-							
8		09/29	09/29	09/29	09/29			10/23	10/09						
9	09/13			09/13	09/13										
10	09/12	09/12	09/12	09/12	09/12	09/14	09/14								
11	09/03	09/03	09/03	09/03	09/03	10/09	09/14	10/09	10/09			07/17			
12	09/12	09/12	09/12	09/11	09/12	09/14	09/14	09/14	09/14			07/17			
13	06/20	07/17	07/17	07/17	07/17							06/20			
14	07/20	07/28	07/28	07/28	07/28	07/28						06/20			
15	06/30	06/30	06/30	06/30	06/30	06/26						06/30			
16	07/28	07/28	07/28	07/28	07/28							06/24			
17	07/28	07/28	07/28	07/28	07/28						06/25				
18						09/29					06/26				
19															
20															
21															
22										06/21	06/24				
23										06/21					

The blocked dates by dark solid line in Table 3-ii are corresponding to Break Date E in the Table 2. Similarly, light solid line are Break Date I, and dotted line are Break Date C.

Table 3-iv continue (Year 2003 and 2004)

Time Slot	West	Genesse	Central	North	Mohawk Valley	Capital	Hudson Valley	Millwood	Dunwood ie	New York City	Long Island	Hydro Quebec	ISO New England	IMO	PJM
0															
1															
2														10/04	
3															
4										01/13					
5										-					
6											<u>01/28</u>				
7								1		r					
8							01/17				01/14	01/12		02/23	
9															
10							<u>06/20</u>								
11								<u>08/24</u>	<u>08/24</u>	01/08	01/15			01/08	
12						04/47	04/47	04/47	04/47	01/09					
13						01/17	01/17	01/17	01/17	01/04					
14									02/10	01/14					
15															
10												10/25		10/25	
10	01/16	01/16	01/16	01/16	01/16				01/16			01/10		10/25	
10	01/10	01/10	01/10	07/21	01/10				01/10			01/10			
20				07721											
21												11/10			
22	01/15	1	01/15	01/15	01/15	01/15	01/15	01/15	01/15			11/10	01/14	01/14	
	00		51,10		00		0.1.0	0.1.0	5.,.5					04/01/08	
23	01/15	1										02/06		04/01/17	

The blocked dates in Table 3-iv are corresponding to Break Date F in the Table 2.

Table 4. Summary of the Results from the Bai-Perron Test

The Number of All the Detected Breaks shows the number of detected breaks throughout the time slots and zones. The Number of Consistent Break Date (Excluding Break Date D) shows the number of breaks whose date is consistent with the PRL programs or the EET agreements and also at which a forward premium decreased. The next category also shows the number of consistent breaks but including Break Date D.

	West Super Zone	East Super Zone	NYC-LongIL Super Zone	Neighbor Super Zone	All Zones
The Number of All the Detected Breaks	145	50	40	40	275
The Number of Consistent Break Dates (Excluding Break Date D)	109	21	14	12	156
percentage	75.2	42.0	35.0	30.0	56.7
The Number of Consistent Break Dates (Including Break Date D)	116	25	16	13	170
percentage	80.0	50.0	40.0	32.5	61.8



Figure 2. The Mean of RT Prices, That of DA Prices, and the Difference of Them, Split by the Detected Break Dates, for West Super Zone (Time Slot 11:00)

