



# Electricity Financial Transmission Rights as Hedging Instruments

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# Outline

1. Introduction:
  1. Transmission costs in an LMP system
  2. Transmission Rights
  3. PTP FTRs
  4. Motivation to study markets of PTP FTRs
2. Observations of market performance from NY ISO and PJM
3. Calculating the fair value of an FTR
  1. Derivation of a formula for the fair value of risk reduction
  2. The fair value of a premium in a FTR
  3. Can we validate the model for the theoretical value of the FTR with data from FTR markets
- Conclusions



# Outline

1. Introduction:
  1. Transmission costs in an LMP system



# Introduction: LMP

Most of restructured electricity markets in the U.S. include an LMP system

In this markets a consolidated authority:

- Collects offers from generators and bids from loads
- Finds the optimal (most economic) production schedule for each supplier, given the transmission constraints on the grid
- Calculates the Locational Marginal Price (LMP) for each node
- Charges loads and pays generators the LMP at their node

**The LMP at any location:**

Is the incremental cost of serving and additional 1 MW of load given the actual dispatch, security constraints, and bids



# Introduction: Transmission Congestion

- The extra cost of scheduling an out-of-merit order generator to supply electricity is the main source of transmission costs
- If there were no transmission congestion, nor transmission losses, then the LMP at every node would be equal
- With transmission congestion however it is often the case that prices at the nodes of electricity withdrawal are higher than prices at the nodes of electricity injection
- In grid systems with parallel flows even one single line constrained can cause LMPs to differ at many nodes
  - Transmission congestion costs are given by differences in LMPs



# Introduction: Payments for transmission congestion

- Bilateral trades are charged a congestion cost based on the difference in LMPs between the point of injection of electricity and the point of withdrawal
- Participants in the spot market also pay transmission costs, because they buy and sell at the LMP prices which already include the effects of congestion
- Congestion charges represent an important part of electricity price
  - Example: PJM → 9% of total billing in 2002, 7% of total billing in 2003
- Congestion charges exhibit high variability
  - *“Differences in monthly congestion continued to be substantial in 2003. These differences were driven by loop flows, varying load and energy import levels, different patterns of generation, weather induced changes in demand and variations in congestion frequency on constraints affecting large portions of PJM load”* (State of the Market 2003, PJM)

# Outline

1. Introduction:
  1. Transmission costs in an LMP system
  2. **Transmission Rights**



# There are different types of transmission rights

According to its relationship with the dispatch process, transmission rights can be

- Physical Rights
  - In the real system the definition of physical rights do not work because of market power issues, and inefficiencies in the use of the grid and generating resources
- Financial Rights
  - Link based / Flow Based / Flow gates
  - Point to point



# Financial Rights: Flowgate financial rights

Associated with a transmission line. The payment is equal to the shadow price of the congestion of that line

## Advantages:

- Can be defined independently on the power flow patterns
- Only congested links require the definition of an FGR. Theoretically there should be a small number of FGRs to trade and this would ensure liquidity of the market

## Disadvantages:

- Flowgates are difficult to identify: It is difficult to forecast which constraints will be binding
- Flowgates are not always the same: there are changing capacity limits on the lines. (Capacity means more than idealized thermal limit. For example if there are contingencies)
- There are many more flowgates than expected. (Active constraints in PJM in 2000: more than 150)
  - A market participant would have to buy 150 flowgate rights to secure a single point-to-point transaction



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  3. **PTP FTRs**



# Point-to-Point Financial Transmission Rights (FTR)

Used in several markets in the U.S:

- PJM (Since 1998)
- NYISO (Since 1999)
- ISO-NE (since 2003)
- MISO (also flowgate rights, options and obligations)

Key part of FERC's Standard Market Design Proposal

Notice of Proposed Rulemaking of August 2002:

*“Remedying Undue Discrimination Through Open Access Transmission Service and Standard Electricity Market Design” (67 Fed. Reg. 55,452)*

# Point-to-Point Obligation Financial Transmission Rights (FTR)

In this talk:

FTR = Point-to-point Obligation Financial Transmission Right

FTR: Gives the “right” to collect (or pay) the difference in LMP between the sink and the source during the period the FTR is defined for

Example:

- An FTR for Source A and Sink B for 1 MW, for the On-peak hours of October 2003 gave the holder the right to collect:

$$FTR_{A,B}^{october} = \sum_{i=1}^{375} LMP_B^i - LMP_A^i$$

Day ahead LMP



# FTR

- FTRs represent both a right and a liability
- Holders of FTRs have the right to get from the ISO the difference in LMP when it is positive, but have also the obligation to pay the ISO when this difference is negative
- Nothing guarantees that the revenue of an FTR will be positive. (Signs of FTR price and rents might be different)
- FTR holders do not need to deliver energy to receive FTR revenues
- FTRs do not represent a right for the physical delivery of power

# FTRs as Hedging Instruments

- FTRs can provide an exact financial hedge to transmission customers
  - Example: A market participant schedules a power transaction that consists of injecting 1MW at point A and withdrawing 1 MW at point B during every peak hour of October. In this case a 1MW  $FTR_{A,B}^{october}$  will provide an exact hedge against congestion charges
  - The price paid for  $FTR_{A,B}^{october}$  is the entire amount paid for congestions costs
- In general FTRs that produce negative rents are sold at a negative price. Is as if market participants who schedule transactions that create counter flow on congested lines are paid in advance for this service



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  3. PTP FTRs
  4. **Motivation to study markets of PTP FTRs**

# Motivation

If PTP FTRs are the paradigm for managing transmission congestion then it is worth to ask:

- How well do PTP-FTR markets perform?
- What can we learn from the recent experience of the markets that have implemented PTP FTRs?

Also:

- There are proposals to treat “Incremental Financial Transmission Rights” as the right incentive to encourage merchant transmission investment
- Proposed tests to draw the line between “market based” and “regulation mandated” transmission investment implicitly assume that there is a way to accurately value those “Incremental Financial Transmission Rights” associated to a grid expansion or update

So it is also worth asking:

- What can we learn about **valuing** FTRs?





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# FTR Markets

## NY ISO

- The holders of historical entitlements to firm transmission capacity are allocated Transmission Congestion Contracts (TCC) for the same paths, quantities and terms so their economic position is unaffected. TCCs corresponding to the remaining transmission capability of the network are allocated to transmission owners.
- All holders of TCCs can offer them for sale in the auctions organized by the ISO
- Long term TCCs for six months, one year, two year and five years are auctioned in several rounds. Monthly TCCs are sold in monthly auctions

# FTR Markets

## PJM

- Assigination of the rights to the auction revenues collected for the sale of the specific FTRs
- Auction Revenue Rights (ARR) are characterized in the same way that FTRs are, specifying a source, a sink and a number of MW. Market participants can present their requirements for ARRs that sink in the nodes where they serve load, and for an amount up to the quantity of the load served
- ARRs are allocated before the annual FTR auction but can be redistributed as LSE gain or lose load during the year



# Simultaneous Feasibility Test and Proration

Both in PJM and NYISO, the number/type of FTRs available is determined by running a *Simultaneous Feasibility Test* that guarantees that all the potential energy flows represented by the FTRs are simultaneously feasible

Sometimes, there are discrepancies between the \$\$ collected for congestion charges and the \$\$ that FTR holders are entitled to receive

All positive differences go to an “FTR fund” to offset any monthly deficiencies. If at the end of the year, there is a net congestion deficiency (the ISO has to pay more for FTRs than what it collected from Congestion charges) then the revenues of FTR holders are prorated.

→ In 2003 in PJM FTRs were paid at 96% of their target allocation. 20



# How well do PTP FTR Systems Perform?

Two papers that look at the results of FTRs auctions in NYISO conclude this market is inefficient:

Siddiqui et al (2003)

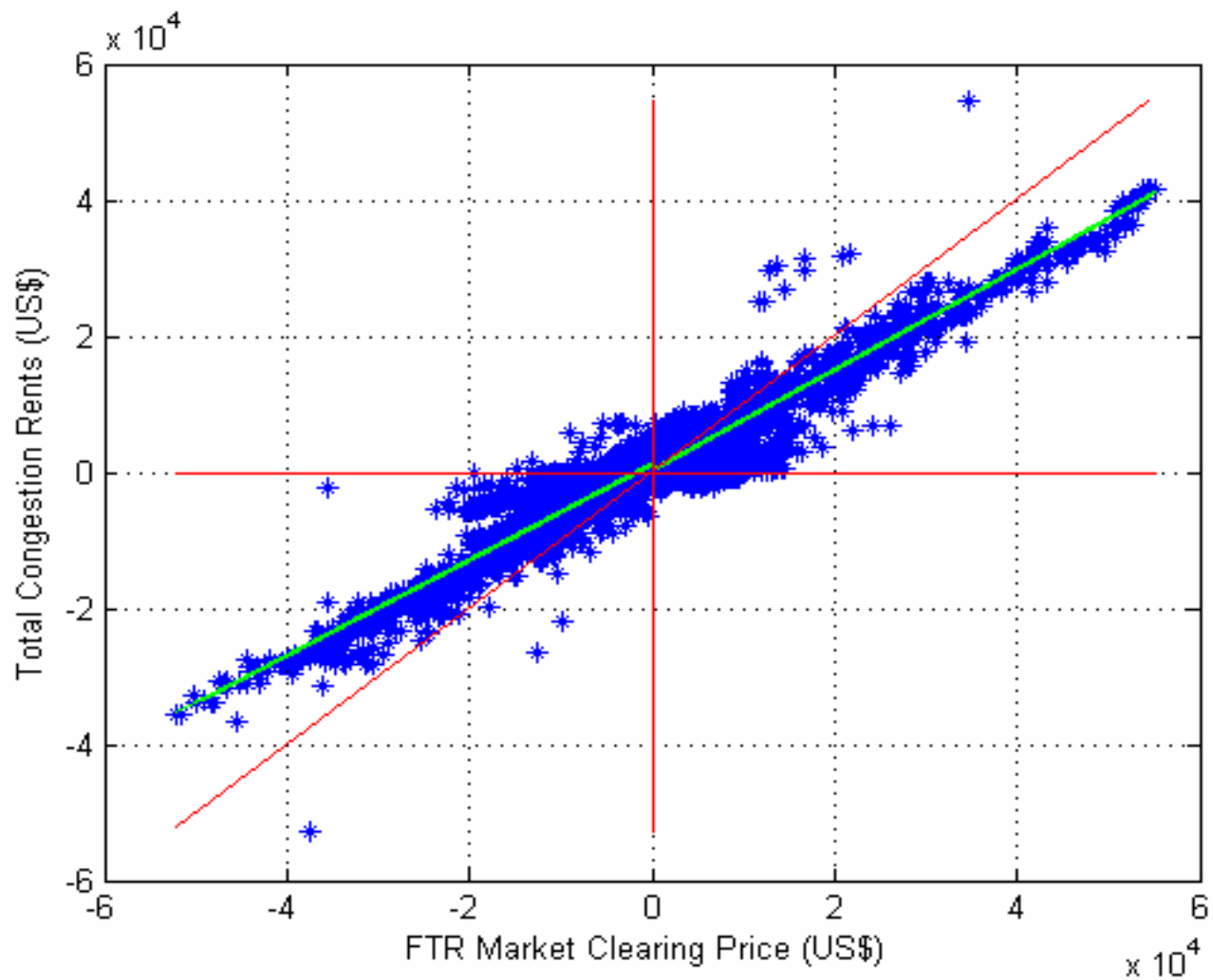
- Studied all rounds of six-month FTRs auctions in NY ISO 2000-2001
- Compared the price paid for each FTR with the rents received
- FTR auctions are highly inefficient because market participants are unable to discover forward LMP
- The illiquidity of this market, in which few market participants bid for an FTR for the same path, makes difficult price discovery of these rights
- Are results due to novelty of the market and the inexperience of the participants, or are evidence of risk aversion?

# How well do PTP FTR Systems Perform? (cont)

Adamson & Englander (2004)

- Studied one-month FTRs traded in 50 monthly auctions from 1998-2003
- Predict the auction clearing price of the one-month FTR on the basis of the historical information of spot prices and volatilities
- FTR price = linear function of the mean and the squared variance of the data on historical congestion charges
- Predicted mean of congestion rents is far from price paid for TCCs, even after accounting for the variance of such congestion rents → there are high inefficiencies in the FTR market

# One-year Buy Obligation FTRs- PJM Annual Auction (2003-2004)





# Results Interpretation (1)

- Market participants who forecast high congestion in the direction source to sink are willing to pay a premium to hedge against the risk in high CC, and end up paying more for the FTR than what they would have paid otherwise
- The market participants who buy the FTR at a negative price, act as speculators
- The transactions in which FTRs are purchased at a negative price can be seen as a way in which generators sell forward the congestion management service





# How well do PTP FTR Systems Perform?

Discrepancies in the price of the FTR and Congestion Costs cannot be used as a proof of market inefficiency

Because FTRs are hedging instruments, a difference between the FTR price and congestion costs is expected. Such a difference is the “premium” and its magnitude depends on the volatilities of the congestion costs

To examine if there are inefficiencies in the PTP FTR market, we need to find a “fair value” of the FTRs to compare to the actual FTR prices paid in auctions

Objective:

To find the fair value of an FTR

Advances:

We found a formula for the fair value of the risk premium



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  1. Derivation of a formula for the fair value of risk reduction



# Options theory and the fair value of the FTR premium

- Although FTRs are not options, options theory can be used to calculate the fair value of the risk reduction that FTRs imply vs. the congestion costs
- In 1973 Black and Scholes derived a general equation to value claims contingent on a traded underlying stock. By applying the appropriate boundary conditions, the equation can be solved to price any such contingent claim
- This formula does not depend on any assumption about the risk preferences of investors
- Options theory has been useful for valuing other contracts in which there is some risk reduction involved, for example insurance premiums



# Options theory and the fair value of the FTR premium

Black and Scholes differential equation:

- Derived from an imaginary portfolio that is assumed to have a known value and return rate as a risk-free portfolio

Our formula for the FTR premium:

- Derived from two portfolios that have same value and return rate:
  - Portfolio with the derivative (the premium for risk reduction) and the FTR
  - Portfolio made of the underlying asset (congestion charges)

# Calculating the value of risk reduction

- P: price paid for the FTR
- C: congestion charges this FTR hedges against
- P-C: Premium of the FTR

- Assume 
$$\frac{dC(t)}{C(t)} = \alpha(C)dt + \sigma dz \quad (\text{Eq.1})$$

- $H(C, P)$ 
  - function that represents the “option of paying P instead of C”
  - First-degree homogeneous function (constant returns to scale) so

$$H(\lambda C, \lambda P) = \lambda H(C, P)$$

- For Euler’s theorem has the general form:

$$H(C, P) = P \frac{\partial H(C, P)}{\partial P} + C \frac{\partial H(C, P)}{\partial C} \quad (\text{Eq.2})$$

$$\longrightarrow \frac{\partial H}{\partial C} > 0$$

$$\longrightarrow \frac{\partial H}{\partial P} < 0$$

$$\Pi_c = C \frac{\partial H}{\partial C}$$

# Calculating the value of risk reduction

- Define two portfolios:

$$\Pi_c = C \frac{\partial H}{\partial C}$$

$$\Pi_p = H - P \frac{\partial H}{\partial P}$$

- With instantaneous returns

$$d\Pi_c = \frac{\partial H}{\partial C} dC \quad (\text{Eq.3})$$

$$d\Pi_p = dH - \frac{\partial H}{\partial P} dP \quad (\text{Eq.4})$$

# Calculating the value of risk reduction

- Risk neutrality implies that  $H(C,P)$  is such that both portfolios represent the same risk

- Portfolios are identical in value  $\rightarrow \Pi_C = \Pi_P$

- Instantaneous returns are identical  $\rightarrow d\Pi_C = d\Pi_P$

- From (3) and (4)  $\rightarrow dH = \frac{\partial H}{\partial P} dP + \frac{\partial H}{\partial C} dC$  (Eq.5)



# Calculating the value of risk reduction

- The fact that  $H(C, P)$  is a function of the stochastic variable  $C$  that follows the process we assumed in (1)

Implies that: 
$$dH = \frac{\partial H}{\partial t} dt + \frac{\partial H}{\partial P} dP + \frac{\partial H}{\partial C} dC + \frac{\sigma^2 C^2}{2} \frac{\partial^2 H}{\partial C^2} dt \quad (\text{Eq.6})$$

- From (5) and (6) we get:

$$0 = \frac{\partial H}{\partial t} + \frac{\sigma^2 C^2}{2} \frac{\partial^2 H}{\partial C^2} \quad (\text{Eq.7})$$



# Calculating the value of risk reduction

Two boundary conditions needed to solve (Eq.7) are given by:

- There is no value in the transaction if the congestion costs are zero

$$H(C, P, \sigma; t) \Big|_{C=0} = 0$$

- In the limit where the uncertainty vanishes, there is no value in paying a fixed price  $P$  except if it is smaller than the cost  $C$

$$H(C, P, T) \Big|_{\sigma=0} = \text{Max}[0, C - P]$$

# Calculating the value of risk reduction

The solution to 7 satisfying these boundary conditions has been derived in classical papers:

$$H(C, P, T) = C \Phi \left( d_1 \left( \frac{C}{P}, T \right) \right) - P \Phi \left( d_2 \left( \frac{C}{P}, T \right) \right) \quad (\text{Eq.8})$$

$T = \sigma^2 t$  : cumulative uncertainty over the period considered

$$d_1(x, T) = \frac{1}{\sqrt{2T}} \left[ \text{Log}(x) + \frac{T}{2} \right] \quad (\text{Eq.9a})$$

$$d_2(x, T) = \frac{1}{\sqrt{2T}} \left[ \text{Log}(x) - \frac{T}{2} \right] \quad (\text{Eq.9b})$$

$$\Phi(d) = \frac{1}{\sqrt{\pi}} \int_{-\infty}^d e^{-\eta^2} d\eta \quad (\text{Eq.9c})$$

# Calculating the value of risk reduction

$H(C,P)$  measures the value of reducing the risk associated with the volatility of  $C$  by paying a fixed price  $P$

$$\frac{\partial H}{\partial T} = \frac{C}{2\sqrt{2T}} e^{-d_1^2} \quad \text{is always positive}$$

→

The larger the cumulative uncertainty  $T$ , the larger the value of hedging against that risk

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# Calculating the fair value of the premium

If the FTR reduces the risk of having to pay a high volatile cost  $C$ , then its selling price  $P$  must exceed the expected value of  $C$  by a premium

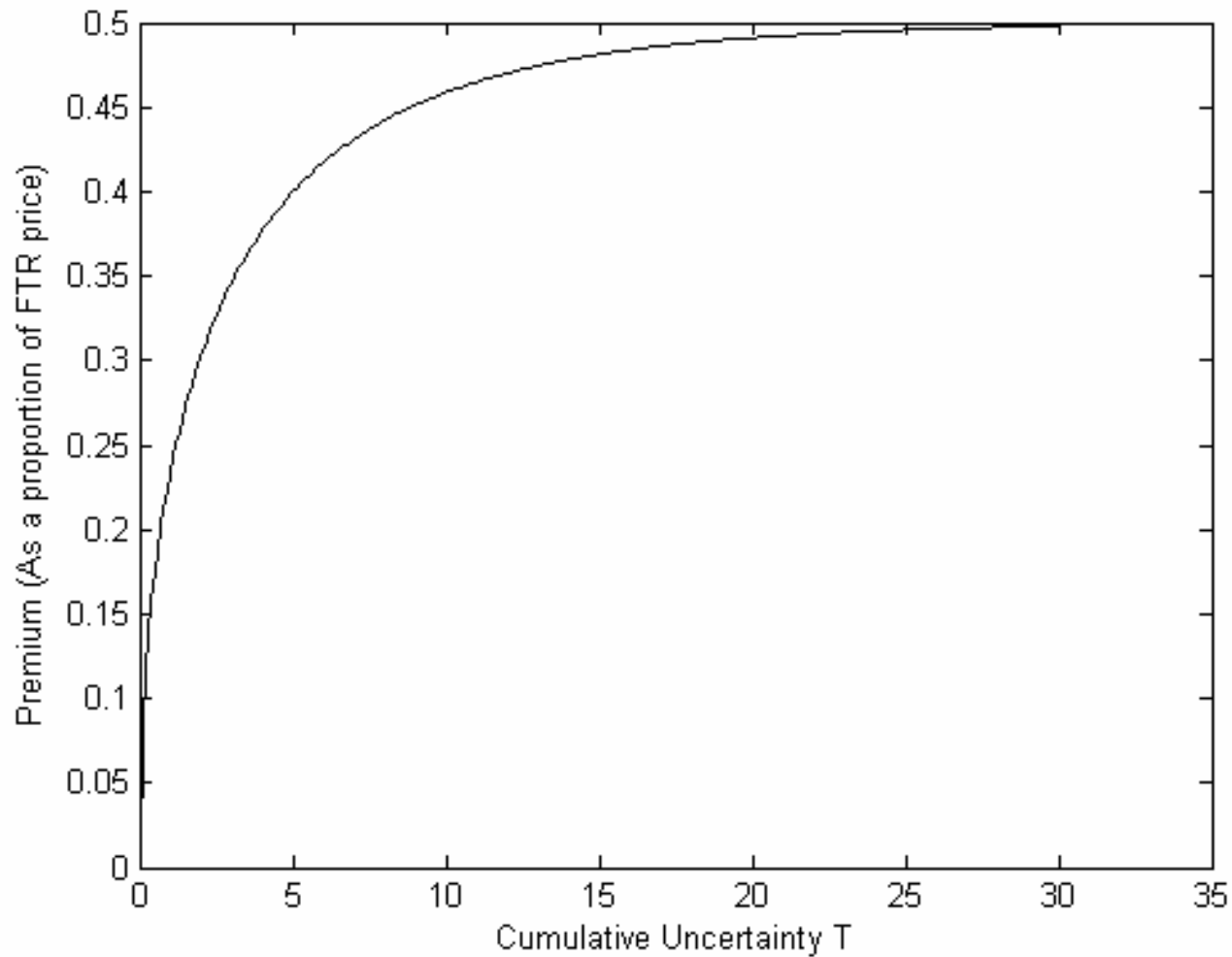
The “fair value” for this premium is the risk neutral value of the option of paying the fixed price  $P$  instead of  $C$

$$\begin{array}{l} \downarrow \\ \rightarrow \end{array} \quad H = P - C$$

$$P - C = C \Phi\left(d_1\left(\frac{C}{P}, T\right)\right) - P \Phi\left(d_2\left(\frac{C}{P}, T\right)\right) \quad (\text{Eq.10})$$

$$1 - x = x \Phi(d_1(x, T)) - \Phi(d_2(x, T)) \quad (\text{Eq.11})$$

# The fair value of the premium



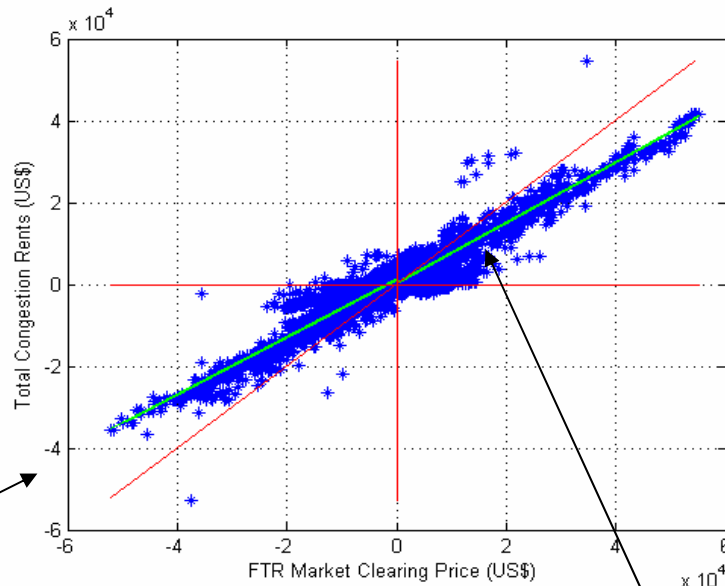


# The fair value of the premium for FTRs

- There is evidence that FTRs hedgers pay a premium for the reduction of the risk this instrument provides
- Given the uncertainty on the total congestion cost over the period of time covered by the FTR, EQ.10 “predicts” what on average that premium should be. The observed values of the premium paid and received by FTR buyers should be distributed around this expected value
- How does the model fit with actual data?
  - Limitation: There is no data to calculate  $T$ 
    - To estimate  $T$  for annual congestion costs we need many years worth of data. FTR markets have operated for only a few years
    - Even if we had  $T$  for many years, the pattern of congestions changes with changes of the grid
    - Hourly data can be useful to find an approximation but is not a substitute

# The fair value of the premium for FTRs

- We can explore what the average value of T should be, in PJM given the observed average of premium paid



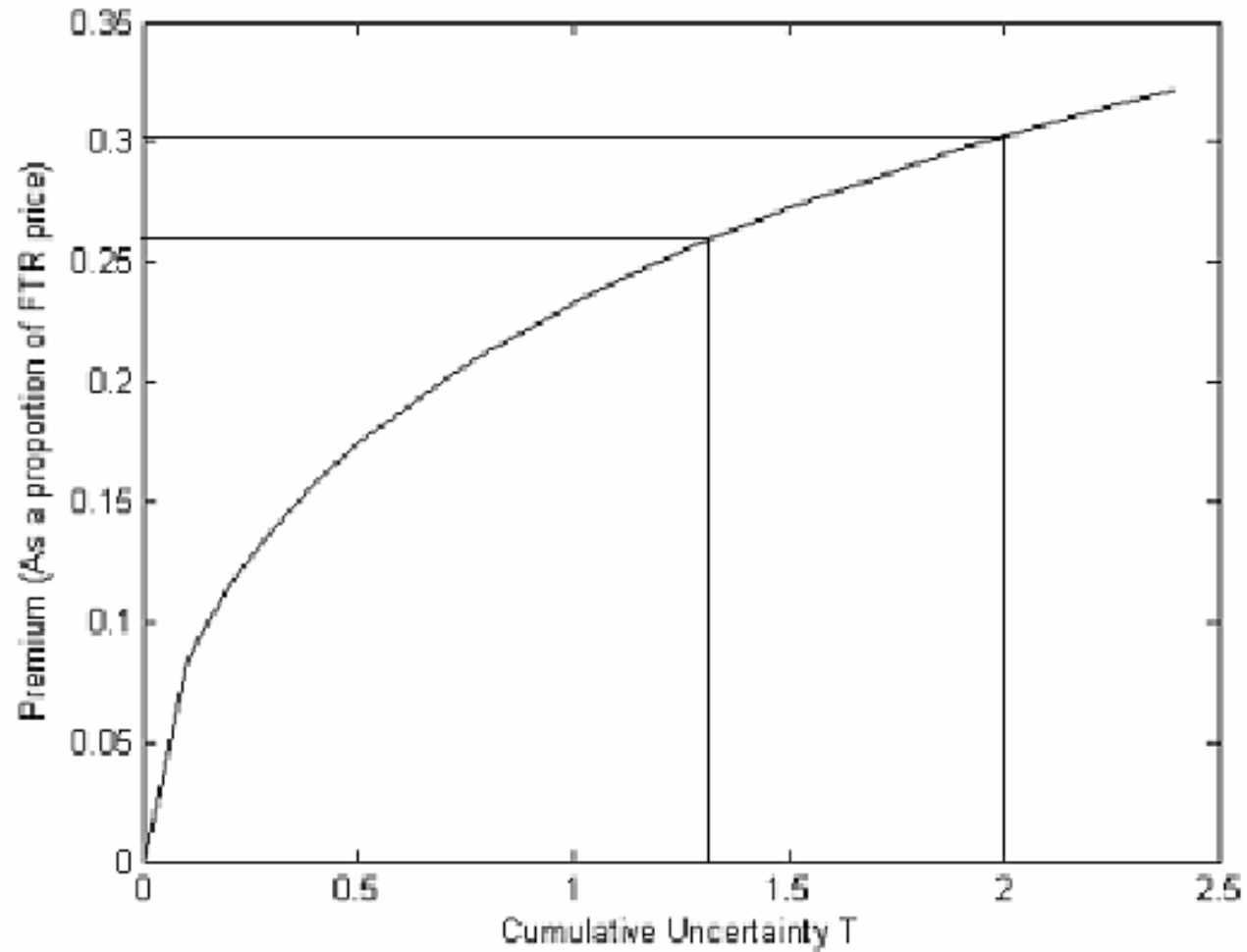
Average premium  
for FTRs sold at a  
positive price is  
 $0.26 = (1-0.74)$

Average premium  
for FTRs sold at a  
negative price is  
 $0.3 = (1-0.7)$

MSE lines  
represent the  
average  
relationship  
between C and P



# Calculating the fair value of the premium



# Conclusions

- Given the size and nature of the uncertainty, and given the fact that auctions select those whose willingness to pay is the highest →
  - The apparent risk aversion displayed by the market participants may correspond to a rational level of hedging on their part
  - The value paid for FTRs may reflect their fair value
- The argument that market participants are paying a premium for their hedge does not exclude the possibility that market inefficiency explains part of the difference between the price paid for FTRs and the congestion charges covered
  - There are no strong arbitrage forces in the FTR market because only a small number of market participants are interested in the same FTR



# Conclusions

We cannot say that FTR markets are inefficient based on a comparison of prices and congestion rents

However other questions remain:

- What are the attributes of an FTR system that matter?
- How does periodicity of the auctions impact the “efficiency” of the FTR market?
- What is the impact of the participation of pure financial speculators in the FTR system?
- How does the FTR system contribute to the competitiveness of the market?
- Are FTRs prices good values to be used as incentives for investments in transmission infrastructure?



Thank you!

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