Agent-based system planning tools

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Jan. 29, 2004

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Goals

Good designs of complex artifacts cannot be obtained without good measures of performance, and good tools for synthesis, analysis, simulation and especially, verification. Our goals are:

1. **a suite of agent-based tools for the simulation and verification of market designs.**
2. **new performance measures for market designs (traditional measures, such as HHI, are inadequate).**
3. **insights and guidelines for market designs.**

Why software-agent-based tools?

1. **Fidelity.**
   Actual markets contain autonomous agents: sellers, ISOs, buyers, …. Autonomous software agents are needed to model their interactions.

2. **Packaging.**
   Autonomous agents are convenient packaging devices. They make it possible to write modular, robust and expandable software.

3. **Efficiency.**
   Experimental work is easier with software agents than human agents

Tools for the conceptual design of quasi-repetitive auctions, such as day-ahead and hour-ahead auctions

Work done at CMU

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What do we need to include in our models?

Markets seek balances between the needs of sellers and buyers. These balances emerge as a result of:

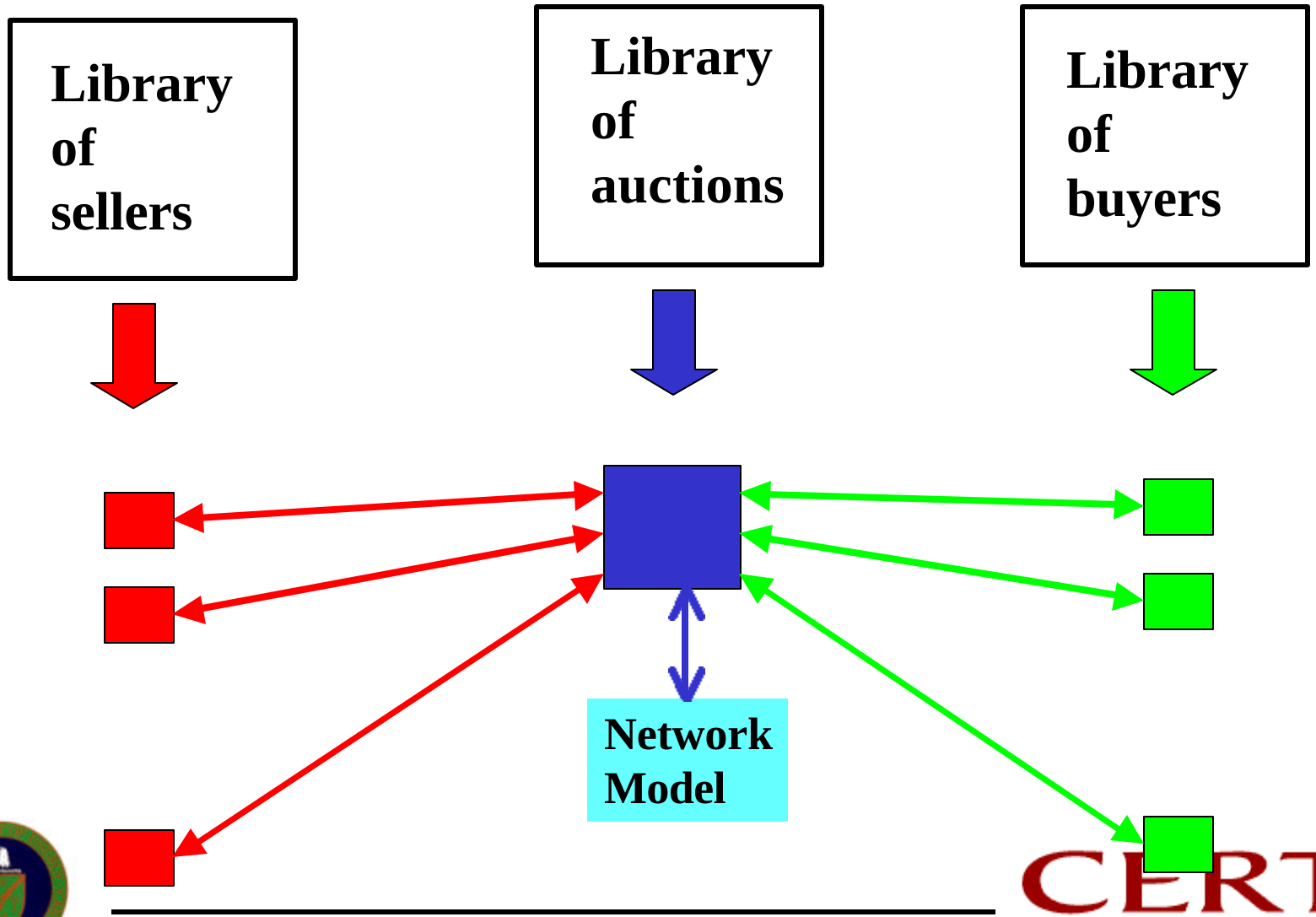
- **Competition**
- **Cooperation**
- **Learning**
- **Spatial and temporal distributions (network conditions)**

What do we want market designs to achieve?

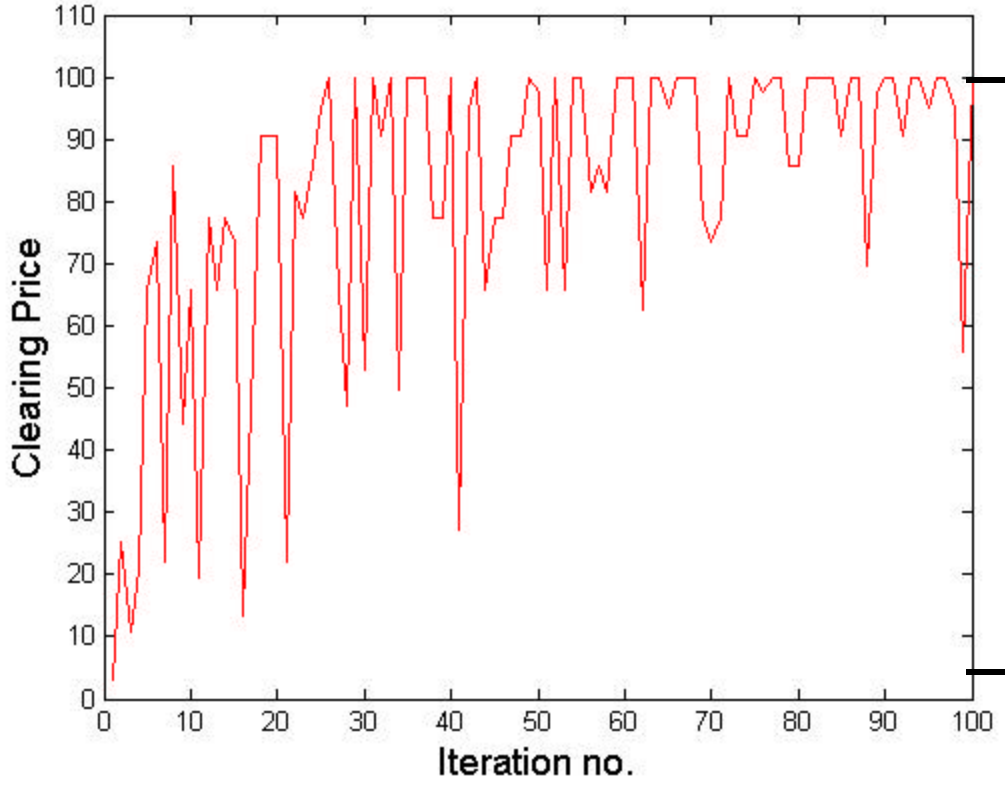
In a multi-agent-system that is distributed in space and time, we want:

Local optimality → global optimality

THE SIMULATOR



Intelligent sellers and fixed demand



Monopolistic Price

Competitive Price

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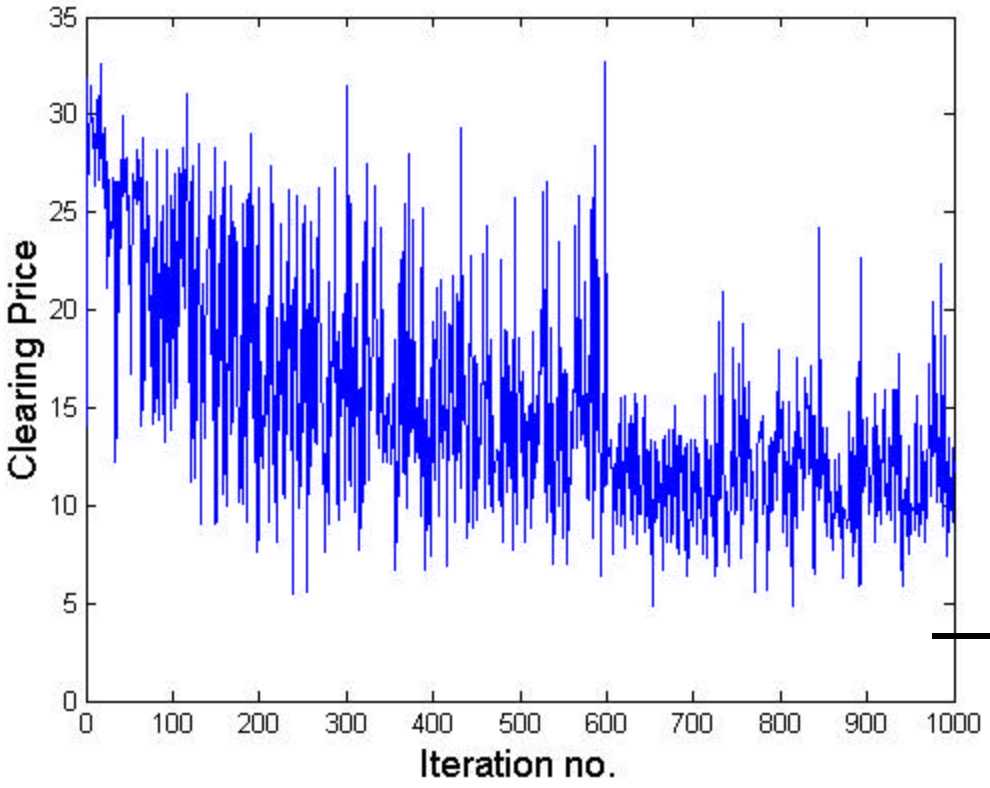
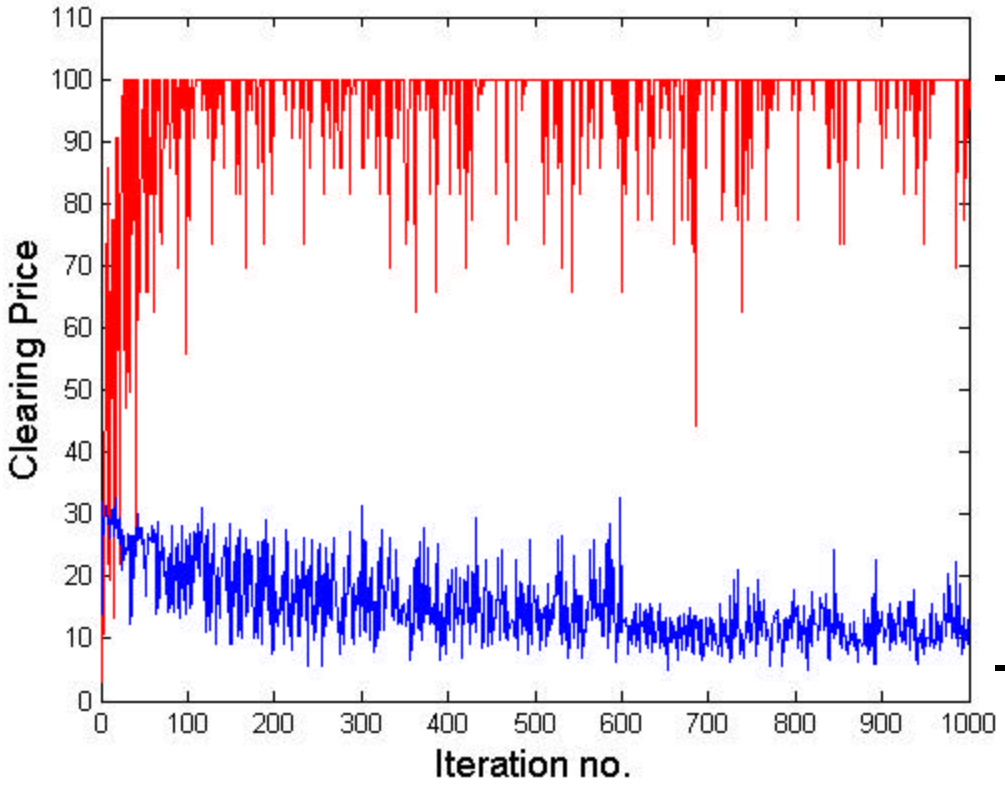
Intelligent sellers and intelligent buyers



Competitive Price

Intelligent sellers and fixed demand

Intelligent sellers and intelligent buyers



Monopolistic Price

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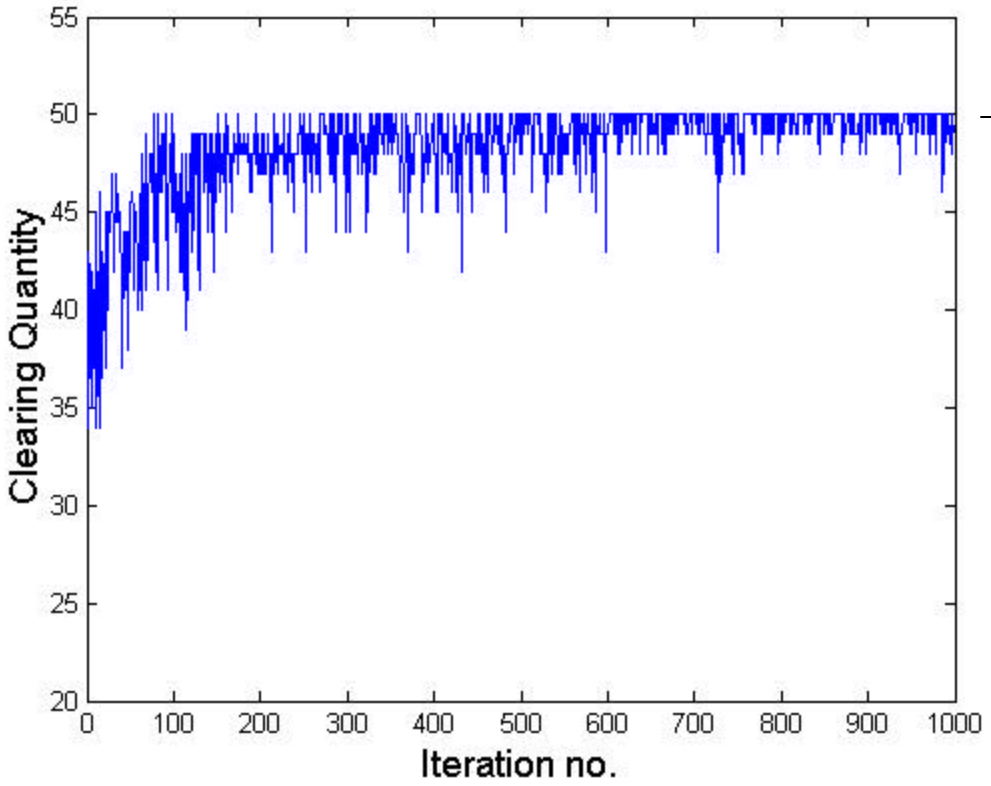
Intelligent sellers and intelligent buyers



Desired Quantity

Insights

1. **Intelligent sellers and passive buyers with fixed or elastic demands**
   - **Sellers Maximize (profit) → Competitive Price**
   - **Sellers Maximize (profit + price) → Monopolistic Price**

2. **Intelligent buyers → Competitive Price**

Elastic (price-sensitive) demand is not enough. To drive prices down to competitive levels requires intelligent buyers capable of learning (adjusting their buying strategies).

Learning ⟷ collusion among the sellers

Two new performance measures for quasi-repetitive markets

1. P_L/P_M : the ratio of the price-with-agent-learning to the monopolistic price

2. P_L/P_C : the ratio of the price-with-agent-learning to the competitive price

The performance of quasi-repetitive markets is critically affected by agent-learning. Measures that do not take learning into account cannot be good indicators of actual performance.

N-ABLE: a simulator for the detailed evaluation of real-time pricing effects on Transco load, pricing and profitability

Work done at Sandia

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Research

- Investigate potential effects of residential real-time price contracts on power system loads, prices, and stability
  - Formulate model of residential power usage and its re-scheduling under RTP contracts
  - Formulate model of Transcos that sell both uniform and RTP contracts
  - Run agent-based simulations based on different contract and consumption scenarios

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Model of Residential Power Consumption

- ***Desired*** **hourly household power consumption is the sum of**
  - **Immovable use - e.g., heating, A/C**
  - **Movable use - e.g., washers, dryers**
  - **Optional use - e.g., lighting**

$$\hat{\mathbf{E}}_{\mathbf{i}}^{\mathbf{h}} = \left[\hat{e}_i^{h,1} \quad \hat{e}_i^{h,2} \quad \ldots \quad \hat{e}_i^{h,24}\right]$$

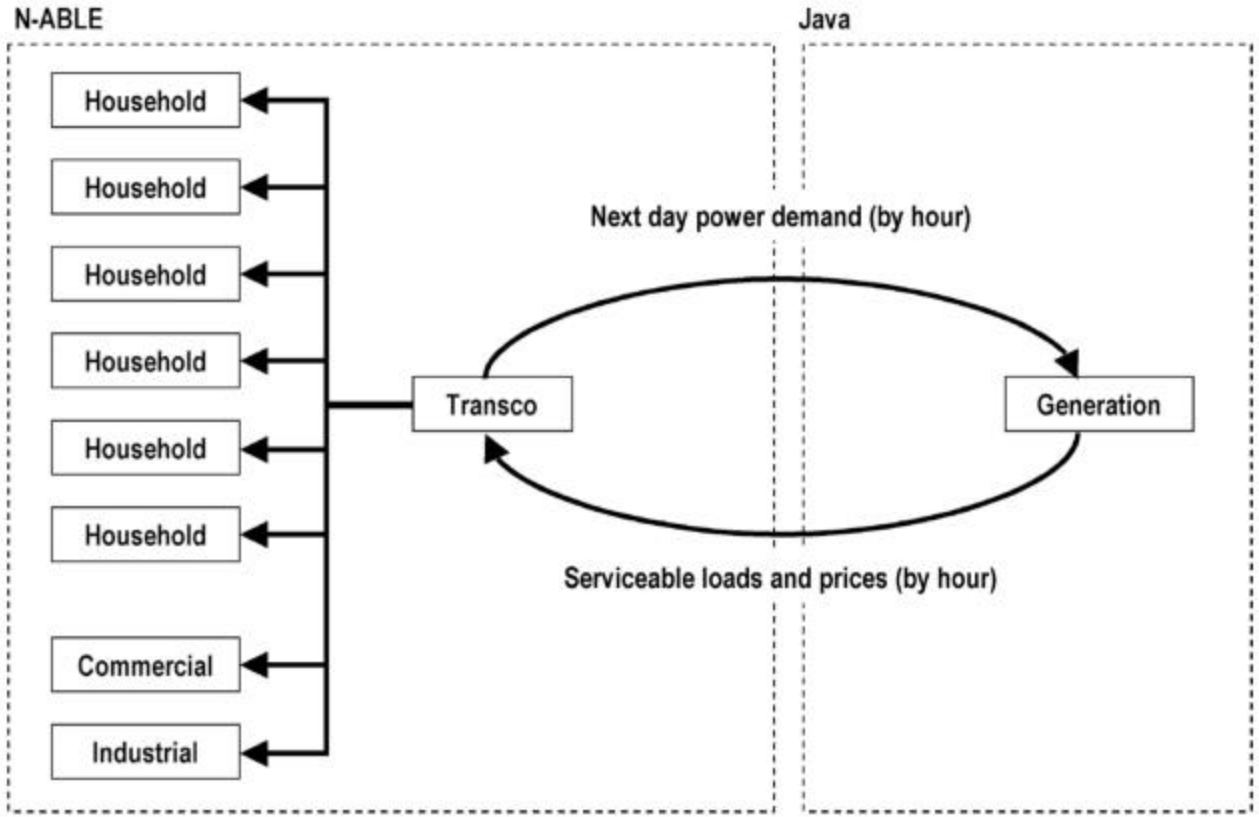
$$\hat{\mathbf{E}}_{\mathbf{m}}^{\mathbf{h}} = \left[\hat{e}_m^{h,1} \quad \hat{e}_m^{h,2} \quad \ldots \quad \hat{e}_m^{h,24}\right]$$

$$\hat{\mathbf{E}}_{\mathbf{o}}^{\mathbf{h}} = \left[\hat{e}_o^{h,1} \quad \hat{e}_o^{h,2} \quad \ldots \quad \hat{e}_o^{h,24}\right]$$

Rescheduling Power Consumption

- Under uniform contracts, households use desired levels.
- Under RTP contracts, some households will reschedule moveable and optional usage, based on
  - **Hourly RTP price distribution,**
  - **Personal monthly/daily budget for power expenses, and**
  - **Inconvenience caused by rescheduling their usage.**
  - **The fraction of households that are very frugal will also discard optional use.**

Simulation Model



Baseline Industry Data

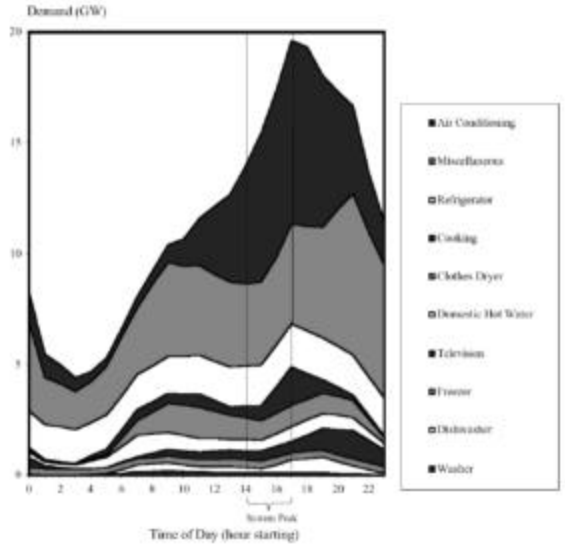
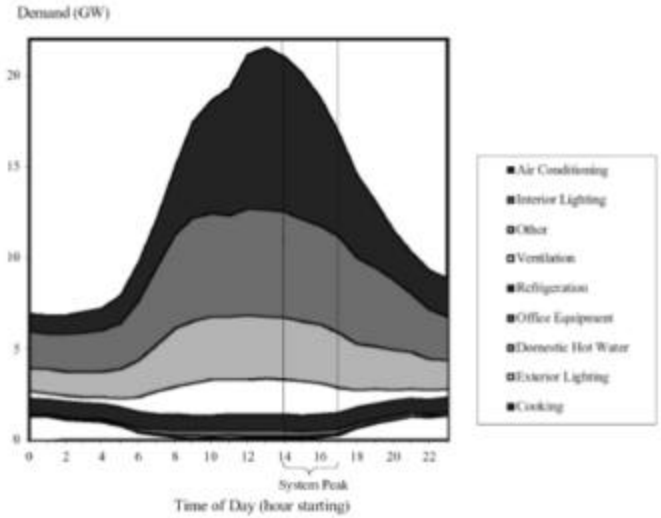


Figure 3: Household Hourly Use Profile (from Bro



se Profile (from Brown and Koomey[6])

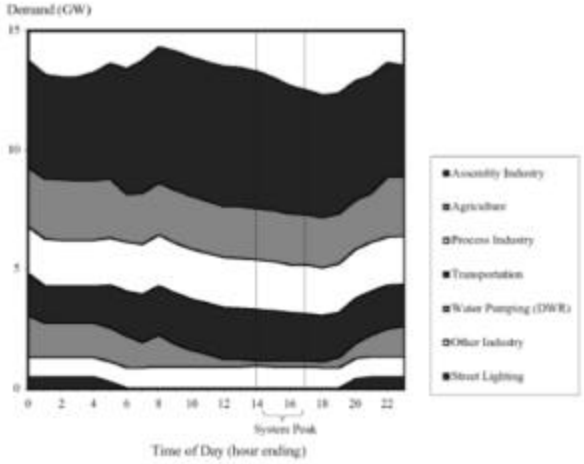


Figure 5: Industrial Hourly Use Profile (from Brown and Koomey[6])

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Results: system usage under uniform-only contracts

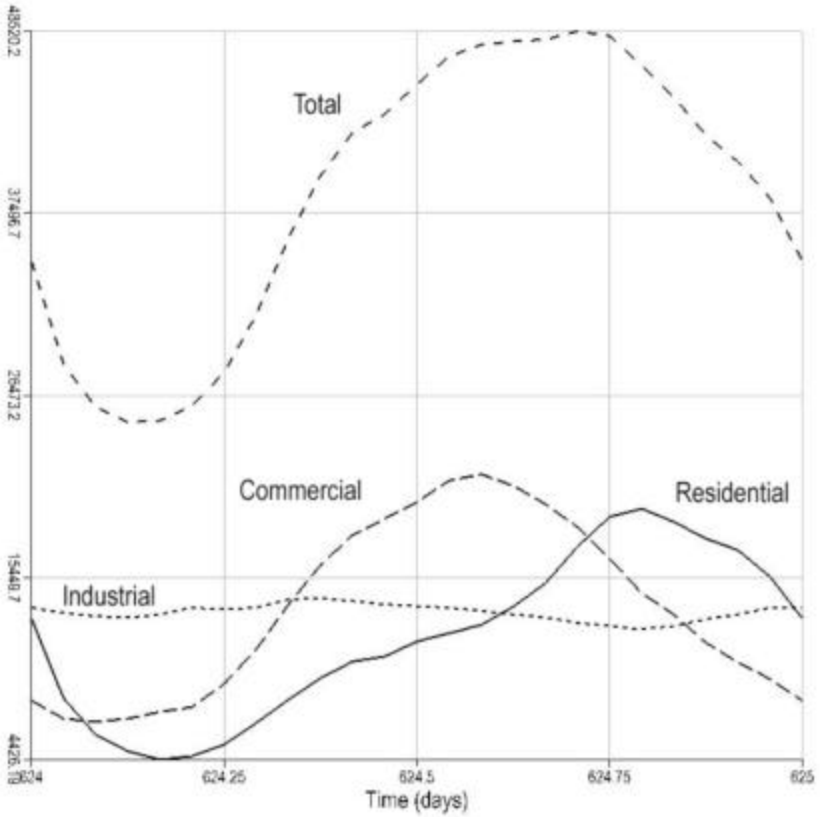


Figure 7: Hourly Usage: Residential, Commerical, and Industrial Usages

Results: RTP Contracts displace loads from peak-price hours

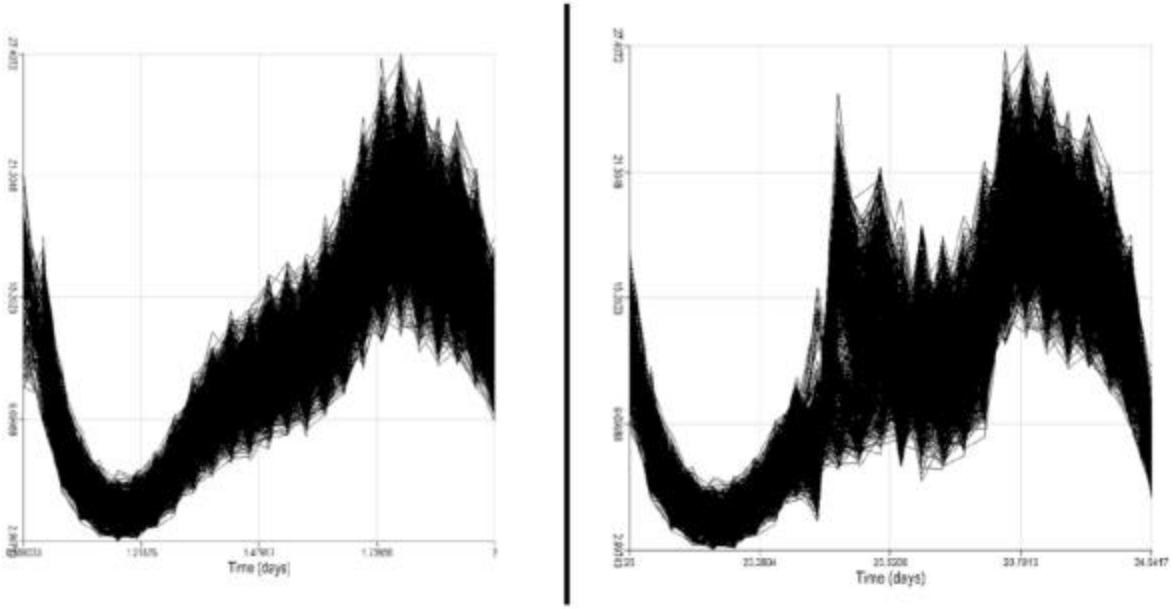
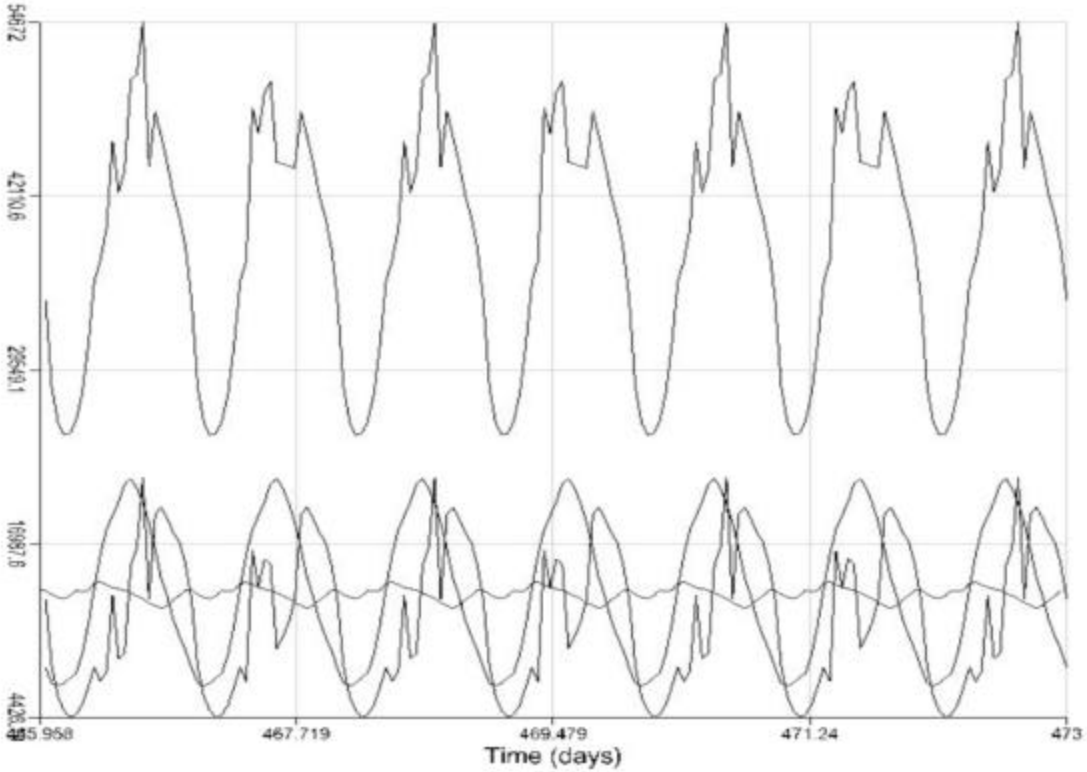


Figure 8: Hourly Usage: Uniform Price-Only (Left) and RTP-Only Contracts (Right)

Results: system loads under RTP-only contracts



Results: RTP market share as a function of households' willingness to experiment with contracts, budgets, rescheduling inconvenience

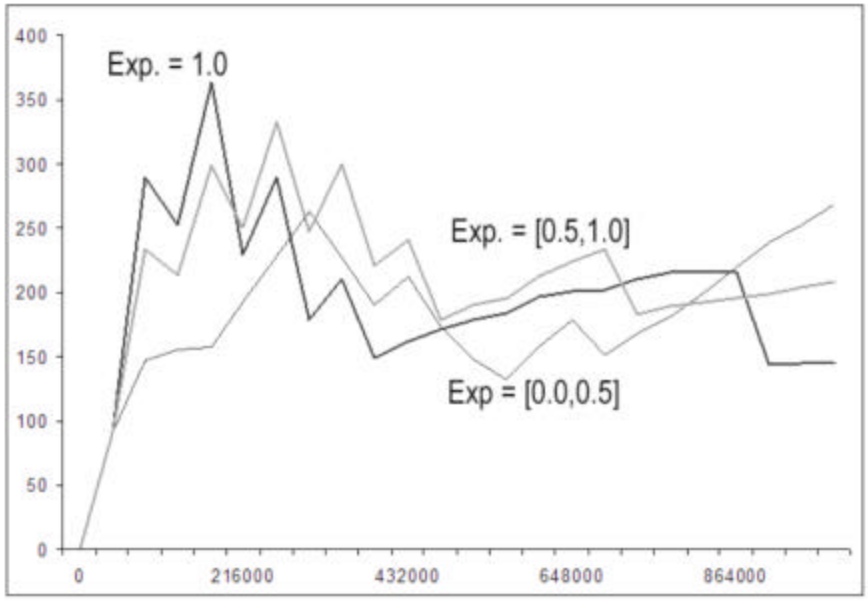


Figure 10: Number of RTP Contracts Over Time: Various Experimenting

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Summary

- **RTP contracts increase the potential excess transmission capacity a Transco can sell in short-term (lucrative) markets.**
- **Transcos that aggressively market RTP contracts can have that capacity before other Transcos have it.**
- **Drastic defection of households from RTP contracts to uniform contracts creates needs for transmission capacity that will likely have to be purchased in short-term (expensive) markets.**
- **Model has sufficient fidelity to do future analysis of other Transco and residential power use policy issues.**

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Measures of market consistency: fractal dimensions of price data

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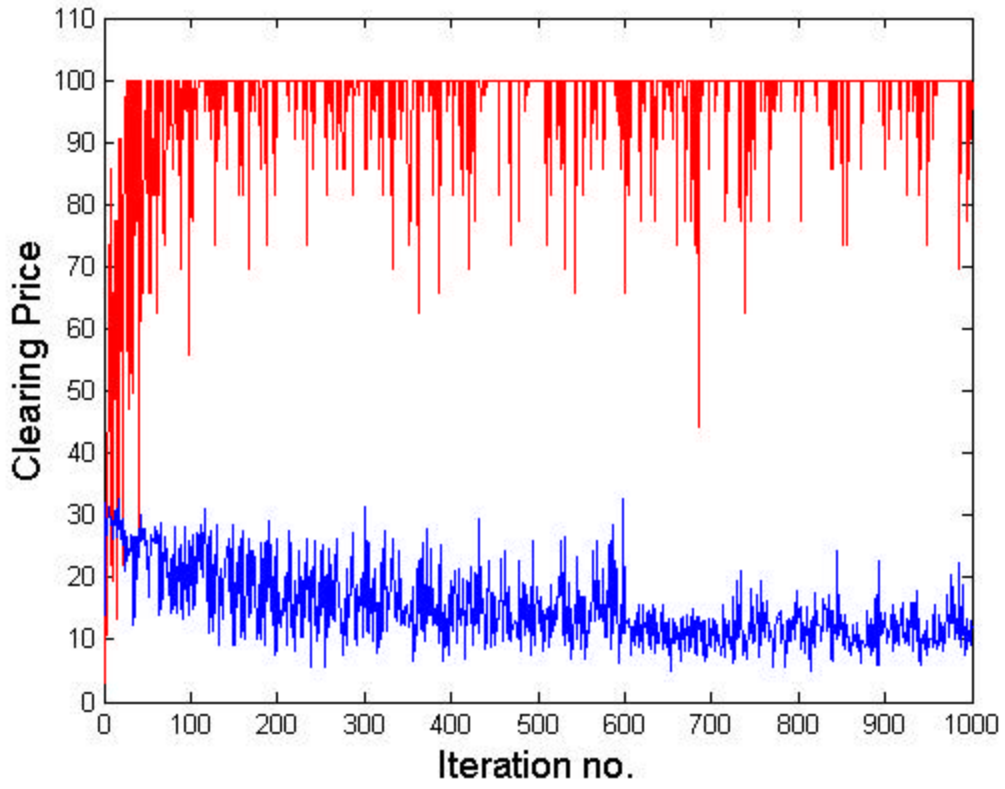
What information is contained in price fluctuations?



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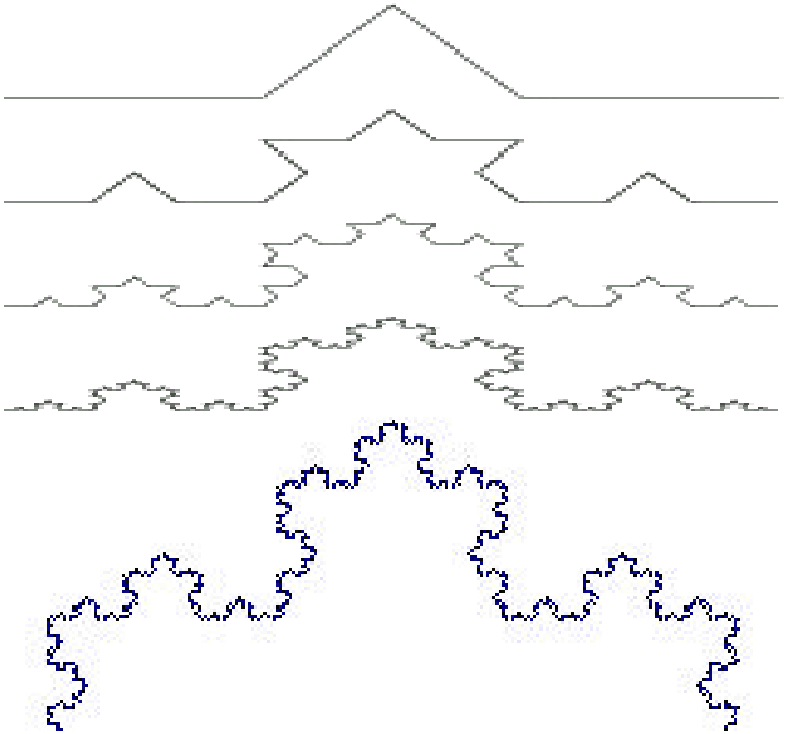
Koch Curve

Fractal dimension = 1.2619

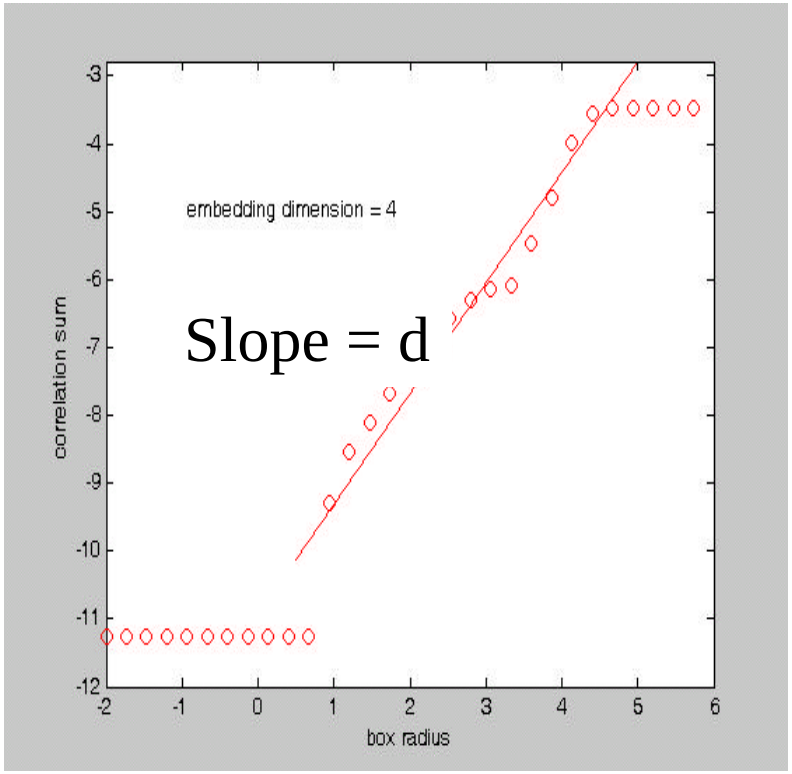


A conjecture

Changes in a fractal dimension of price data can be useful in assessing market performance

A fractal dimension

- Correlation sum, C(ε);
  overall frequency of visit to ε–neighborhood
- For a very small ε,
  C(ε) contains one point
- For a very large ε,
  C(ε) engulfs the whole state
- Only from intermediate ε,
  d = slope in log-log plot →

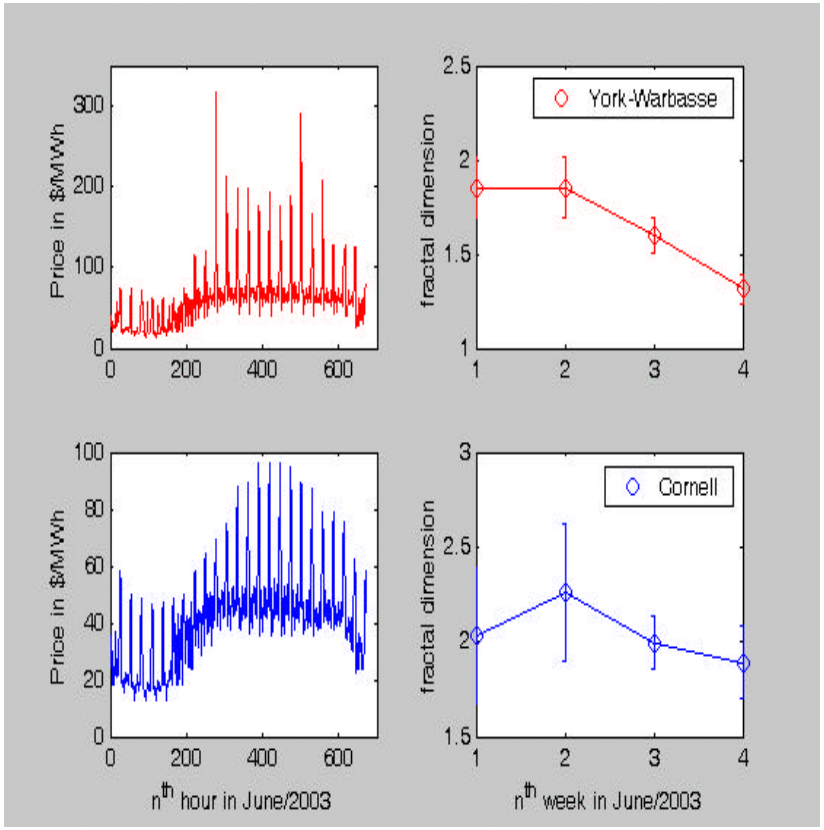


NYISO DATA IN JUNE 2003

- High demand period starts
- York-Warbasse (locational benefit)

  - change in dimension
- Cornell (no locational benefit)

  - no change in dimension
- Something happened at York-Warbasse



CONCLUSIONS

- Price is a good measure of the state of a market
- Some fractal dimensions reflect the state of the market
- Changes in the values of these dimensions indicate changes in seller strategies, and could prove useful to the ISO.

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Major accomplishments

1. Tools for the identification of flaws at the conceptual stage of designing quasi-repetitive markets
2. Tools for the detailed simulation of real-time-pricing
3. New measures of market performance
   P_L/P_M, P_L/P_C, fractal dimension
4. Design insights

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Future Work

- Tools for seams-issues
- Tools for bi-lateral trades
- Tools for designing customer strategies
- Continuing work on measures and insights
- Refinement of current tools

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Linkages

PSERC
CEIC
ABB
NYISO