Price Convergence in California's Wholesale Electricity Markets

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Outline of Talk

- Relationship between forward & spot market prices in an efficient market
- Why we should care
- Has the California market been efficient?
- Transmission congestion and efficiency
- Concluding remarks

Relationship Between Forward and Spot Markets

- Forward and Spot Markets trade the same product just during different times
  - In a word of certainty, i.e. prices were known ahead of time:
    - You wouldn't buy the product in the forward market if the spot market price was less (and vice versa)
    - Likewise, you wouldn't sell in the forward market if the spot market price was higher (and vise versa)

Relationship Between Forward and Spot Markets

- Electricity market prices are not certain
  - However, the same intuition holds in this environment, but instead we focus on the **expectation** of price:
    - You wouldn't buy in the market with a higher expected price
    - You wouldn't sell in the market with a lower expected price

Forward and Spot Market Prices

- Together these imply that, for delivery of electricity at the same point of time and place, the forward price and the spot price should have the same expected price
- They also imply that, in an efficient market, the forward price will be your best guess as to what the spot price will be
  - Therefore, no information available at the time the PX price is set should help in forecasting the ISO price

Forward and Spot Market Prices

- Formally, let the forward price be set one period ahead of time and let Ω_{t-1} be the information available when the forward price is set, then we have:

$$ {}_{t-1}P_t^{forward} = E\left[P_t^{spot} \mid \Omega_{t-1}\right] $$

or

$$ {}_{t-1}P_t^{PX} = E\left[P_t^{ISO} \mid \Omega_{t-1}\right] $$

Testing for Efficiency

- One consequence of this condition is that:

$$P_t^{ISO} = P_t^{PX} + \varepsilon_t$$

  - where ε_t has mean zero and is independent of all information available when the PX price is set.
  - We test this condition by estimating:

$$P_t^{ISO} - P_t^{PX} = \alpha + \varepsilon_t$$

  - An efficient market would imply that α=0

Why We Should Care?

- Might be suggestive of institutional rules that lead to inefficiency in other areas
  - For example, systematic ISO-PX price differences may lead suboptimal dispatch
- Also gives a picture as to how integrated the different markets are
  - Can a decentralized system rely on the market for efficiency?

The Data

- We look at hourly SP15 and NP15 PX and ISO prices
  - The sample is from 4/1/98 to 8/19/99

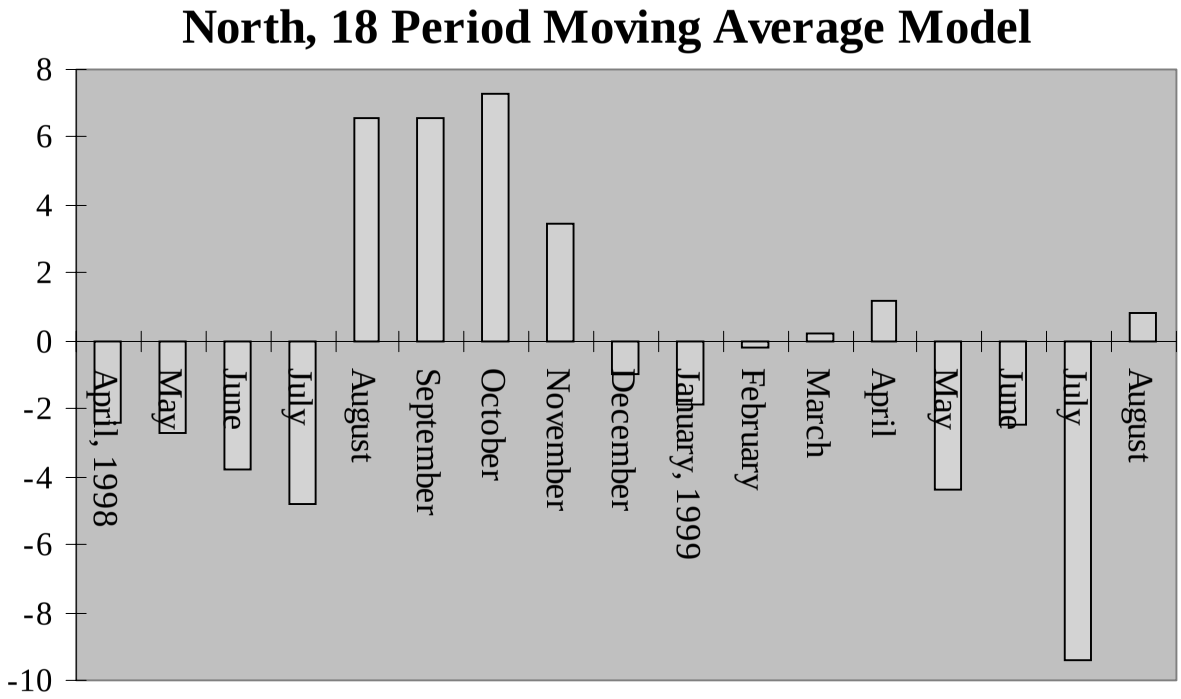
Estimation Issues

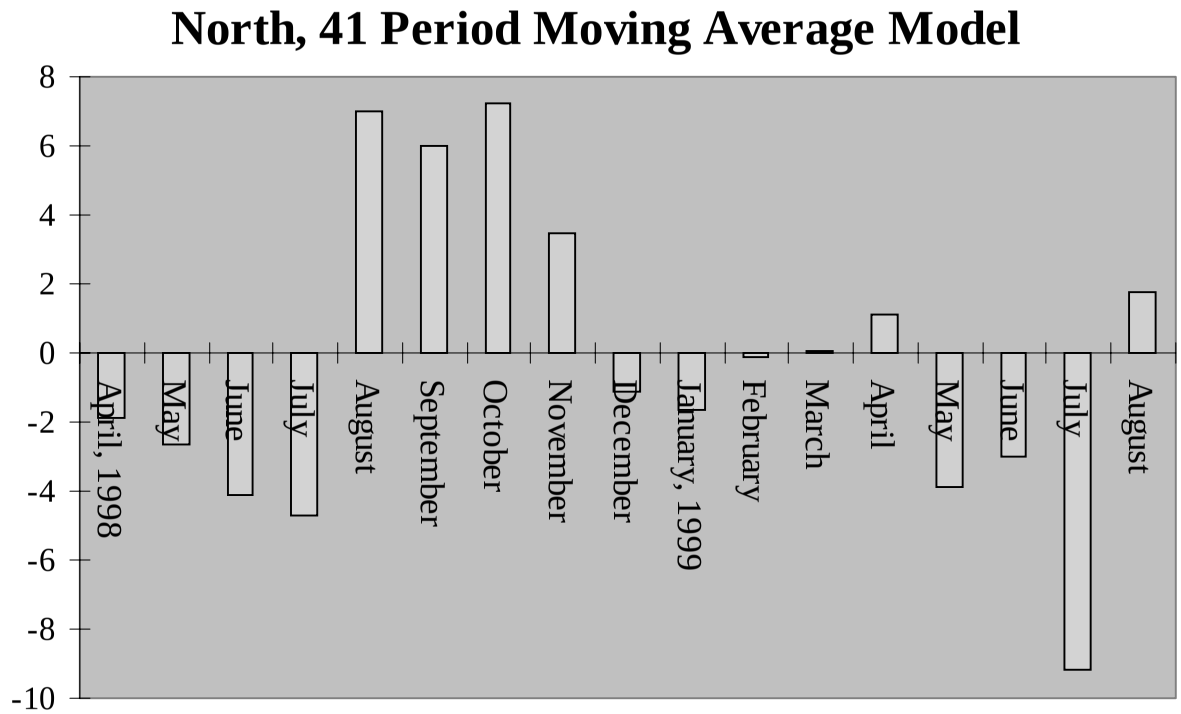
- Because PX prices are set at 7am the previous day in 24 hour blocks, any shock (e.g. change in weather) will have an effect throughout the day
  - This instills serial correlation in the ISO-PX price differences, implying we have fewer **independent** observations
  - This is analogous to reducing your sample size, which in turn inflates your standard errors

Dealing with Serial Correlation

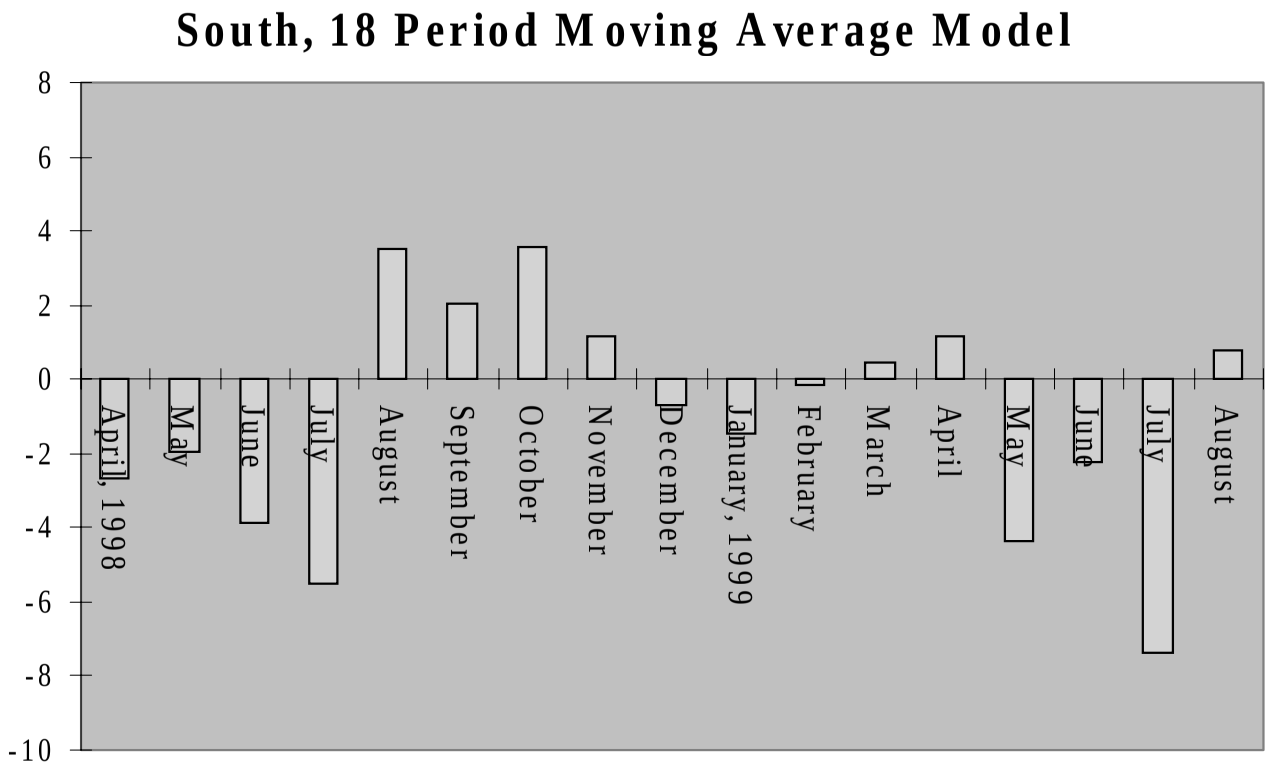
- The actual model of serial correlation is complex since each hour is correlated with a different number of previous hours, creating an asymmetry across hours
  - e.g. hour 1 in each day is correlated with the previous 18 hours (back to 7am the previous day), while
  - Hour 23 is correlated with the previous 41 hours

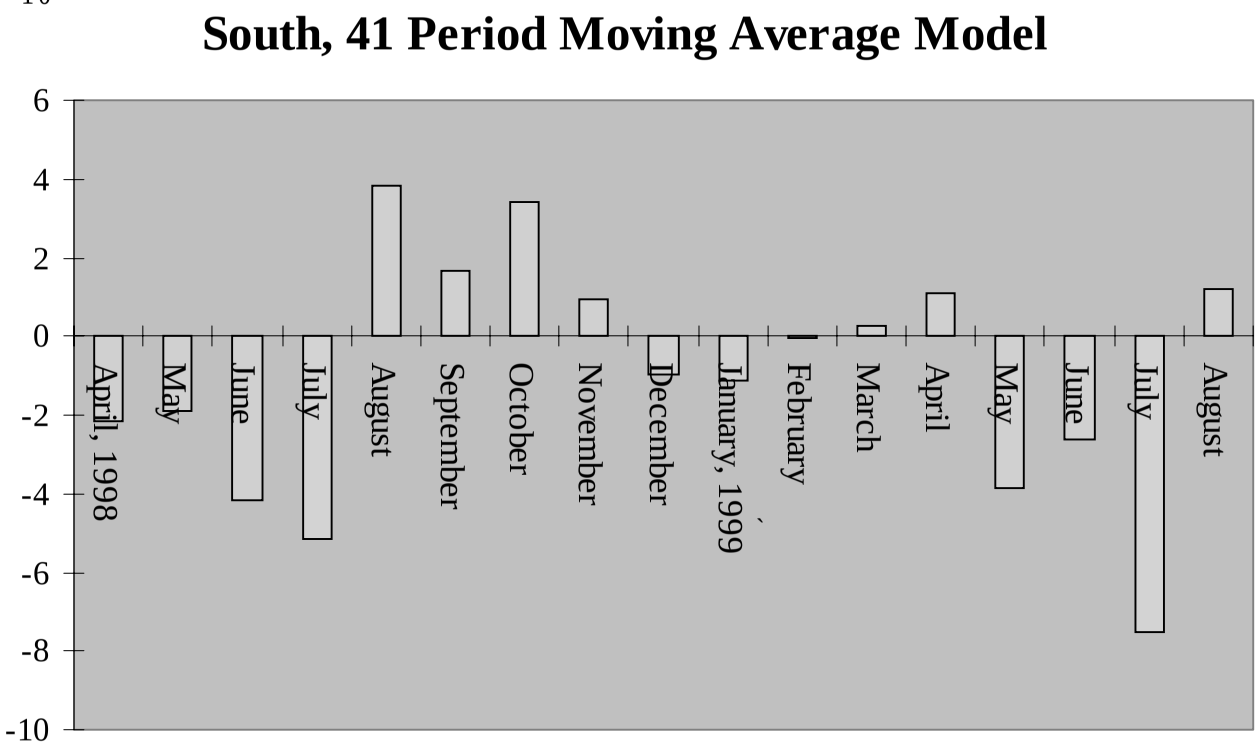
North Results





South Results





Lessons Learned from This (table 5)

- The market as a whole looks to have become more efficient over time
  - After December 1998, the average ISO-PX price difference in only July is statistically significant in each of the 4 models
    - This might suggest learning by market agents
- The South appears to be more efficient than the North
  - This difference can only be explained by differences in the two regions during congestion

Testing for a Profitable Trading Rule

- Could a generator outperform the naïve strategy of selling everything in the PX market?
  - Specifically, what if a generator were to sell in the market that had the highest expected price in the previous month?
    - This is a very simple trading rule, that could likely be improved upon
  - Using this rule, a Northern generating company selling 1,000,000 mWh each month would have made a statistically significant amount of **$855,000 per month** more than the naïve rule

Additional Tests of Efficiency

- Another consequence of an efficient market is that no information available when the PX price is set should help explain the ISO-PX price difference
- We test for this by including:
  - The 48 hour previous ISO-PX price difference
  - The Day of Week and the Hour in the Day

$$P_t^{ISO} - P_t^{PX} = \alpha + \rho\left(P_{t-48}^{ISO} - P_{t-48}^{PX}\right) + \sum_{i=1}^{6} \beta_i W_i + \sum_{j=1}^{23} \delta_j H_j + \varepsilon_t$$

Lessons Learned from the Additional Tests (tables 9-10)

- No strong evidence that the previous ISO-PX price difference is statistically significant
- Appears to be a **"Weekend Effect"**
  - The ISO price appears to be systematically higher than the PX price during the weekend, relative to the rest of the week
- *Some* evidence of a **"Peak Period Effect"**
  - The ISO price appears to be systematically higher than the PX in the North during hours 3pm to 5pm (only during 4pm in the South)

Congestion and "Asymmetric" Congestion

- 82.6% of the time North and South are one market
  - In only 5.7% of the time has there been congestion in both the PX and the ISO (and never from North to South)
- In the remaining 11.8% of the hours one market indicated congestion, while the other did not
  - We call this *Asymmetric Congestion*

Inefficient Asymmetric Congestion

- Surprisingly, 3.22% of the time (18.5% of the congested hours), the ISO was congested while the PX was not
  - This indicates the existence of inefficiency

Asymmetric Congestion and Inefficiency

- Consider the case were the PX forecasts **no** congestion and congestion is only likely to be in one direction (e.g. only South to North)
- As long as there is **some** possibility that there will be congestion in real-time, then there is a positive probability the North and South prices will differ in **real-time** and this difference is predictable (e.g. North≥South)
- Therefore, it is impossible for both the North and South PX prices to be unbiased predictors of the ISO prices

Asymmetric Congestion and Arbitrage Opportunities

- Assume congestion is likely in only the South to North direction and the PX is not congested
  - An Arbitrageur could buy power in the North PX market and sell power in the South PX
  - If there is no congestion in the ISO, then by not fulfilling her commitments she sells power in the North and buys in the South and breaks even
  - If there is congestion in the ISO, then by not fulfilling her commitments she **makes money**

Summer Example

- Assume the PX forecasts no congestion and an arbitrageur buys 1,000 MWs of power in the North and sells 1,000 MWs of power in the South
- There are two possibilities:

1. There is no congestion in real time
   - By not fulfilling her commitment, she breaks even
2. There is congestion South to North in real time, say the prices are $30 and $40 in the South and North, respectively
   - By not fulfilling her commitment she is forced to sell 1,000 MWs in the North at $40 (revenue of $40,000), and buy 1000 MWs in the South (cost of $30,000)
   - She makes $10,000!!

Asymmetric Congestion and Arbitrage Opportunities

- This inefficiency also appears to have dissipated as the market has become more mature
  - In each month in 1998, this occurred in more than 50 hours
  - In January 1999 it occurred in only 3 hours, while from February on, it has not occurred

Conclusions

- The analysis thus far indicates a movement toward greater efficiency
  - The expected difference between the ISO and PX prices in the majority of the months in 1999 have been statistically indistinguishable
  - The incidence of inefficient asymmetric congestion also has diminished

Caveats

- With that said, the ability to arbitrage may be becoming more difficult
  - The ISO has recently increased the costs of purchasing power in the real time by reallocating the costs of reserves
  - The ISO is also considering moving to a system with settlements every 10 minutes
    - This would make the hourly PX price less of a signal for the ISO prices
  - The ISO also plans to add a new congestion zone and redesign transmission pricing
- Finally, an arbitrage free environment does not imply that the entire market is efficient