Mechanism Design for the Environment

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Caltech

10/26/07

Hurwicz Lecture

Congratulations

"for having laid the foundations of mechanism design theory"

Mechanism Design

- Mechanism design is the art and science of designing rules of a game to achieve a specific outcome. (Wikipedia)
  - The systematic analysis of information and incentives in resource allocation.
- Economists were once just commentators on economic systems, but now have become architects who design institutions to solve resource allocation problems.

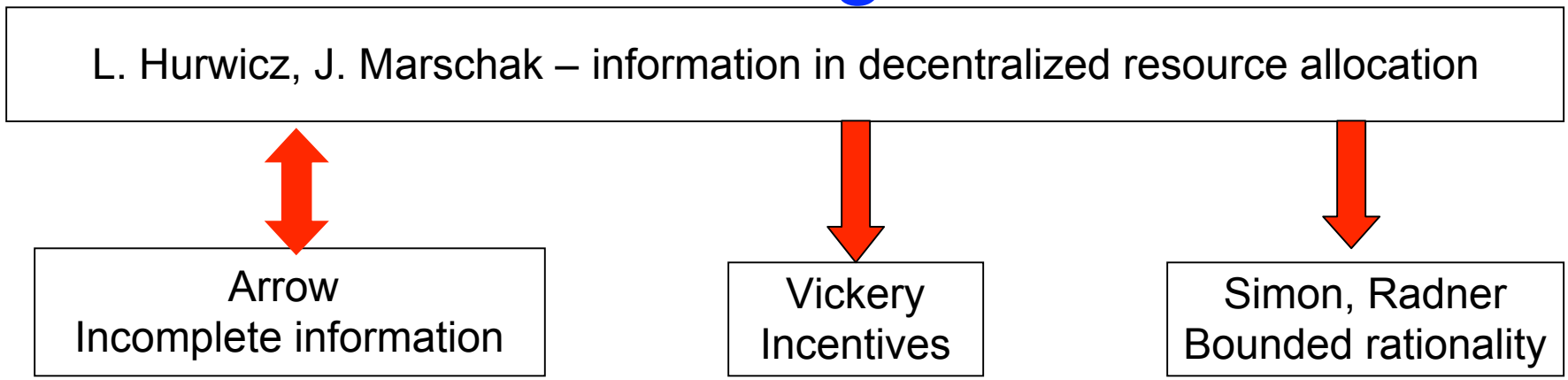
Mechanism Design for Policy

Examples:

- How should economics students and graduate schools be matched?
  - Matching mechanisms
- How should we privatize publicly owned assets?
  - Auction design: FCC selling of electromagnetic spectrum
- How should we regulate to correct market failure?
  - Environmental regulation
    - Command and Control
    - Carbon taxes
    - Cap and Trade

From: Dan McFadden

Mechanism Design: The Flow



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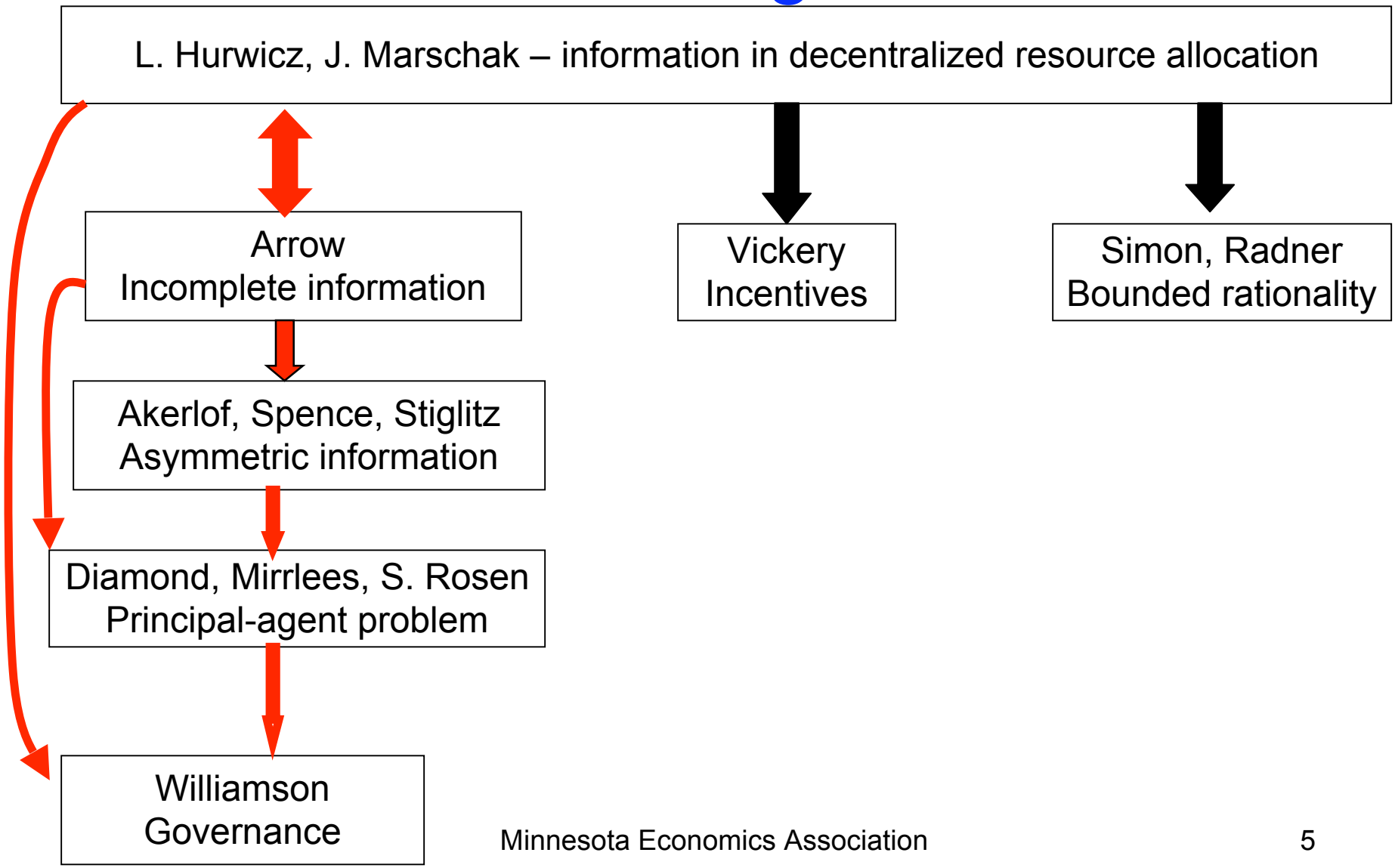

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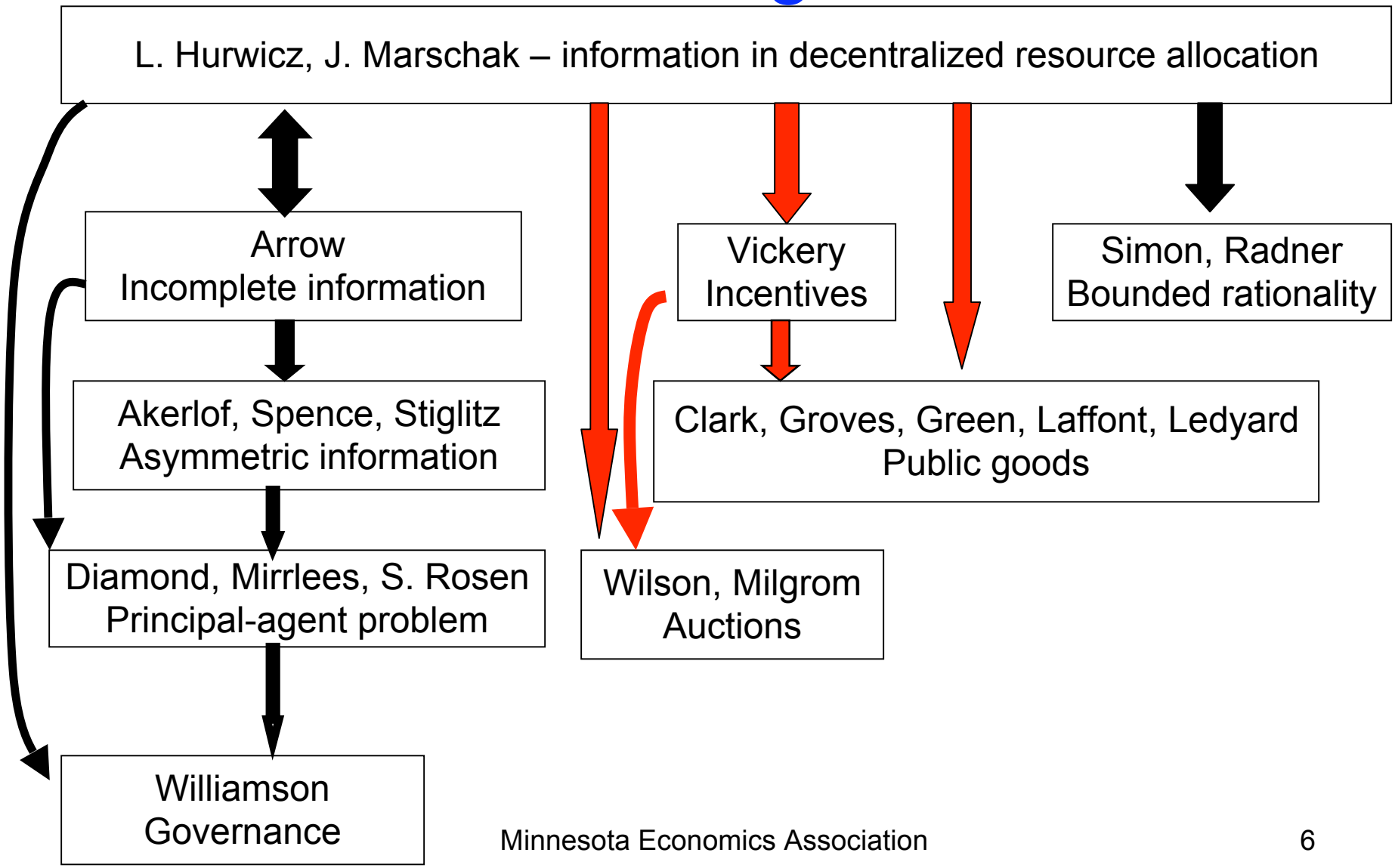

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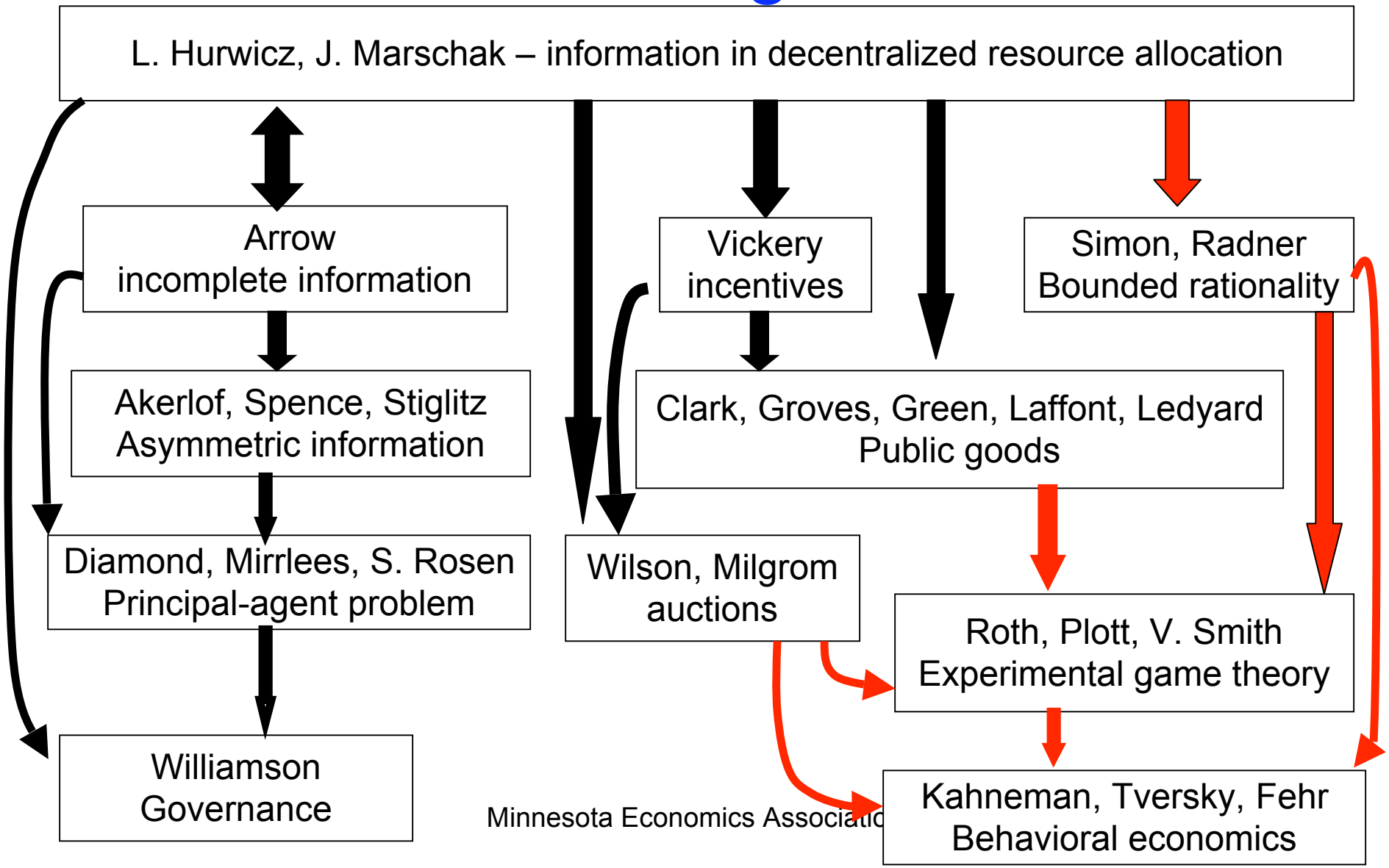


My Lecture

- Mechanism Design as a Policy Tool
- Example: Environmental Regulation
  - (using LA's RECLAIM as an example)
- Subtext 1: Creating markets to efficiently allocate multiple heterogeneous objects is crucial to successful policy implementation.
- Subtext 2: New technology enables new types of markets.

The Problem

And …….

We have to give up something to fix the problem.

- Targets
  - Kyoto - 5% below 1990 levels by 2012
  - Vienna - 25-40% of 1990 levels by 2020
- Costs for Greenhouse Gases
  - 30% reduction costs 1-3% reduction in GDP
    - For the US this is $135 -$405 B
    - For the world this is $480 - $1,445 B
- Costs for LA SOX and NOX
  - 25% reduction costs 1.5% LA gross income

The Solution is Distributed

- Lower cost abatement possibilities are widely spread and highly fragmented across geography and industry.
- Some estimate developing countries account for more than half the total abatement available at a cost less than $50 a ton.
  - Deforestation rates reduced by 50% in Africa and 75% in Latin America could generate nearly 3 giga-tons of annual abatement by 2030.

The Challenge

- To realize abatement in order of increasing cost, policy makers must find ways to effectively address opportunities world wide by aligning the incentives of companies and consumers.

- Two problems
  - Market Failure
  - Government failure

Market Failure

- To reduce emissions by 30%
  - World population is ~ 6.6 B
  - Cost is ~ $480 B - $1445 B
  - This means the cost per person is $73 - $219.
- Two problems
  - Income distribution - some just can't pay that.
    - If only US, 30% => $300B/300M = $1000/person
  - The free rider problem

Government Failure

- Command and Control is very costly
- The regulated have an incentive to hide relevant information
  - More studies (academics)
  - More monitoring (police)
  - More bureaucracy (lawyers)
  - "Penetrate the technology" (engineers)
  - Higher costs of Administration

  CENTRAL PLANNING MECHANISM

The economist's solution

- Use markets to correct market failure.
  - It doesn't need to be so costly and counter-productive.
- Change the game!
  - Move the incentives to where the information is
- Similar to the old socialist planning vs. capitalism debates that stimulated Hurwicz's research.

A Cap and Trade Program

- Allocate permits equal to the desired total level of emissions.
- Firms regularly report own emissions and hand back the appropriate number of permits
- Regulator monitors
- A violation exists only if firm doesn't have enough permits.
- Levy high fines when violations occur.
- This is the same as Command and Control

Let them trade

- Achieves the least cost result.
  - First welfare theorem
- Makes voluntary what is now forced
  - Firms (indirectly) “reveal” their information
  - Incentives for new and cheaper abatement technology
  - A bonus is lower administrative costs
- Relies on efficiency improving trades.

Some Estimates of the gains from trading (approximate)

- Greenhouse Gases
  - 30% reduction costs 1-3% reduction in GDP or $135 - $405B
  - With full international trading, cost is reduced to only a 1/4% reduction in GDP (with Europe alone, 1.6%)
- LA SOX and NOX
  - 25% reduction costs 1.5% LA gross income ($130B) or $175M/yr
  - With RECLAIM (in 1996), 58% reduction in costs saving $100M/yr (and less labor market disruption)

A Puzzle

- Cap&Trade is a Pareto-Superior move.
  - Firms share the cost of abatement fairly.
  - Firms are better off than under command and control
  - So is the public.

- So why don't we see more Cap&Trade?

The arguments against Cap&Trade

- Regulators have problems with Cap.
  - Loss of control
  - Bad distribution of the benefits
  - It is like a contract, difficult to renegotiate
- An example
- South Coast Air Quality Management District (Los Angeles)

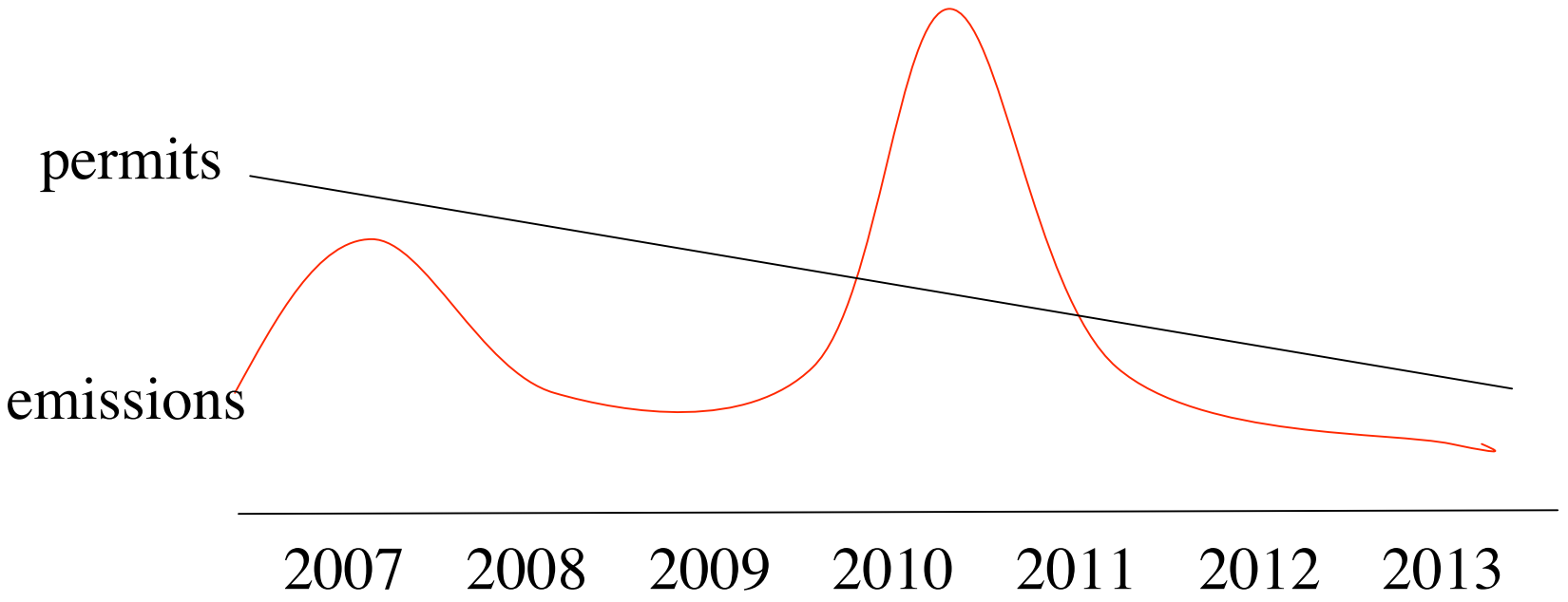
RECLAIM

- The Mandate: Reduce emission levels by some 50% - 70% from 1994 to 2003.
  - This was really scary to regulator and regulated!
- The Problem: Huge increased costs expected
  - Firms seriously considering exit from LA
- Triage: The basis for a deal
  - Desperately needed a lower-cost solution
  - Willing to take a chance on economists
- In 1993, RECLAIM is created

What the politicians and regulators desired

- Prevent hot spots
- Justice
  - Prevent unequal impacts on disadvantaged or low-income
- Protect against employment losses
- Keep options open
  - Be able to respond to unanticipated emergencies

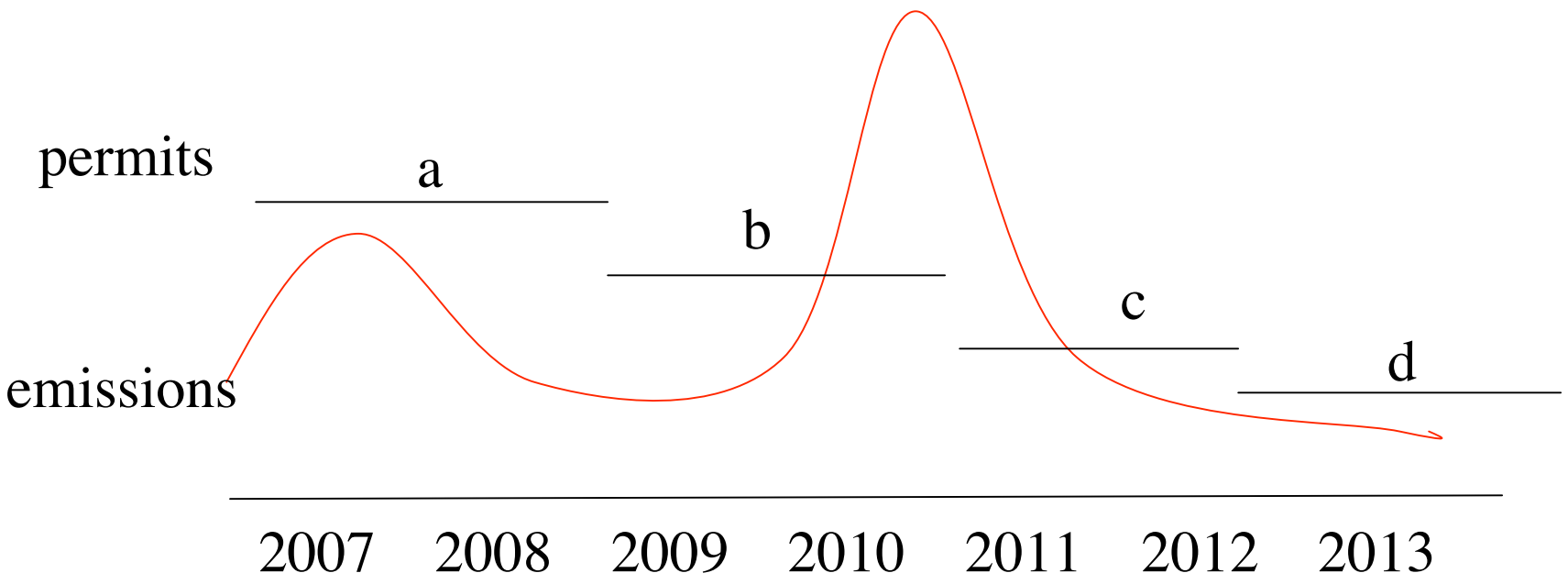
Hot spots - in time



On average, emissions are less than permits.

But, maximum emissions are too high.

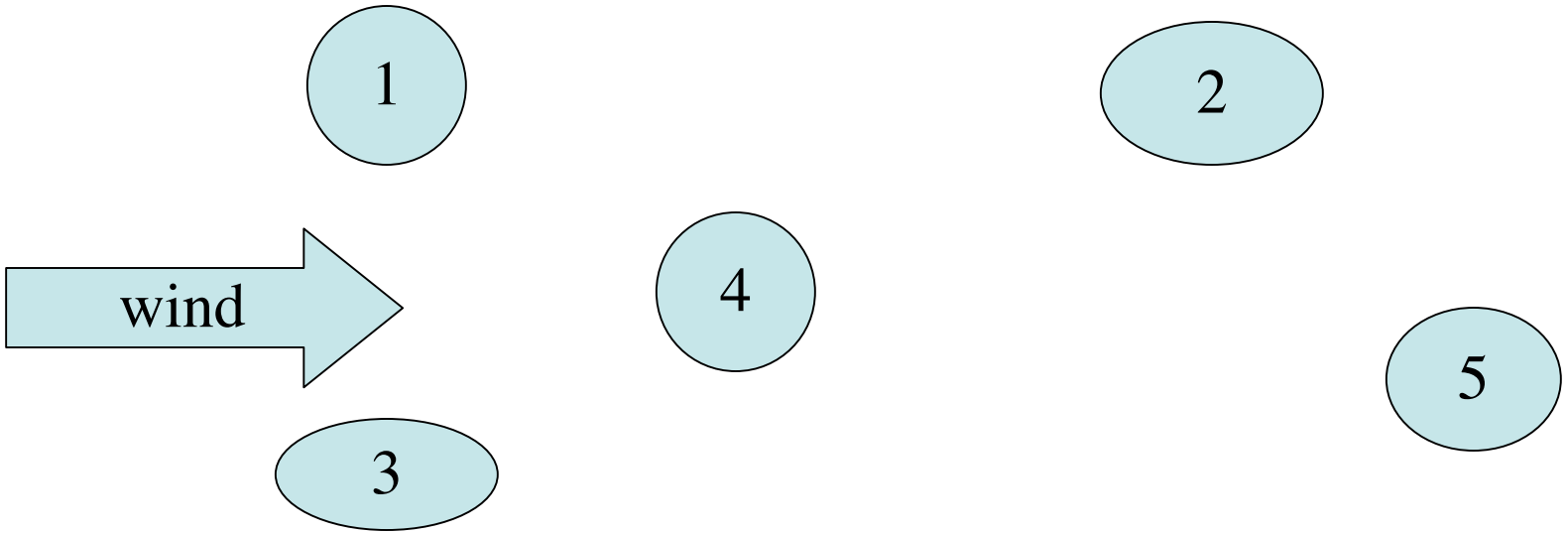
An Answer - Expiring Permits



Can only use “a” permits in 2007 and 2008, etc.

Hot Spots - in space

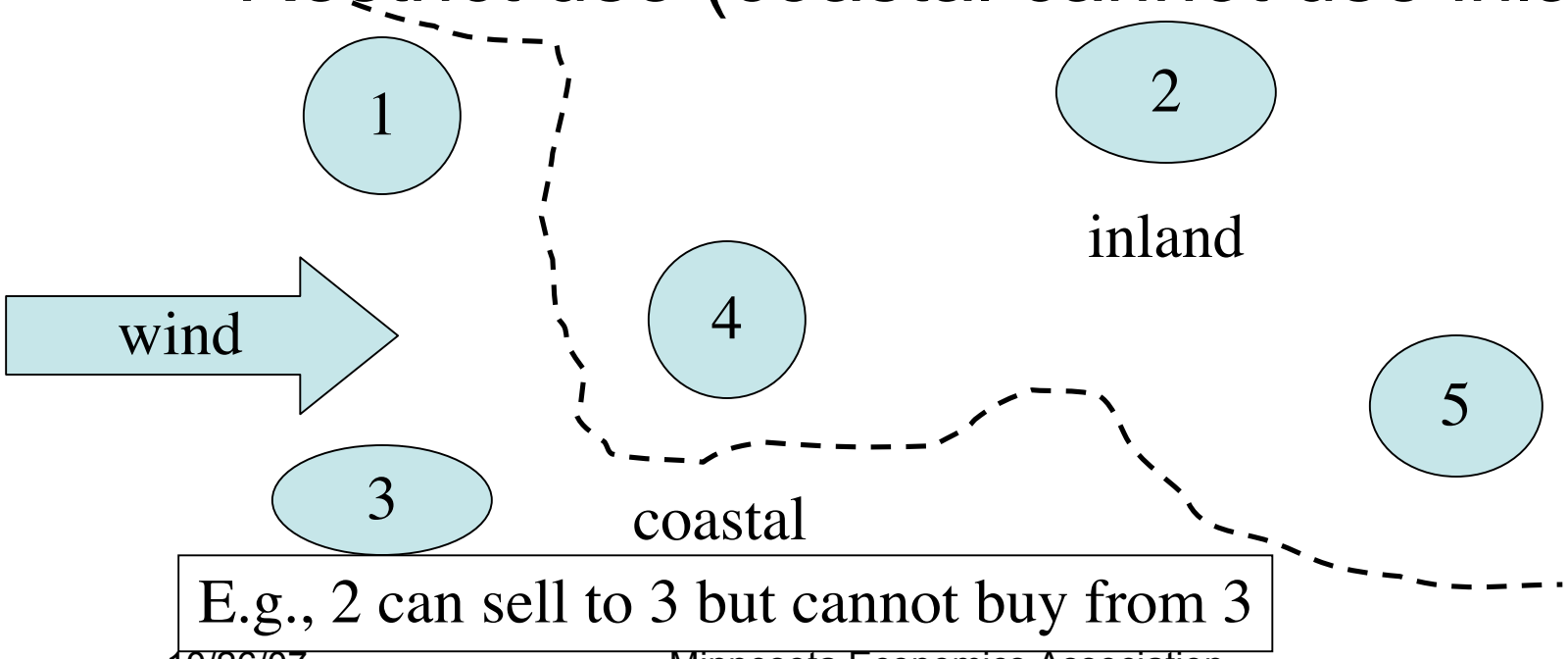
- Regulators lose control if there is only one type of permit. They control the aggregate level but not the distribution.



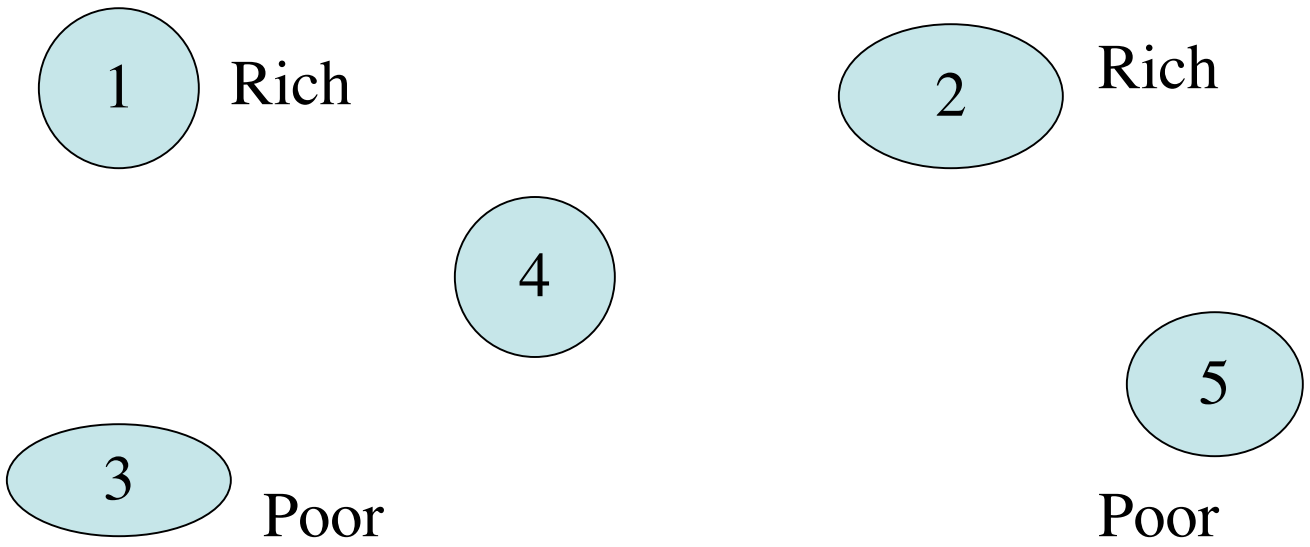
Sales of permits from 5 to 1 increases pollution in both places.

An Answer - Zones

- Create 2 different permits. (coastal &inland)
- Restrict use (coastal cannot use inland)



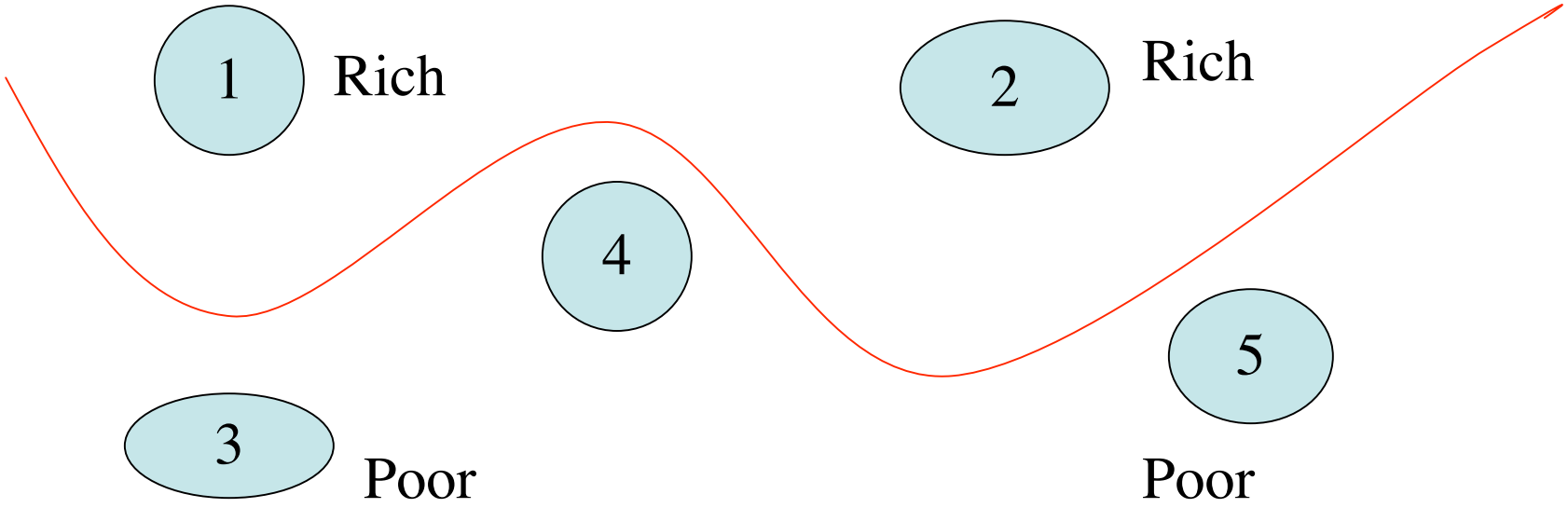
Justice



Sales of permits from 1 or 2 to 3 or 5 hurt the poor and help the rich (exporting pollution to the poor)

An Answer

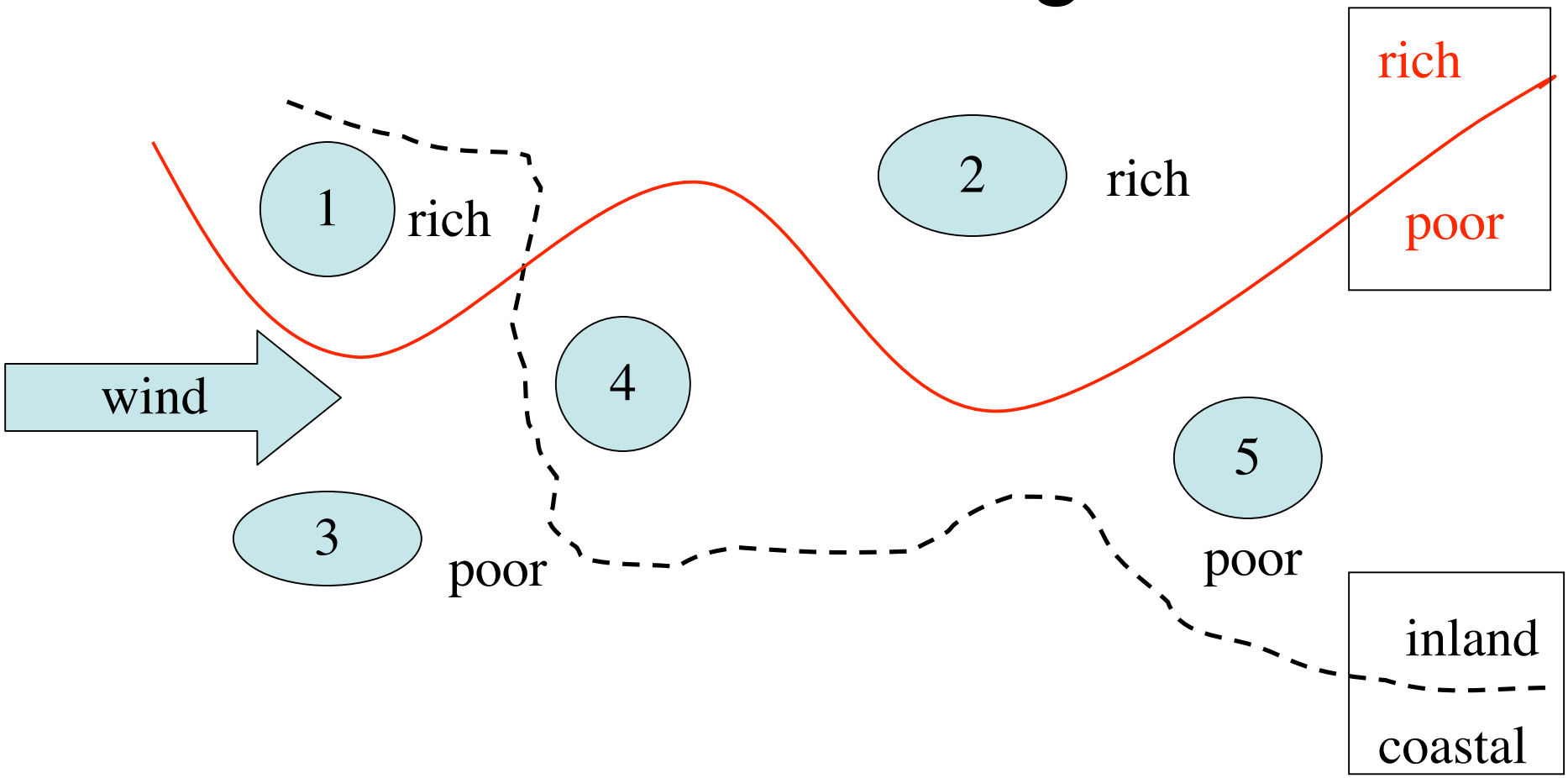
- Create more permits, restrict sales
  - (rich cities can't sell to poor cities)



What was proposed?

- No banking - daily caps
- 37 wind zones
- No job loss from any trade
- Retain right to cancel program

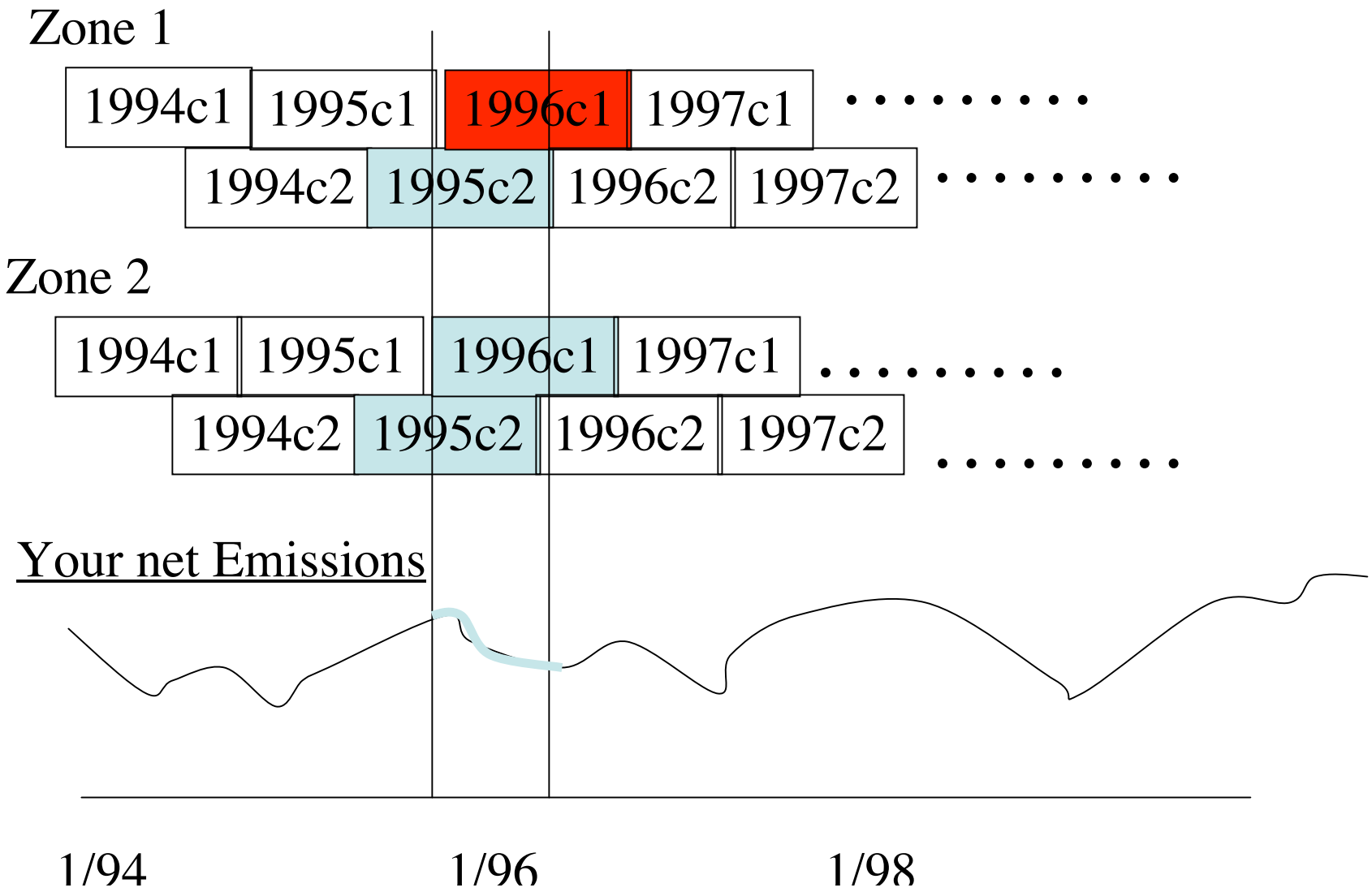
A Regulator's Dream, An Economist's Nightmare



What happened?

- RTCs (ReclaimTradingCredits) are a compromise
  - Imposed yearly caps on NOx and SOx
    - 2x17 = 34 different "securities" (1994-2010)
  - Created 2 overlapping cycles
  - Created 2 wind zones
    - versus 37 which would have meant 2516 "securities"
- Total of 2x2x2x17=136 different credits

You are in zone 1 and on cycle 1. You own red and can use green.



What would you recommend your firm do?

The Firm's Problem

- If they know all the prices of the various "assets"

$$\begin{aligned} &\text{Min } pt^i \\ &\text{subject to} \\ &R^i(w^i + t^i) \geq e^i \end{aligned}$$

- And compare that answer to the cost of installing abatement equipment.

What happened?

- SCAQMD said “let there be trade” but…..
  - Very little trading between firms occurred.
    - Bilateral trading was very difficult.
    - Brokers offered to “negotiate deals”
      - Charging as much as 40% on each side
      - No public market information
  - There were increased costs of administration.
  - There were little reduced costs for the firms.
- This solved the Cap but now there is a problem with the Trade.

Understanding the Trade Problem

- Experimental Economics
- The mechanism designer's wind tunnel
- The right algorithm for human behavior

Bossaerts/Kleinman/Plott (testing the CAPM)

- Created a scaled down version of multiple asset markets and tested it in the lab.
- Computer-based trade through a widely tested Multiple Unit Double Auction system (MUDA)
  - Usual result: equilibrium is quick and efficient
- Used 8-15 subjects

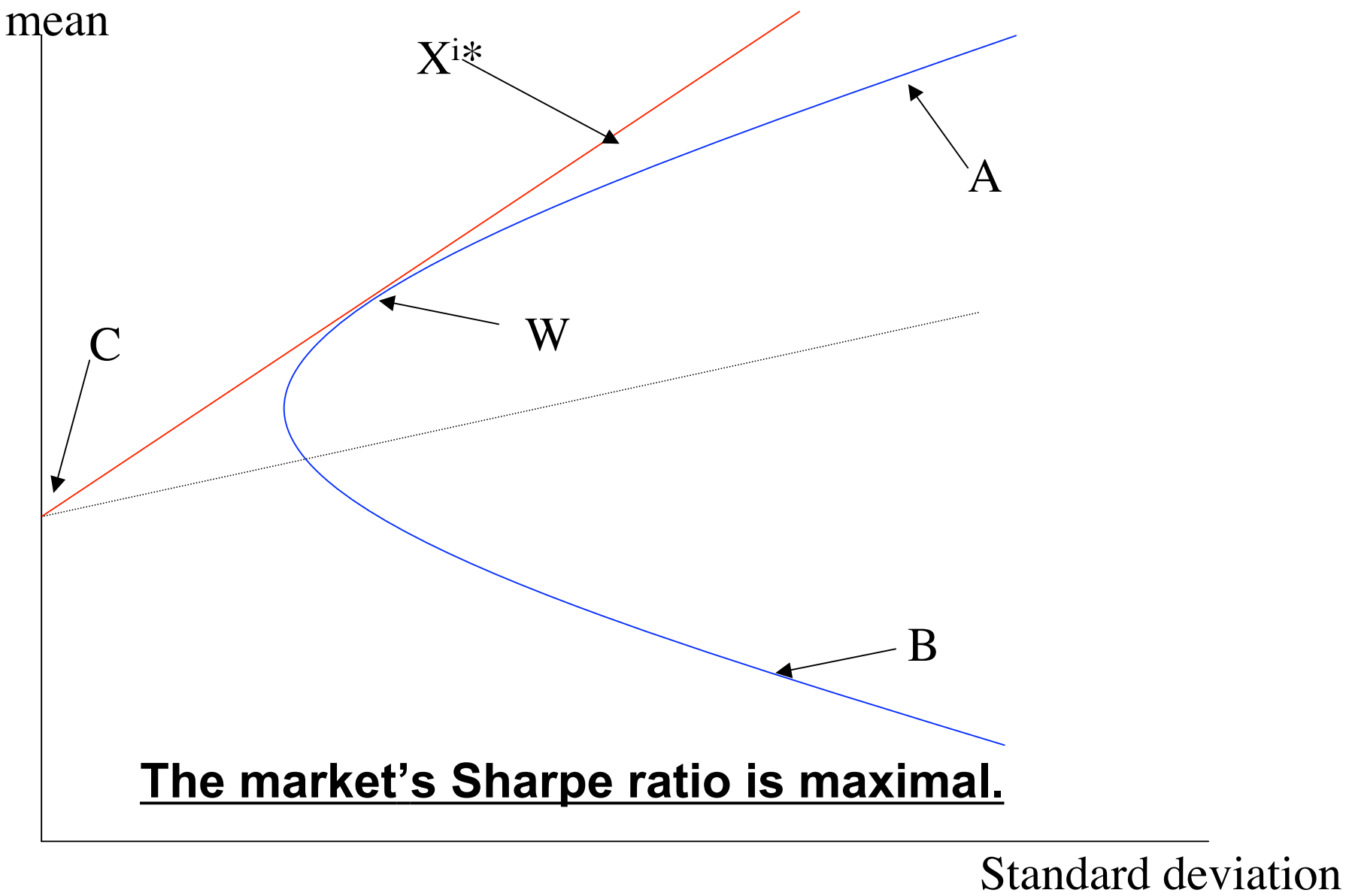
Specific Situation

- Three markets (short sales allowed in the one risk free asset)
- Three equally likely states with payout

Security	State X	State Y	State Z
A	170	370	150
B	160	190	250
NOTES	100	100	100

The Theory (simple CAPM)

- K assets
  - Expected return **m**, covariance **S**
- N traders
  - Initial endowment, w^i where $W = \sum w^i$
  - Allocation: assets, x^i, and of money,
  - Utility $U^i = mx^i - (a^i/2)x^{i\prime}Sx^i + y^i$

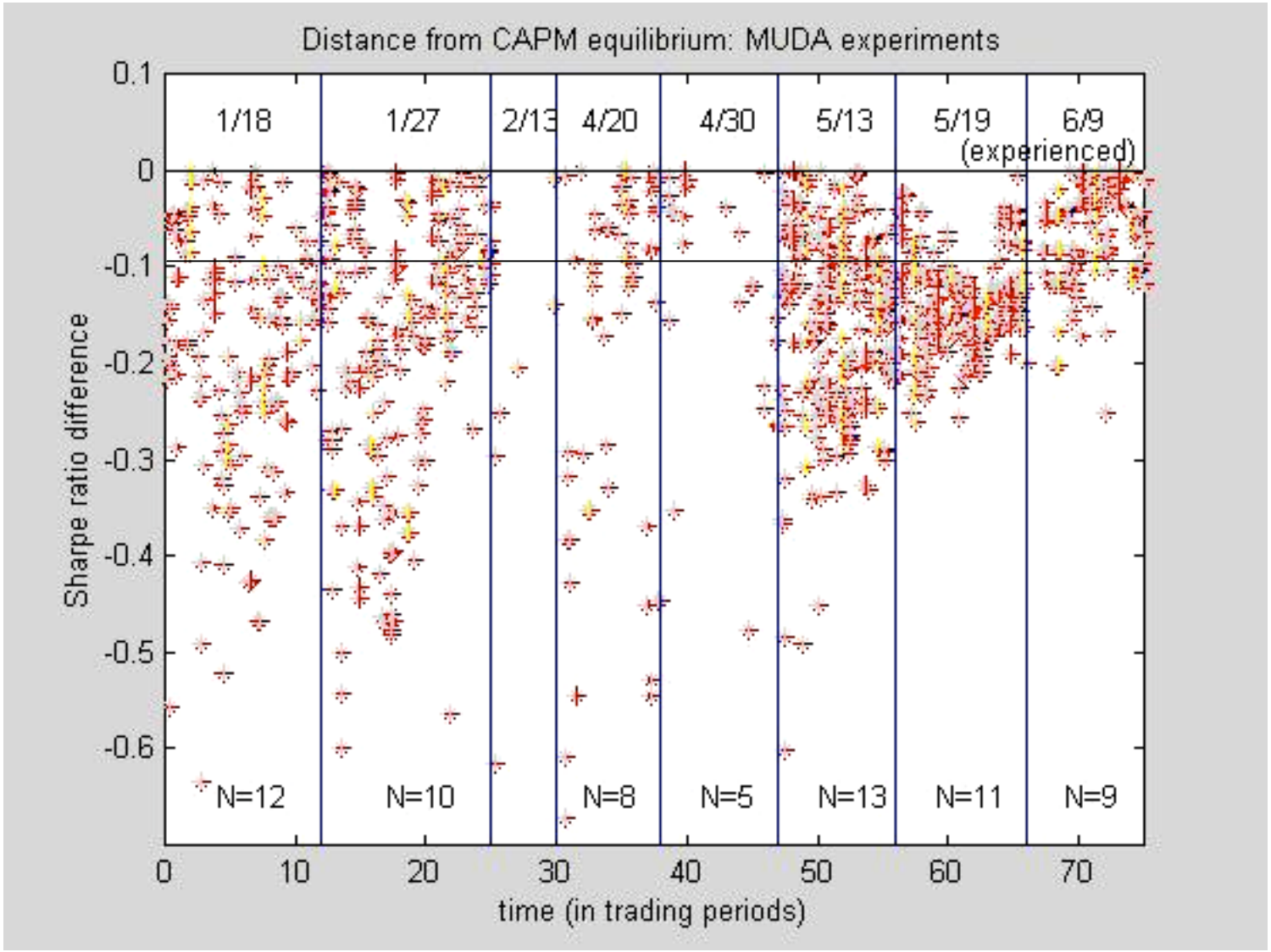


The market's Sharpe ratio is maximal.

Specific Situation

- Endowment of risky assets and cash refreshed each period
  - E.g., 5 of A, 4 of B, and 400 cash
  - May vary across subjects
  - Loan repayment of, say, 1900 at end of each period - (leverage!)
- **Let them trade, then draw state, then pay $, then restart**
- **Subjects did not know market portfolio. So couldn't use CAPM to predict prices.**

Bossaerts-Plott



So what went wrong?

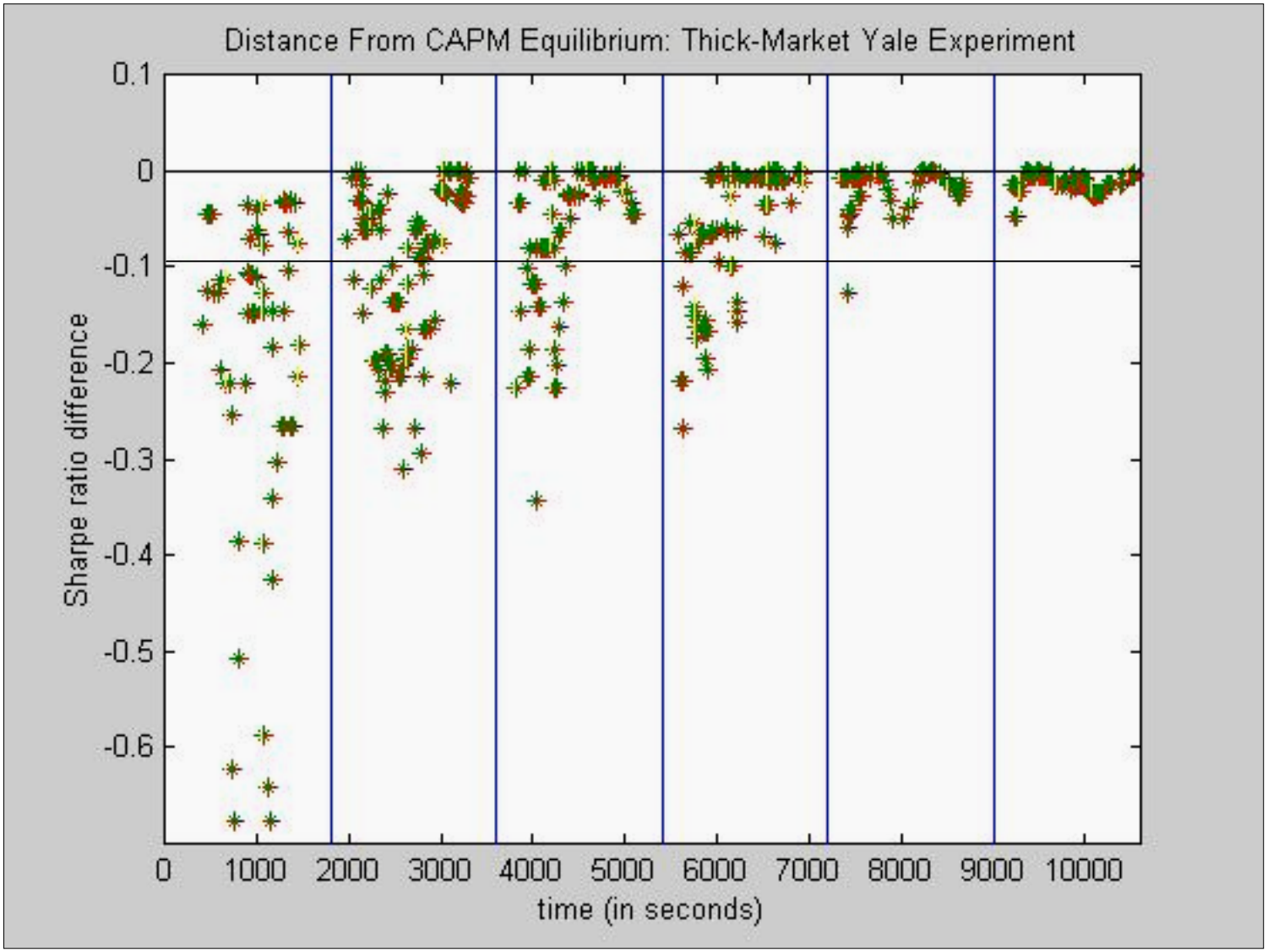
- Conjecture 1: Subjects didn't understand asset markets
  - Used MBAs at Stanford, UCLA and Yale
- Conjecture 2: Too few participants
  - Hampers price discovery
  - Attempted manipulation

Scaling Up: Bossaerts/Plott

- Large scale - up to 66 subjects
  - Cost = about $3000/run

- Trading was done through a web-based open book system, *Marketscape*, developed at Caltech (Plott)

Bossaerts-Plott N=40



Diagnosis

- "Transaction risk" leads traders to require larger spreads (fewer trades)
- Creates opportunities for intermediation
- Traders lose most of the potential surplus
  - From trades made - to the broker
  - From trades not made - because of inappropriate or inadequate price discovery

Are we doomed to choose between

- Good control with no trading or

  Good trading with no control?

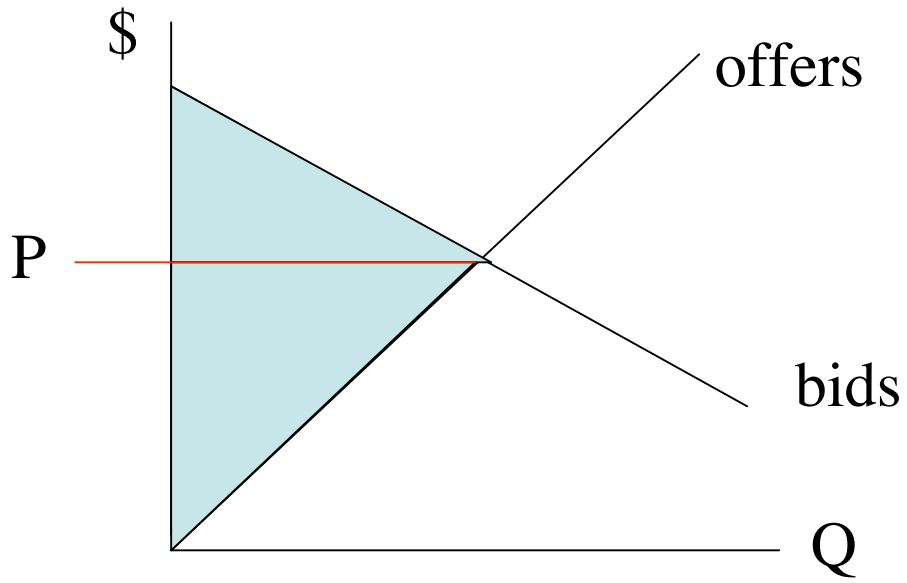
- Using the new science and technology of Market Design, we can improve the situation.
  - The traders in RECLAIM came to Caltech and requested a new “market”
  - We created a better multi-lateral bargaining system with no brokers

The Proposed Solution

- Use the power of computation and internet to allow simultaneous, linked trading across multiple individual markets.
- Design a portfolio trading mechanism
  - Vickrey: too complex with many commodities
  - Myerson-Satterthwaite: k double auction

K-Double Auction Call Market

– Match bids to max surplus (1st welfare theorem)
– Price to support optima (2nd welfare theorem)
– Price to provide good incentives



A call market for portfolio trading

- Allow package bids

Bid is (B^i, w^i, e^i, R^i) to be read as

"I will pay upto B^i for any t^i such that $R^i(w^i + t^i) \geq e^i$"

Maximize Reported Surplus

$$\text{Maximize} \sum B^i \delta^i$$

$$\text{subject to}$$

$$\sum t^i \delta^i \leq 0$$
$$\{R^i(w^i + t^i) - e^i\}\delta^i \geq 0$$
$$\delta^i \in \{0, 1\}$$

Set Prices

Prices P satisfy:

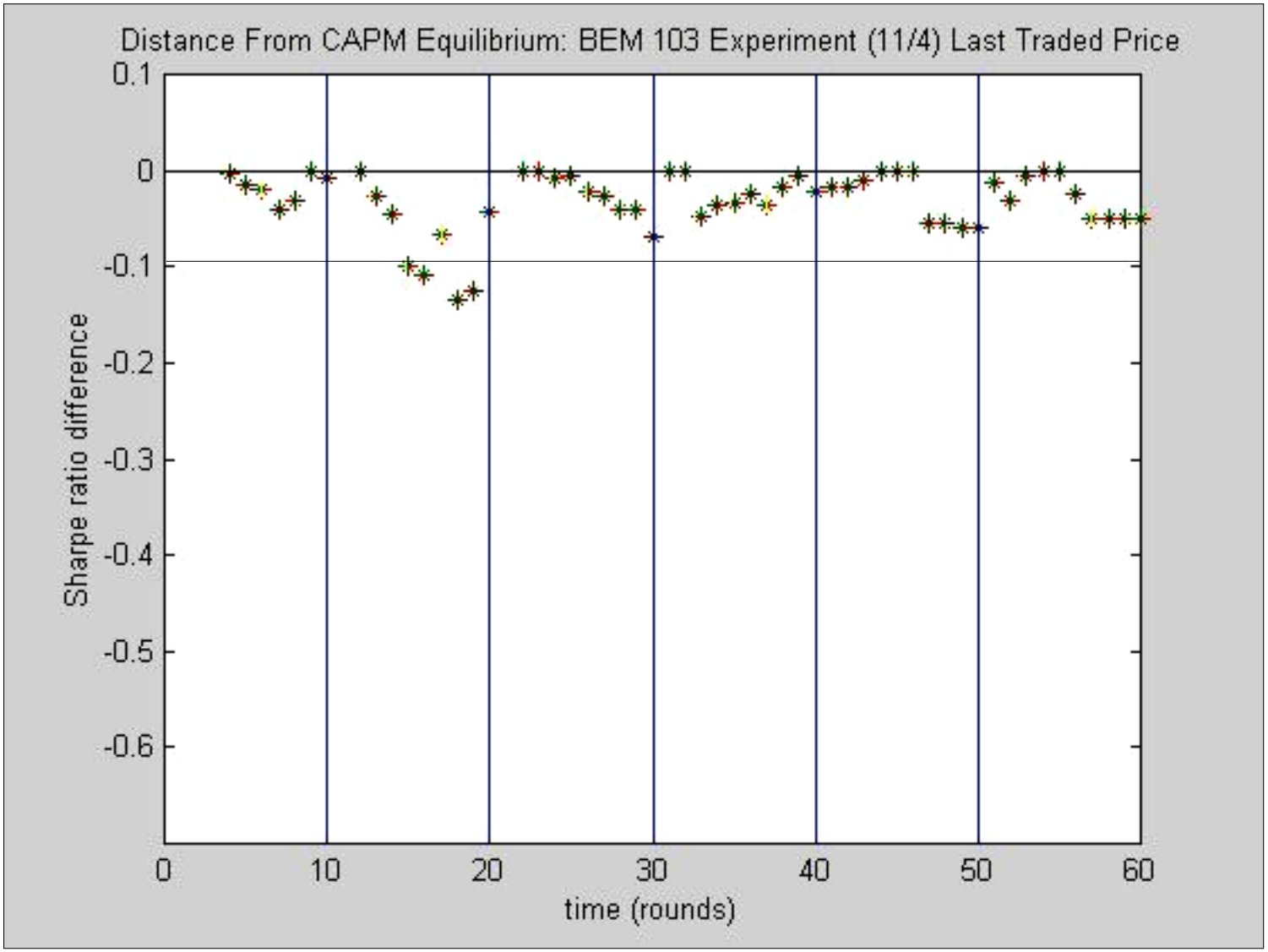
$B^i \geq Pt^i$ if $\delta^i = 1$
$B^i \leq Pt^i$ if $\delta^i = 0$

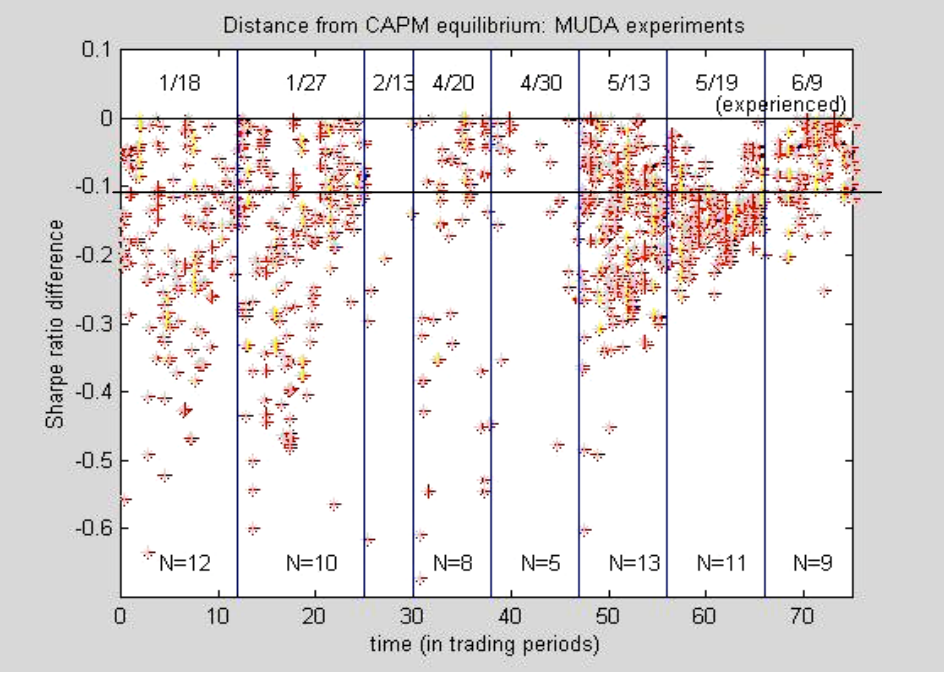
Bidder i pays $\delta^i Pt^i$.

This works fine if $\delta^i \in [0, 1]$
but needs to be modified if $\delta^i \in \{0, 1\}$

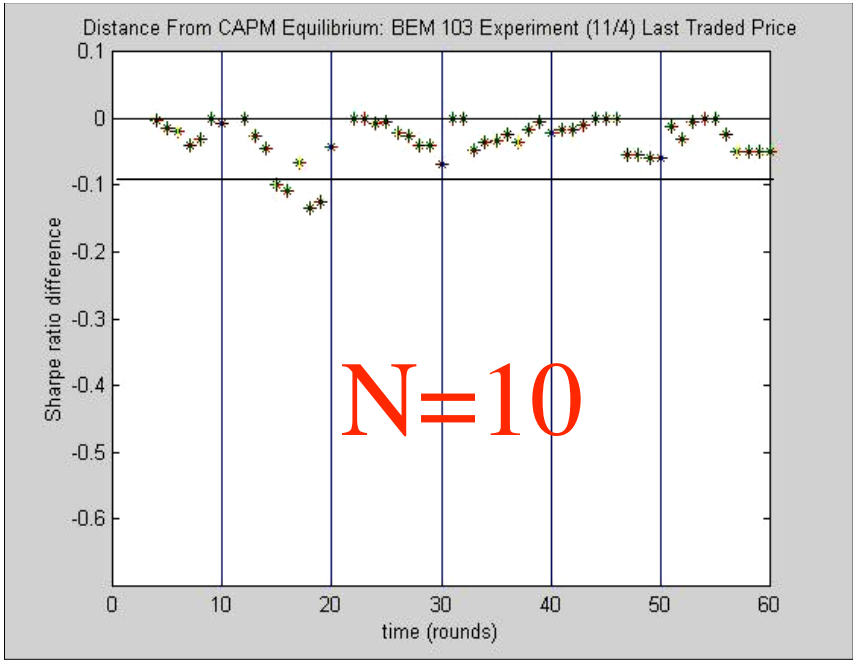
What a CVM can do to a thin market!

N=12

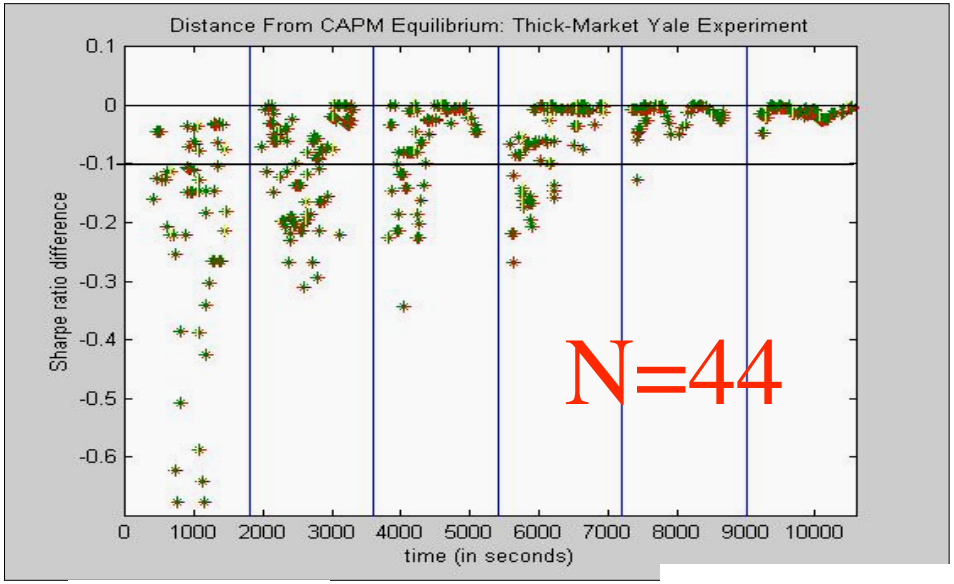




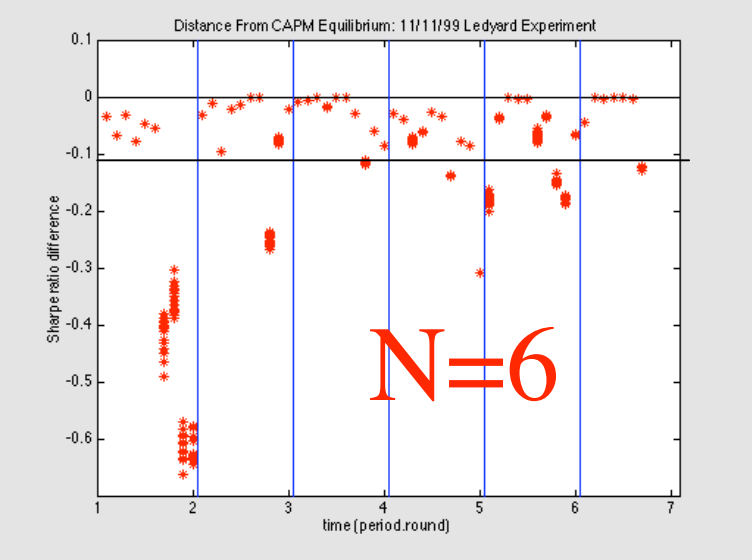
BP thin



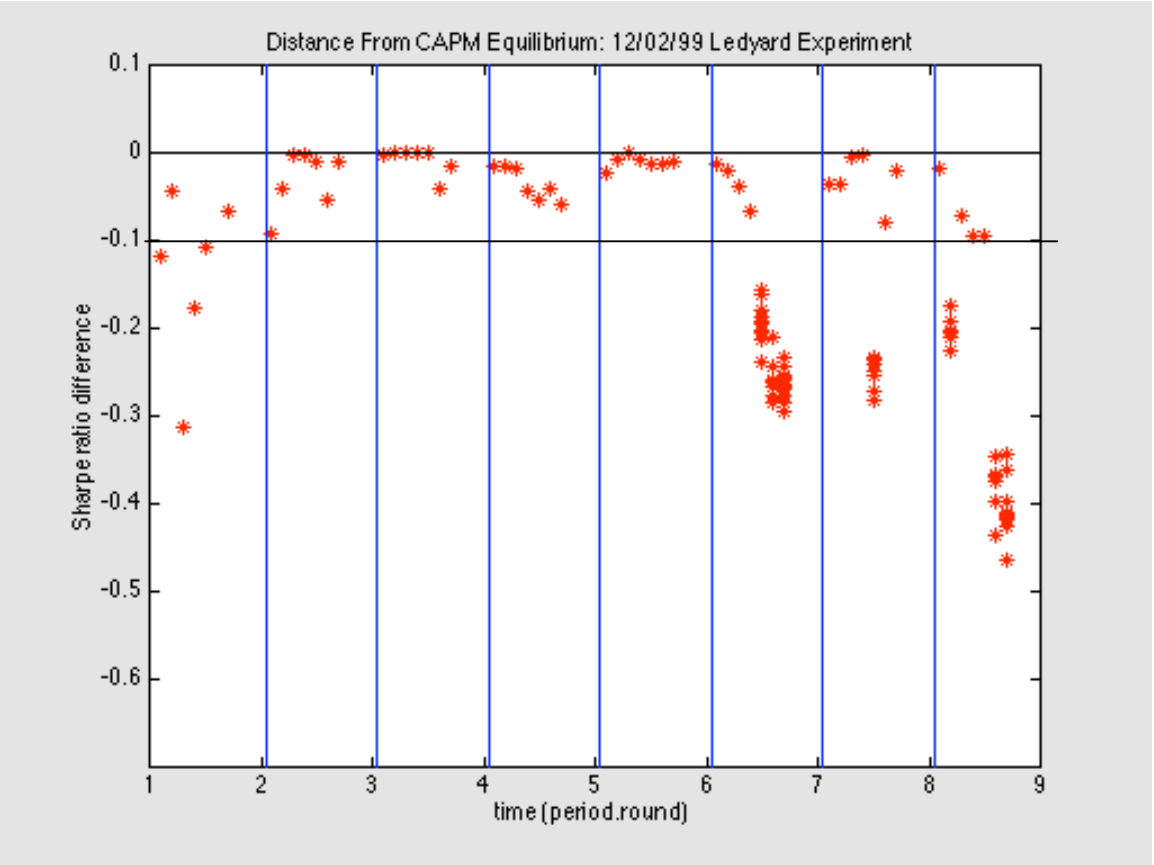
BFL



BP thick



BFL



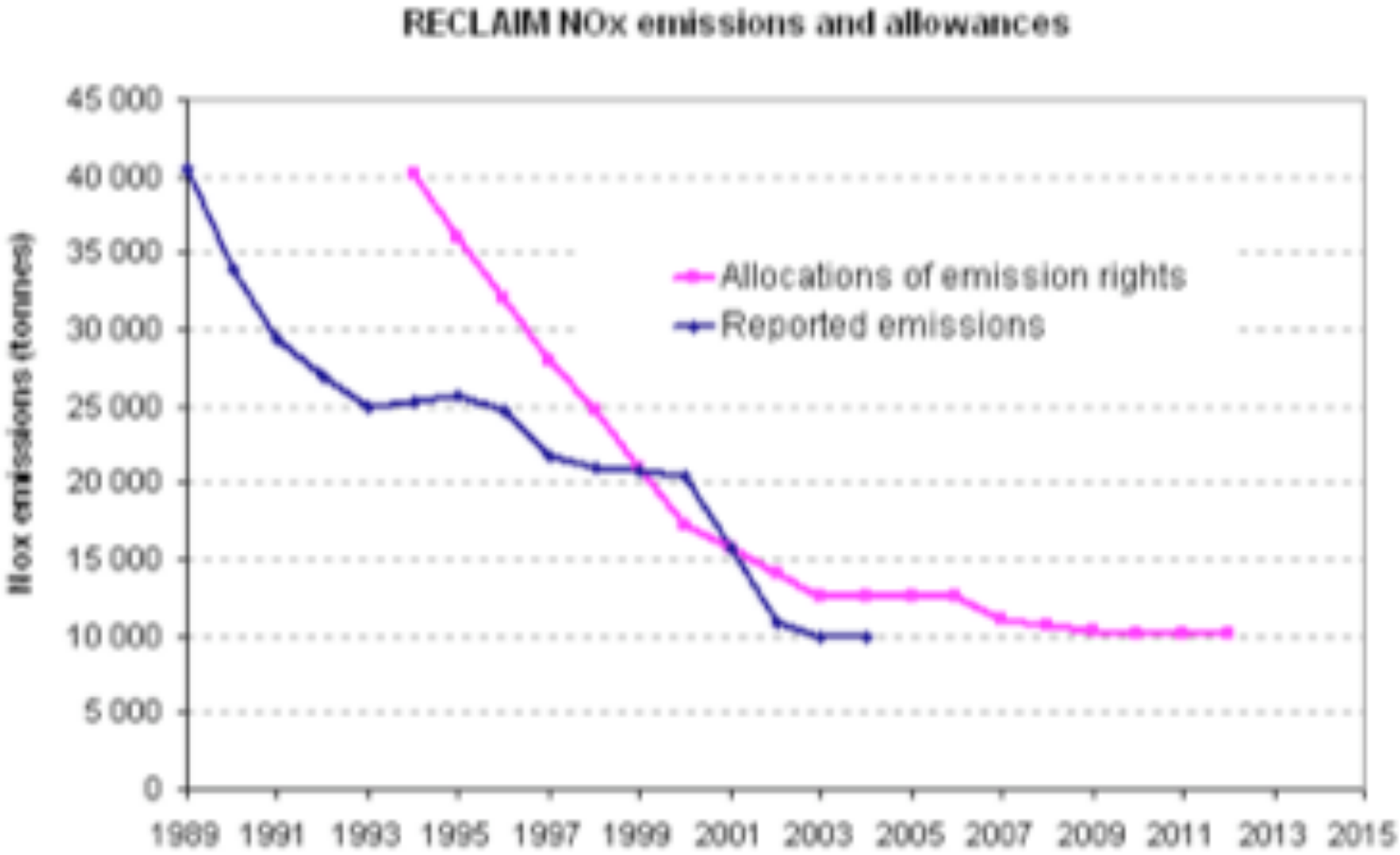
Typical pattern: near end, get trades done fast then very thin.

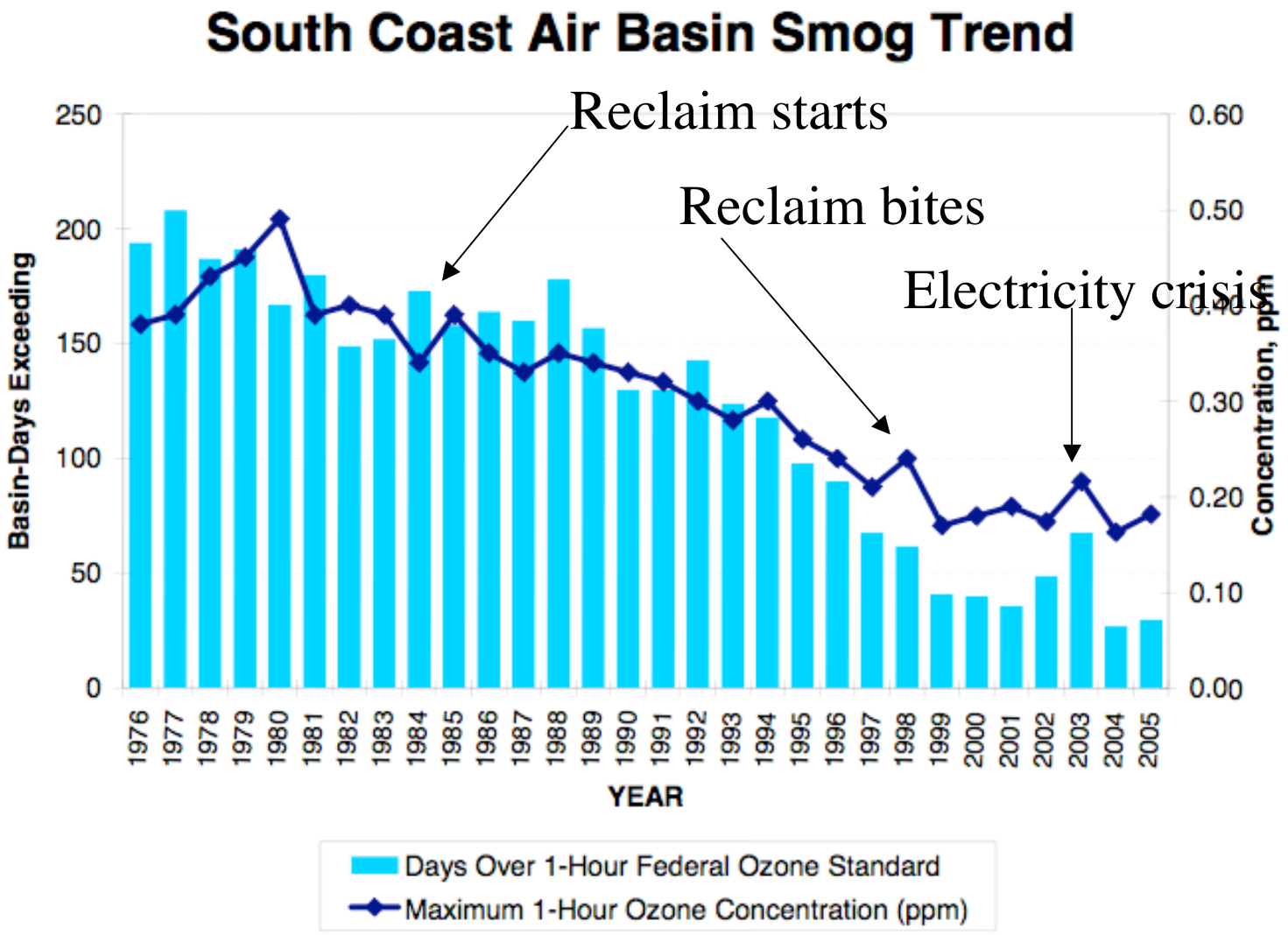
Automated Credit Exchange created.

- Most trading shifted from Cantor to ACE
  - Was dominant trading medium until the electricity market problems caused AQMD to pause RECLAIM
- Trading volume increased significantly.
- Contingent trades were 20% of all trades.
- The structure of prices was as one might predict.
- The reason: Transparency and ease of use

Where RECLAIM succeeded

- Complaining about costs of compliance went down
- Emissions went down
- Technology development proceeded


RECLAIM NOx emissions and allowances
NOx emissions (tonnes)
45 000
40 000
35 000
30 000
25 000
20 000
15 000
10 000
5 000
0
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Allocations of emission rights
Reported emissions


South Coast Air Basin Smog Trend
Reclaim starts
Reclaim bites
Electricity crisis
Basin-Days Exceeding
Concentration, ppm
250
200
150
100
50
0
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1976
1977
1978
1979
1980
1981
1982
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1984
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1988
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1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
YEAR
Days Over 1-Hour Federal Ozone Standard
Maximum 1-Hour Ozone Concentration (ppm)

Where RECLAIM fell short

- “Let there be markets”
- Weak initial reductions
- Justice issues remain
- Electricity crisis caused real problems for RECLAIM but would also have done so for the old command and control.

Why Cap&Trade Programs?

- Emission cap and trade programs can significantly reduce the costs of any abatement program.
  - They provide incentives for the lowest cost abatement possibilities to be used first.
  - They provide significant incentives for technical change in abatement technologies.
- SOX and NOX cap and trade programs have generated significant cost savings, making greater reductions possible than with volunteerism or direct regulation.

Final Thoughts

- Market failure requires government regulation

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- Market failure requires government regulation
- Government failure requires markets
- Cap&Trade can reduce costs, but ……
- "Let there be trade" is not enough to ensure that cost efficiencies will be realized.
- Modern technology and new market design techniques can be used to increase the realization of the potential gains.

End