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Congestion at Locks on Inland Waterways: An Experimental Testbed of a Policy of Tradable Priority Permits for Lock Access

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How Markets Work℠

Overview

- Background
- Problem
- Proposal
  - General
  - Proposed policy features
- Expected effects
  - What will be the relationship of prices?
  - What happens to profits?
  - What types of traffic benefit and what are hurt?
- Experimental Testbed
- Results

NRC report and Congressional budgets

- National Research Council, *Inland Navigation System Planning: the Upper Mississippi River – Illinois Waterway*, National Academy Press, Washington, DC, February 28, 2001.
  - encouraged further examination of steps like tradable permits (slots)
- Water Resources Development Act
  - Passed House (H.R. 2864), now in Senate
  - $1.8 billion for several larger locks on Mississippi and Illinois
  - $235 million for lock upgrades
- The Economist (10/13/2005)

Lock 20 – Canton, MO

Sources: TerraServer and USACE.

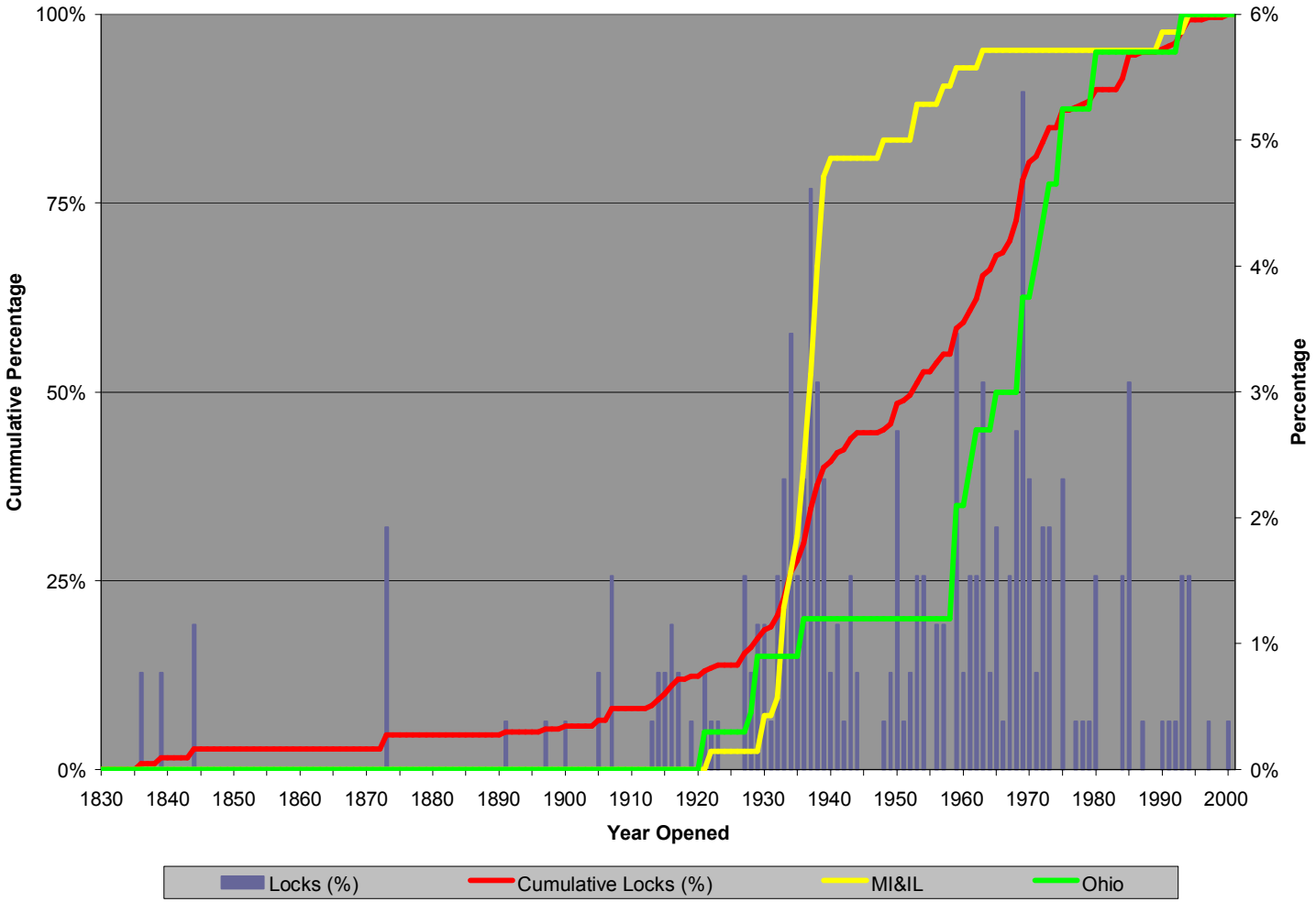
Double Lockage

Sources: USACE.

Where are the locks?

Sources: USACE.

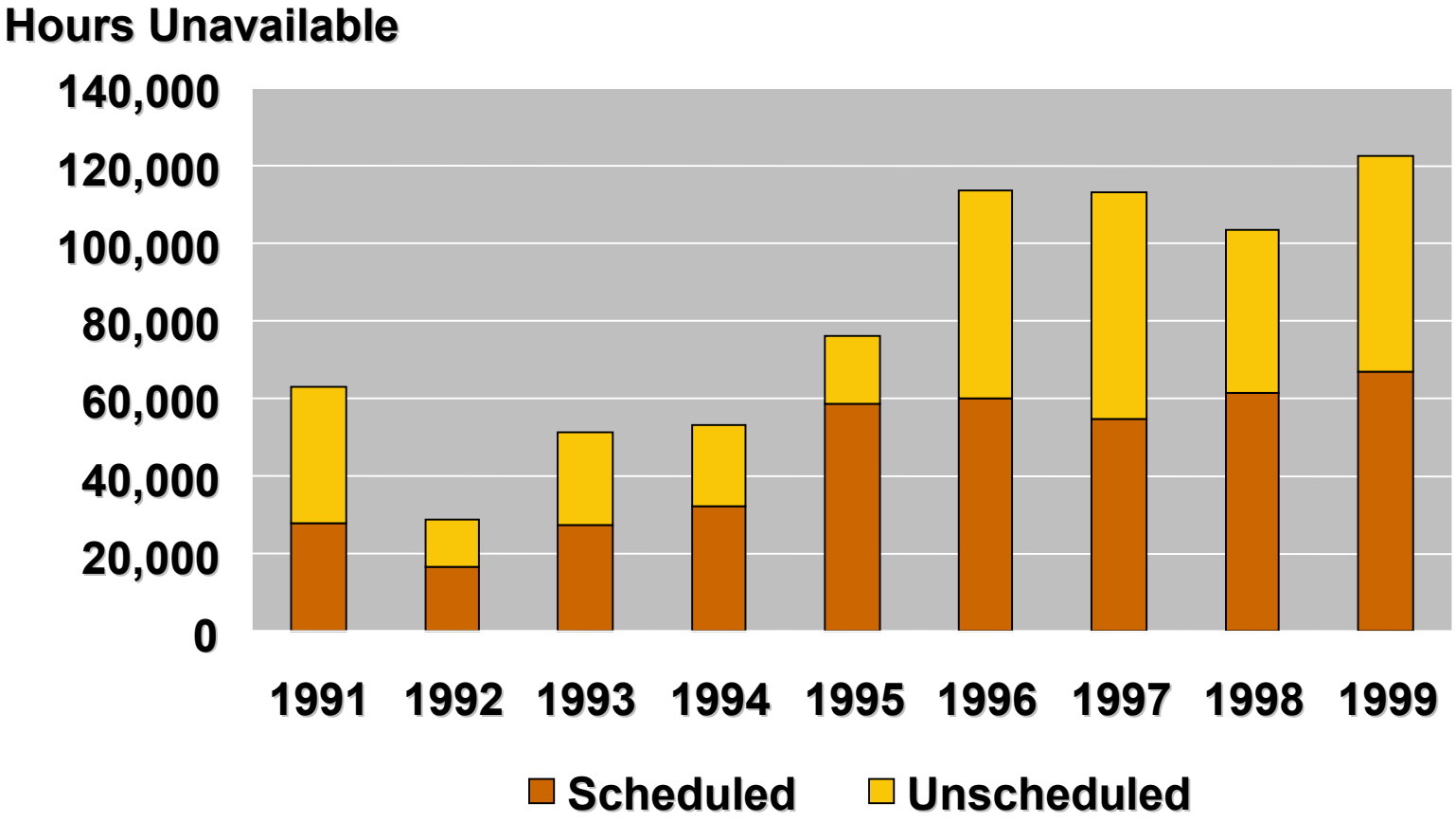
Locks on the Mississippi and Illinois are "old" and the Ohio's are "young"



- Peak builds
  - 1930s
  - 1960s
- Average Age
  - Overall: 57
  - MI&IL: 64
  - Ohio: 43

Sources: USACE.

Lock Outages

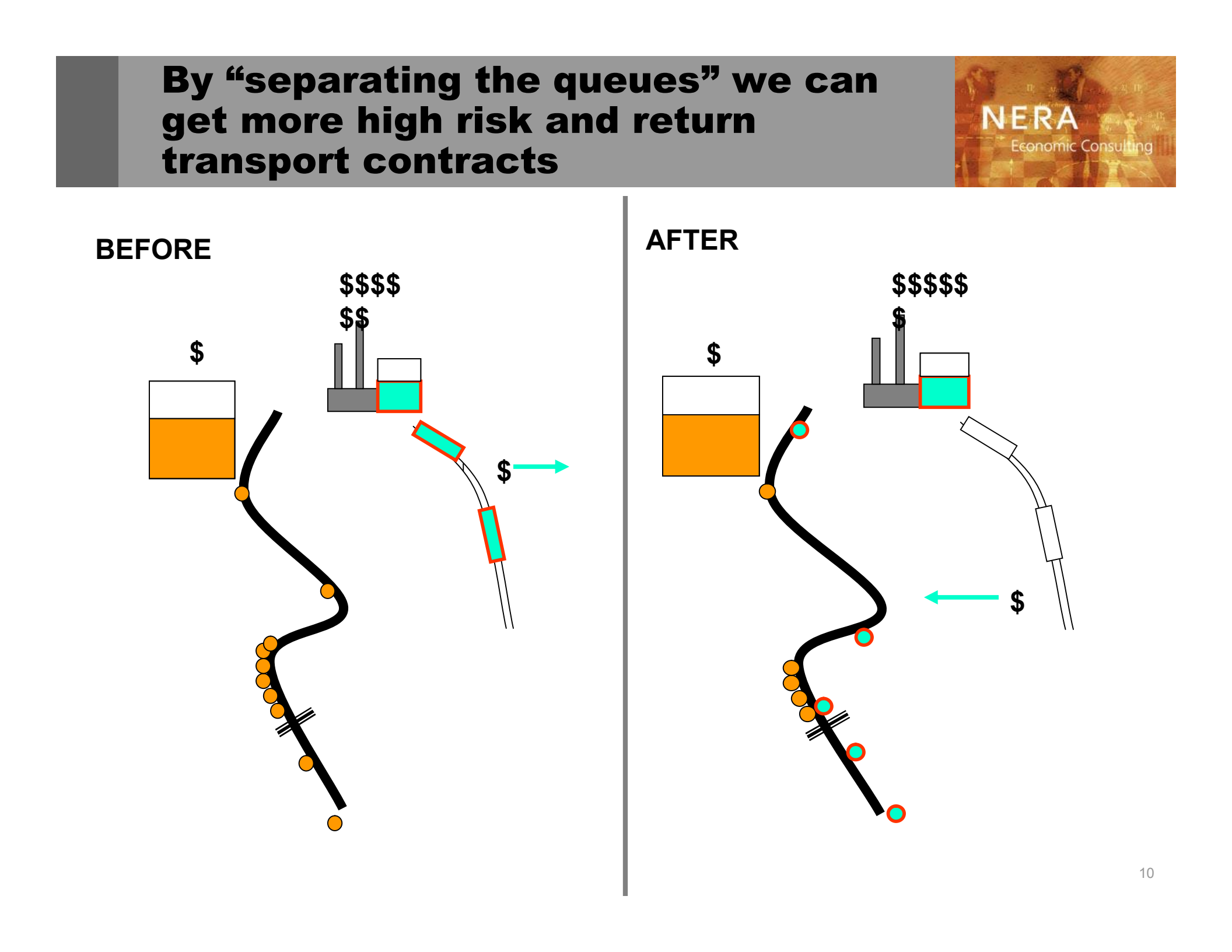


Sources: USACE.

The Problem to be Solved

- Lock outages, both scheduled and unscheduled, are one source of congestion leading to delay for commercial traffic.
  - Greenup lock on the Ohio River: planned 18 day outage stretched to 52 days.
  - Lock 27 on the Mississippi River: auxiliary lock delayed by an average of 25 hours in the peak month.
- Delays caused by lock outages have significant costs: congestion costs estimated at $209 million annually (MARC 2000).
- Cargo choices are impacted by uncertainty, as is competition with other modes of transportation.
- Location of potential demanders may also be impacted by these externalities.
- Can a system of tradable permits be designed to provide relief?

By “separating the queues” we can get more high risk and return transport contracts



Proposed Policy Features

- Tradable Priority Permits:
  - "A permit will give to the holder the right to move ahead of all barges waiting for access to the lock and traveling in the same direction, up to the holder of a permit in the queue being exercised with equal rights."
- Features
  - Master Instrument and Two-week Permits
  - Marketable and Transferable
  - Priority in levels
  - Initial allocation could be based on historical usage
  - Permits will be numbered and recorded by the Corps
  - Lock masters and the Corps will be responsible for enforcement

Expected Effects

- Militate against the disincentive to make high-risk-high-return contracts with quick delivery requirements present in the 'first-come-first-served' policy. Thus,
  - More high-risk high-return contracts
  - Better realized value on contracts
  - Permit prices adjusting to equate the expected profit for contracts of each risk type
  - Increased profits
  - Increased profits for the operators

Experimental Testbed

- "Proof of principle"
- In order to demonstrate the effects of the proposal, an experimental testbed was designed as follows:
  - The lock has a capacity of nine lockages per day
  - There are nine operators and each owns five vessels
  - A permit's period of validity is 5 days
  - There are twenty-two 5-day periods in the testbed
    - 1st ten periods under "first-come-first-served"
    - Subsequent periods include priority permits
  - Time of arrival at the lock is random
  - Permits traded in a standard double-oral auction
  - Subjects were students at California Institute of Technology and were experienced with the double-oral auction format

Payoff structure

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Table 1

Delay, Contract Type and Contract Value

Contract Type	Day on which the boat passes through the lock				
	1st	2nd	3rd	4th	5th
	(value)				
(a)	(b)	(c)	(d)	(e)	(f)
A	1,000	0	-100	-500	-750
B	500	400	0	-100	-200
C	400	300	200	0	-100
D	300	200	100	100	100

Theoretical Prices

Table 2

Equilibrium For Competition Model Given Testbed Environment

Permit Regime (a)	Permit (b)	Price (c)	Contract Type (d)	Cargo Value (e)
First Come, First Served				
	No Permits	0	D	100
Priority Permits				
	1st priority	900	A	1,000
	2nd priority	300	B	400
	3rd priority	100	C	200
	4th priority	0	D	100

Distribution of contracts shifts towards high-risk-high-return with permits.

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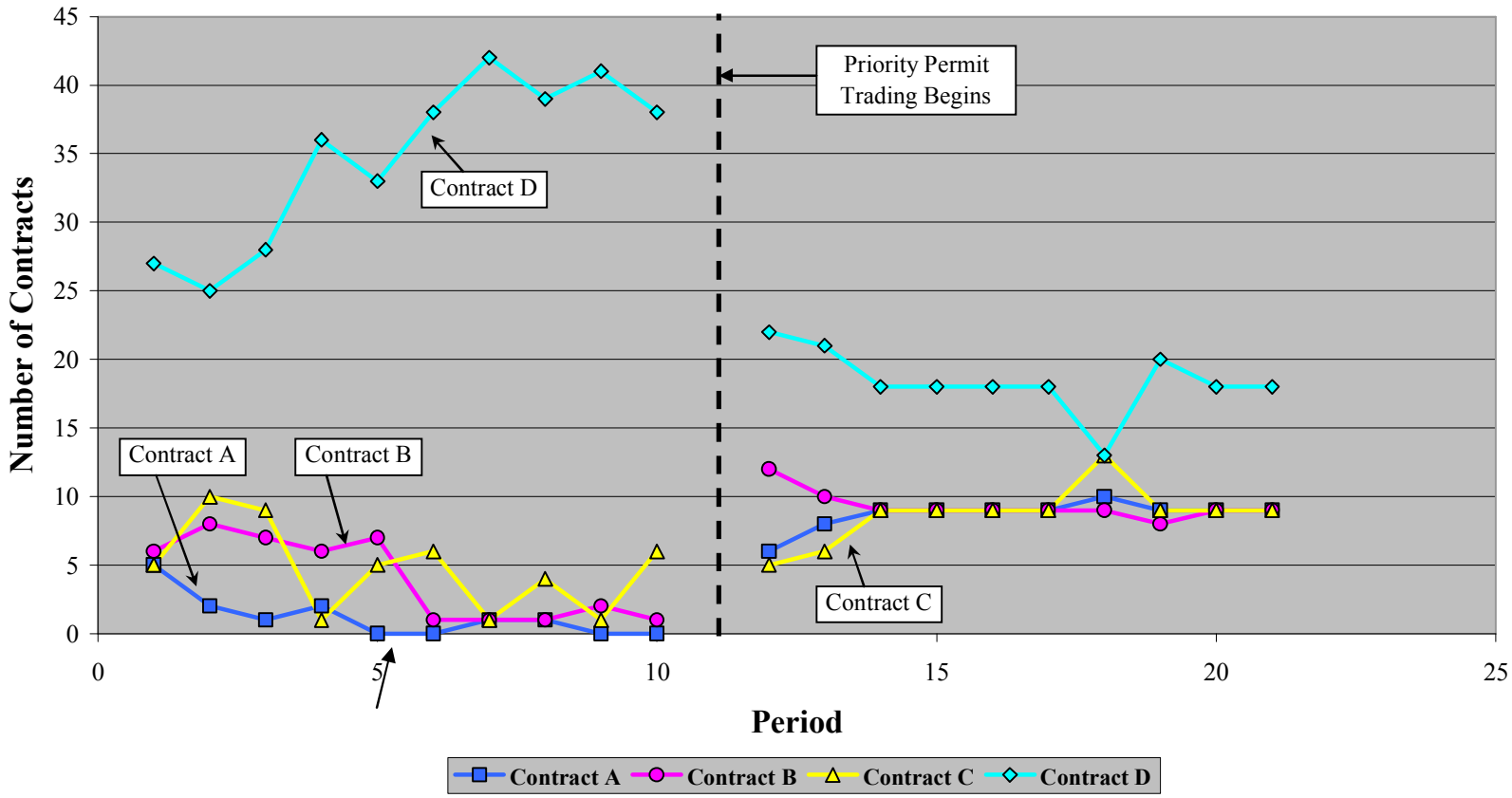
Figure 2: Number of Contracts Made by Type



Source: Testbed Data.

Distribution of contracts shifts towards high-risk-high-return with permits.

Table 3: Difference of Means Tests for the Number of Transportation Contracts Executed by Type

	Contract Types				
	A	**B**	**C**	**D**	**Total**
	(a)	**(b)**	**(c)**	**(d)**	**(e)**
Mean Before Permit Trading $(\bar{x}_A)$	1.2	4.0	4.8	34.8	44.8
Mean After Permit Trading $(\bar{x}_B)$	8.7	9.3	8.6	18.4	45.0
t-Statistic	-12.637	-5.239	-3.138	7.760	-1.000
H_o: Diff = 0					
Prob H_{a1}: $(\bar{x}_A - \bar{x}_B) < 0$	0.000	0.000	0.003	1.000	0.165
Prob H_{a2}: $(\bar{x}_A - \bar{x}_B) \neq 0$	0.000	0.000	0.006	0.000	0.331
Prob H_{a3}: $(\bar{x}_A - \bar{x}_B) > 0$	1.000	1.000	0.997	0.000	0.835

The realized value of contracts of high-risk types increase along with total value, while the value of low-risk contracts decrease.

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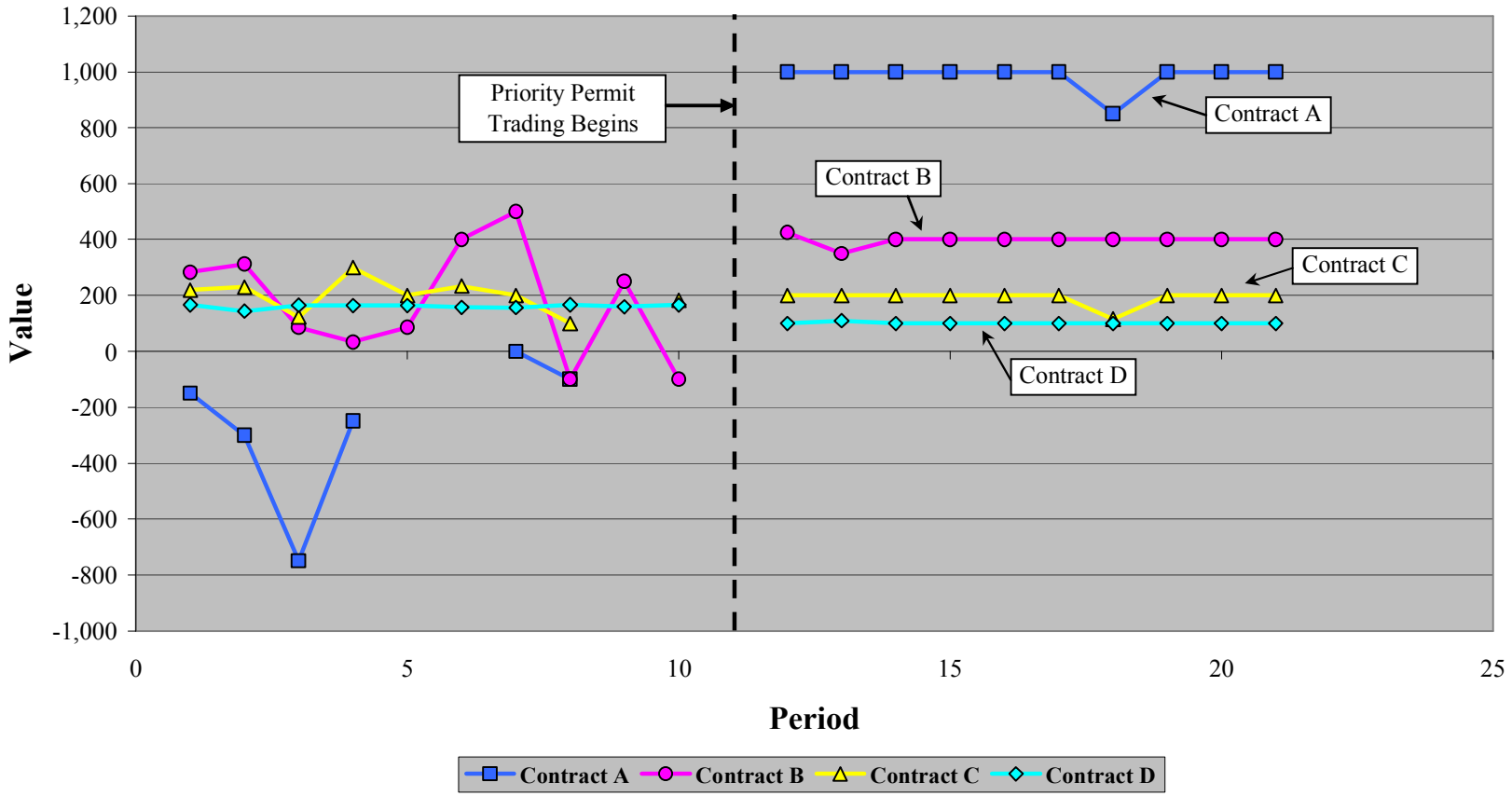
Figure 3: Average Realized Value of Contracts by Type



Source: Testbed Data.

The realized value of contracts of high-risk types increase along with total value, while the value of low-risk contracts decrease.

Table 4: Difference of Means Tests for the Value of Transportation Contracts Executed by Type

	Contract Types				
	A	**B**	**C**	**D**	**Total**
	(a)	**(b)**	**(c)**	**(d)**	**(e)**
Mean Before Permit Trading $(\bar{x}_A)$	-270.0	680.0	890.0	5610.0	6910.0
Mean After Permit Trading $(\bar{x}_B)$	8,550.0	3,700.0	1,620.0	1,860.0	15,730.0
t-Statistic	-27.525	-9.959	-3.089	10.890	-26.943
H_o: Diff = 0					
Prob H_{a1}: $(\bar{x}_A - \bar{x}_B) < 0$	0.000	0.000	0.003	1.000	0.000
Prob H_{a2}: $(\bar{x}_A - \bar{x}_B) \neq 0$	0.000	0.000	0.006	0.000	0.000
Prob H_{a3}: $(\bar{x}_A - \bar{x}_B) > 0$	1.000	1.000	0.997	0.000	1.000

Ashenfelter-El Gamal

- Permit price time series regressions

$$z_t = B_1 \frac{1}{t} + B_2 \frac{t-1}{t} + u_t$$

- Profit time series regressions

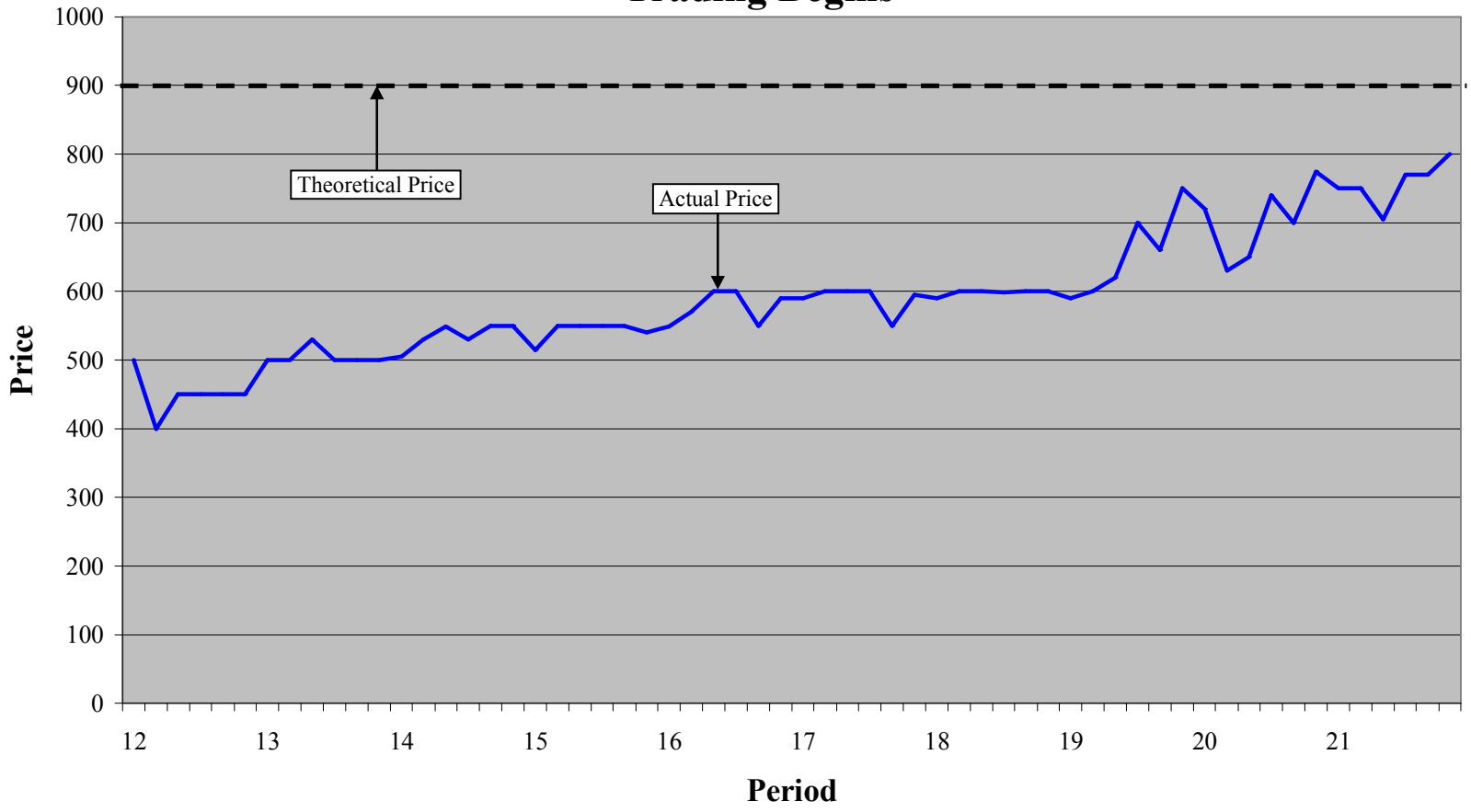
$$y_t = B_1 \frac{1}{t} + B_2 \frac{t-1}{t} + B_3 d \frac{t-1}{t} + u_t$$

- Profit panel regressions

$$y_{it} = B_1 \frac{1}{t} + B_2 \frac{t-1}{t} + \sum_1^m B_{i3} D_i \frac{t-1}{t} + u_{it}$$

Priority 1 Permit Prices

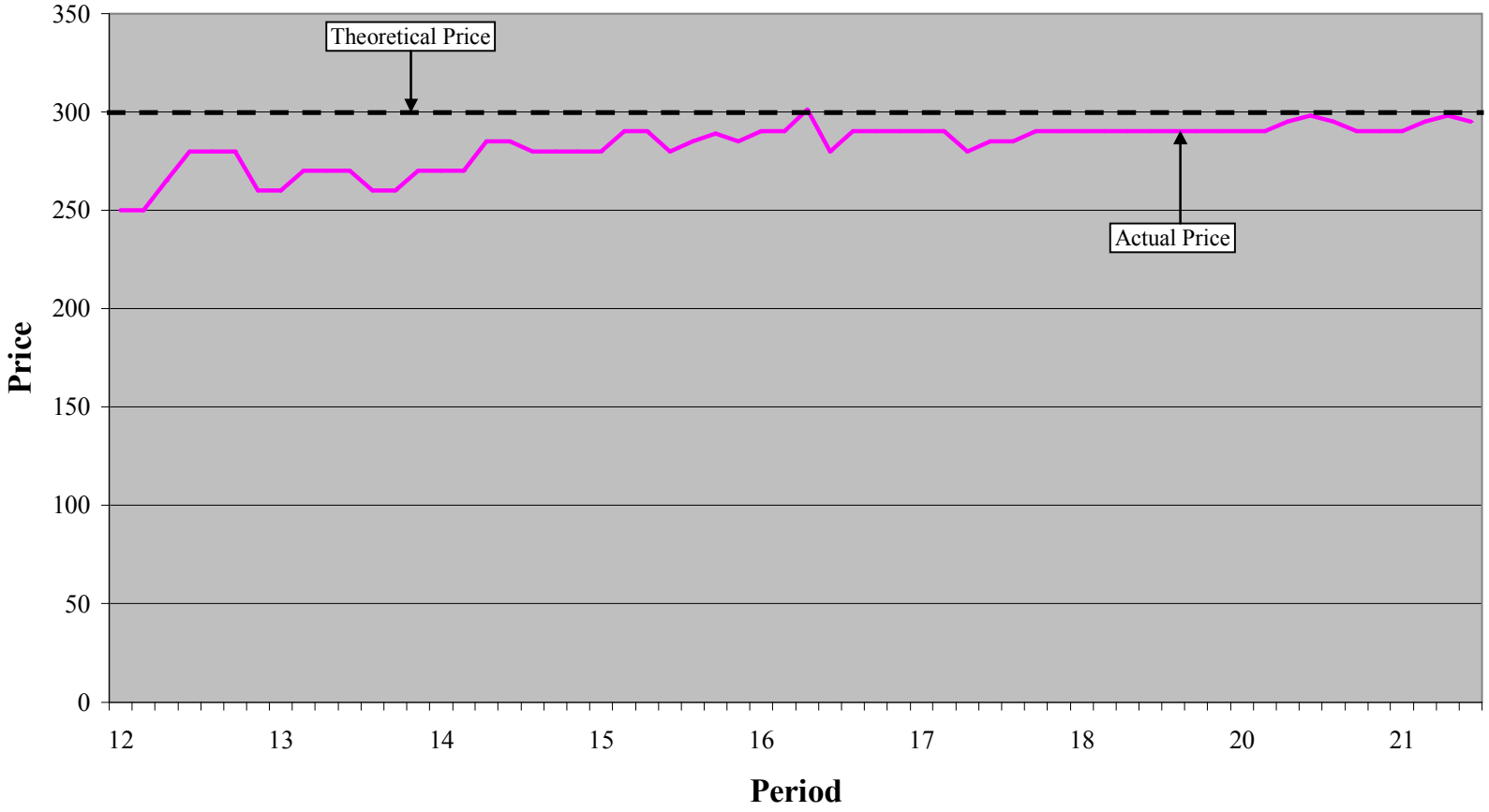
Figure 4: Market for Priority 1 Permits After Priority Permit Trading Begins



Source: Testbed Data.

Priority 2 Permit Prices

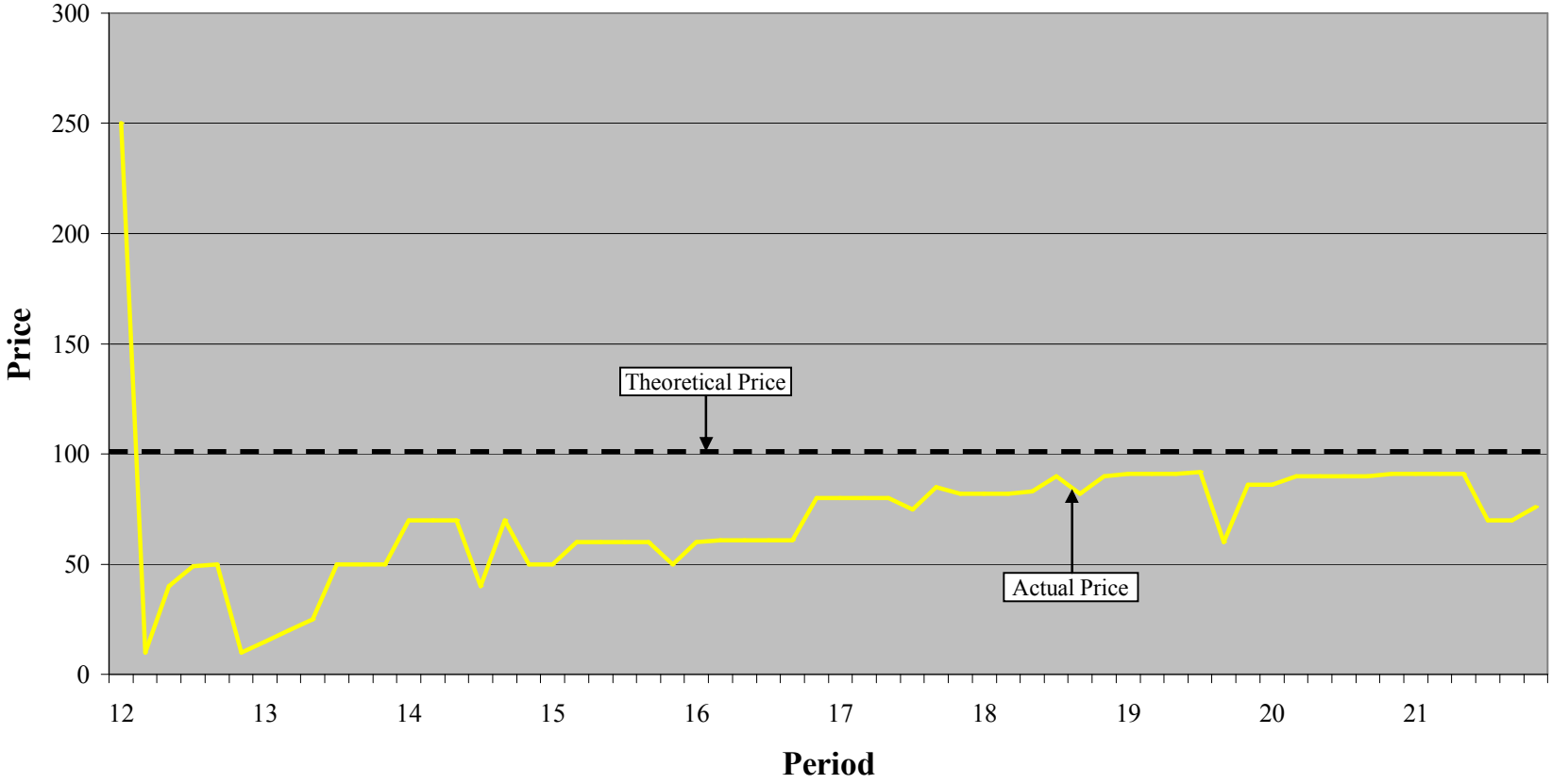
Figure 5: Market for Priority 2 Permits After Priority Permit Trading Begins



Source: Testbed Data.

Priority 3 Permit Prices

Figure 6: Market for Priority 3 Permits After Priority Permit Trading Begins



Source: Testbed Data.

Prices converge toward the theoretical prediction

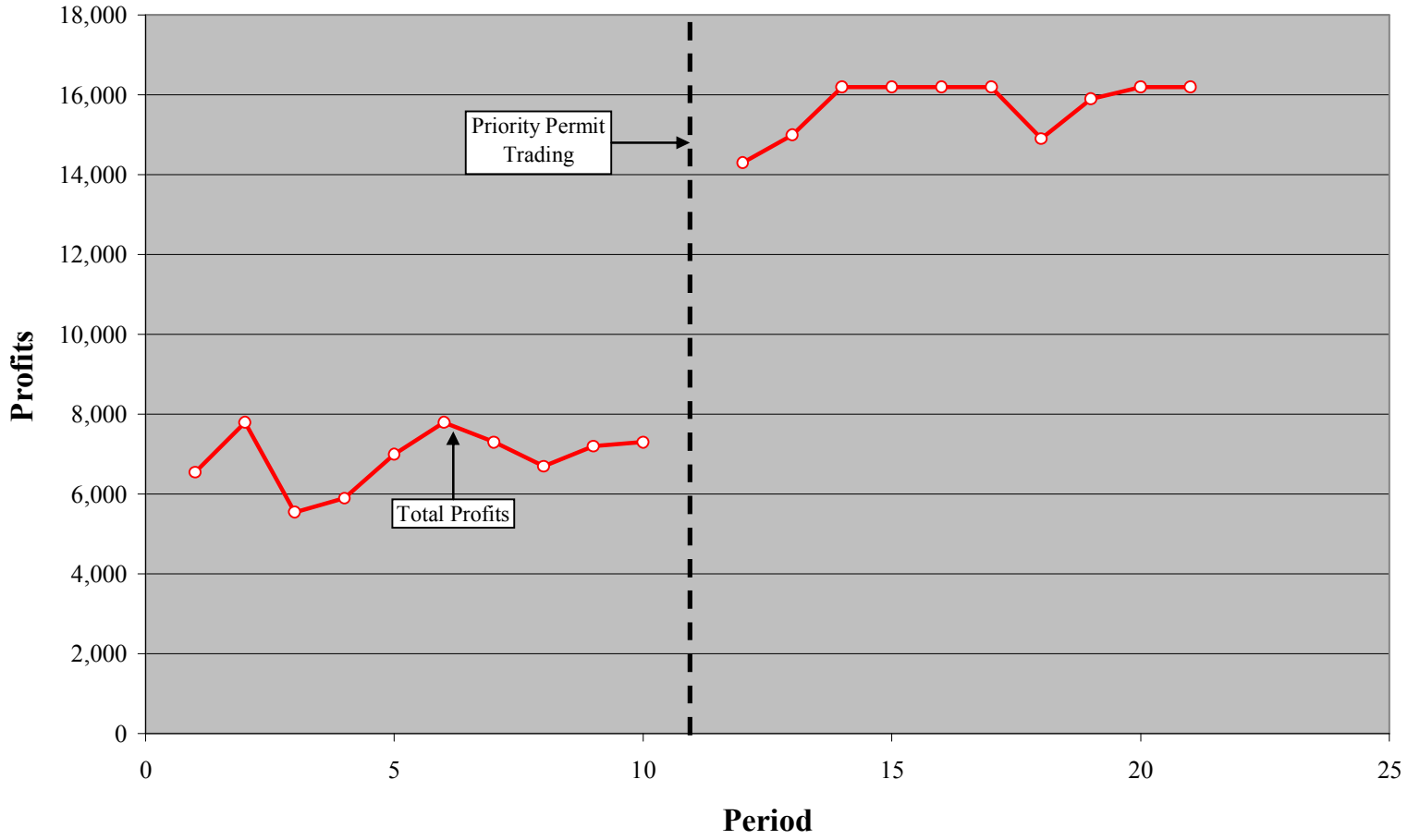
Table 5: Regression Results for the Permit Prices of Each Priority Level

Priority Level of Permit (a)	Number of Observations (b)	Origin (c)	Asymptote (d)	Theoretical Equilibrium Price (e)
1	10	399.923 * (39.464)	663.513 * (45.014)	900
2	10	260.639 * (4.493)	292.084 * (2.835)	300
3	10	56.514 * (15.040)	75.632 * (10.830)	100

Notes: - Standard Errors are listed in parentheses.
* Number is significant at the 0.01 level.

Total profits increase

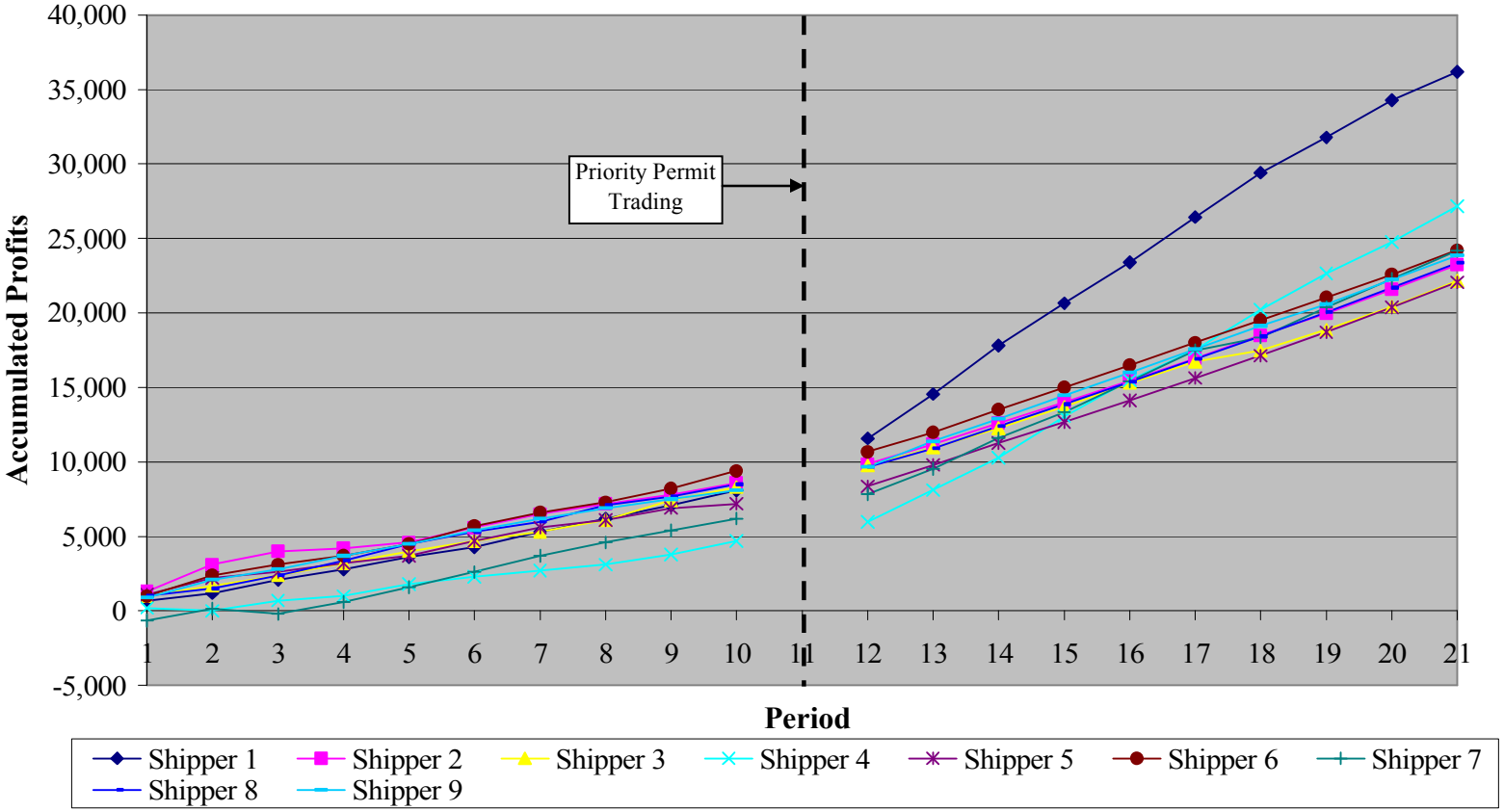
Figure 7: Total Profits to All Shippers



Source: Testbed Data.

Profits for each shipper increase

Figure 8: Accumulated Profits by Individual Shippers After Priority Permit Trading Begins



Source: Testbed Data.

Separate regression models for total profits and individual profits

Table 6: Regression Results for Total Profits and Profits for Each Individual

Participants	Number of Observations	Origin	Asymptote	Permit Effect
(a)	(b)	(c)	(d)	(e)
Total	20	-10,238.58 (13,435.52)	56,210.65 * (9,595.38)	110,848.60 * (28,868.04)
1	20	-1,687.38 (1,959.01)	6,405.59 * (1,233.32)	20,192.37 * (4,884.47)
2	20	-119.94 (1,195.55)	7,453.41 * (909.11)	10,118.48 * (2,693.97)
3	20	-815.36 (1,410.36)	6,503.94 * (1,110.70)	10,497.02 * (2,604.58)
4	20	-1,625.09 (1,507.42)	3,417.04 * (833.32)	14,503.39 * (4,109.75)
5	20	-467.40 (1,273.80)	6,237.97 * (931.88)	9,943.04 * (2,735.33)
6	20	-873.45 (1,494.41)	7,623.18 * (1,179.80)	11,036.06 * (2867.84)
7	20	-2,695.18 (1,684.20)	4,415.44 * (1,297.69)	13,036.69 * (3,366.79)
8	20	-1,088.56 (1,566.77)	7,074.67 * (1,151.54)	10,495.06 * (2,874.91)
9	20	-866.23 (1,378.68)	7,079.41 * (977.43)	11,026.53 * (2,824.90)

Notes: - Standard Errors are listed in parentheses.
- Permit Effect = *Permit Dummy* * ((t-1)/t).
* Number is significant at the 0.01 level.

Panel regression of individual profits

Table 7: Regression Results for Profits of the Individual Testbed Participants Before and After the Introduction of Tradable Permits

Regressors	Number of Observations	R^2	$\overline{R}^2$	Coefficient Values
(a)	(b)	(c)	(d)	(e)
Origin	180	0.7765	0.9204	-1,137.62 **
				(559.63)
Asymptote	180	0.7765	0.9204	6,245.63 *
				(424.35)
Permit Effect for Individual:				
1	180	0.7765	0.9204	20,313.04 *
				(3,893.49)
2	180	0.7765	0.9204	11,398.98 *
				(2,089.42)
3	180	0.7765	0.9204	10,778.36 *
				(1,897.13)
4	180	0.7765	0.9204	11,639.97 *
				(3,342.86)
5	180	0.7765	0.9204	9,983.28 *
				(2,121.65)
6	180	0.7765	0.9204	12,432.50 *
				(2,119.86)
7	180	0.7765	0.9204	11,095.19 *
				(2,514.08)
8	180	0.7765	0.9204	11,327.61 *
				(2,153.80)
9	180	0.7765	0.9204	11,879.71 *
				(2,185.60)

Notes: - Standard Errors are listed in parentheses.
- Permit Effect = *Permit Dummy* * ((t-1)/t).
* Number is significant at the 0.01 level.
** Number is significant at the 0.05 level.

Summary effects

- The risk of lock delay impacts the nature of the cargo and contracts transported through the river system.
- The ‘first-come-first-served’ policy discourages high value contracts with fast delivery requirements.
- The introduction of a system of tradable priority permits changes the distribution of the types of contracts found in use.
- Contracting shifts to the more valuable types of contracts and fills the available capacity for such contracts.
- The priority permit system operates to maximize total profits of operators.