More Competitive Electricity Markets:
Structural vs Behavioral Measures

An Experimental Investigation Guided by Theory and Policy Concerns

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1. Theoretical Physics

$$P = \int_{\infty}^{r_o} F \, dr = \int_{\infty}^{r_o} -\frac{Gm_1m_2}{r^2} \, dr$$

$$= -Gm_1m_2 \int_{\infty}^{r_o} \frac{1}{r^2} \, dr$$

$$= -Gm_1m_2 \left(-\frac{1}{r} \right) \Bigg|_{\infty}^{r_o}$$

$$= -Gm_1m_2 \left(-\frac{1}{r_o} - 0 \right)$$

$$= -Gm_1m_2 \left(-\frac{1}{r_o} \right)$$

$$P = \frac{Gm_1m_2}{r_o}$$


2. Bridge model experimentation


3. Bridge

1. Theory

Theoretical Physics

$$
\begin{aligned}
P &= \int_{\infty}^{r_o} g\,dr = \int_{\infty}^{r_o} -\frac{Gm_1m_2}{r^2}\,dr \\
&= -Gm_1m_2\int_{\infty}^{r_o}\frac{1}{r^2}\,dr \\
&= -Gm_1m_2\left(-\frac{1}{r}\right)\Big|_{\infty}^{r_o} \\
&= -Gm_1m_2\left(-\frac{1}{r_o}-0\right) \\
&= -Gm_1m_2\left(-\frac{1}{r_o}\right) \\
P &= \frac{Gm_1m_2}{r_o}
\end{aligned}
$$

Theoretical Economics

$$
\begin{aligned}
v &= \lim_{h\to 0}\frac{f(t+h)-f(t)}{h} \\
&= \lim_{h\to 0}\frac{[490(t+h)^2]-[490t^2]}{h} \\
&= \lim_{h\to 0}\frac{[490(t^2+2ht+h^2)]-[490t^2]}{h} \\
&= \lim_{h\to 0}\frac{[490(2ht+h^2)]}{h} \\
&= \lim_{h\to 0}[490\{2t+h\}] \\
&= 980t
\end{aligned}
$$

2. Engineering

Bridge Experimentation

Market Experimentation

Experimental & Computational Economics

3. Implementation

Bridge

Competitive Market

E.g., Energy Market

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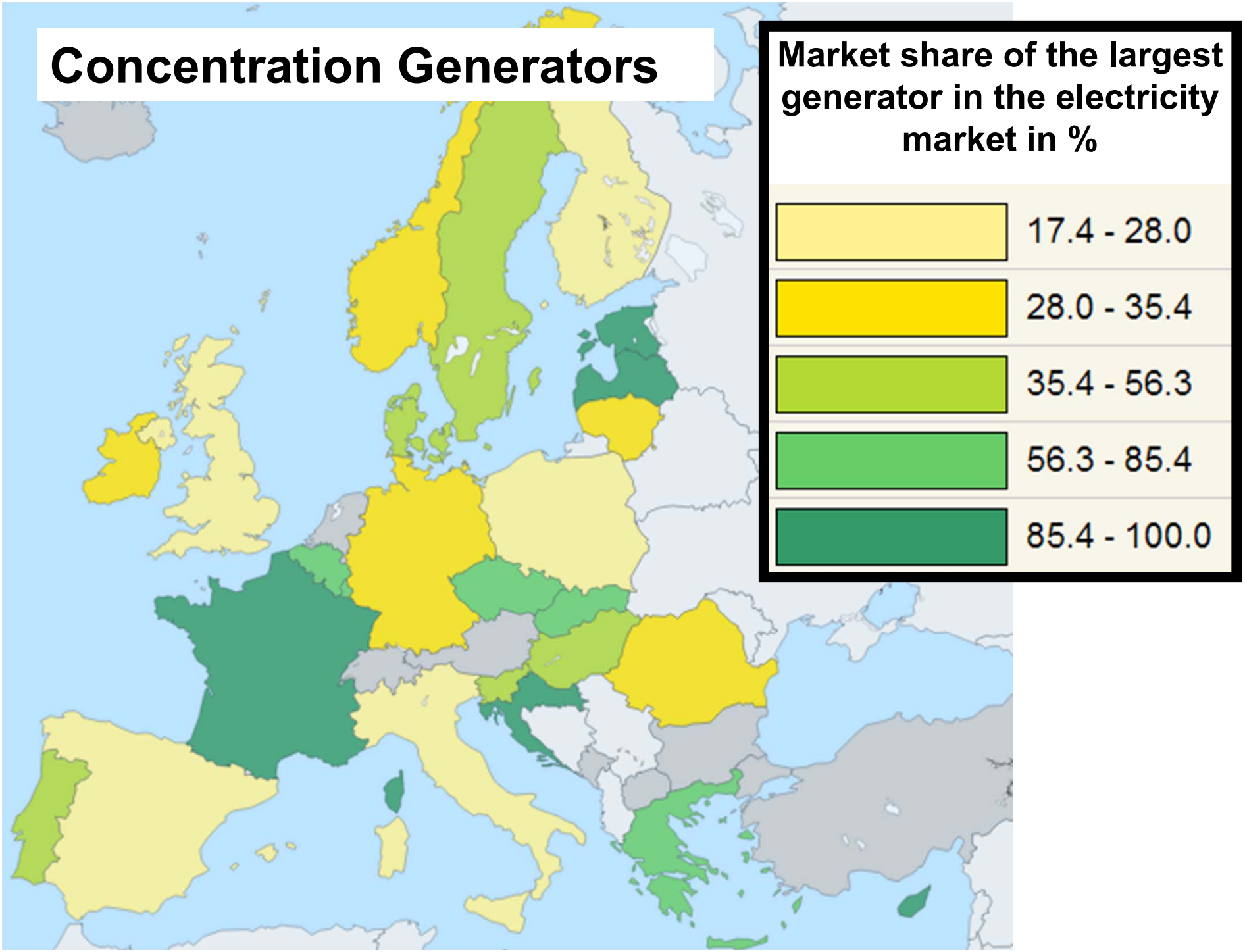
Concentration Generators



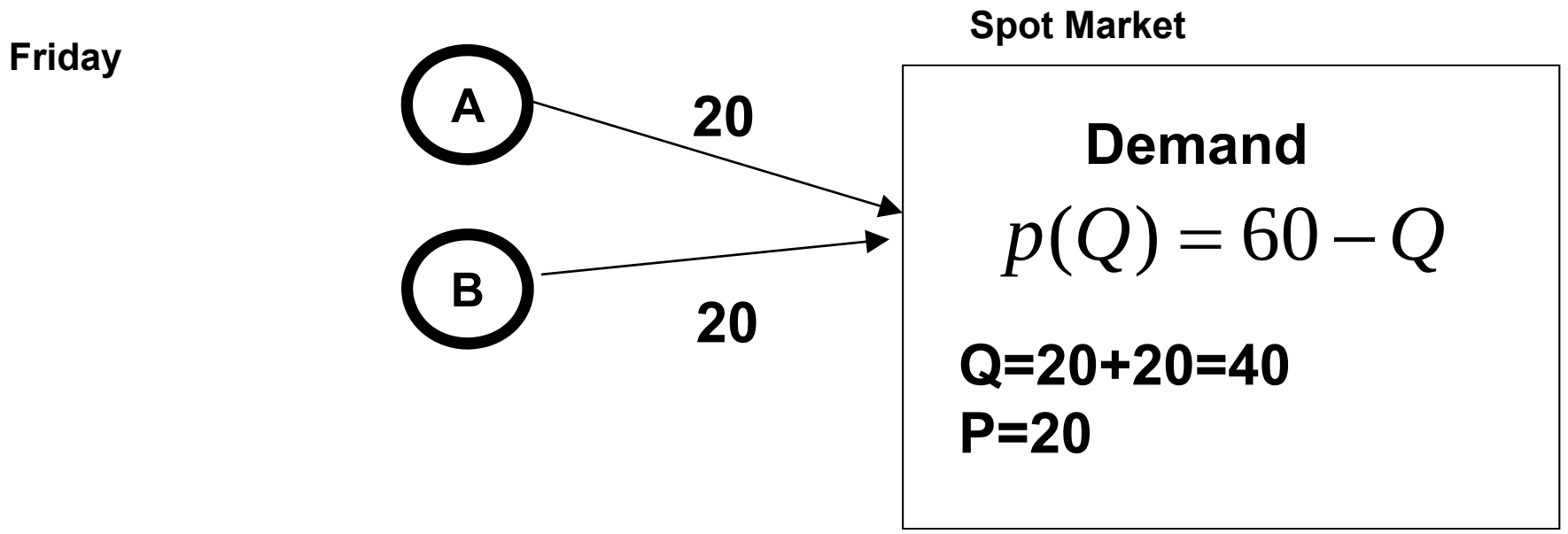
What is the most effective pro-competitive policy?

1. Behavioral Remedy
   - Introduce a forward market (Allaz & Vila, JET 1993)

2. Structural Remedy
   - Add one more competitor by divestiture

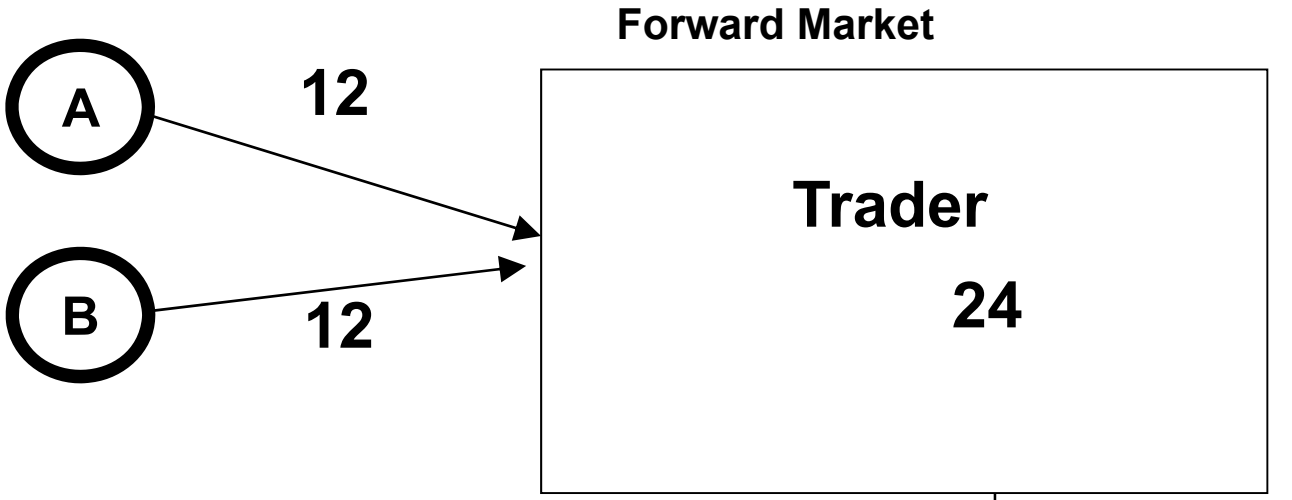
Behavioral:
forward market

Week 5

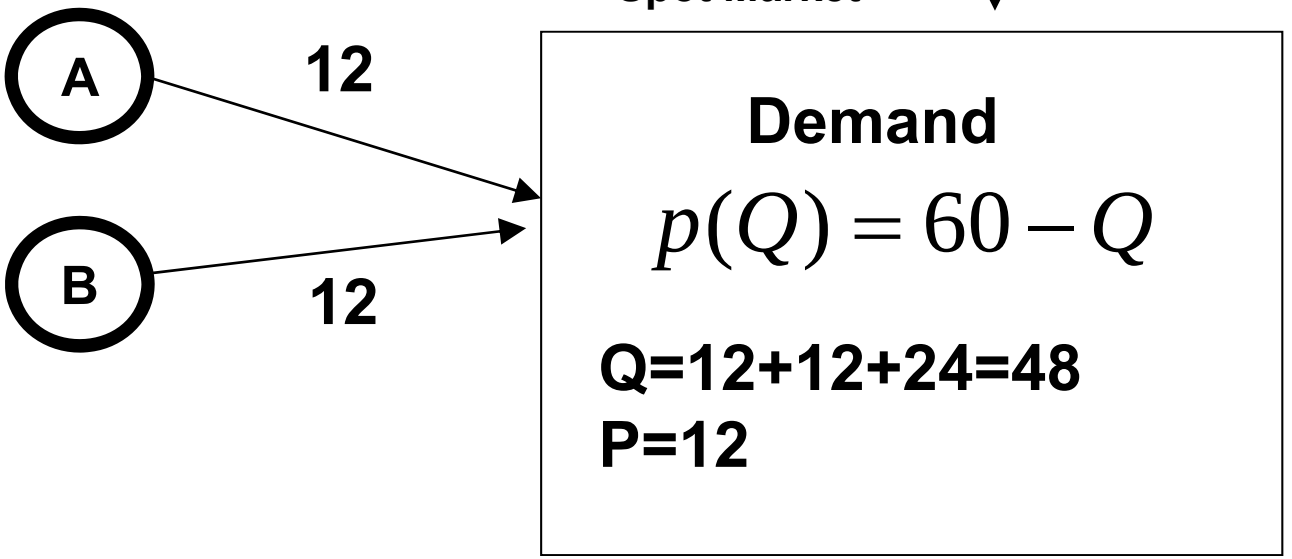


Week 5

Monday



Friday



Spot Market

$$p(Q) = 60 - Q$$

Q=40

P=20

Spot Market + Forward Market

$$p(Q) = 60 - Q$$

Q=48

P=12

Allaz & Villa (JET 1993): Cournot competition

Demand Schedule (Duopoly) $p[q_1 + q_2] = 60 - q_1 - q_2$

q_i Total Production (Forward + Spot)

f_i Production sold in Forward Market

$(q_i - f_i)$ Production sold in Spot Market

Spot Market Profit Function

$$\pi_1 = \underbrace{(60 - q_1 - q_2)}_{\text{Price}}\underbrace{(q_1 - f_1)}_{\text{Spot Market Production}}$$

First Order Conditions

$$60 - 2q_1 - q_2 + f_1 = 0$$

$$\Leftrightarrow \quad 2q_1 = 60 - q_2 + f_1$$

Reaction function $2q_1 = 60 - q_2 + 12$

"Forward market boycott"

$f_1 = 0 \;\&\; f_2 = 0$ $\qquad \pi_1 = \pi_2 = 400$

"Backstabbing" ("Stackleberg Equilibrium")

$f_1 = 15 \;\&\; f_2 = 0$

$\pi_1 = 450$

$\pi_2 = 225$

Nash-Equilibrium

$f_1 = 12 \;\&\; f_2 = 12$ $\qquad \pi_1 = \pi_2 = 288$

- **Theory shows that a forward market has a pro-competitive effect (Allaz & Villa, JET, 1993)**

Can we trust this theory?

"2 are few and 4 are many" Huck et al. (JEBO, 2004)

	2 Firms	3 Firms	4 Firms
Without Forward Market	M2 92.7%	M3 102.7%	M4 102.9%

Can we trust this theory?

"2 are few and 4 are many" Huck et al. (JEBO 2004)

	2 Firms	3 Firms	4 Firms
Without Forward Market	M2 92.7%	M3 102.7%	M4 102.9%
With Forward Market	M2F 80%? 100%?	M3F 92%? 110%?	–

Structural:

One more competitor

What is the right comparison?

Add one more competitor:

- **By entry? Brandts et al (EJ, 2008)**
  1. Increased competition
  2. Cheaper aggregate production
  3. Capital cost of new plants

- **By divestiture?**
  1. Only increased competition

Experiment comparing

Behavioral measure

Introducing a forward market

with

Structural measure

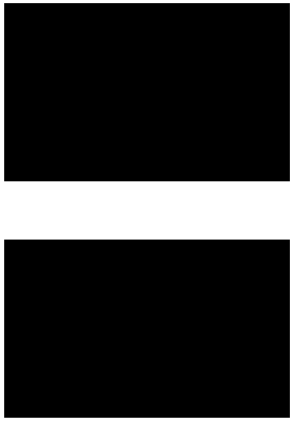
Adding one more competitor by **divestiture**

- Treatments:
  - M2, M2F, M3, M3F & M4
- Demand: $p(Q) = Max(0, 2000 - 27Q)$
  - As in Brandts et al (2008)
- Costs: Steeply increasing marginal costs
  - (Newbery, EER 2002).
  - As in treatment **M3** of Brandts et al (2008)

$$mc_3(q) = 2q^2$$

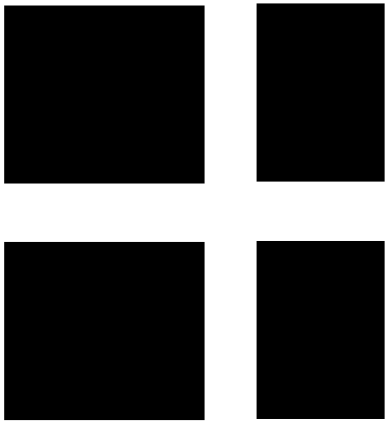
$$c_3(q) = \sum_{x=1}^{q} 2x^2 = \tfrac{2}{3}x^3 + x^2 + \tfrac{1}{3}x$$

M2



M3

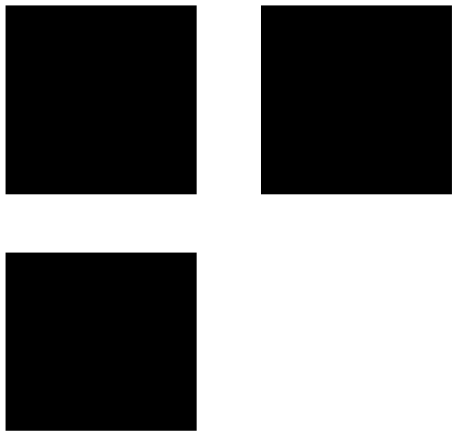
M2



M3

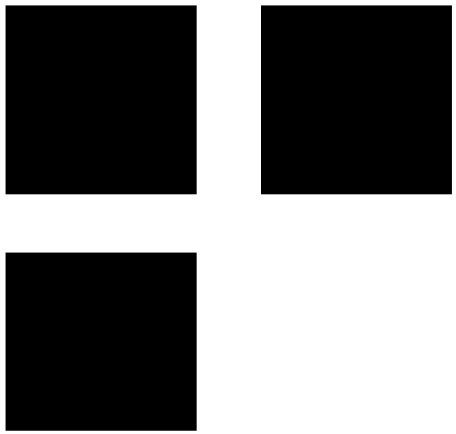
M2

M3



M2

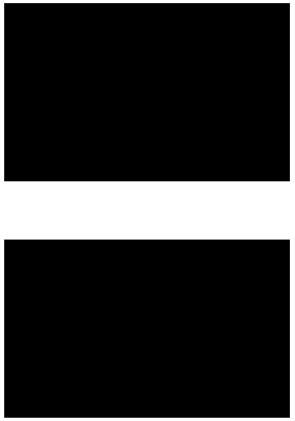
M3



M3

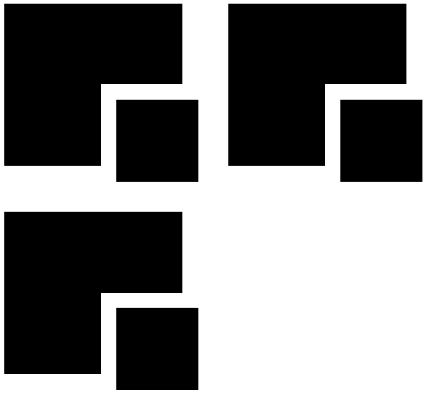
M4

M2

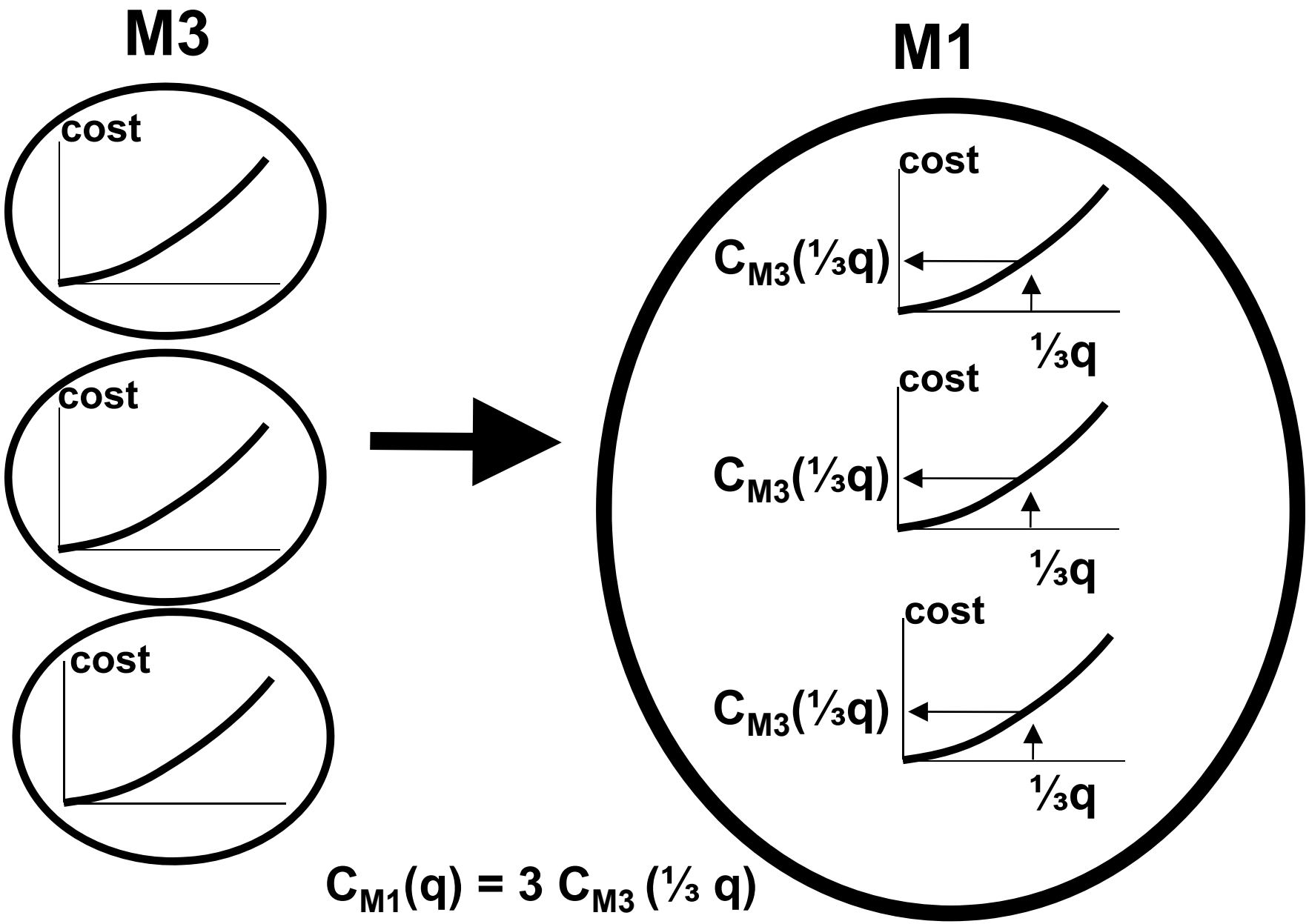


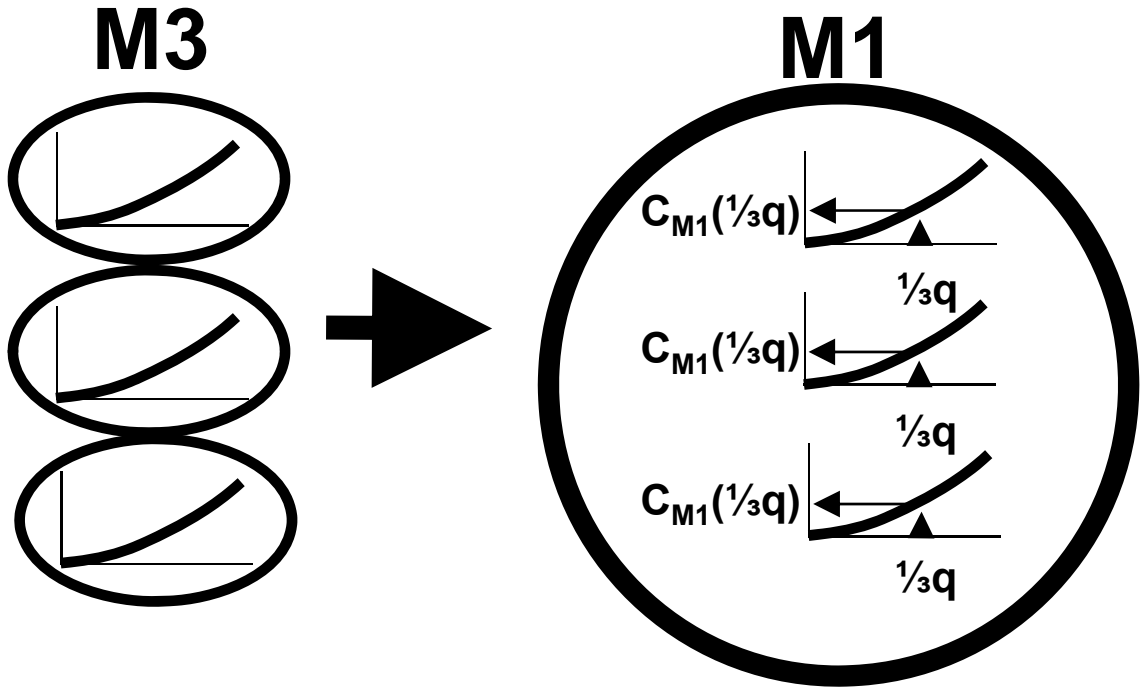
M3

M3



M4


M3
cost
cost
cost
M1
cost
$C_{M3}(⅓q)$
⅓q
cost
$C_{M3}(⅓q)$
⅓q
cost
$C_{M3}(⅓q)$
⅓q
$C_{M1}(q) = 3\ C_{M3}\ (⅓\ q)$



$$C_{M1}(q) = 3C_{M3}(\tfrac{1}{3}q)$$

$$C_{M1}(q) = xC_{Mx}(\tfrac{1}{x}q)$$

$$C_{My}(q) = \frac{x}{y}C_{Mx}(\tfrac{y}{x}q)$$

M3

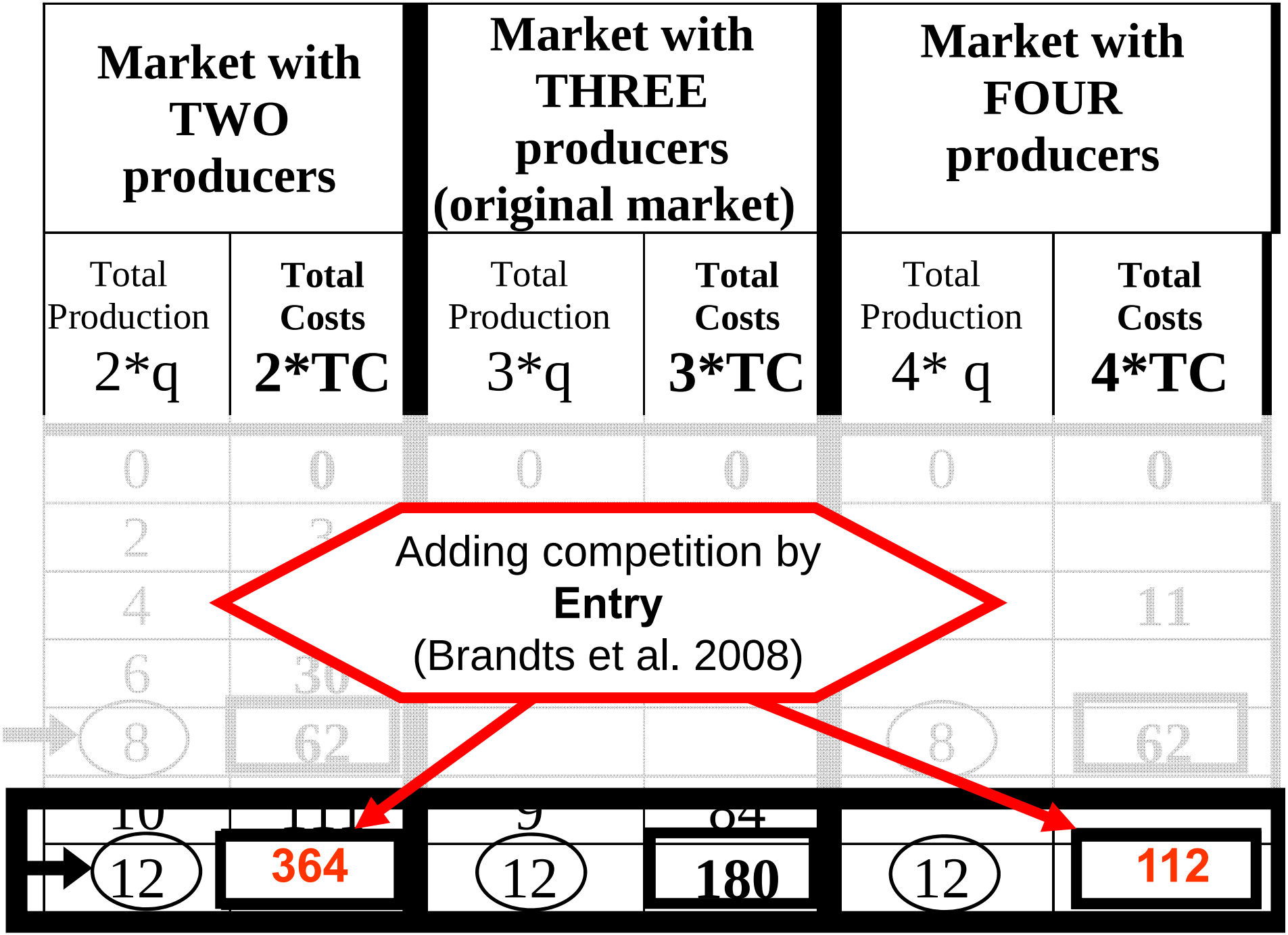
$$c_3(q) = \sum_{x=1}^{q} 2x^2 = \frac{2}{3}x^3 + x^2 + \frac{1}{3}x$$

M2

$$c_2[q] = \frac{3}{2} \cdot c_3[\frac{2}{3} \cdot q]$$

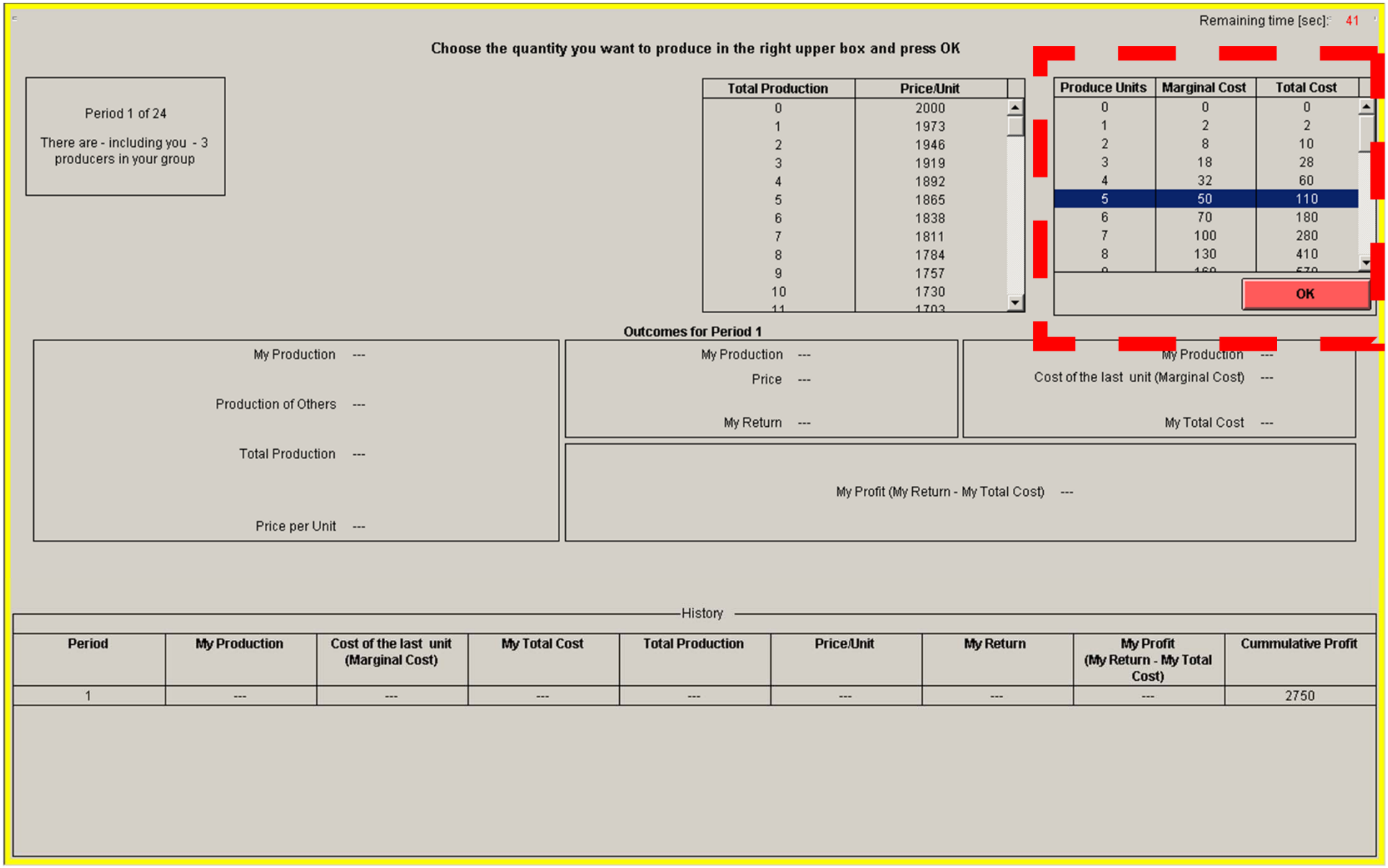
M4

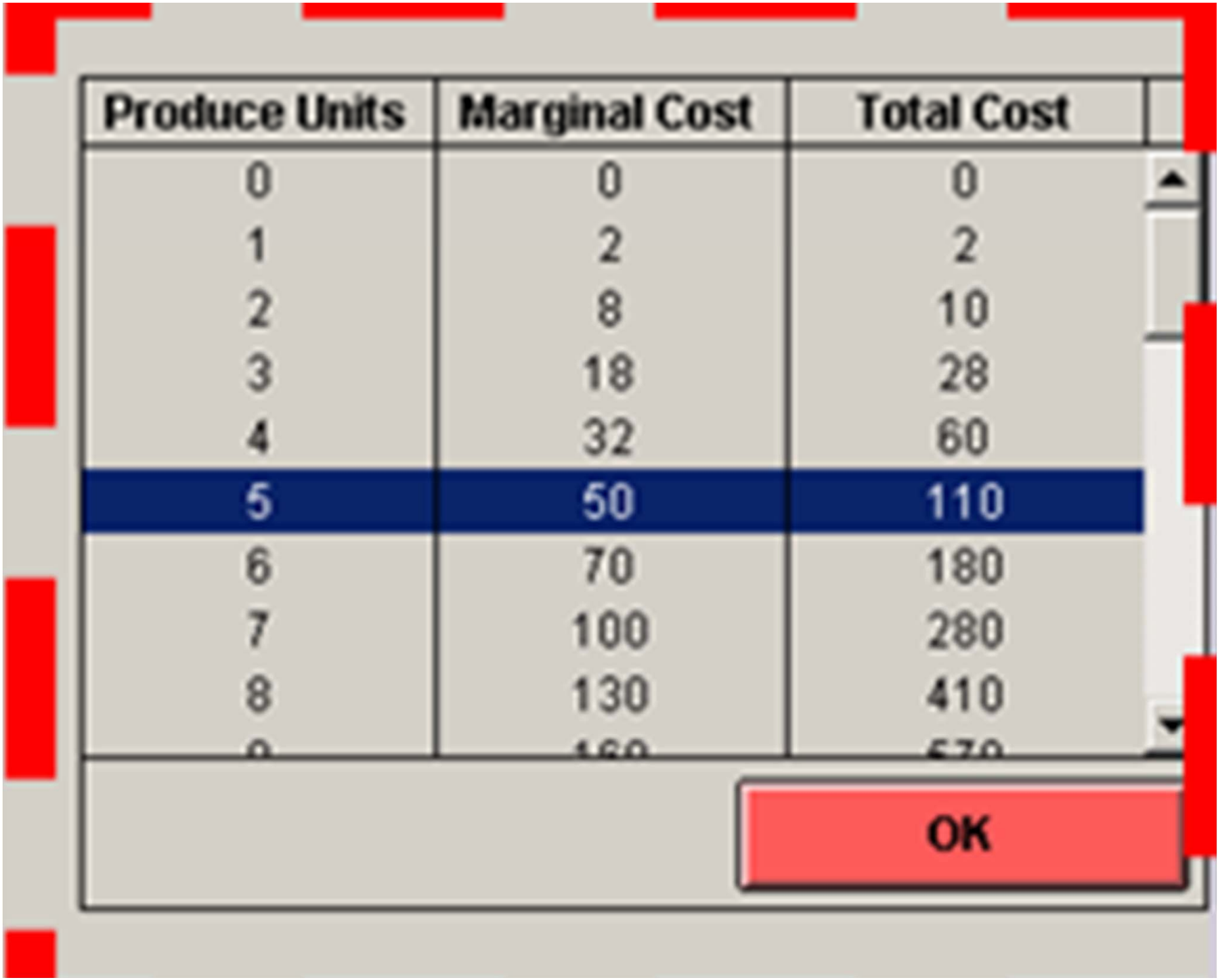
$$c_4[q] = \frac{3}{4} \cdot c_3[\frac{4}{3} \cdot q]$$


Market with TWO producers
Market with THREE producers (original market)
Market with FOUR producers
Total Production 2*q
Total Costs 2*TC
Total Production 3*q
Total Costs 3*TC
Total Production 4* q
Total Costs 4*TC
0 0 0 0 0 0
2
4 11
6 30
8 62 8 62
10 84
12 364 12 180 12 112
Adding competition by
Entry
(Brandts et al. 2008)

- Ran main sessions in:
  - October 2009, December 2009, and April 2010
- Ran robustness tests in:
  - October 2010 and January 2013

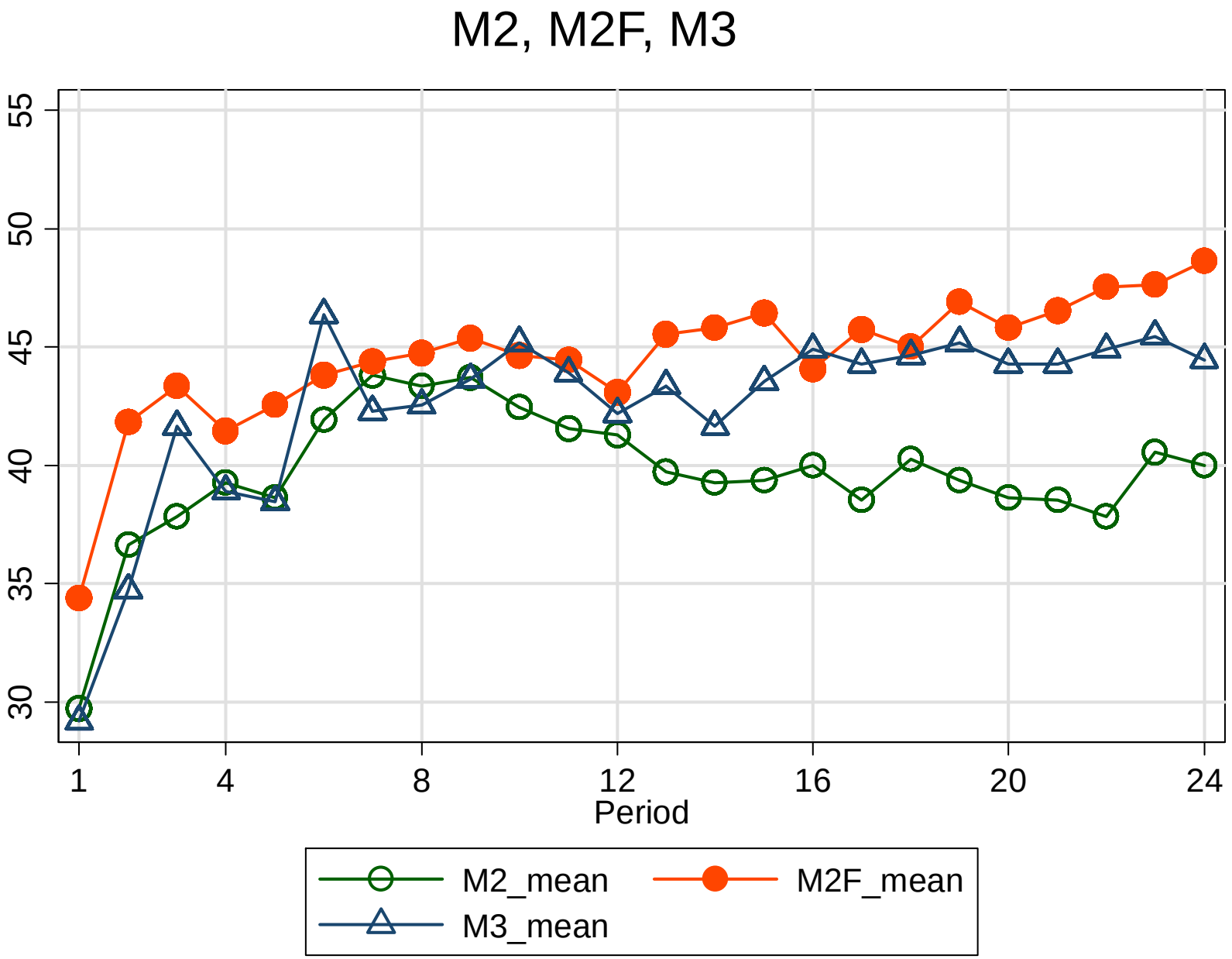
- 11 independent obs (groups) for each treatment
- Total of 198 subjects
  - Prague business school
- Average Earning 500CKZ = €20
  - PPP: €34
  - Minimum: 330 CKZ
  - Maximum: 1080 CKZ

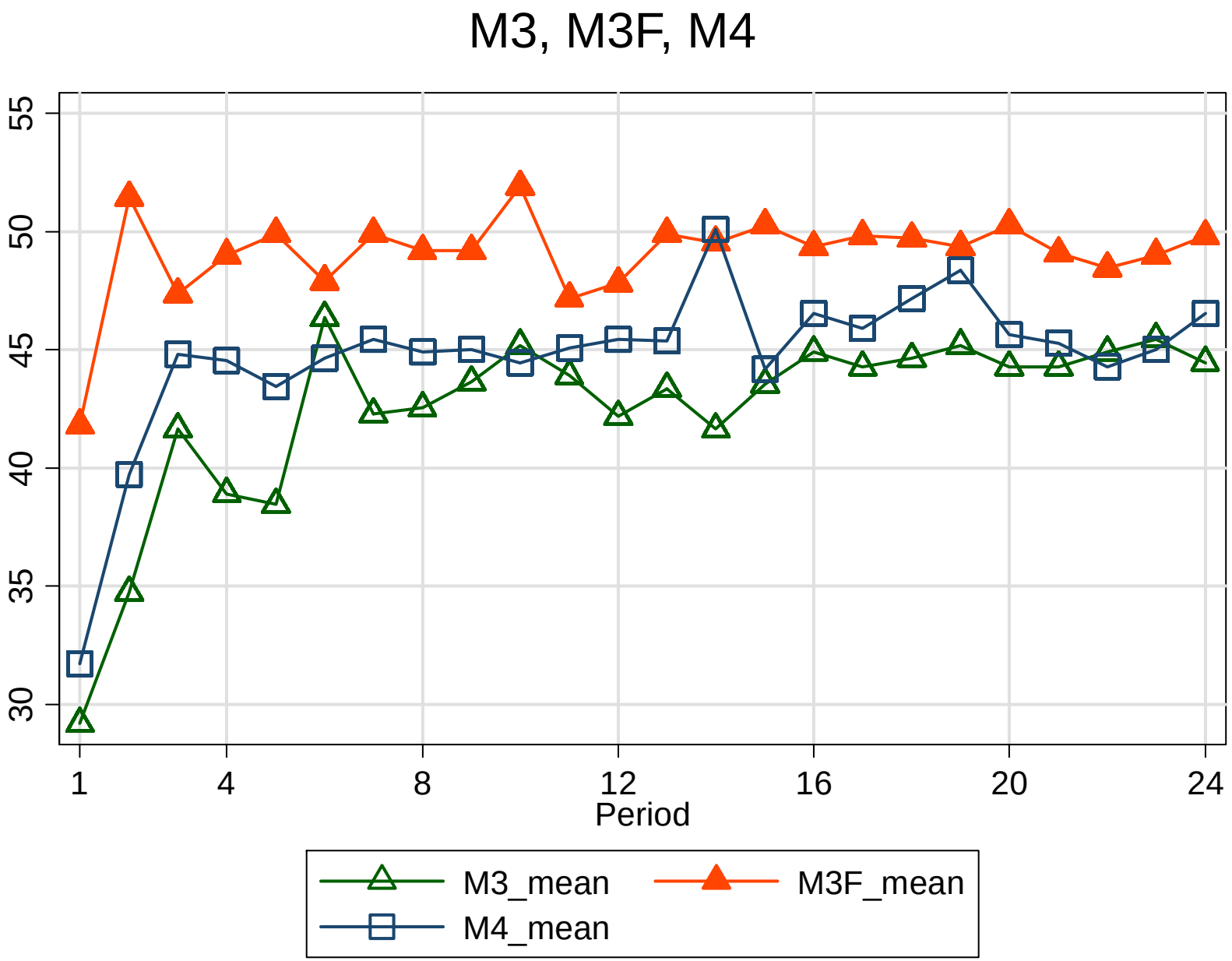

Remaining time [sec]: 41
Choose the quantity you want to produce in the right upper box and press OK
Period 1 of 24
There are - including you - 3 producers in your group
Total Production
Price/Unit
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
10 1730
Produce Units
Marginal Cost
Total Cost
0 0 0
1 2 2
2 8 10
3 18 28
4 32 60
5 50 110
6 70 180
7 100 280
8 130 410
OK
Outcomes for Period 1
My Production ---
Production of Others ---
Total Production ---
Price per Unit ---
My Production ---
Price ---
My Return ---
My Production ---
Cost of the last unit (Marginal Cost) ---
My Total Cost ---
My Profit (My Return - My Total Cost) ---
History
Period
My Production
Cost of the last unit (Marginal Cost)
My Total Cost
Total Production
Price/Unit
My Return
My Profit (My Return - My Total Cost)
Cummulative Profit
1 --- --- --- --- --- --- --- 2750


Produce Units
Marginal Cost
Total Cost
0 0 0
1 2 2
2 8 10
3 18 28
4 32 60
5 50 110
6 70 180
7 100 280
8 130 410
OK

Predictions

	2 Firms	3 Firms	4 Firms
Without Forward Market	**M2** **40**	**M3** **43**	**M4** **44**
With Forward Market	**M2F** **40/44**	**M3F** **45**	–


M2, M2F, M3
55
50
45
40
35
30
1
4
8
12
16
20
24
Period
M2_mean
M2F_mean
M3_mean


M3, M3F, M4
55
50
45
40
35
30
1
4
8
12
16
20
24
Period
M3_mean
M3F_mean
M4_mean

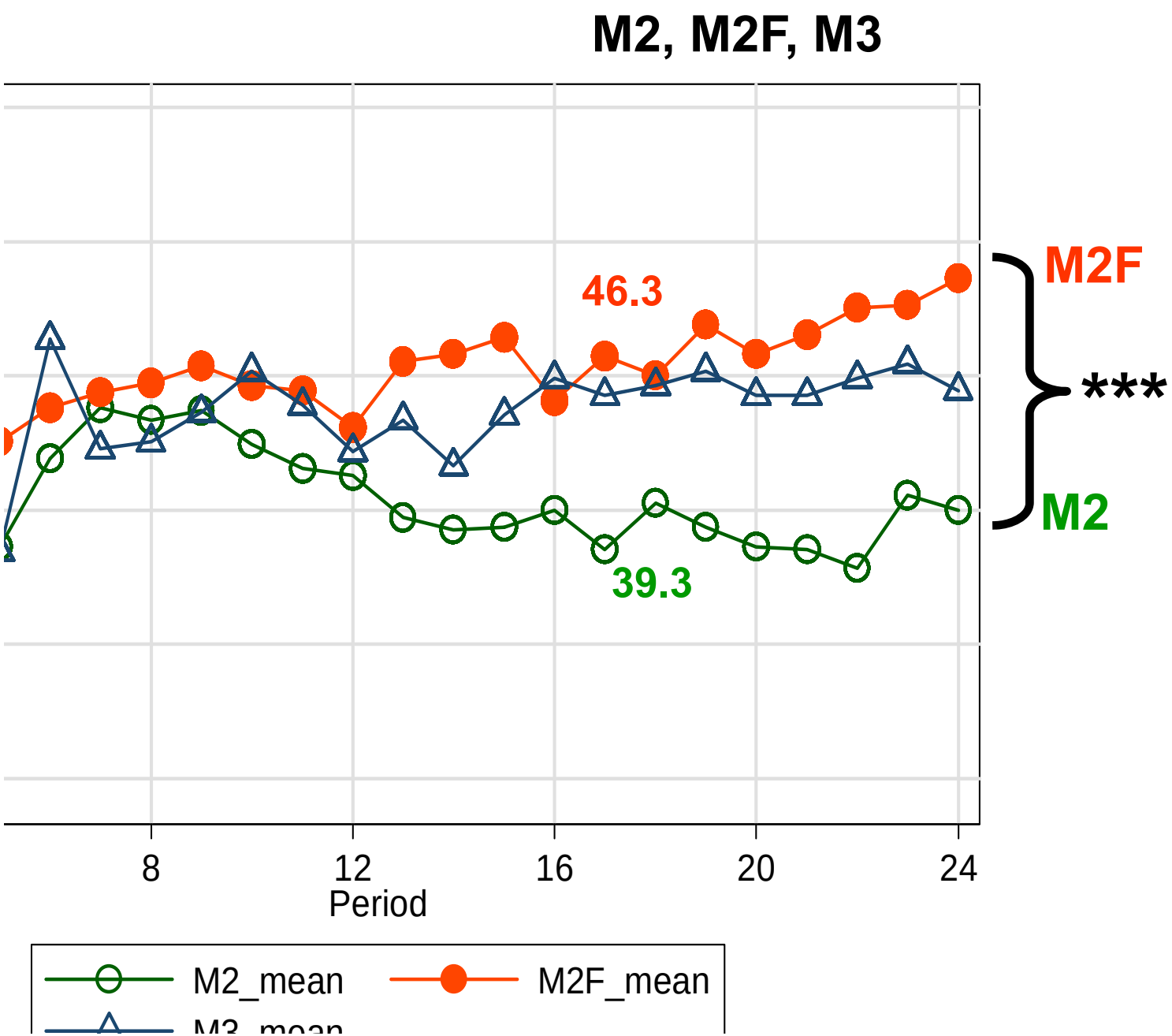
Averages

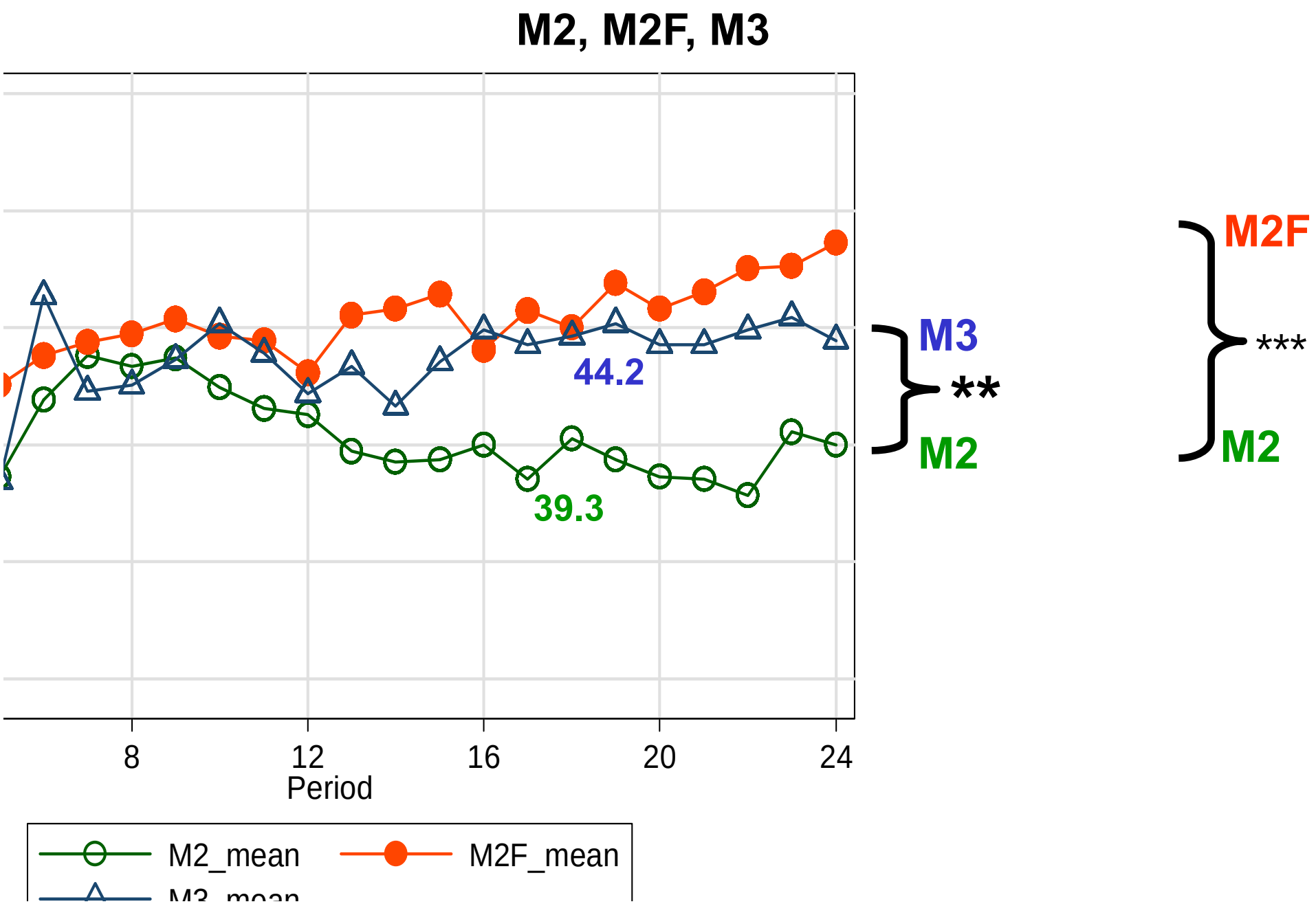
Standard errors based on groups (N=11)

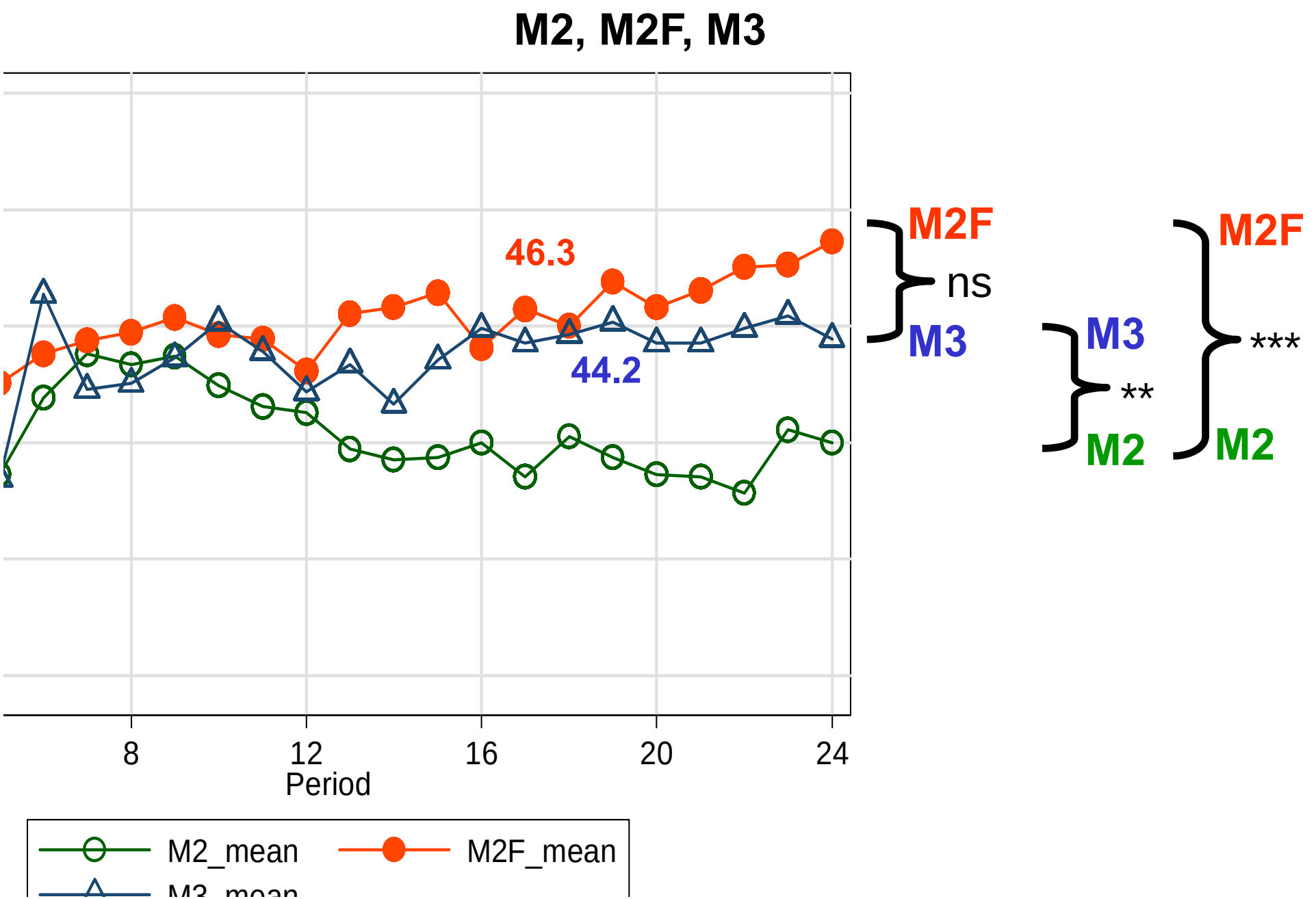
	2 Firms	3 Firms	4 Firms
Without Forward Market	**M2** 39.4 *98.7%*	**M3** 44.1 *102.5%*	**M4** 46.1 *104.9%*
With Forward Market	**M2F** 46.1 *115%* *105%*	**M3F** 49.4 *110.0%*	–

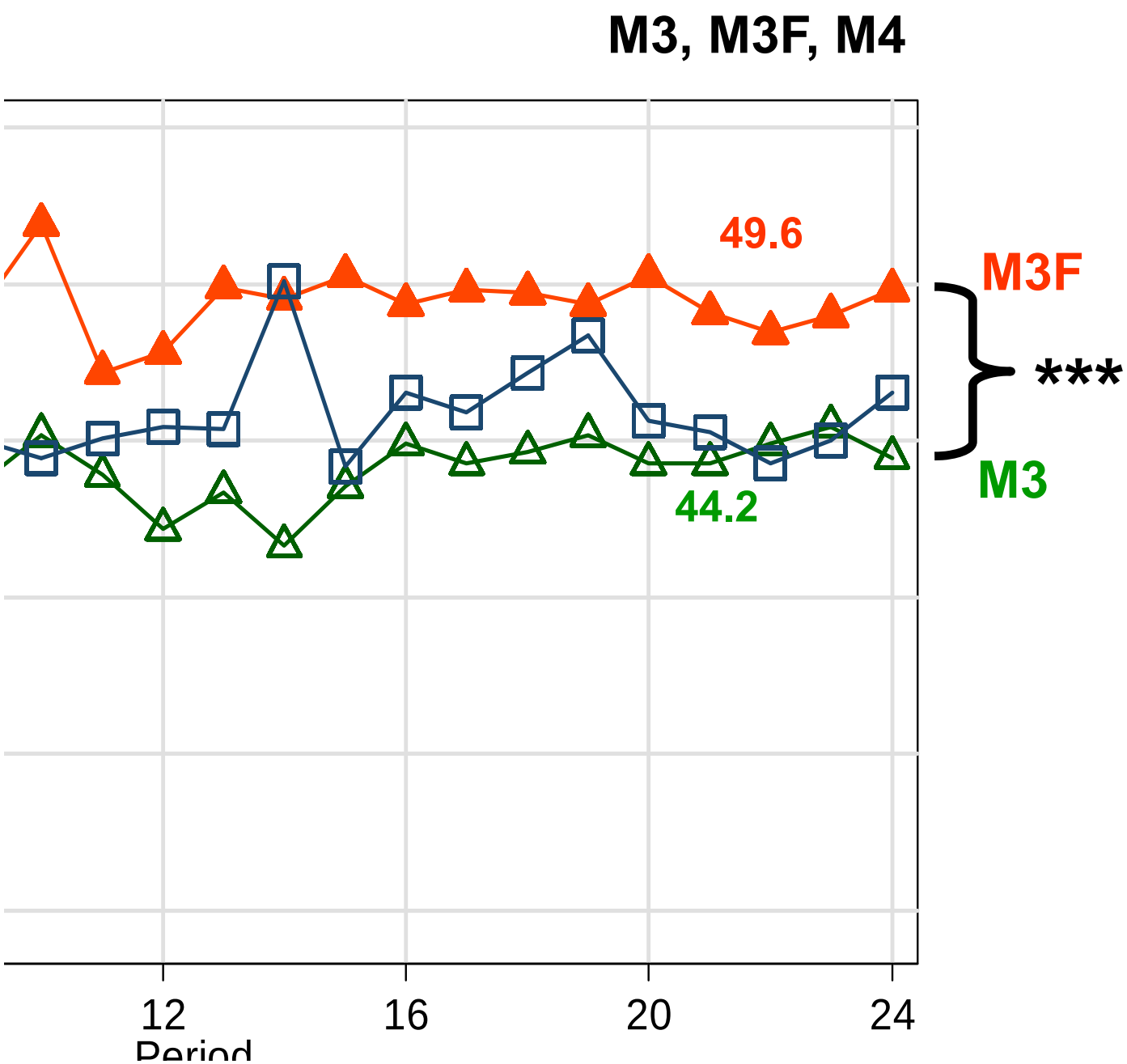
Confirming meta-analysis Huck et al. (JEBO 2004)

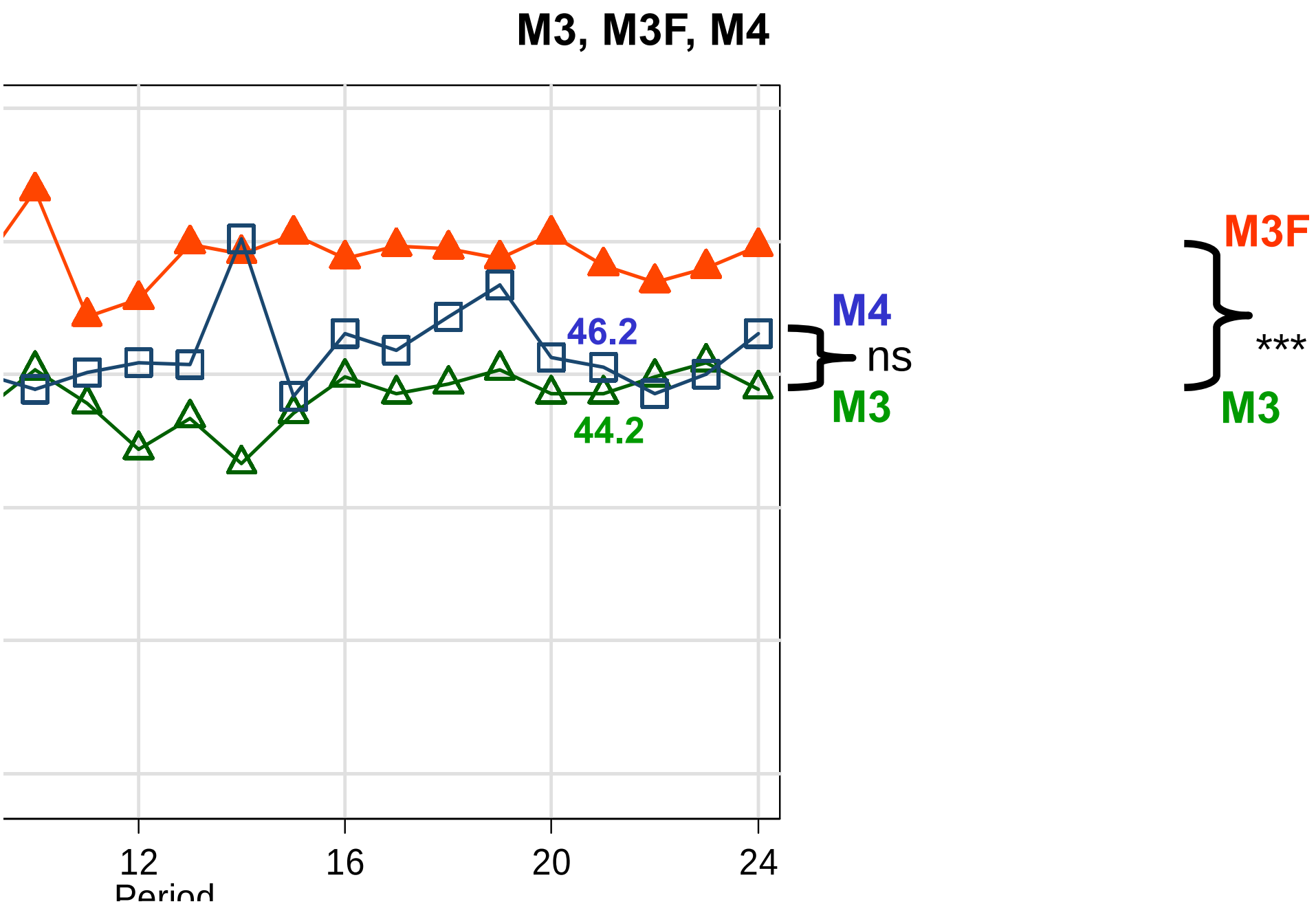
Percentages of the Nash-Equilibrium prediction

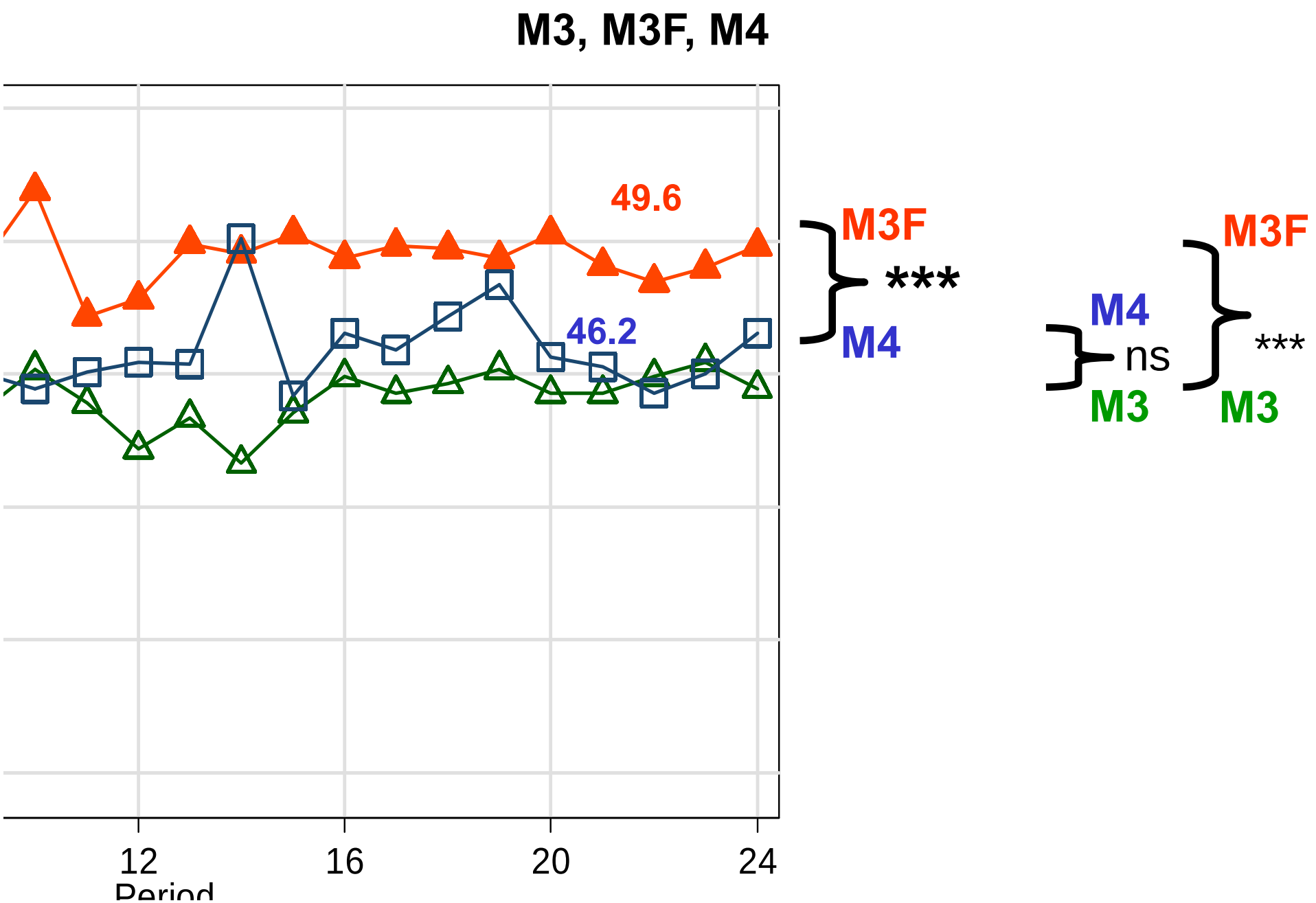

M2, M2F, M3
46.3
39.3
M2F
***
M2
8
12
16
20
24
Period
M2_mean
M2F_mean
M3_mean


M2, M2F, M3
44.2
39.3
M3
**
M2
M2F
***
M2
8
12
16
20
24
Period
M2_mean
M2F_mean
M3_mean


M2, M2F, M3
46.3
44.2
M2F
ns
M3
M3
**
M2
M2F
***
M2
8
12
16
20
24
Period
M2_mean
M2F_mean
M3_mean


M3, M3F, M4
49.6
M3F
***
M3
44.2
12
16
20
24
Period


M3, M3F, M4
46.2
44.2
M4
ns
M3
M3F
***
M3
12
16
20
24
Period


M3, M3F, M4
49.6
46.2
12
16
20
24
Period
M3F
***
M4
M4
ns
M3
M3F
***
M3

Conclusions of comparison

Behavioral measure

Introducing a forward market

with

Structural measure

Adding one more competitor by **divestiture**

- **Are equally effective in M2**
- **Behavioral measure *more* effective in M3**
  - Contrast with Brandts et al (2008)
    - Are equally effective in M3 if adding one more competitor is done by *entry*

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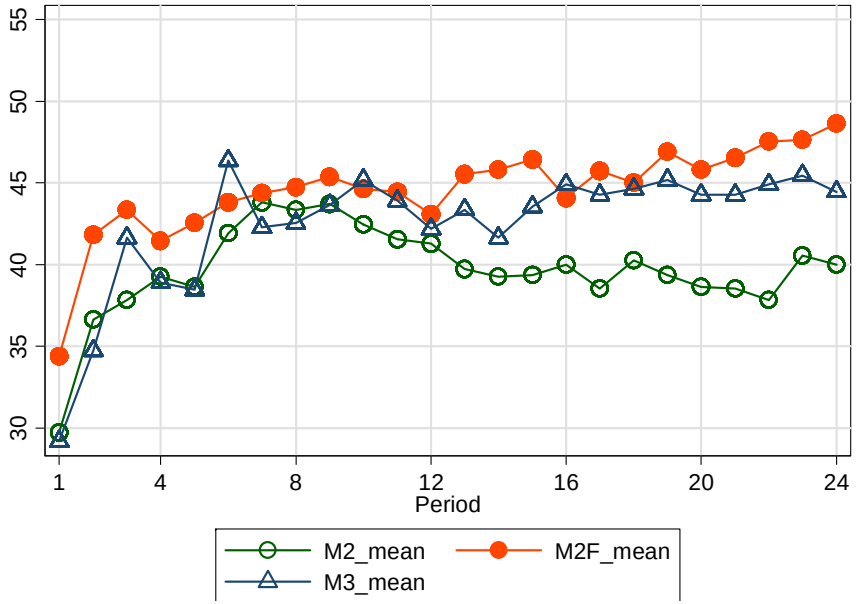
Are these results robust for experienced players?

Ferreira, Kujal & Rassenti, 2009

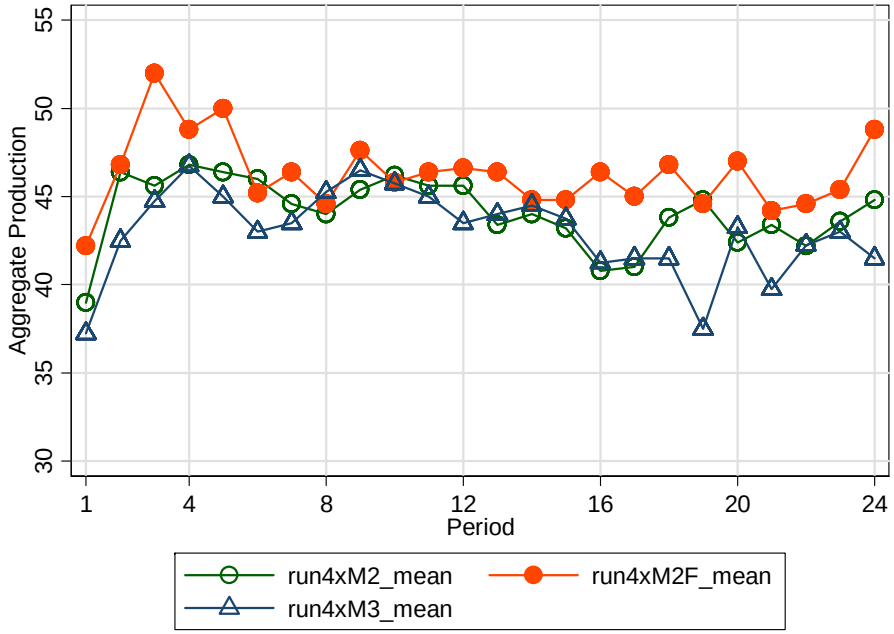
Forward Market	Predicted	Observed: Inexperienced	Observed: Experienced
2 firms	85.7	85.6	62.5
4 firms	89.1	99.9	76.8

Inexperienced

M2, M2F, M3

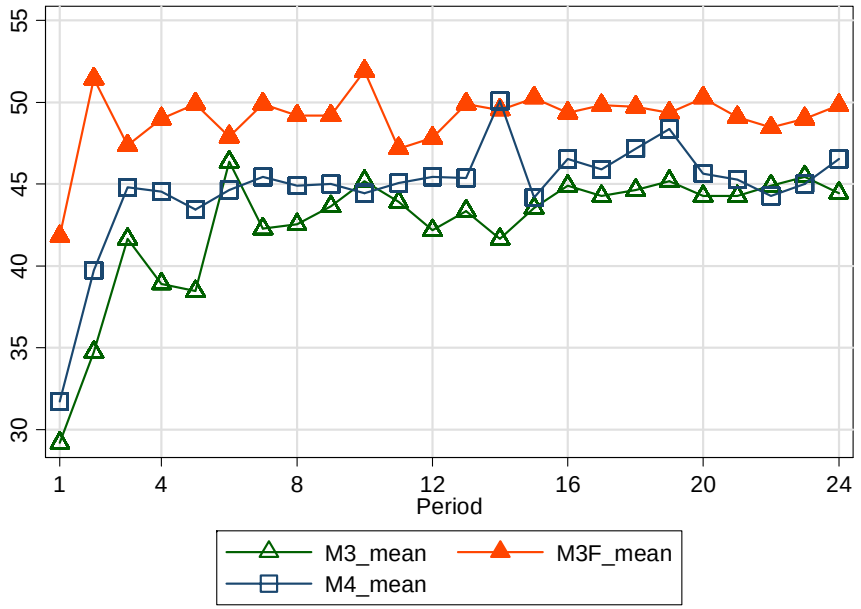


Experienced

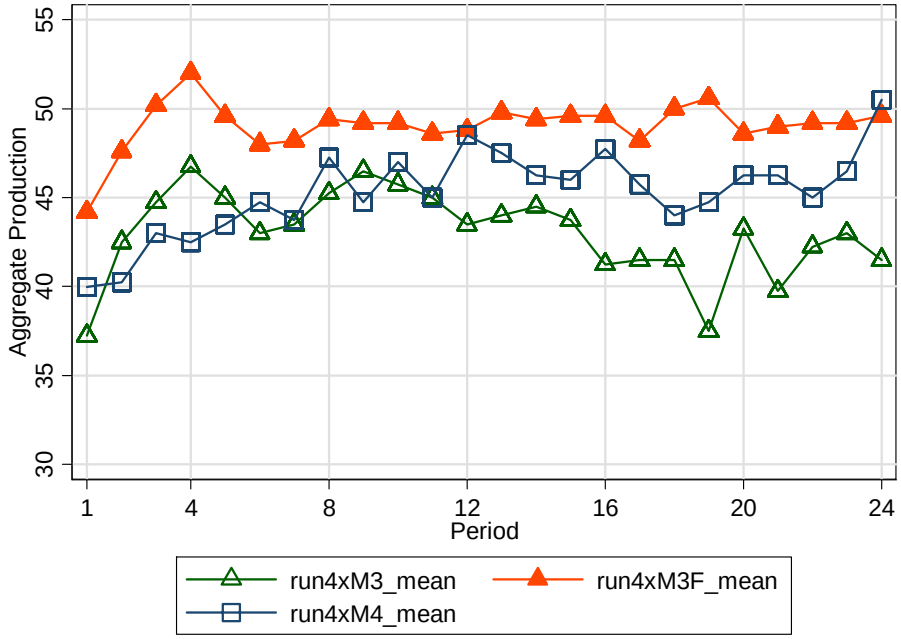


Inexperienced

M3, M3F, M4



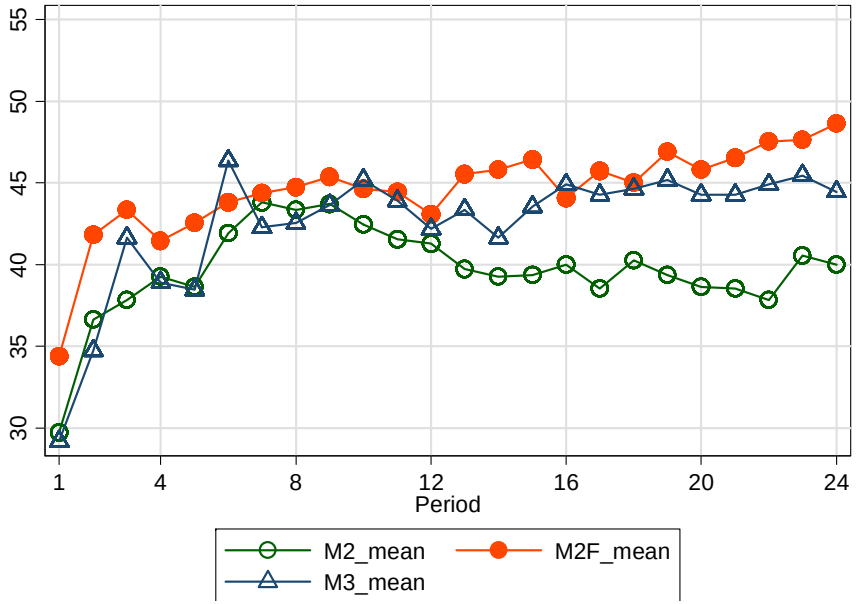
Experienced



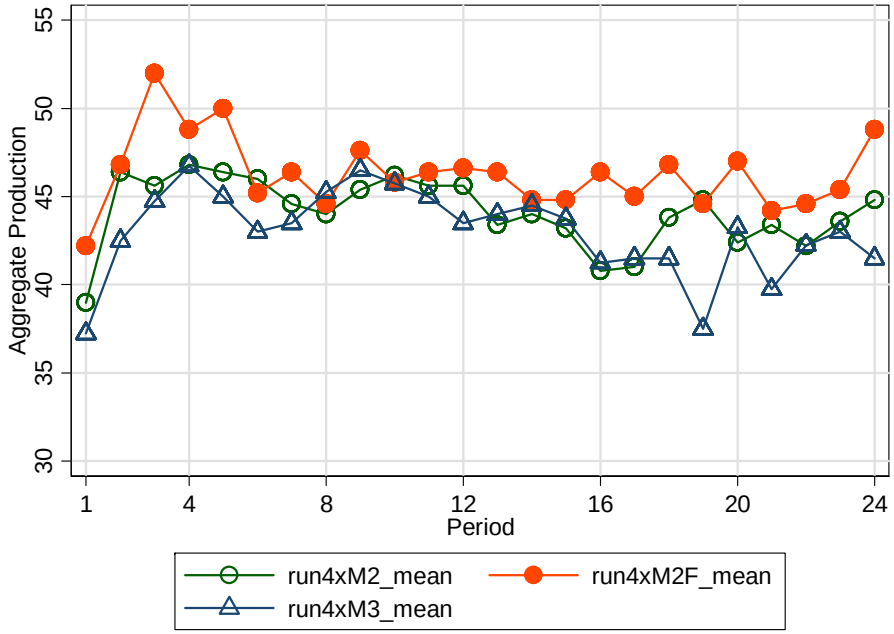
	M2	M2F	M3	M3F	M4
run123 (Inexperienced)	39.3 (1.5)	46.3 (2.0)	44.2 (1.2)	49.6 (0.6)	46.2 (1.0)
run4 (Experienced)	43.1 (1.5)	45.7 (2.4)	42.0 (1.6)	50.9 (0.2)	46.4 (0.9)
Effect Experience					
Significance (two-sided test)					

Inexperienced

M2, M2F, M3

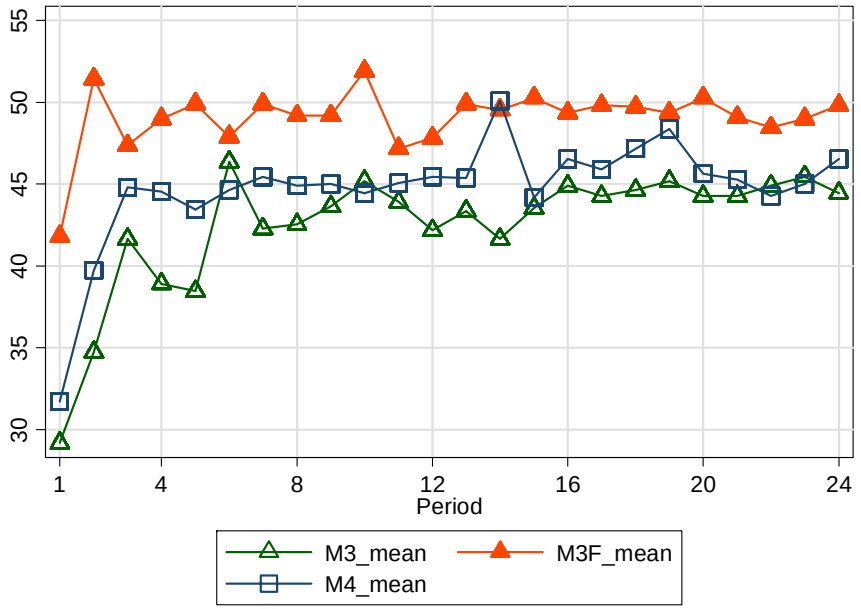


Experienced

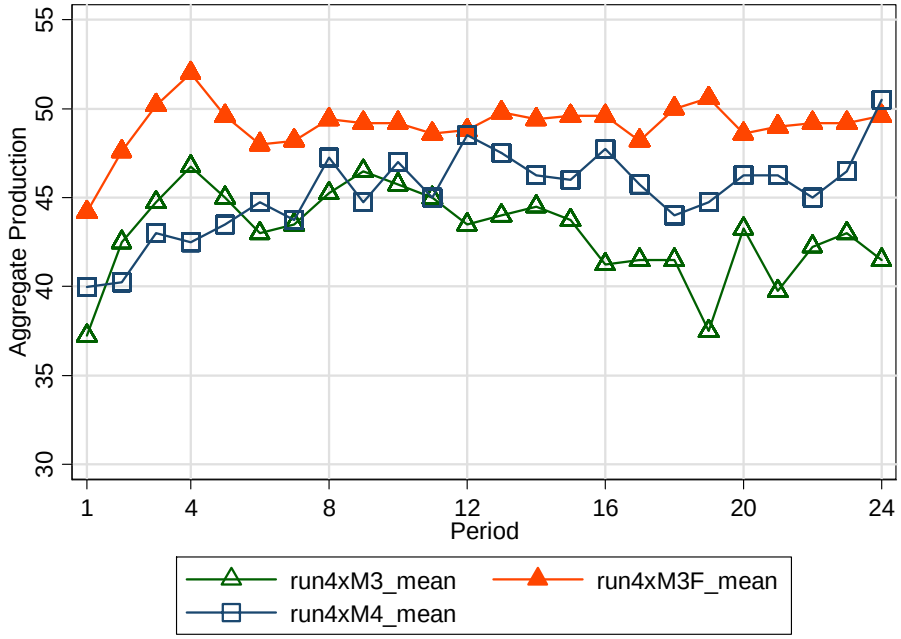


Inexperienced

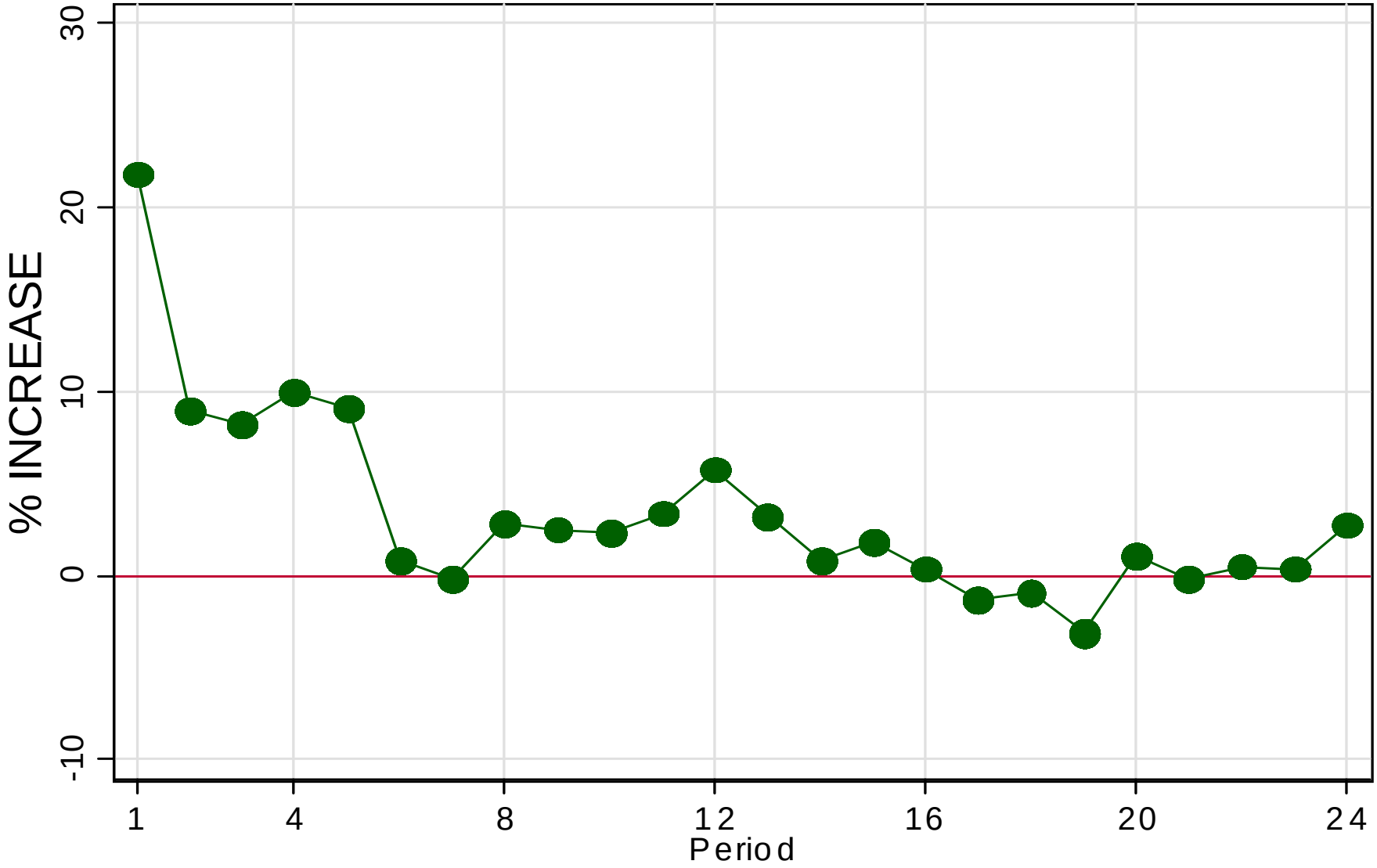
M3, M3F, M4



Experienced



Increase in production by Experienced Subjects



More Competitive Electricity Markets:
Structural vs Behavioral Measures

An Experimental Investigation Guided by Theory and Policy Concerns

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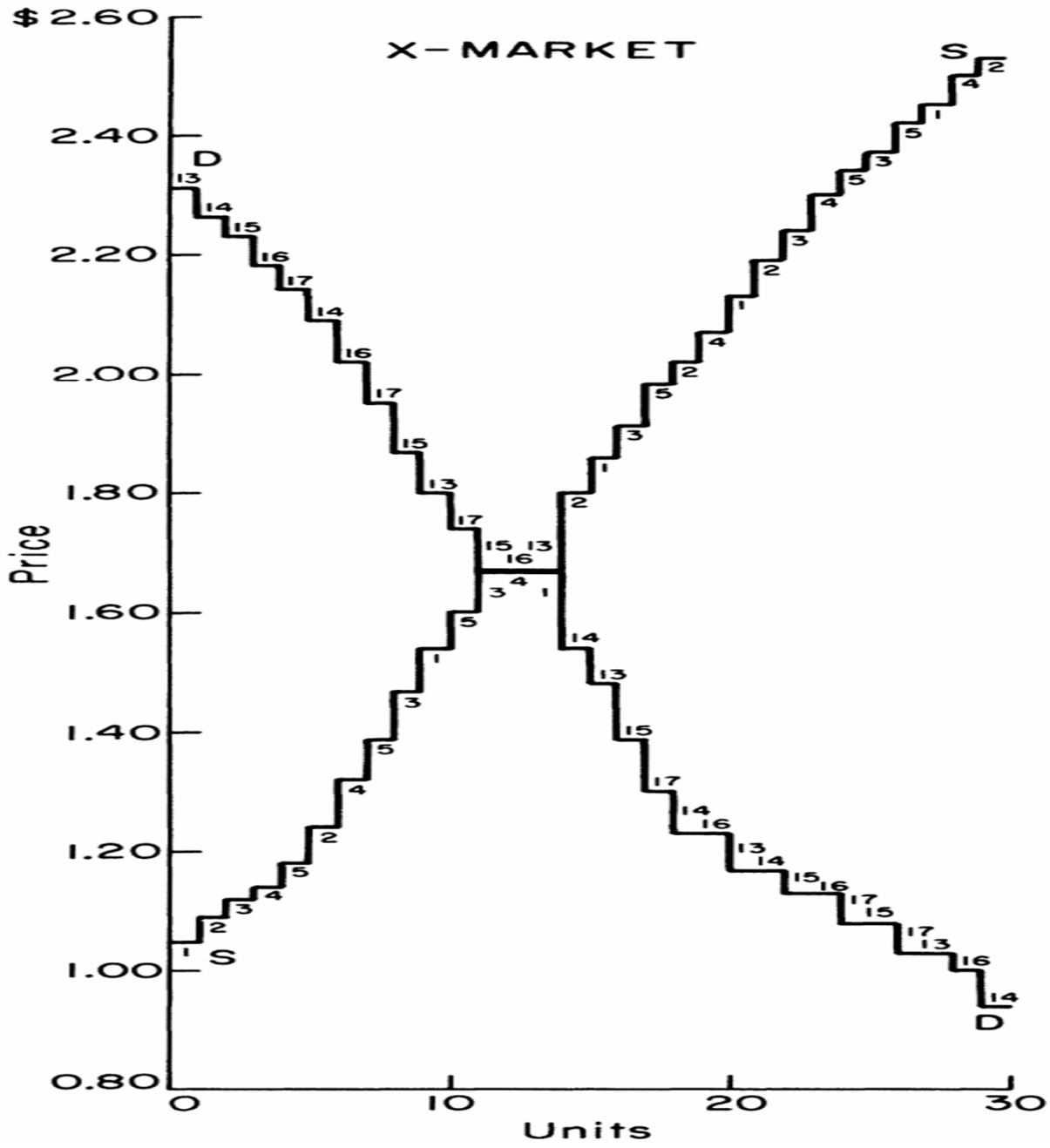
Plot & Uhl, SEJ, 1981



Plot & Uhl, SEJ, 1981

Figure 4. Y-Market Contract Prices in Sequence of Occurrence

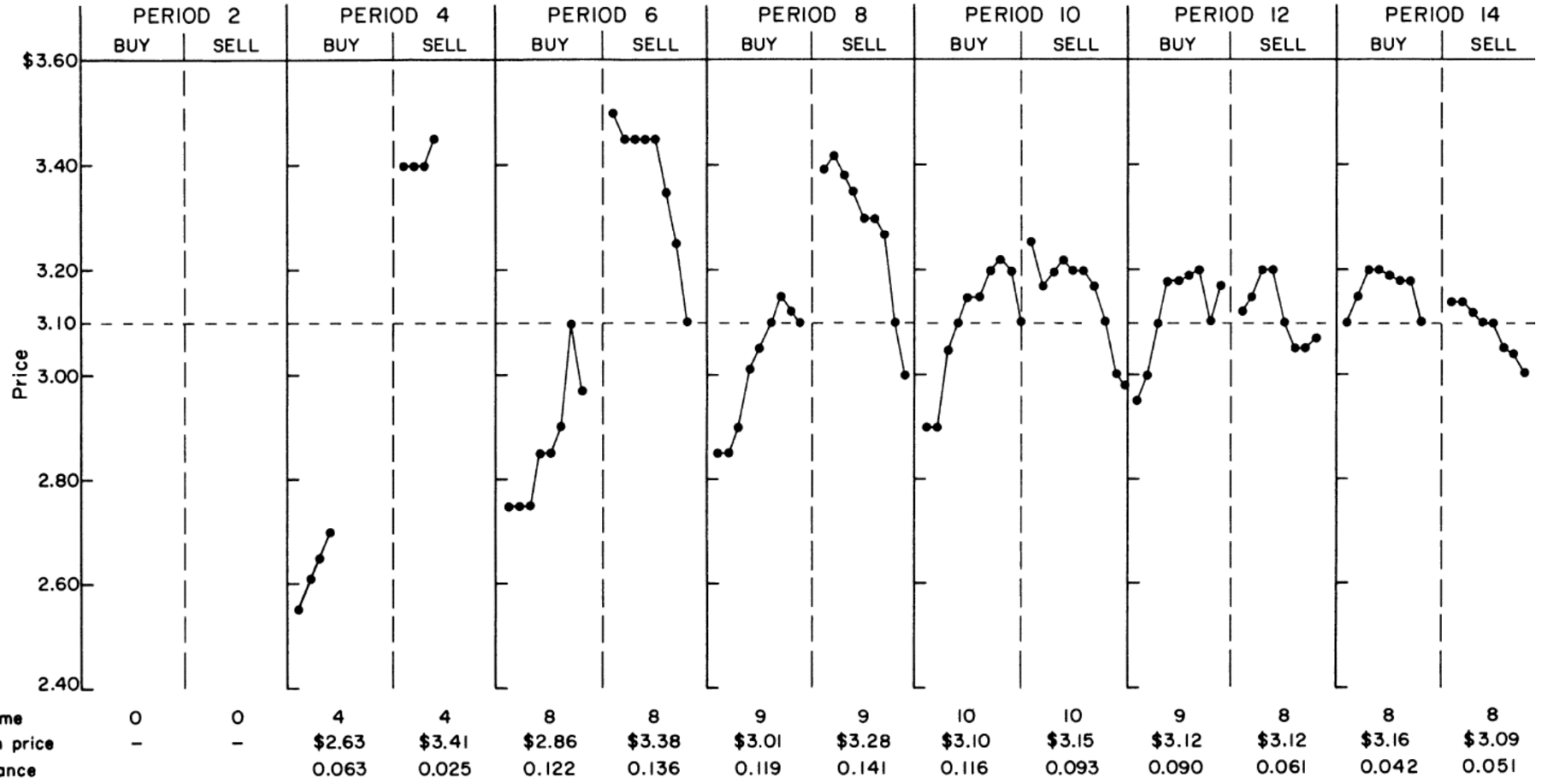
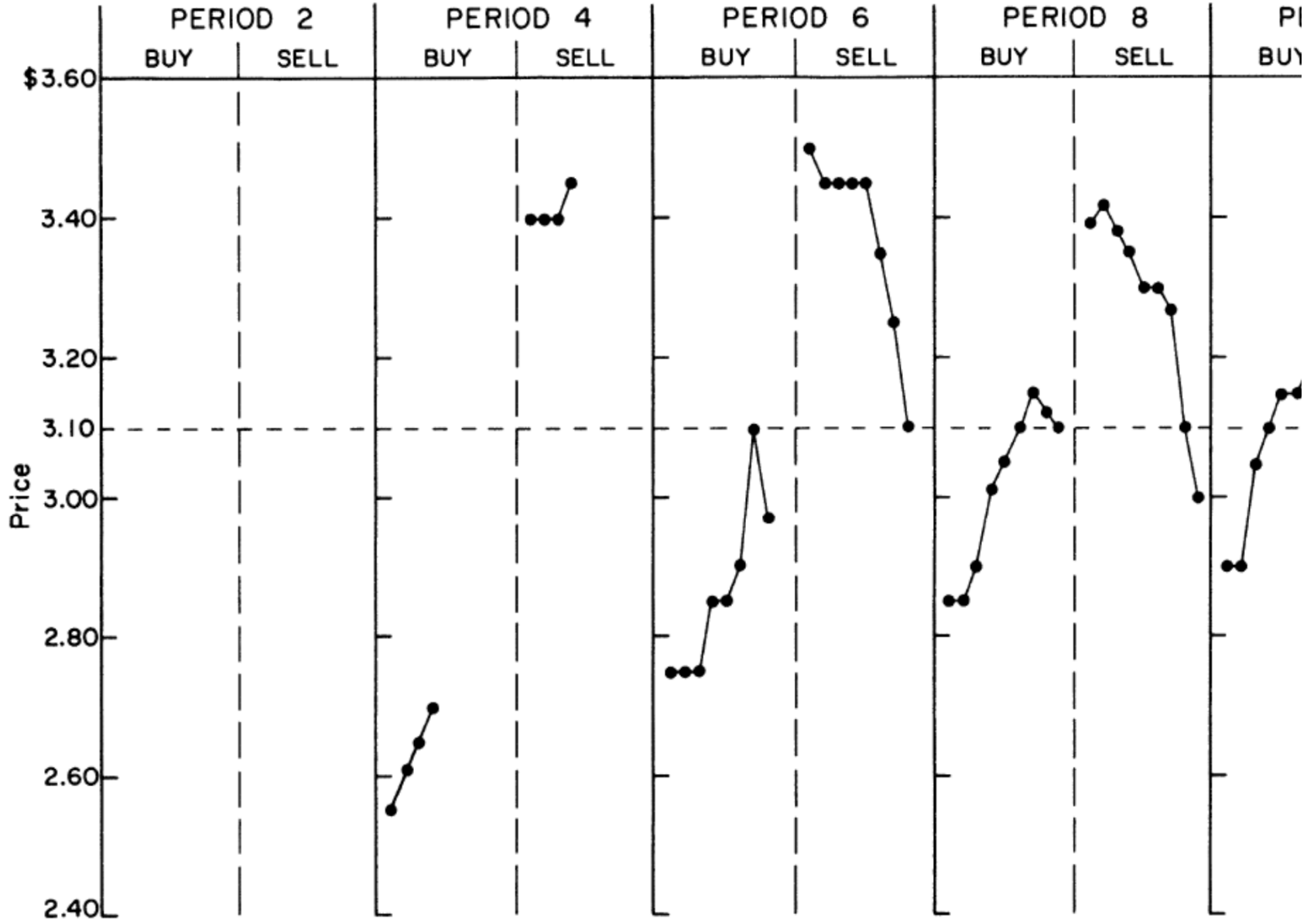


Figure 4. T-Market Contract Prices in Sequence of Occurrence



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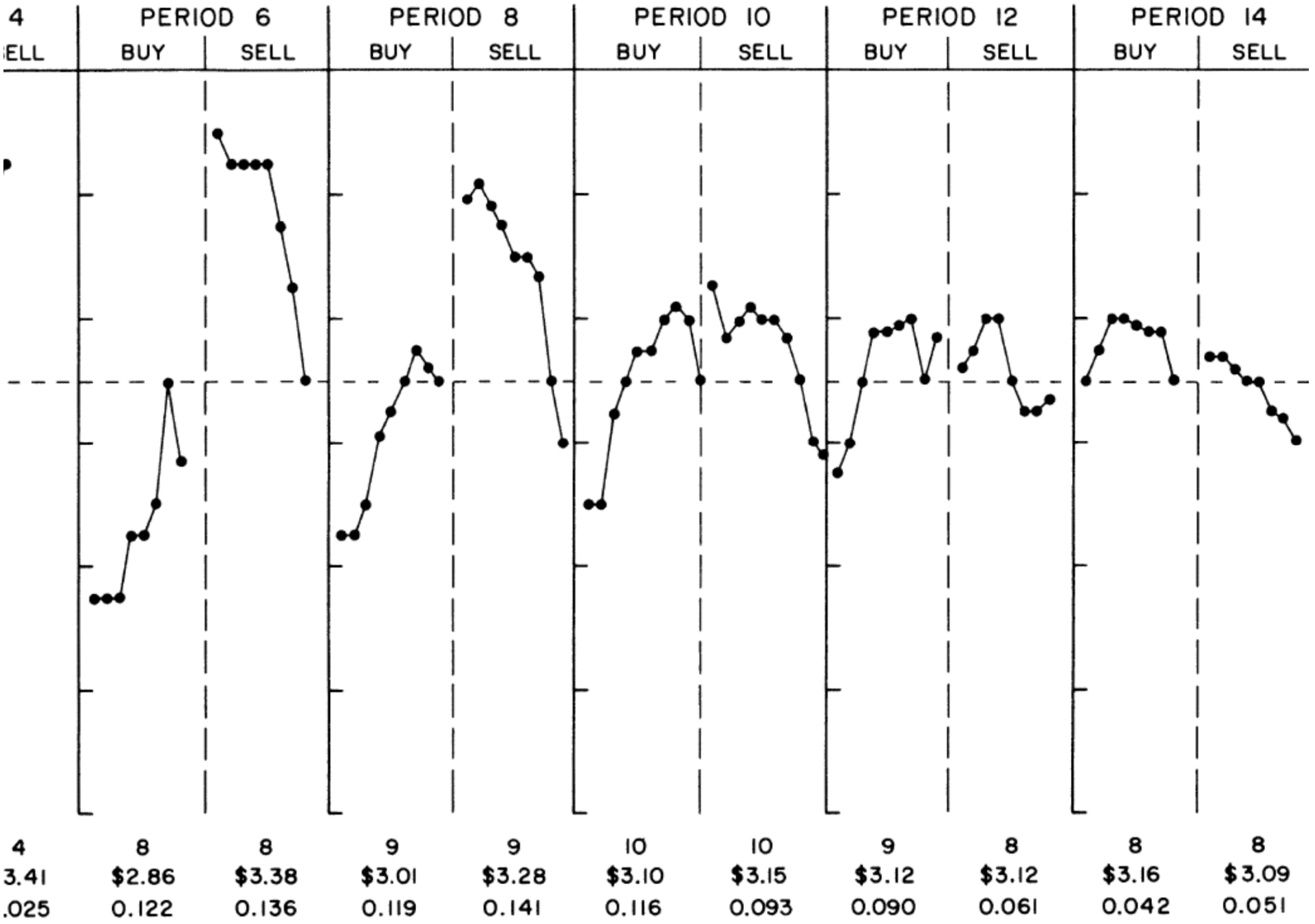
4
ELL
PERIOD 6
BUY
SELL
PERIOD 8
BUY
SELL
PERIOD 10
BUY
SELL
PERIOD 12
BUY
SELL
PERIOD 14
BUY
SELL
4 8 8 9 9 10 10 9 8 8 8
3.41 $2.86 $3.38 $3.01 $3.28 $3.10 $3.15 $3.12 $3.12 $3.16 $3.09
.025 0.122 0.136 0.119 0.141 0.116 0.093 0.090 0.061 0.042 0.051

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