More Competitive Electricity Markets:
Structural vs Behavioral Measures

An Experimental Investigation Guided by Theory and Policy Concerns

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

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

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

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

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

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


2. Bridge model experimentation


3. Bridge

1. Theory

Theoretical Physics

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

Theoretical Economics

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

2. Engineering

Bridge Experimentation

Market Experimentation

Experimental & Computational Economics

3. Implementation

Bridge

Competitive Market

E.g., Energy Market

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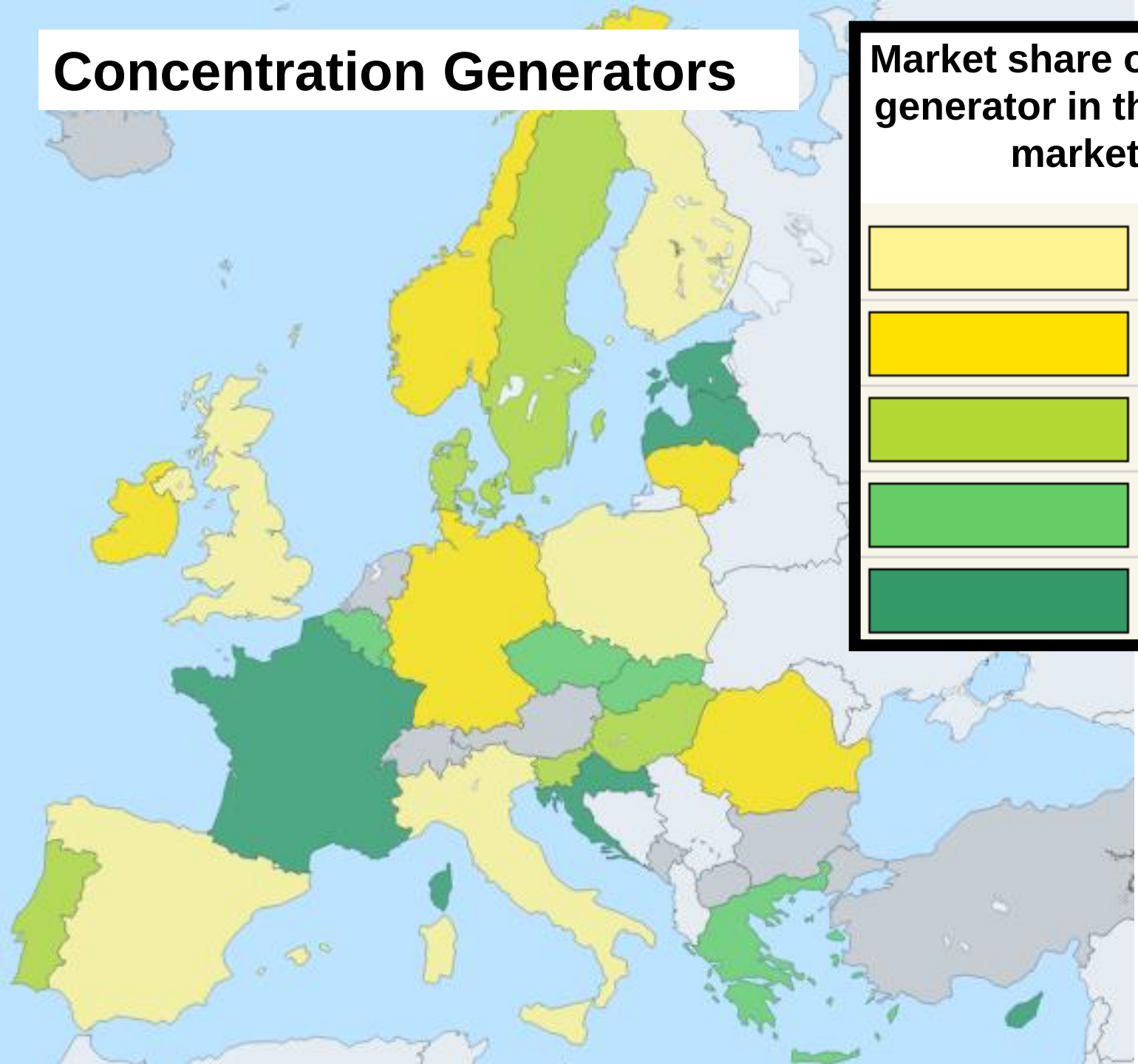
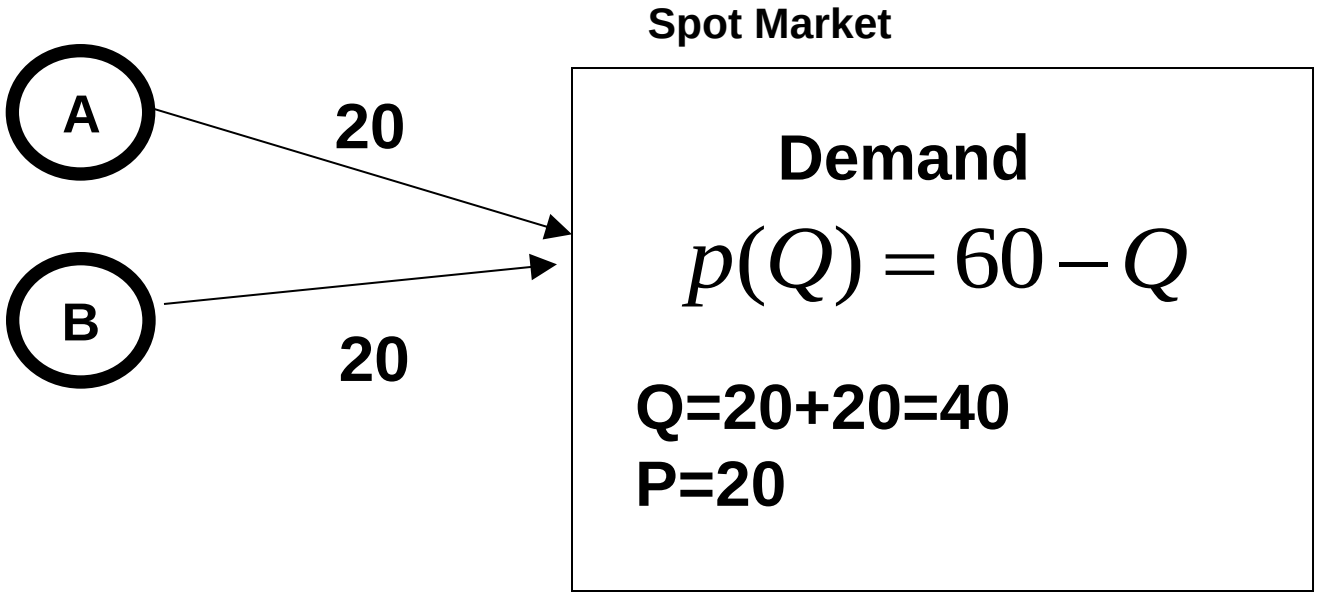
Concentration Generators



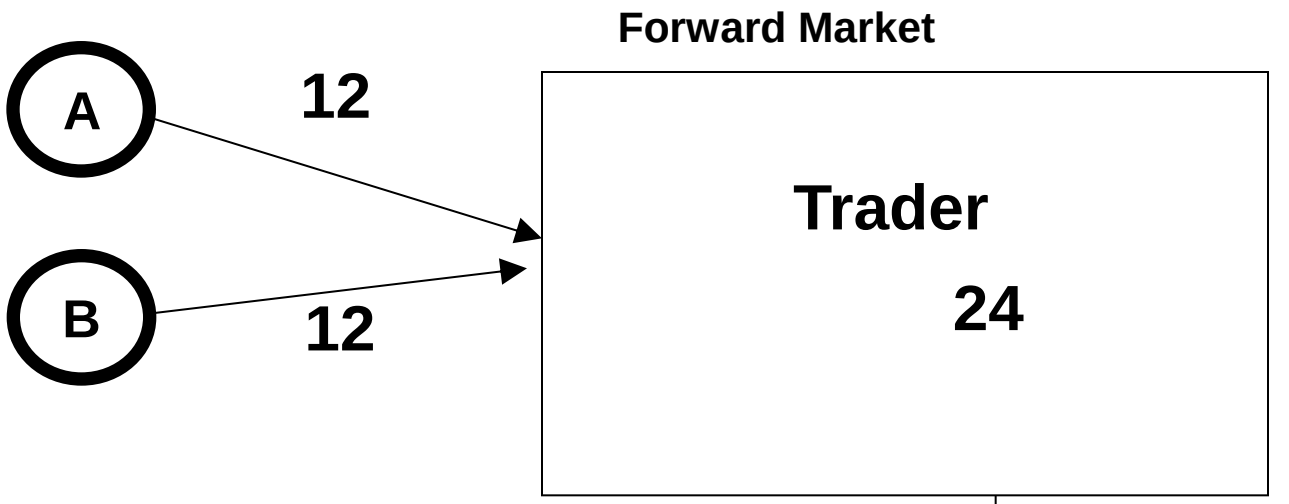
Week 5

Friday

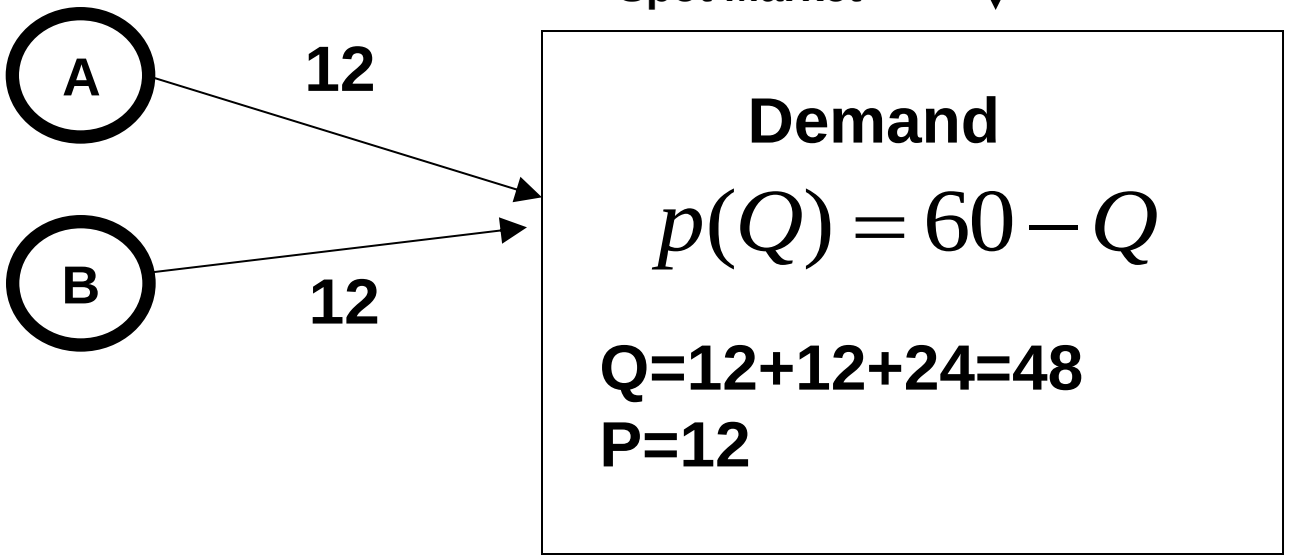


Week 5

Monday



Friday



Spot Market
+
Forward Market

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

Q=48
P=12

Spot Market

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

Q=40
P=20

Allaz & Villa (1993)

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

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

$$60 - 2q_1 - q_2 + f_1 = 0 \quad \Leftrightarrow$$

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

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

"Naïve/ principled"

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

"Backstabbing" (Stackleberg Equilibrium)

$f_1 = 15 \;\&\; f_2 = 0$ $\qquad \pi_1 = 450$, $\pi_2 = 225$

Nash-Equilibrium

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

"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%

"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%?**	–

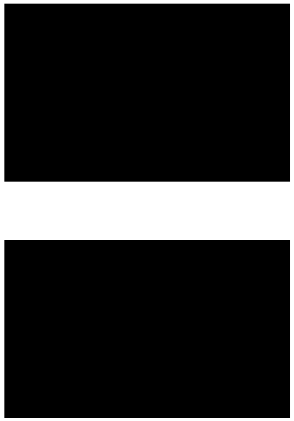
Experiment

- Number of firms: 2, 3 & 4
- Demand schedule: $p(Q) = Max(0, 2000 - 27Q)$
  - As Brandts et al (2008)
- Costs: Steeply increasing marginal costs (Newbery, EER 2002).

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

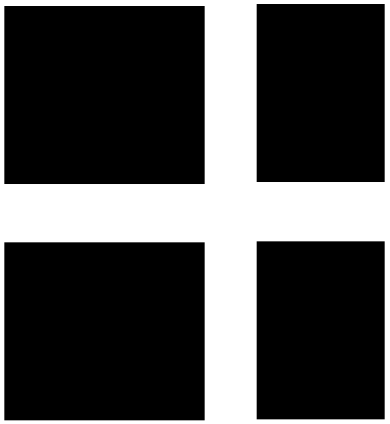
$$c_3(q) = \sum_{x=1}^{q} 2x^2 = \tfrac{2}{3}x^3 + x^2 + \tfrac{1}{3}x$$

M2



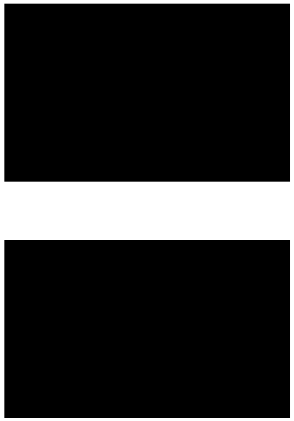
M3

M2

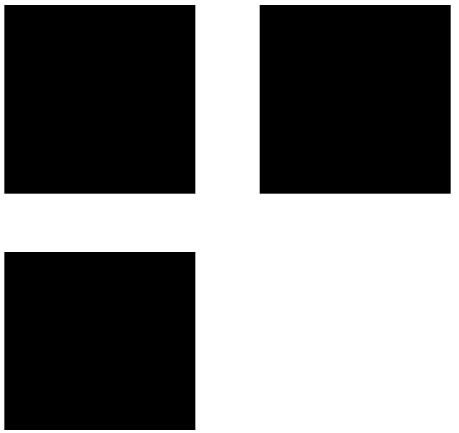


M3

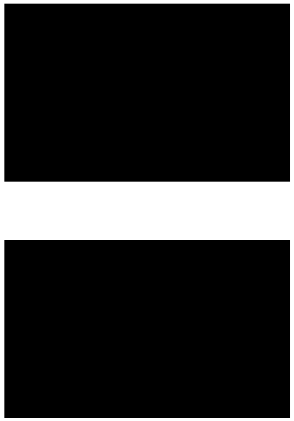
M2



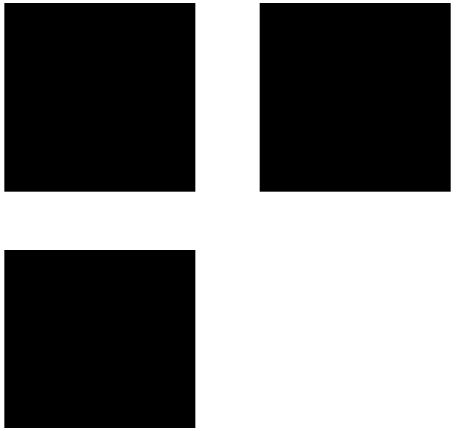
M3



M2



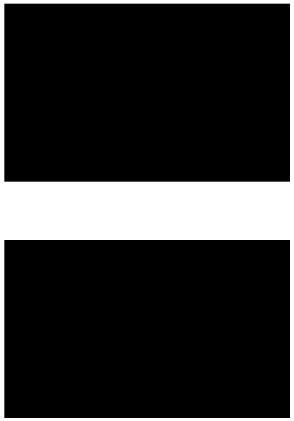
M3



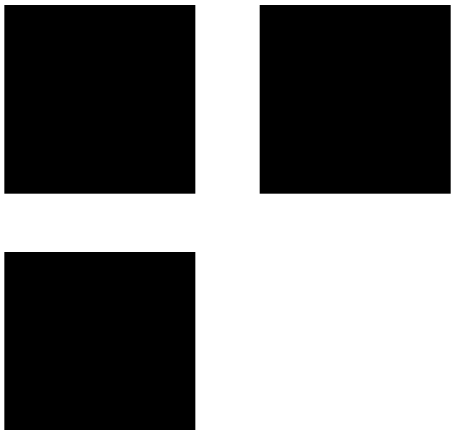
M3

M4

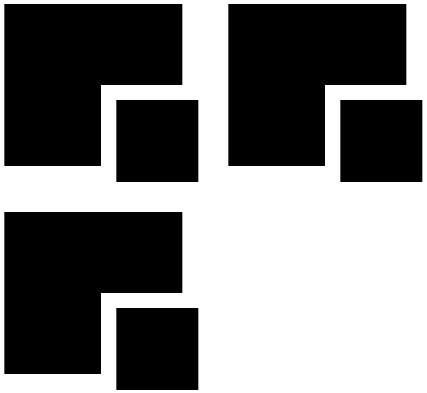
M2



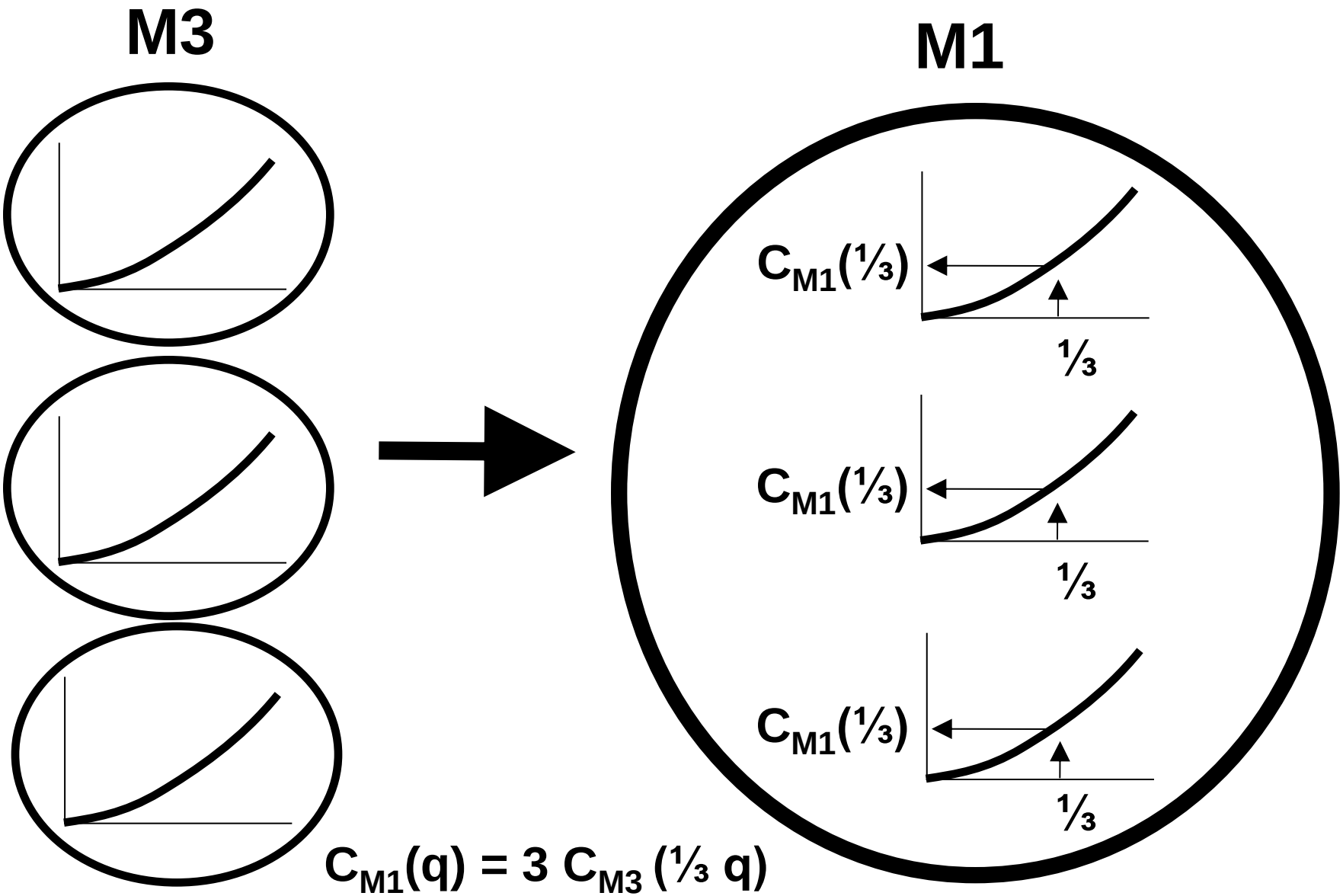
M3



M3

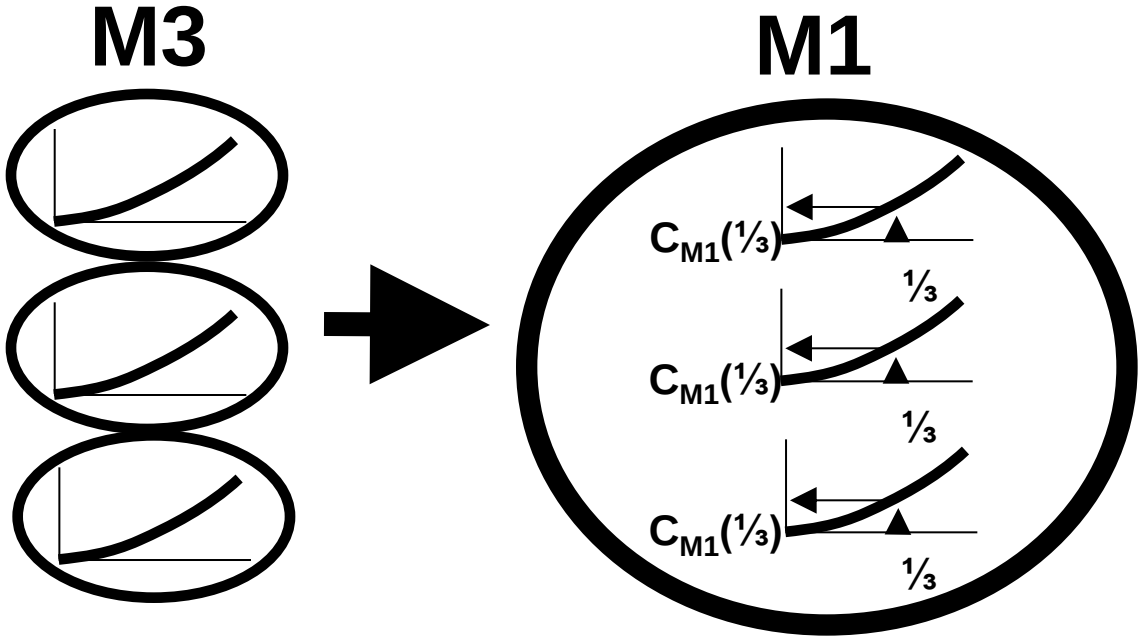


M4



$$C_{M1}(q) = 3\, C_{M3}(⅓\, q)$$

$$C_{M1}(q) = 3\, C_{M3}(⅓\, q)$$



$$C_{M1}(1) = 3\, C_{M3}(⅓)$$

$$C_{M1}(q) = 3\, C_{M3}(⅓\ q)$$

$$C_{M1}(q) = 2\, C_{M2}(½\ q)$$

$$C_{M1}(q) = 4\, C_{M4}(¼\ q)$$

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	3				
4					11
6	30				
8	62			8	62
10	111	9	84		
12	364	12	180	12	112

Adding competition by
Entry
(Brandts et al. 2008)

- Ran sessions in
  - October 2009, December 2009, April 2010
  - October 2010 as a robustness test
- 11 independent groups for each treatment
- In total 198 subjects
  - Prague business school, the economic institute and the Prague technical school
- Average Earning 350CKZ/hour = €14/hour
  - PPP: €20/hour
  - Minimum: 330 CKZ
  - Maximum: 1080 CKZ

The new state-of-the-art LEE Laboratory in Prague (www.vse-lee.cz)

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
11	1703

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 ---

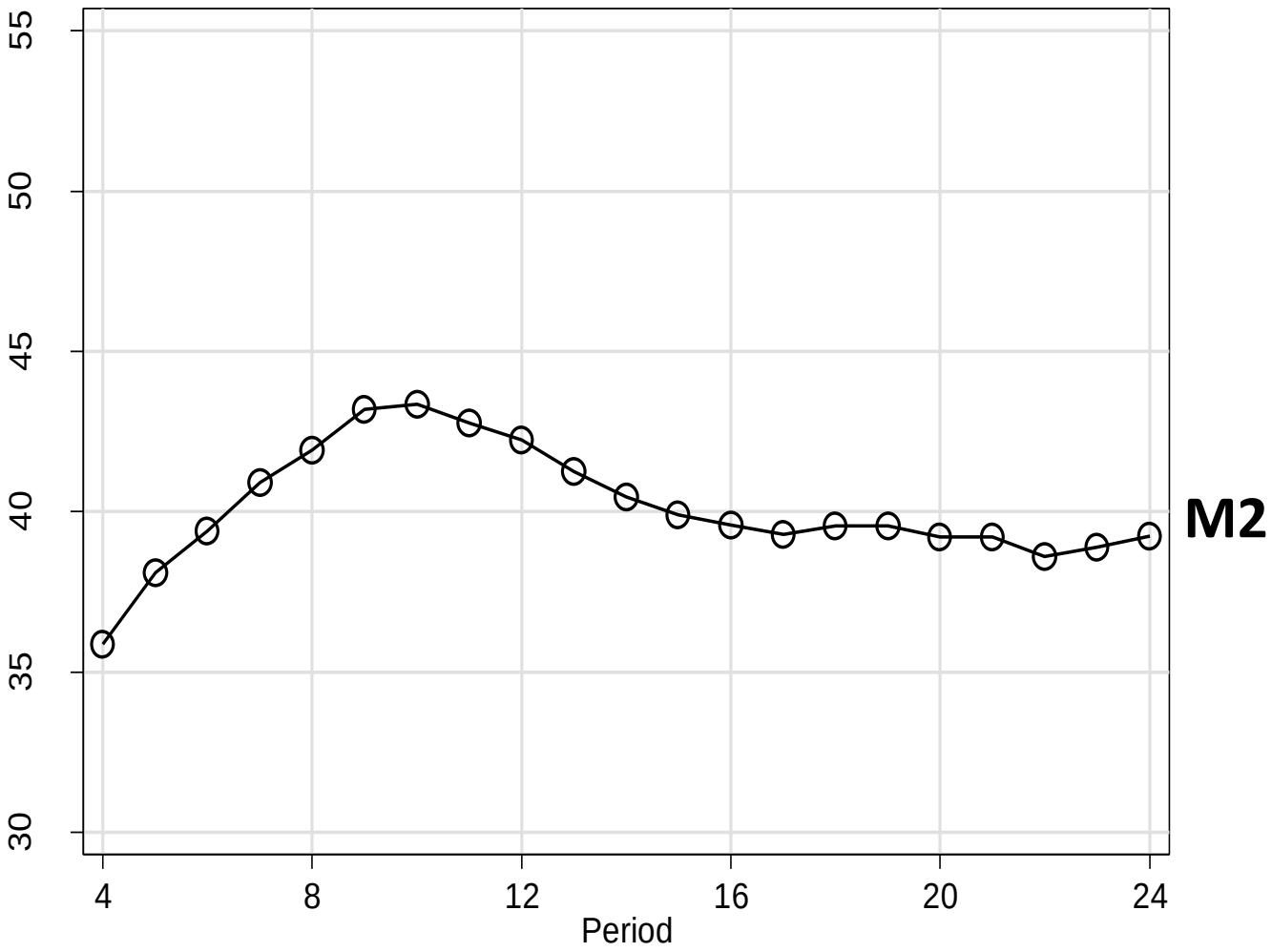
My Profit (My Return - My Total Cost) ---

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
9	160	570

OK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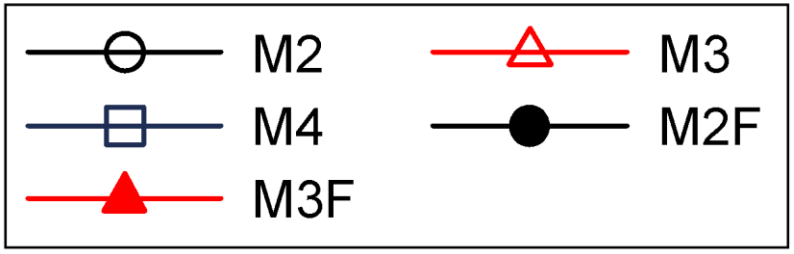
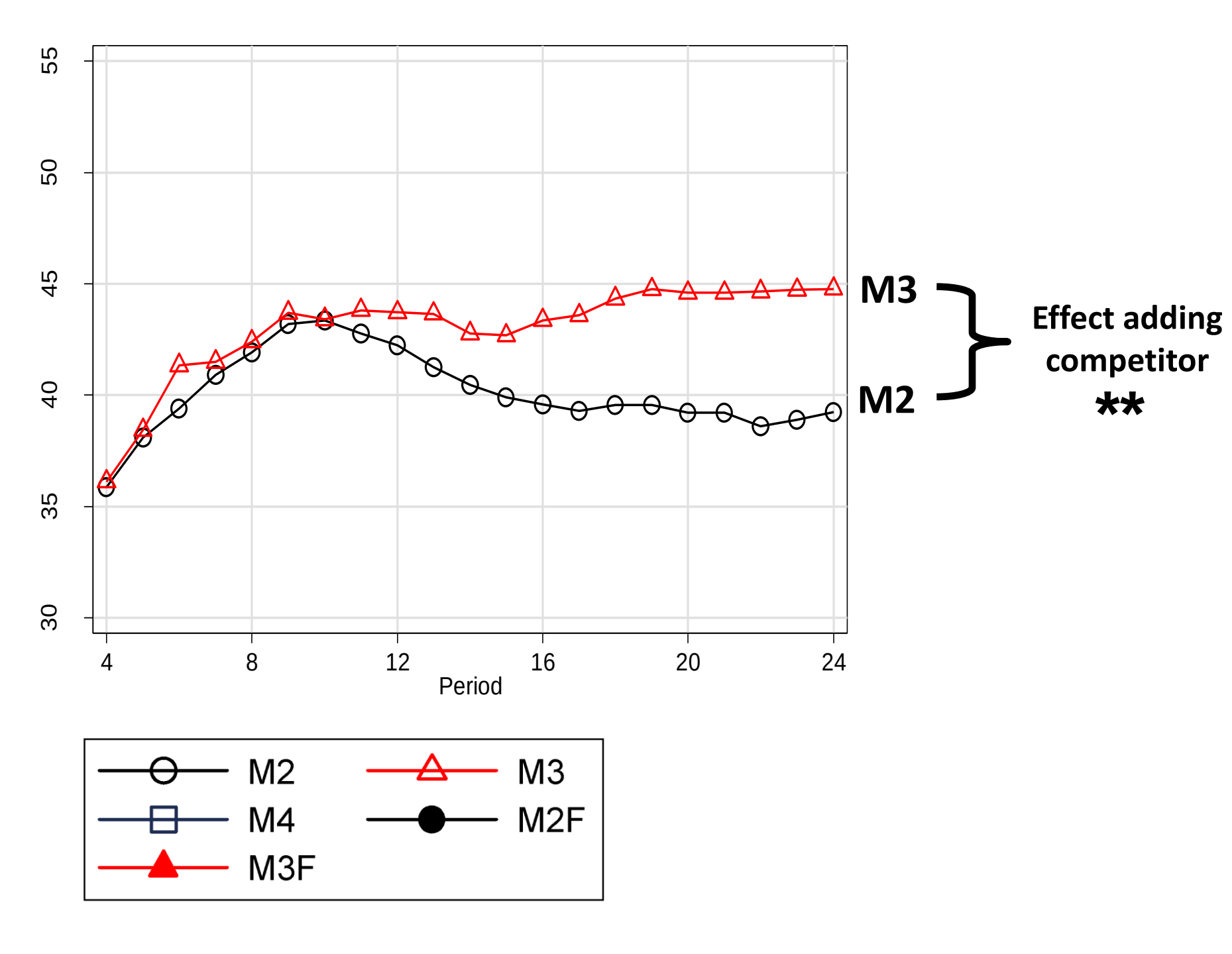
Period
M2


M2
M3
M4
M2F
M3F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Period
M3
M2
Effect adding competitor
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M2
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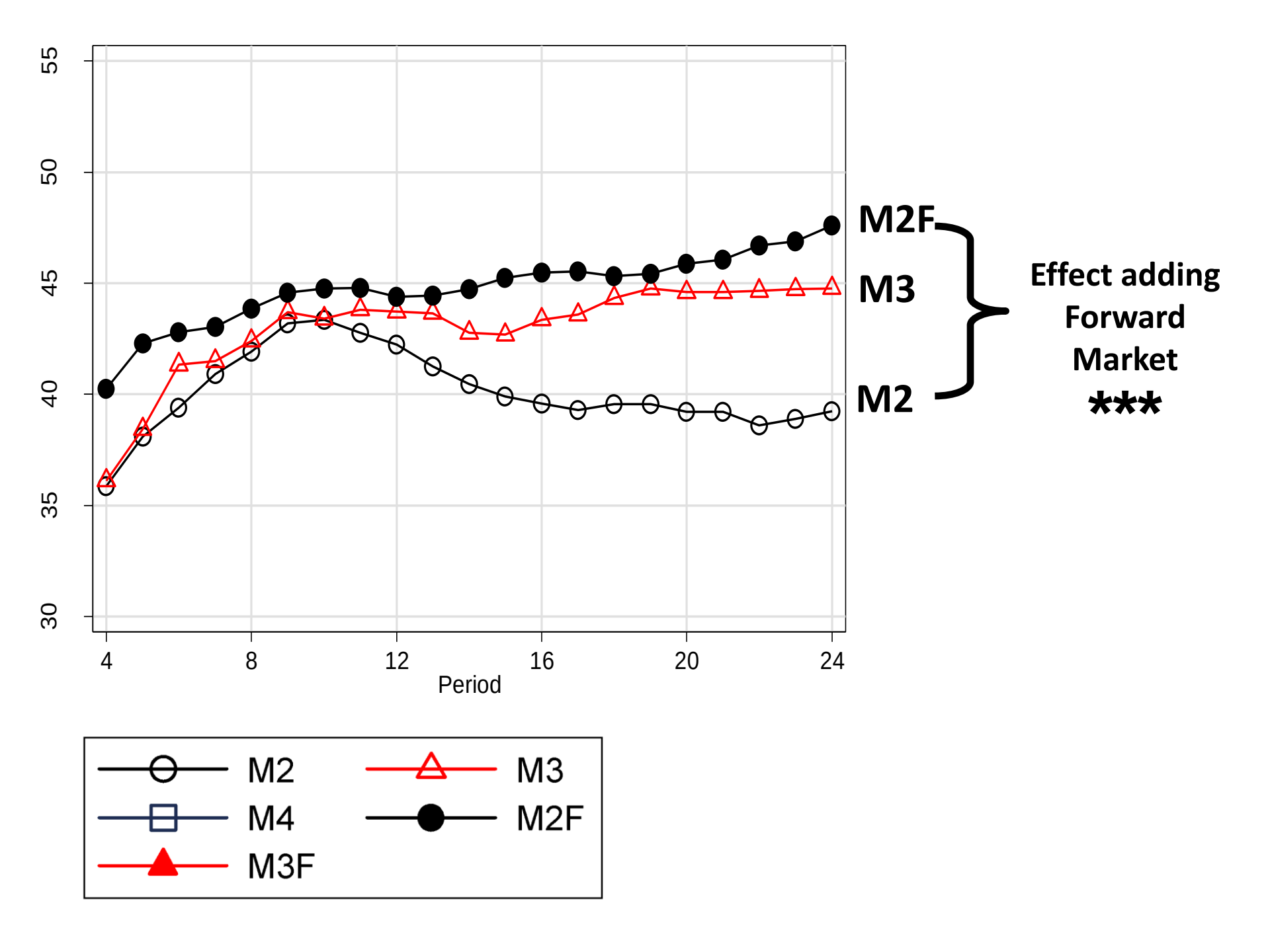
M4
M2F
M3F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Effect adding
Forward
Market
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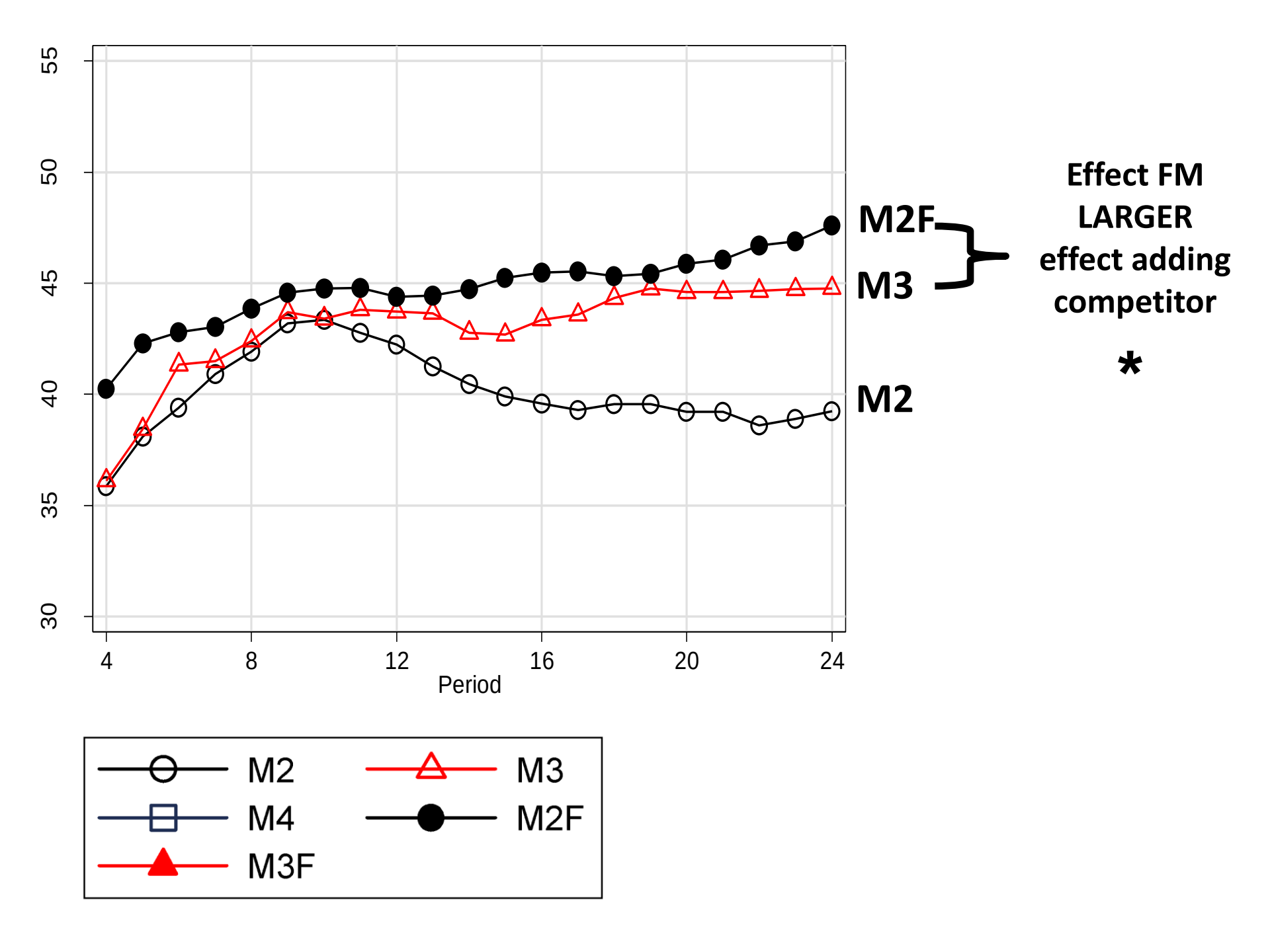
M3
M4
M2F
M3F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Effect FM LARGER effect adding competitor
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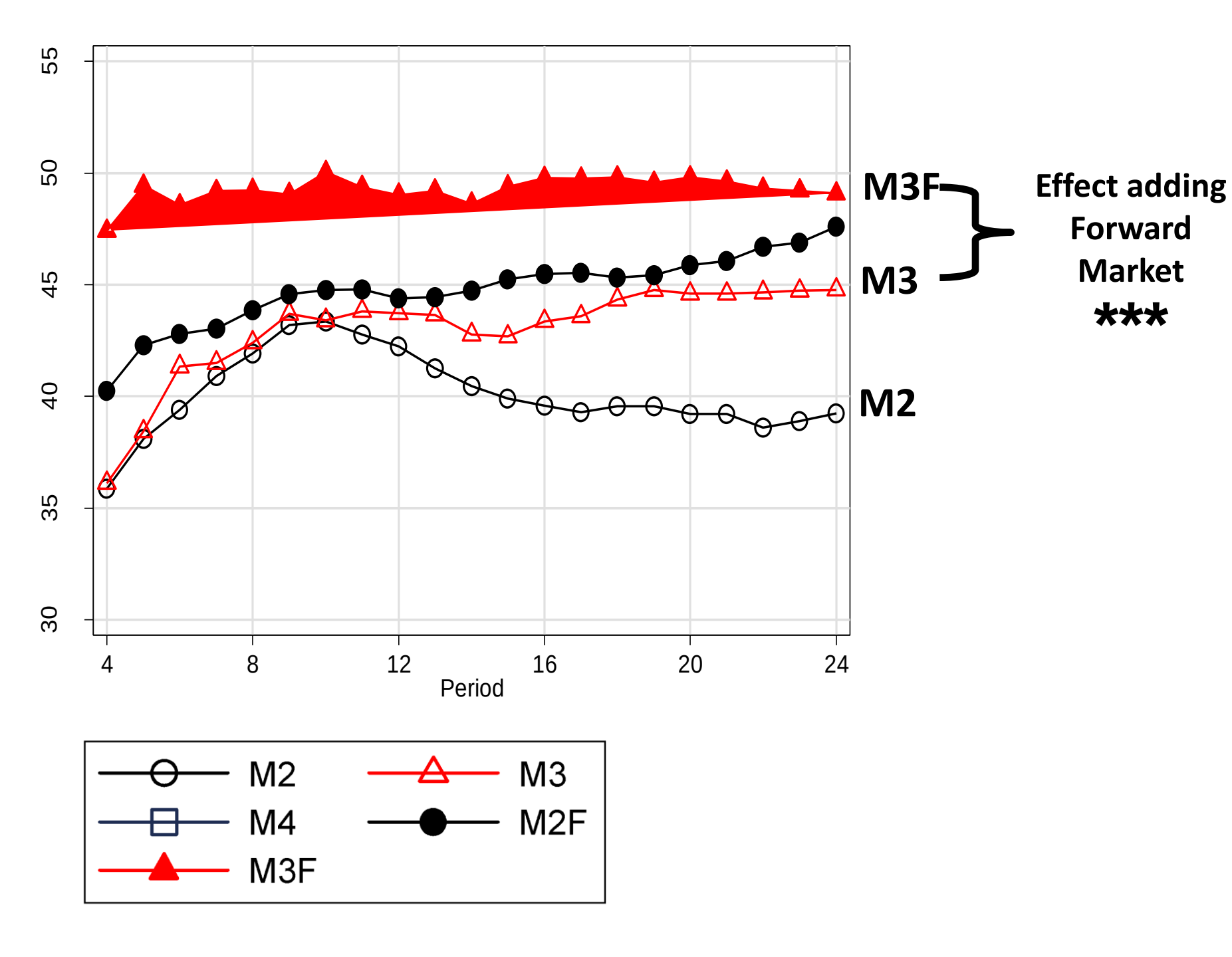
M2
M3
M4
M2F
M3F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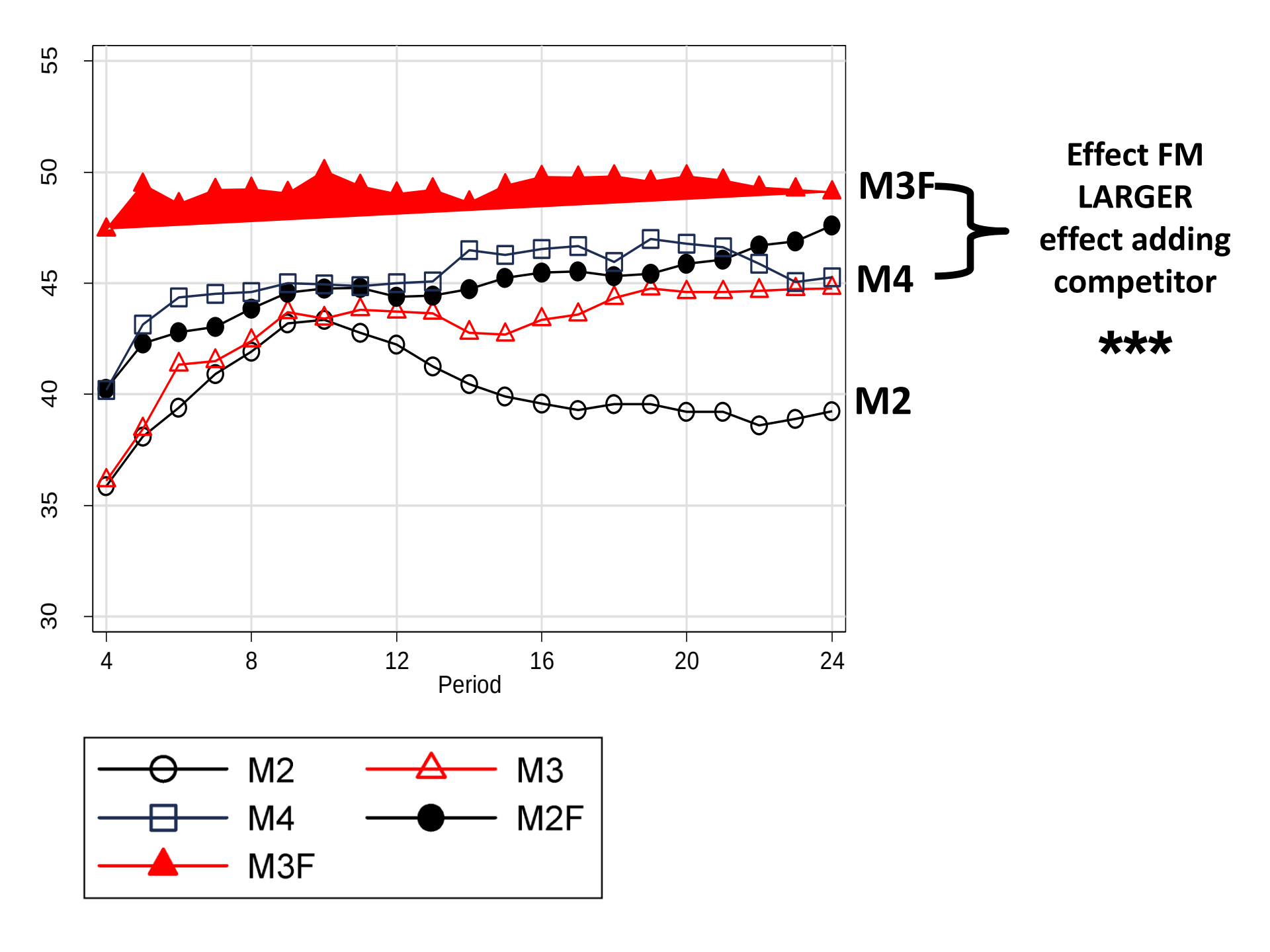
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Period
M3F
M4
M2
Effect FM
LARGER
effect adding
competitor
***
M2
M3
M4
M2F
M3F

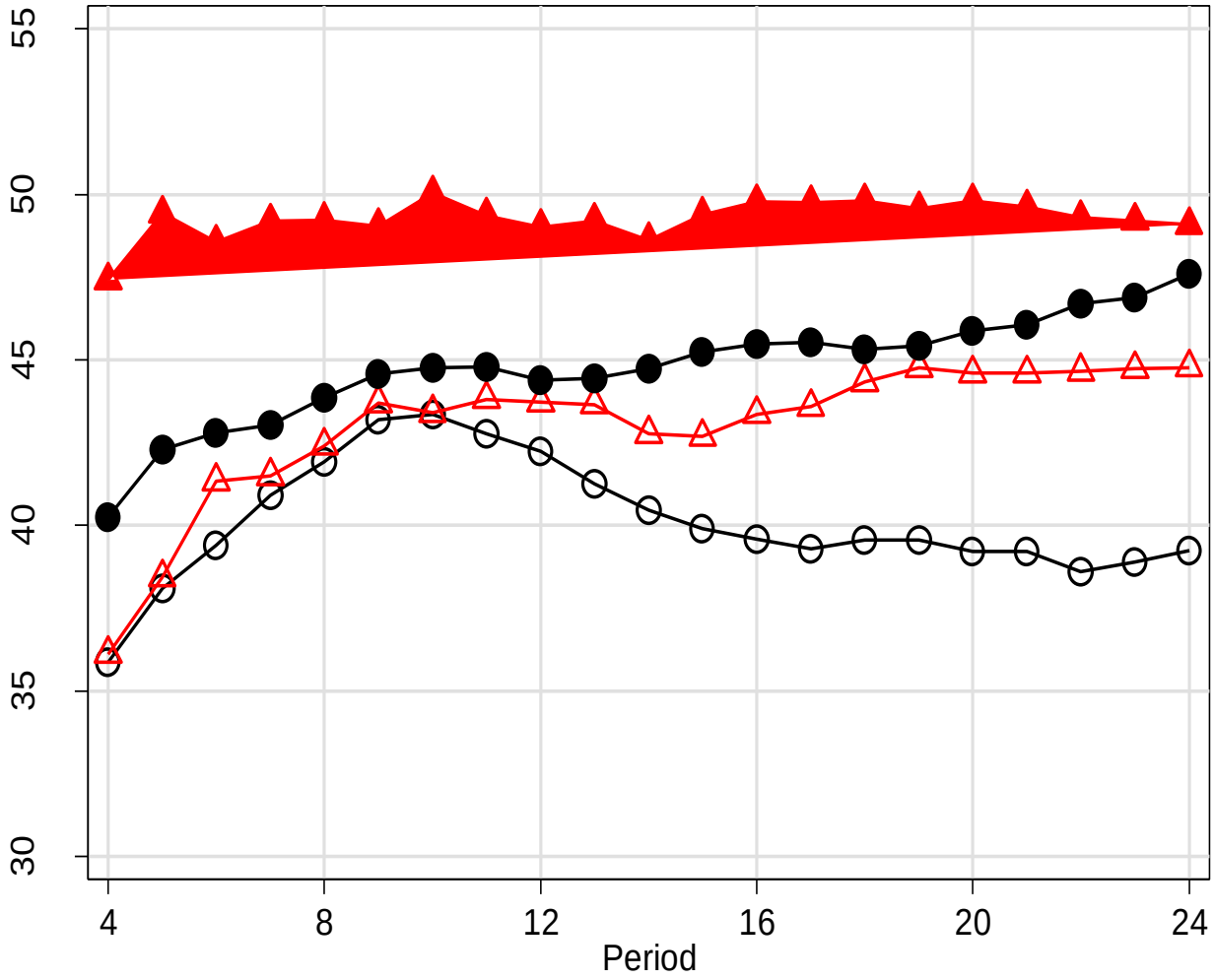
Averages

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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20
24
Period
M3F
M3
M2
Effect adding
Forward
Market
***

Policy lesson

- Forward market has a pro-competitive effect
- Sufficient degree of market transparency necessary
  - (REMIT? MIFID 1 & 2?)

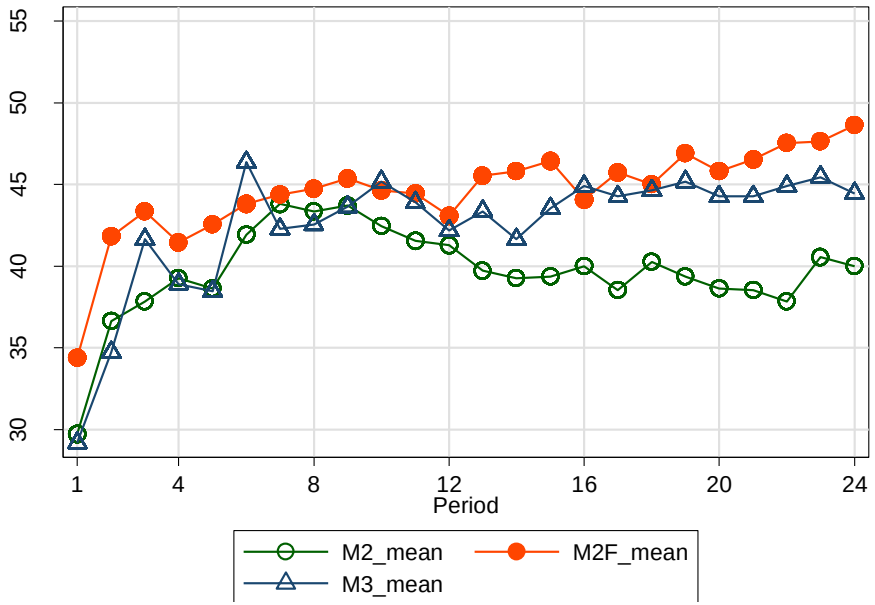
Are these results robust for experienced players?

Ferreira, Kujal & Rassenti, 2009

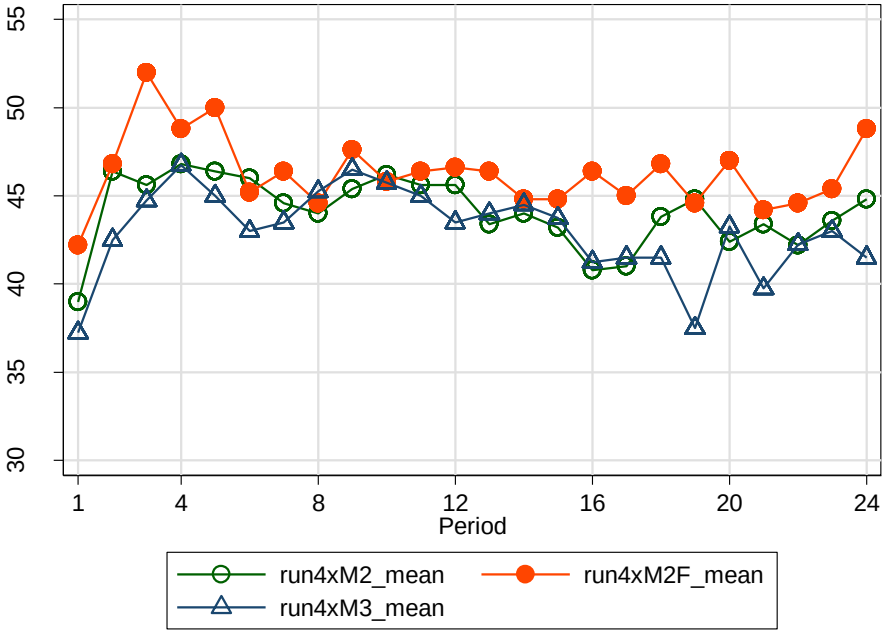
Forward Market	Predicted	Observed: Inexperienced	Observed: Experienced
2 firms	85.7	85.6	62.5
4 firms	89.1	99.9	76.8

Inexperienced

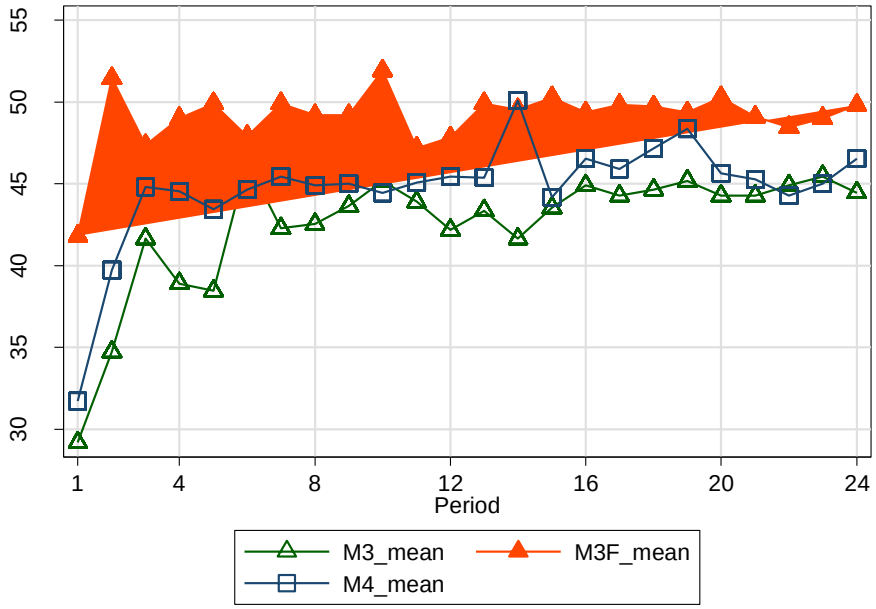
M2, M2F, M3



Experienced

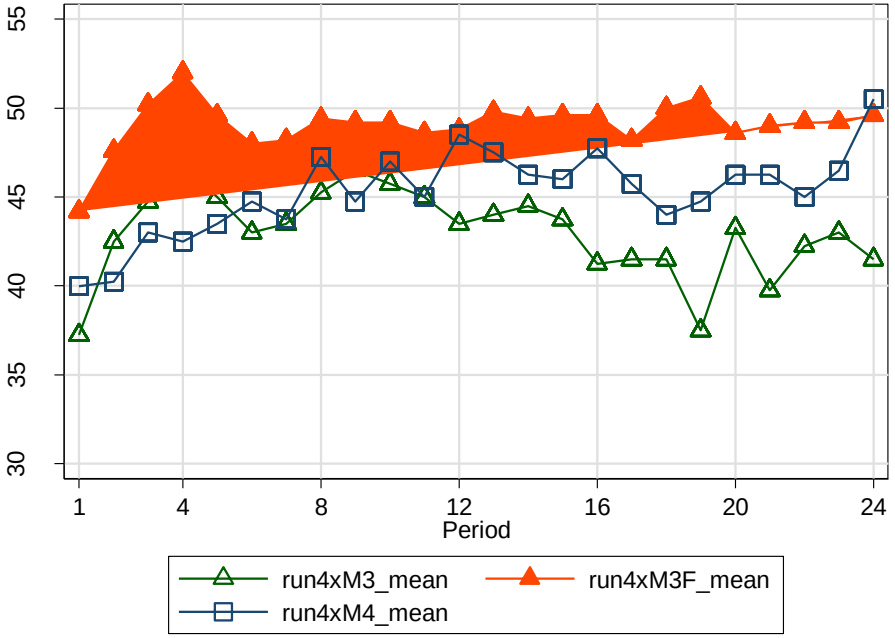


Inexperienced



M3, M3F, M4

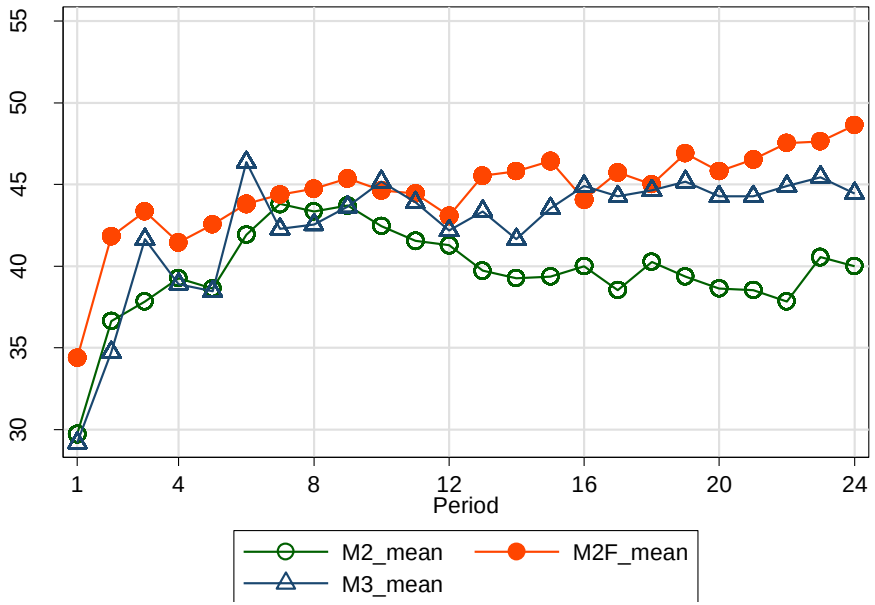
Experienced



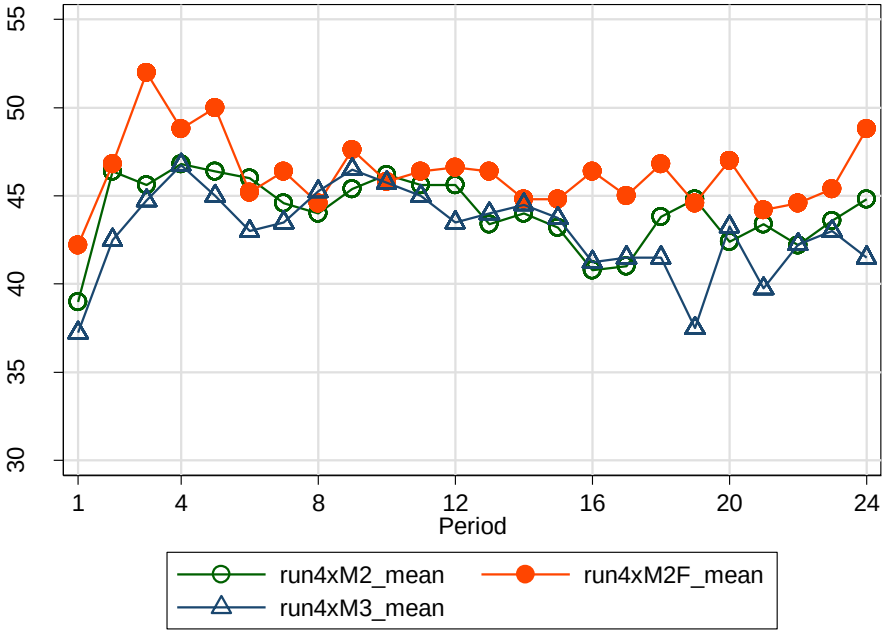
	M2	M2F	M3	M3F	M4
run123 (Inexperienced)	39.3 (1.5)	46.3 (2.0)	44.2 (1.2)	49.6 (0.6)	46.2 (1.0)
run4 (Experienced)	43.1 (1.5)	45.7 (2.4)	42.0 (1.6)	50.9 (0.2)	46.4 (0.9)
Difference					
Significance (two-sided test)					

Inexperienced

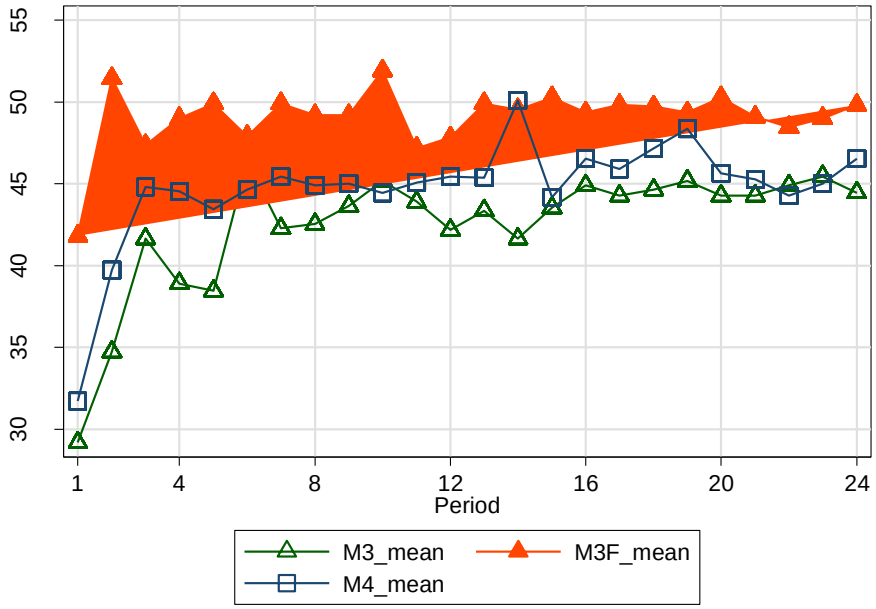
M2, M2F, M3



Experienced

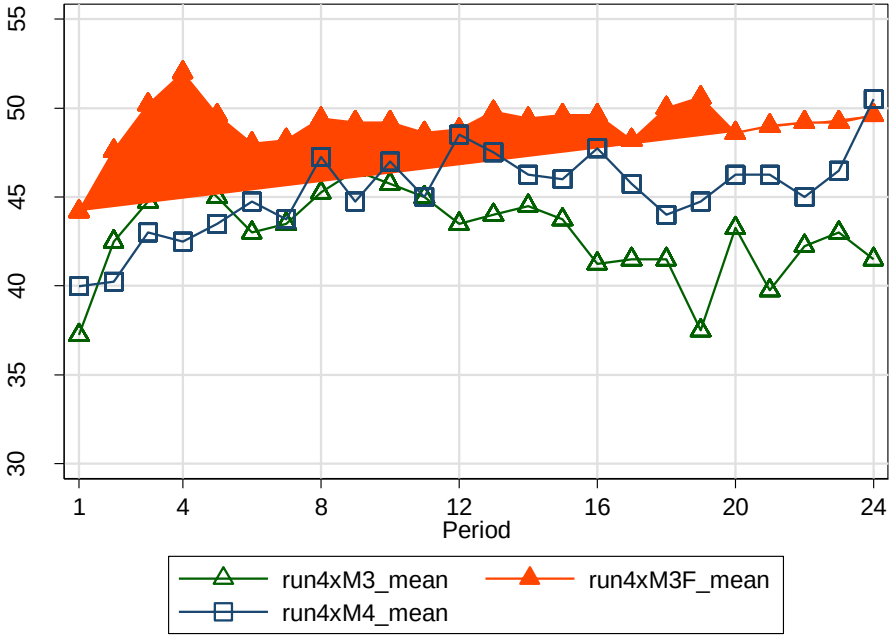


Inexperienced

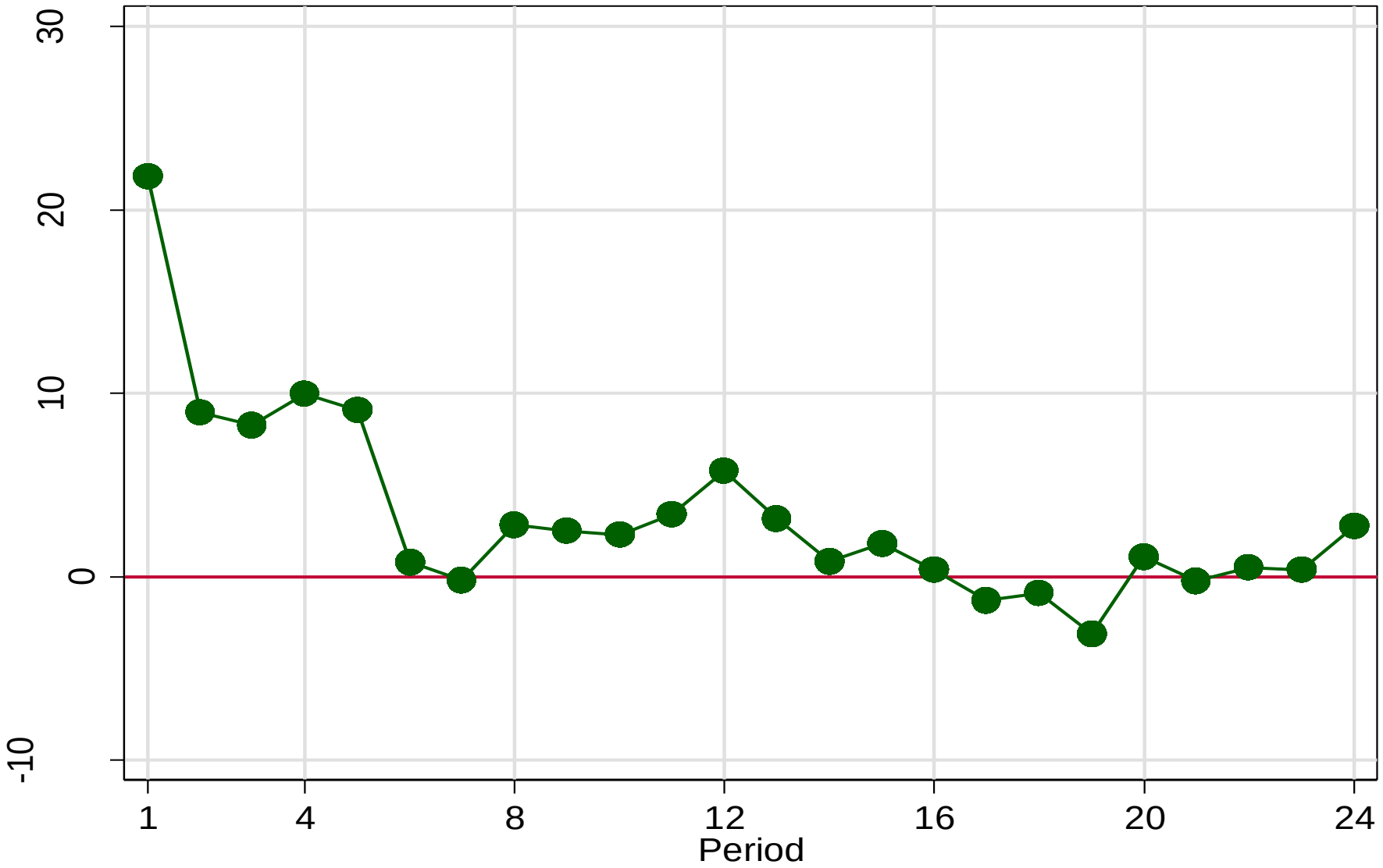


M3, M3F, M4

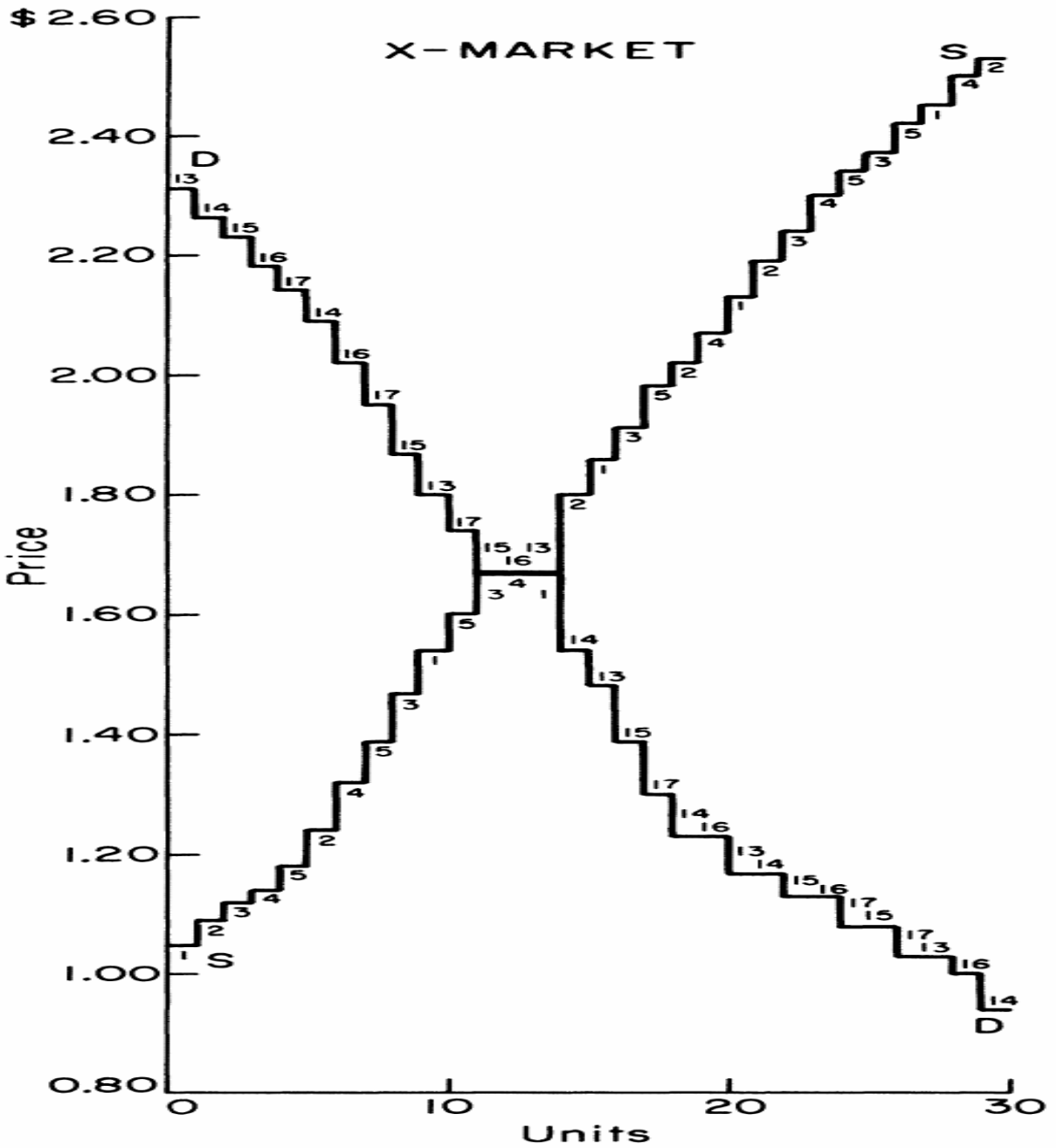
Experienced



Increase in production by Experienced Subjects

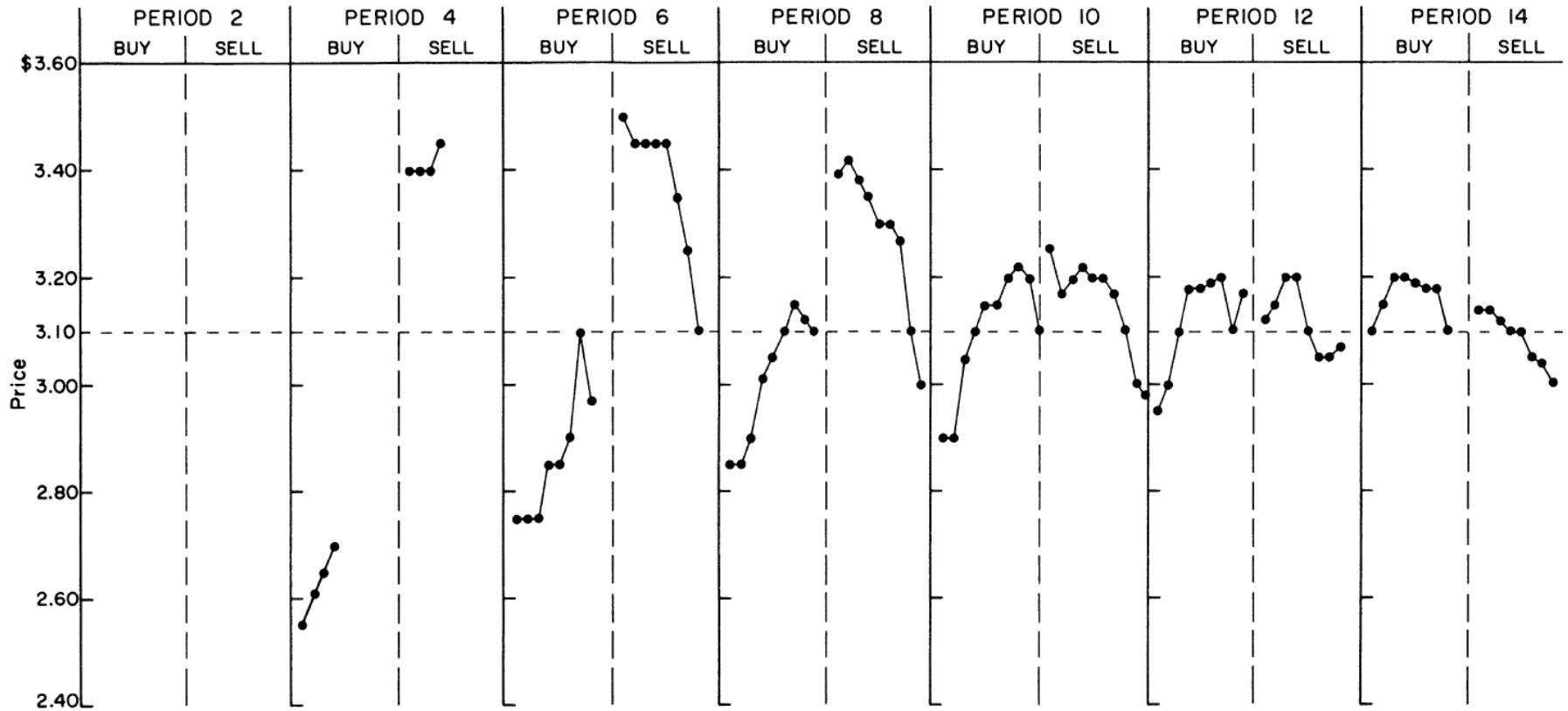


Plot & Uhl, SEJ, 1981



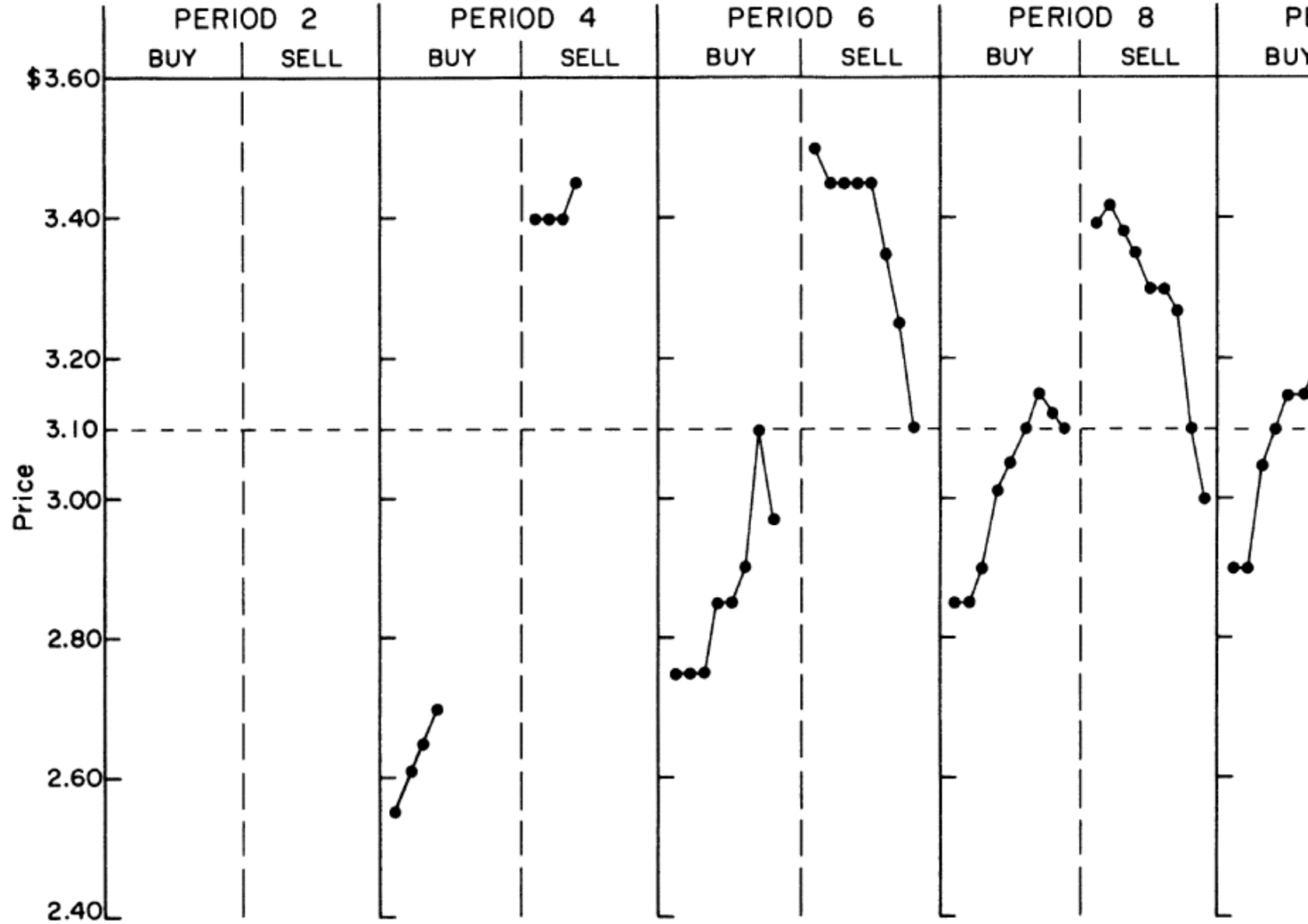
Plot & Uhl, SEJ, 1981

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



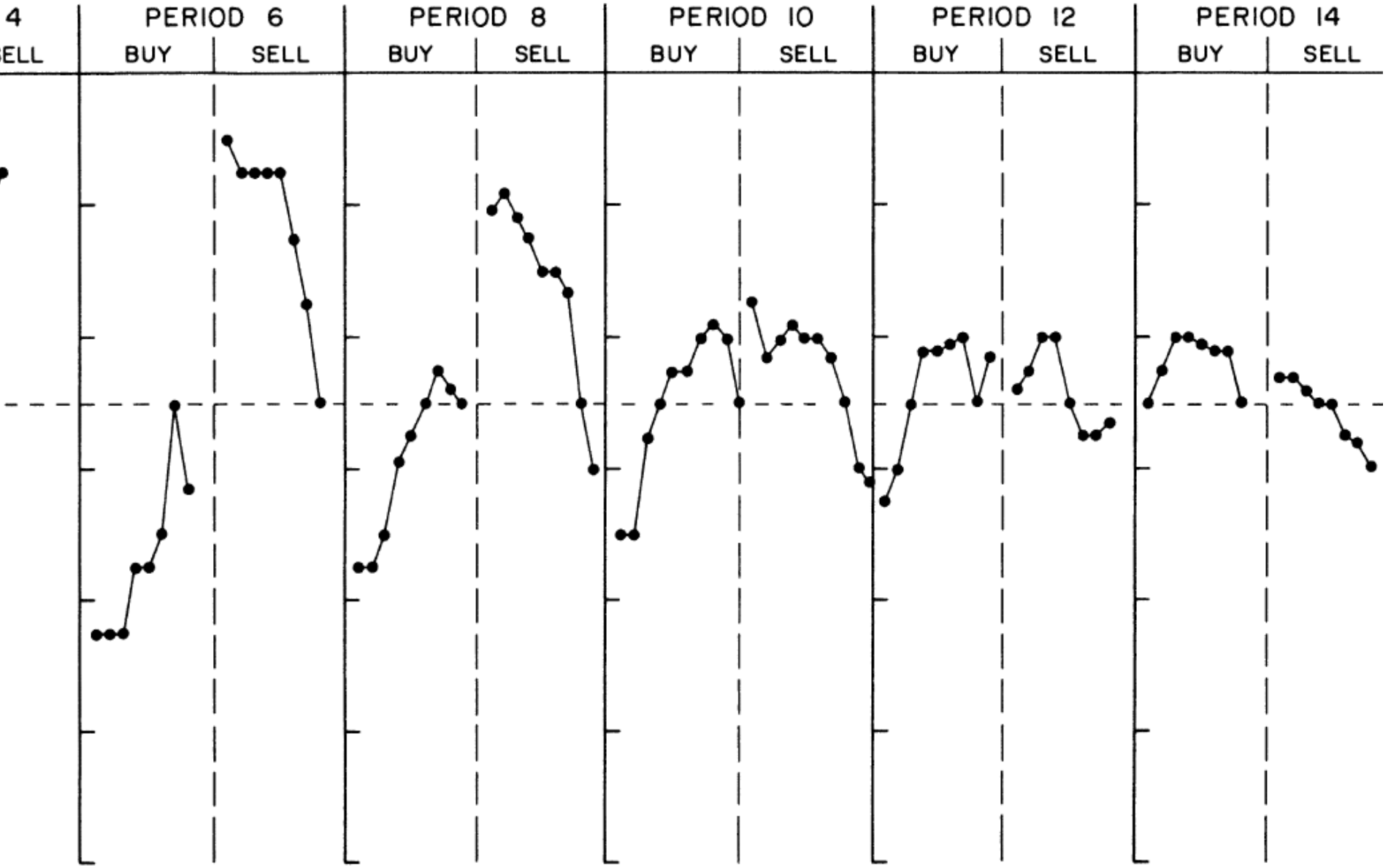
	PERIOD 2		PERIOD 4		PERIOD 6		PERIOD 8		PERIOD 10		PERIOD 12		PERIOD 14	
	BUY	SELL	BUY	SELL	BUY	SELL	BUY	SELL	BUY	SELL	BUY	SELL	BUY	SELL
Volume	0	0	4	4	8	8	9	9	10	10	9	8	8	8
Mean price	–	–	$2.63	$3.41	$2.86	$3.38	$3.01	$3.28	$3.10	$3.15	$3.12	$3.12	$3.16	$3.09
Variance			0.063	0.025	0.122	0.136	0.119	0.141	0.116	0.093	0.090	0.061	0.042	0.051

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



Volume	0	0	4	4	8	8	9	9	10
Mean price	–	–	$2.63	$3.41	$2.86	$3.38	$3.01	$3.28	$3.1
Variance			0.063	0.025	0.122	0.136	0.119	0.141	0.11

Occurrence



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