Belief-Driven Price Stickiness: an Experimental Study

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Motivation

- Price stickiness
  - Key to monetary policy and macroeconomics
- Sources?
  - Explicit rigidity (menu cost, predetermined timing)
  - Imperfect information
  - Others? e.g. money illusion, cognitive limitations, strategic reason
- Experimentally analyze whether price is sticky
  - when removing above factors except for a strategic reason.

Literature

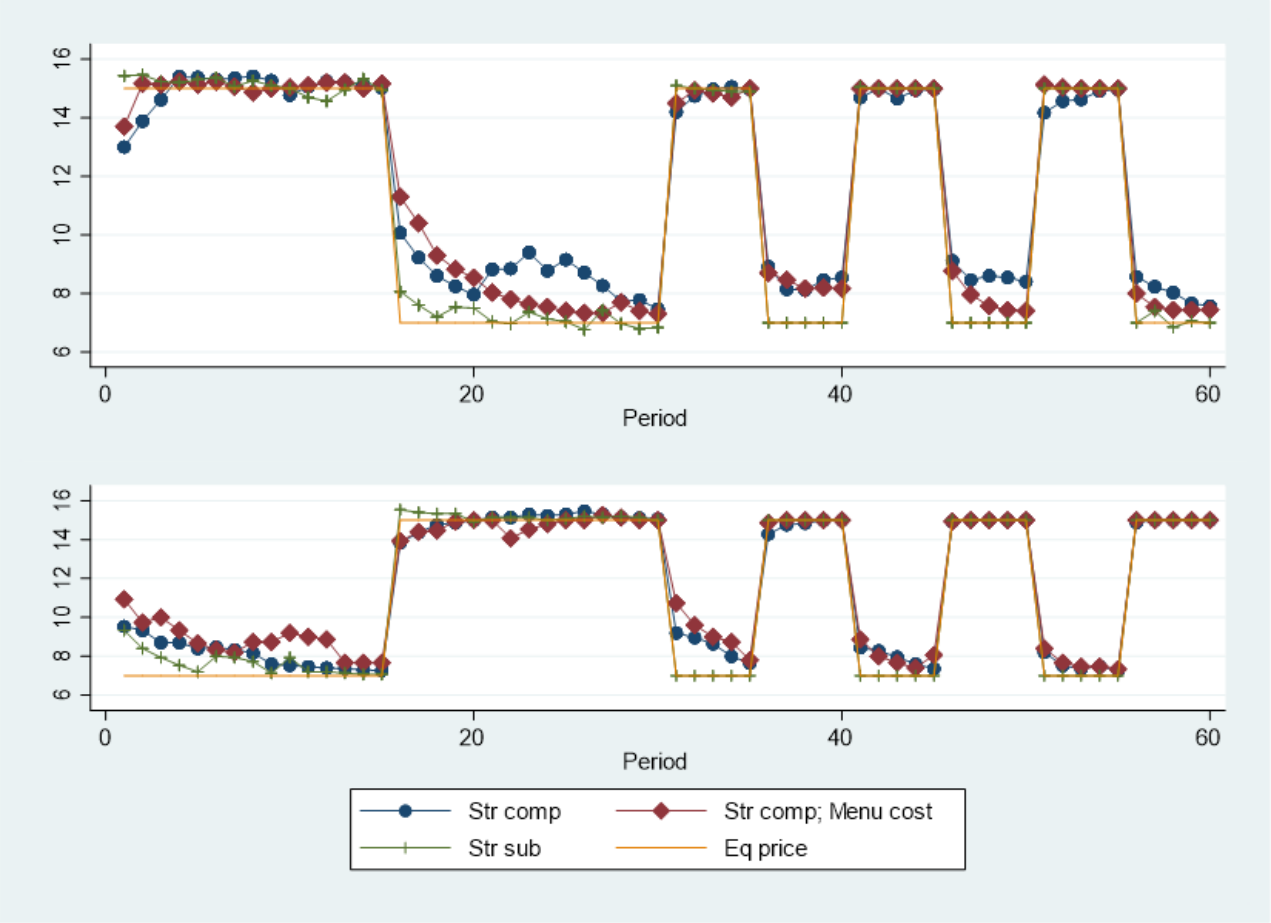
- Not many
- Fehr and Tyran (2001AER, 2008ECTA)
  - Combination of money illusion and strategic complementarity generates price stickiness
  - Money illusion: real or nominal
    - Cognitive ability? Petersen and Winn (2014AERcom)
- With explicit price rigidity
  - Wilson (1998JEBO), Davis and Korenok (2011JME), Magnani, Gorry, and Oprea (2016AEJ:Macro)
- Strategic uncertainty in markets
  - Giamattei and Lambsdorff (2015) and others

What We Do

- Experimentally analyze if prices are sticky in response to an (anticipated) shock
  - Environment in standard macro models (e.g. demand function)
    - Unlike Fehr and Tyran (2001, 2008)
  - Perfect information except for others' actions: minimize the subjects' cognitive burden
    - Simple environment
    - No money illusion unlike Fehr and Tyran (2001, 2008)
    - Test for understandings before experiments
  - Repetition of shocks

Preview: Experiment Results

– Strategic complementarity causes price setters to gradually adjust their prices for a shock, generating price stickiness.



Preview

- We observe price stickiness
  - under strategic complementarity
  - repetition of shocks attenuates but does not eliminate stickiness
  - subjects largely best respond to their beliefs
  - elicited beliefs predict post-shock prices well
- Beliefs (and hence prices) are adjusted slowly after certain anticipated shocks
  - **“belief-driven price stickiness”**
  - role of strategic uncertainty

Setup

- Students at Waseda University
- N=5: 1 group consists of 5 students
  - 6 groups (30 persons in total)
- T=60 (t=1,2,…,T=60)
- $\zeta = 0.5$ or -0.5, $\varepsilon = 6$ (next page)
- Cost c changes at t=16,31,36,41,46,51,&56.
- Show only profit tables
  - No need to solve an optimization problem
  - X: others' average price, Y: own price
- (Menu cost payments when revising price)

Environment (Standard in Macro)

Firm i as a price setter

Demand function $\mathrm{Y}_i = \left(\frac{P_i}{P_{-i}}\right)^{-\varepsilon} \mathrm{Y}$

where $\varepsilon > 1$ and $P_{-i} = \left(\frac{1}{N}\sum_{j=1¥i}^{N} P_j{}^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$.

Period profit in a real term $\Pi_i = \frac{P_i\,\mathrm{Y}_i - \mathrm{C}(P_{-i})\mathrm{Y}_i}{P_{-i}}$,

which leads to the following best response:

$$\boldsymbol{P_i = \frac{\varepsilon}{\varepsilon-1}\mathrm{C}(P_{-i}) = \frac{\varepsilon}{\varepsilon-1}\mathrm{c}P_{-i}{}^{\zeta}}.$$

$\zeta > 0$: strategic complementarity

$\zeta < 0$: strategic substitute

Profit Table (Example $\zeta = 0.5$)

- Under a negative cost-push shock, eqm p=7
- chosen to avoid collusion
- extreme values truncated

グループ内の他の企業の平均価格

あなたの価格	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	−5.929	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10
2	−0.015	−2.728	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10
3	0.006	−0.020	−1.310	−9.633	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10
4	0.002	0.035	0.063	−0.465	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10
5	0	0.020	0.094	0.206	5.000	−8.186	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10
6	0	0.010	0.058	0.179	10	5.000	2.247	−2.819	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10
7	0	0.005	0.033	0.114	10	5.053	5.000	5.011	4.092	1.209	−5.009	−10	−10	−10	−10	−10	−10	−10	−10	−10
8	0	0.003	0.020	0.071	8.254	3.646	4.088	5.000	5.987	6.720	6.761	5.506	2.139	−4.405	−10	−10	−10	−10	−10	−10
9	0	0.002	0.012	0.045	5.380	2.478	2.926	3.823	5.000	6.361	7.779	9.060	9.927	9.996	8.764	5.585	−0.351	−10	−10	−10
10	0	0.001	0.008	0.029	3.554	1.678	2.038	2.753	3.745	5.000	6.496	8.187	9.990	10	10	10	10	10	10	7.034
11	0	0	0.005	0.019	2.399	1.151	1.424	1.961	2.728	3.736	5.000	6.524	8.300	10	10	10	10	10	10	10
12	0	0	0.003	0.013	1.656	0.804	1.006	1.405	1.983	2.759	3.757	5.000	6.504	8.277	10	10	10	10	10	10
13	0	0	0.002	0.009	1.168	0.572	0.723	1.019	1.452	2.042	2.814	3.792	5.000	6.460	8.188	10	10	10	10	10
14	0	0	0.002	0.007	0.841	0.415	0.528	0.749	1.075	1.524	2.117	2.878	3.831	5.000	6.406	8.070	10	10	10	10
15	0	0	0.001	0.005	0.617	0.306	0.391	0.558	0.806	1.150	1.607	2.199	2.947	3.873	5.000	6.350	7.942	9.797	10	10
16	0	0	0	0.004	0.460	0.229	0.294	0.422	0.612	0.877	1.232	1.694	2.282	3.015	3.914	5.000	6.293	7.813	9.580	10
17	0	0	0	0.003	0.349	0.174	0.225	0.323	0.471	0.677	0.954	1.317	1.781	2.363	3.082	3.954	5.000	6.238	7.688	9.368
18	0	0	0	0.002	0.268	0.134	0.174	0.251	0.366	0.528	0.747	1.034	1.403	1.867	2.443	3.146	3.993	5.000	6.186	7.568
19	0	0	0	0.002	0.209	0.105	0.136	0.196	0.288	0.416	0.590	0.819	1.114	1.488	1.952	2.520	3.208	4.029	5.000	6.137
20	0	0	0	0.001	0.164	0.083	0.107	0.156	0.228	0.331	0.471	0.655	0.893	1.195	1.571	2.033	2.594	3.266	4.063	5.000

（注）色がついているセルは、縦の各列において、最大の利得をもたらす価格を指す。

Profit Table (Example $\zeta = 0.5$)

– Under a positive cost-push shock, eqm p=15

グループ内の他の企業の平均価格

あなたの価格	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
2	-0.095	-6.388	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
3	-0.002	-0.341	-4.298	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
4	0	-0.022	-0.468	-3.053	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
5	0	0.005	-0.045	-0.473	-2.202	-7.191	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
6	0	0.005	0.011	-0.049	-0.403	-1.575	-4.543	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
7	0	0.003	0.015	0.024	-0.027	-0.294	-1.087	-2.939	-6.683	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
8	0	0.002	0.011	0.030	0.048	0.016	-0.167	-0.694	-1.873	-4.169	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
9	0	0.001	0.008	0.025	0.053	0.081	0.076	-0.034	-0.368	-1.116	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
10	0	0	0.005	0.018	0.044	0.082	0.124	0.146	0.099	-0.093	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
11	0	0	0.004	0.013	0.033	0.068	0.118	0.175	0.223	0.230	5.000	-1.581	-6.029	-10	-10	-10	-10	-10	-10	-10
12	0	0	0.003	0.010	0.025	0.054	0.098	0.159	0.231	0.304	10	5.000	2.253	-0.336	-3.588	-7.971	-10	-10	-10	-10
13	0	0	0.002	0.007	0.019	0.041	0.078	0.132	0.204	0.292	10	6.766	5.000	3.796	2.453	0.646	-1.887	-5.411	-10	-10
14	0	0	0.001	0.005	0.014	0.032	0.061	0.106	0.170	0.253	10	6.692	5.517	5.000	4.568	3.990	3.100	1.742	-0.253	-3.075
15	0	0	0.001	0.004	0.011	0.024	0.048	0.085	0.138	0.211	10	5.981	5.175	5.002	5.000	5.001	4.898	4.596	3.997	2.988
16	0	0	0	0.003	0.008	0.019	0.037	0.067	0.112	0.173	8.854	5.117	4.551	4.548	4.739	5.000	5.259	5.459	5.540	5.438
17	0	0	0	0.002	0.006	0.015	0.030	0.054	0.090	0.141	7.311	4.291	3.885	3.962	4.228	4.591	5.000	5.420	5.816	6.149
18	0	0	0	0.002	0.005	0.012	0.023	0.043	0.072	0.115	6.010	3.567	3.269	3.380	3.664	4.049	4.502	5.000	5.522	6.045
19	0	0	0	0.001	0.004	0.009	0.019	0.034	0.059	0.094	4.939	2.955	2.733	2.854	3.128	3.500	3.945	4.449	5.000	5.586
20	0	0	0	0.001	0.003	0.007	0.015	0.028	0.048	0.077	4.067	2.450	2.281	2.400	2.652	2.993	3.407	3.883	4.416	5.000

（注）色がついているセルは、縦の各列において、最大の利得をもたらす価格を指す。

Profit Table (Example $\zeta = -0.5$)

– Under a negative cost-push shock, eqm p=7

グループ内の他の企業の平均価格

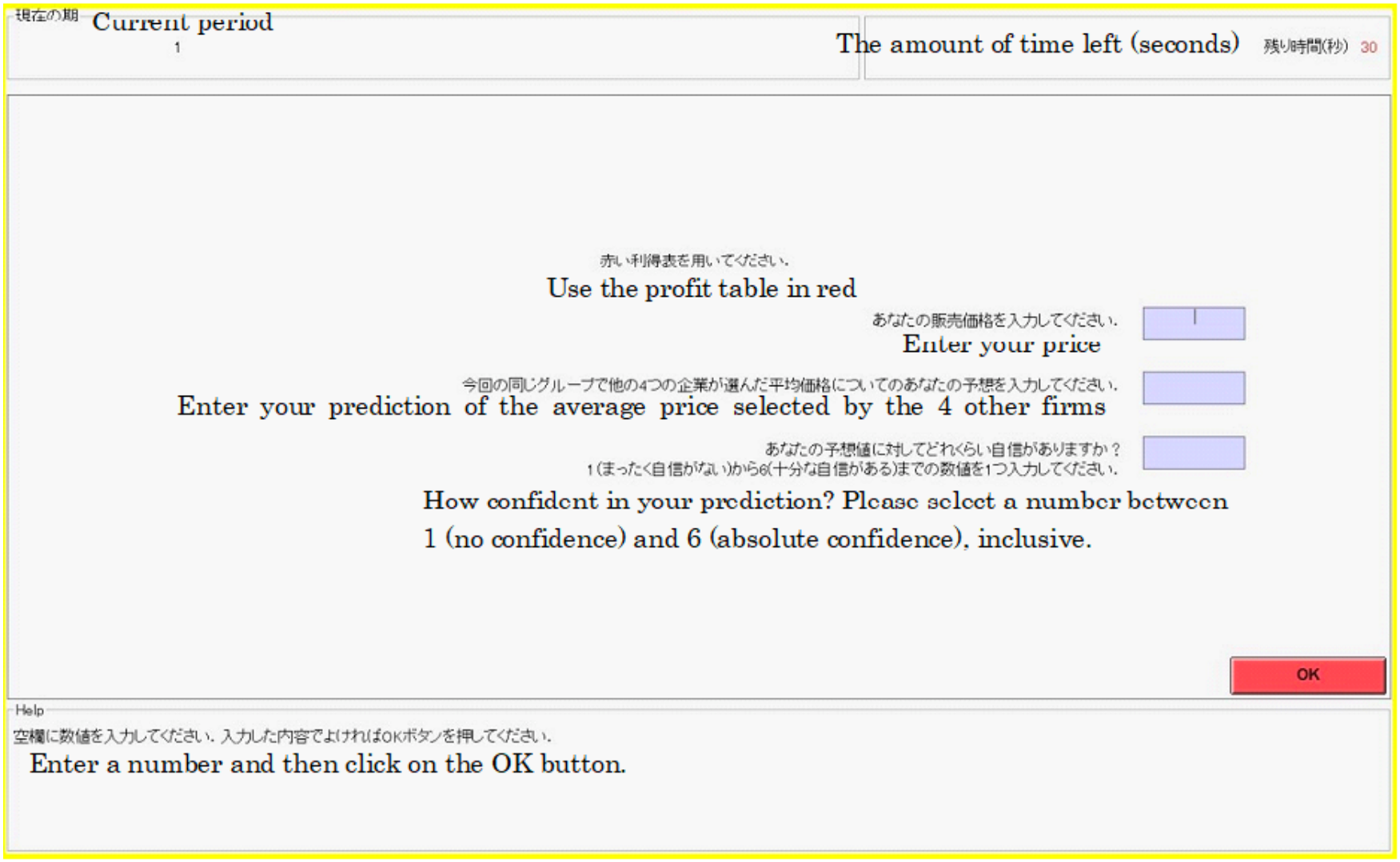
あなたの価格	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
2	-1.049	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
3	-0.085	-1.737	-9.851	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
4	-0.014	-0.270	-1.457	-4.646	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	10	10	10	10	10	10
5	-0.003	-0.061	-0.304	-0.890	-1.902	-3.237	-10	-10	-6.374	7.468	10	10	10	10	10	10	10	10	10	10
6	-0.001	-0.017	-0.076	-0.188	-0.302	-0.251	1.801	6.002	10	10	10	10	10	10	10	10	10	10	10	10
7	0	-0.005	-0.020	-0.031	0.013	0.231	5.000	6.761	10	10	10	10	10	10	10	10	10	10	10	10
8	0	-0.002	-0.004	0.006	0.065	0.252	4.167	5.000	7.507	10	10	10	10	10	10	10	10	10	10	10
9	0	0	0	0.012	0.062	0.197	3.004	3.436	5.000	7.571	10	10	10	10	10	10	10	10	10	10
10	0	0	0.001	0.012	0.048	0.144	2.101	2.341	3.346	5.000	7.462	10	10	10	10	10	10	10	10	10
11	0	0	0.001	0.009	0.036	0.103	1.471	1.613	2.278	3.374	5.000	7.311	10	10	10	10	10	10	10	10
12	0	0	0.001	0.007	0.027	0.074	1.041	1.129	1.582	2.329	3.434	5.000	7.156	10	10	10	10	10	10	10
13	0	0	0.001	0.006	0.020	0.054	0.749	0.805	1.122	1.643	2.413	3.503	5.000	7.010	9.657	10	10	10	10	10
14	0	0	0	0.004	0.015	0.040	0.547	0.585	0.811	1.183	1.732	2.508	3.573	5.000	6.877	9.306	10	10	10	10
15	0	0	0	0.003	0.011	0.030	0.406	0.432	0.596	0.868	1.268	1.832	2.605	3.640	5.000	6.758	8.997	10	10	10
16	0	0	0	0.003	0.008	0.022	0.306	0.324	0.446	0.647	0.944	1.362	1.933	2.698	3.703	5.000	6.651	8.725	10	10
17	0	0	0	0.002	0.007	0.017	0.233	0.246	0.339	0.490	0.714	1.028	1.459	2.034	2.788	3.762	5.000	6.555	8.485	10
18	0	0	0	0.002	0.005	0.013	0.180	0.190	0.260	0.377	0.548	0.788	1.116	1.555	2.131	2.873	3.816	5.000	6.469	8.271
19	0	0	0	0.001	0.004	0.010	0.141	0.148	0.203	0.293	0.426	0.612	0.866	1.205	1.650	2.224	2.952	3.866	5.000	6.391
20	0	0	0	0	0.003	0.008	0.112	0.117	0.160	0.231	0.335	0.481	0.680	0.946	1.294	1.743	2.312	3.027	3.913	5.000

（注）色がついているセルは、縦の各列において、最大の利得をもたらす価格を指す。

Setup 2

- Students answer every period
  - Own price
  - Expectations of the average price set by others
  - Confidence on the average price
- Other points
  - Within 1 minute. If not, warning displayed.
    - 3 minutes at t=1 and 16.
  - Income effect adjusted
    - Reward from random periods
  - Collusion motive prevented in the profit table
  - Pre-experiment test to answer the group's average price & a profit given prices
  - At the end of every period, results about the profit and average price are shown.

Display

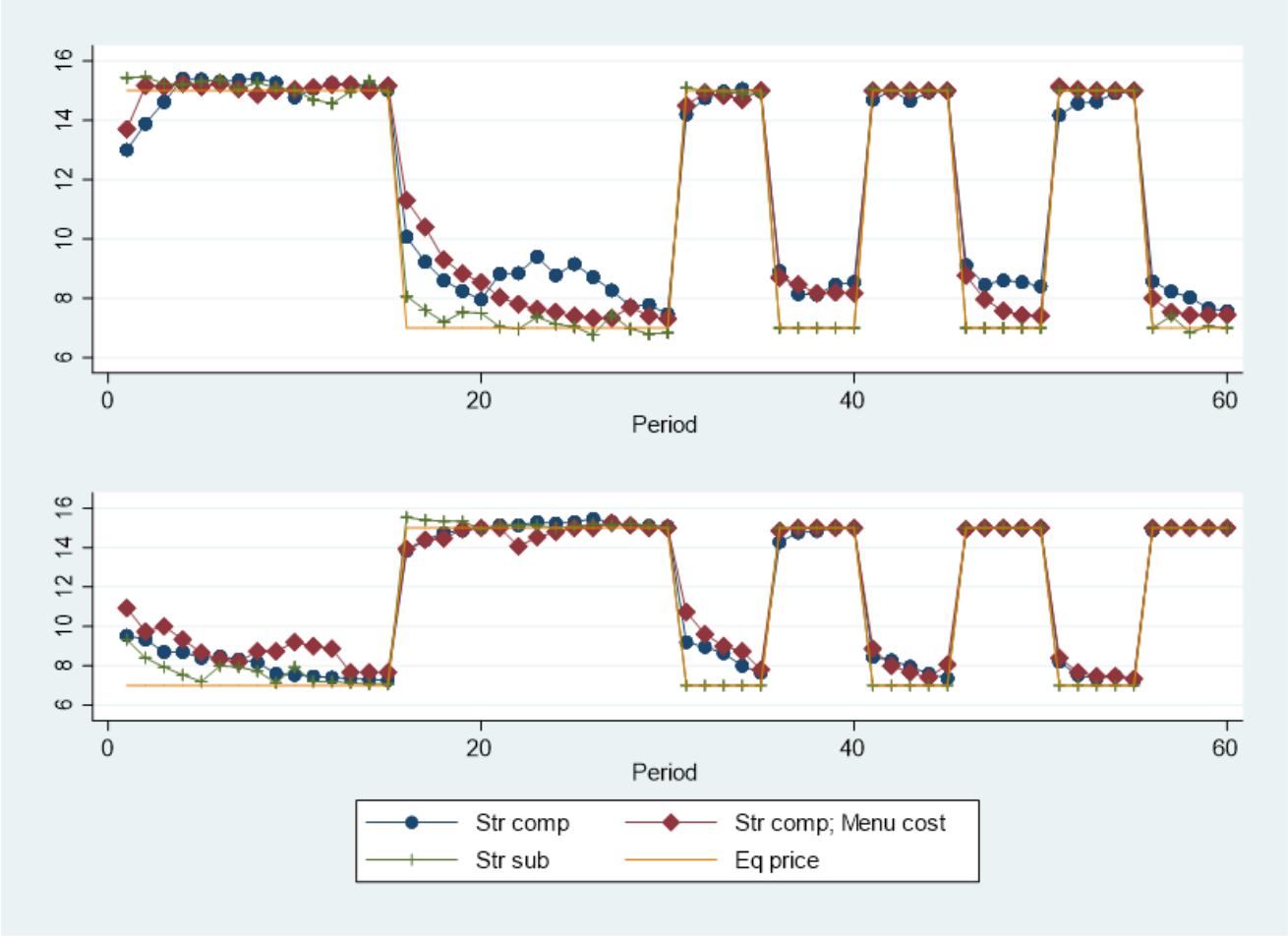

現在の期
Current period
1
The amount of time left (seconds)
残り時間(秒) 30
赤い利得表を用いてください.
Use the profit table in red
あなたの販売価格を入力してください.
Enter your price
今回の同じグループで他の4つの企業が選んだ平均価格についてのあなたの予想を入力してください.
Enter your prediction of the average price selected by the 4 other firms
あなたの予想値に対してどれくらい自信がありますか？
1(まったく自信がない)から6(十分な自信がある)までの数値を1つ入力してください.
How confident in your prediction? Please select a number between
1 (no confidence) and 6 (absolute confidence), inclusive.
OK
Help
空欄に数値を入力してください. 入力した内容でよければOKボタンを押してください.
Enter a number and then click on the OK button.

Differences from Fehr and Tyran (2001, 2008)

	Our experiment	Fehr and Tyran (2001, 2008)
Strategic parameter ζ	0.5 or −0.5 (0 around eqm for ζ =0.5)	1 or -1 (0 around eqm)
Payoff table	Standard macro model Efficient eqm Asymmetric	Artificial Efficient eqm Symmetric
Real vs nominal payoff	Real only	Both real and nominal. BR is shown in real, but not in nominal. Eqm clear only for real
Comparability	Environment other than ζ is not the same	Environment other than ζ is the same
Agents in one group	Homogenous	Heterogeneous
Earnings	Random periods	All periods
Repetition	Yes	No
Menu costs	Yes or no	No

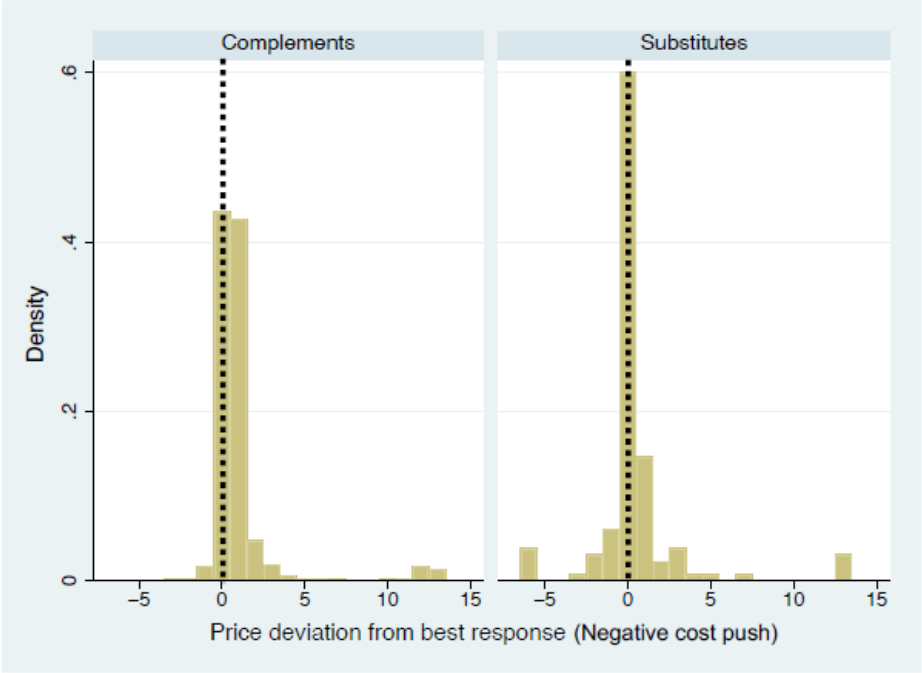
Price Changes Slowly

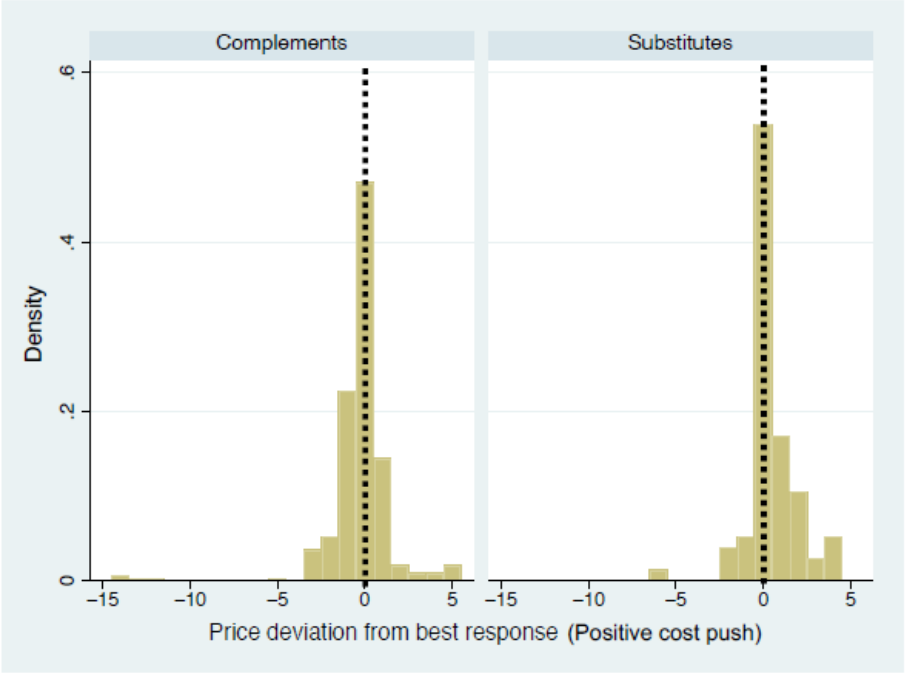
- Price stickiness when
  - strategic complementarity ($\zeta = 0.5$)
  - costs go down
  - irrespective of menu costs



Response to Beliefs

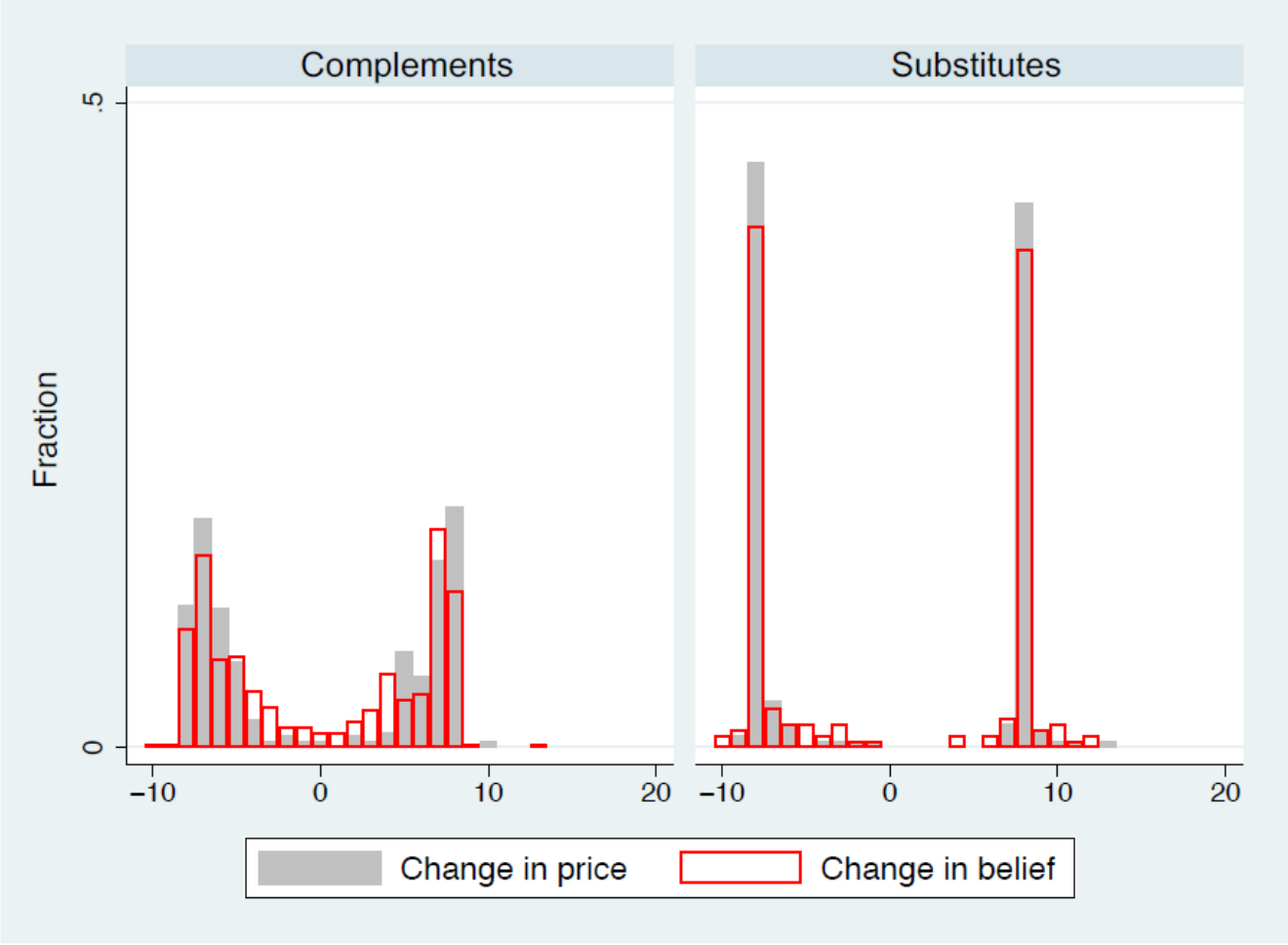
- Almost rational
- Price higher by one when str comp and neg shock (left panel)





Changes in Prices and Beliefs

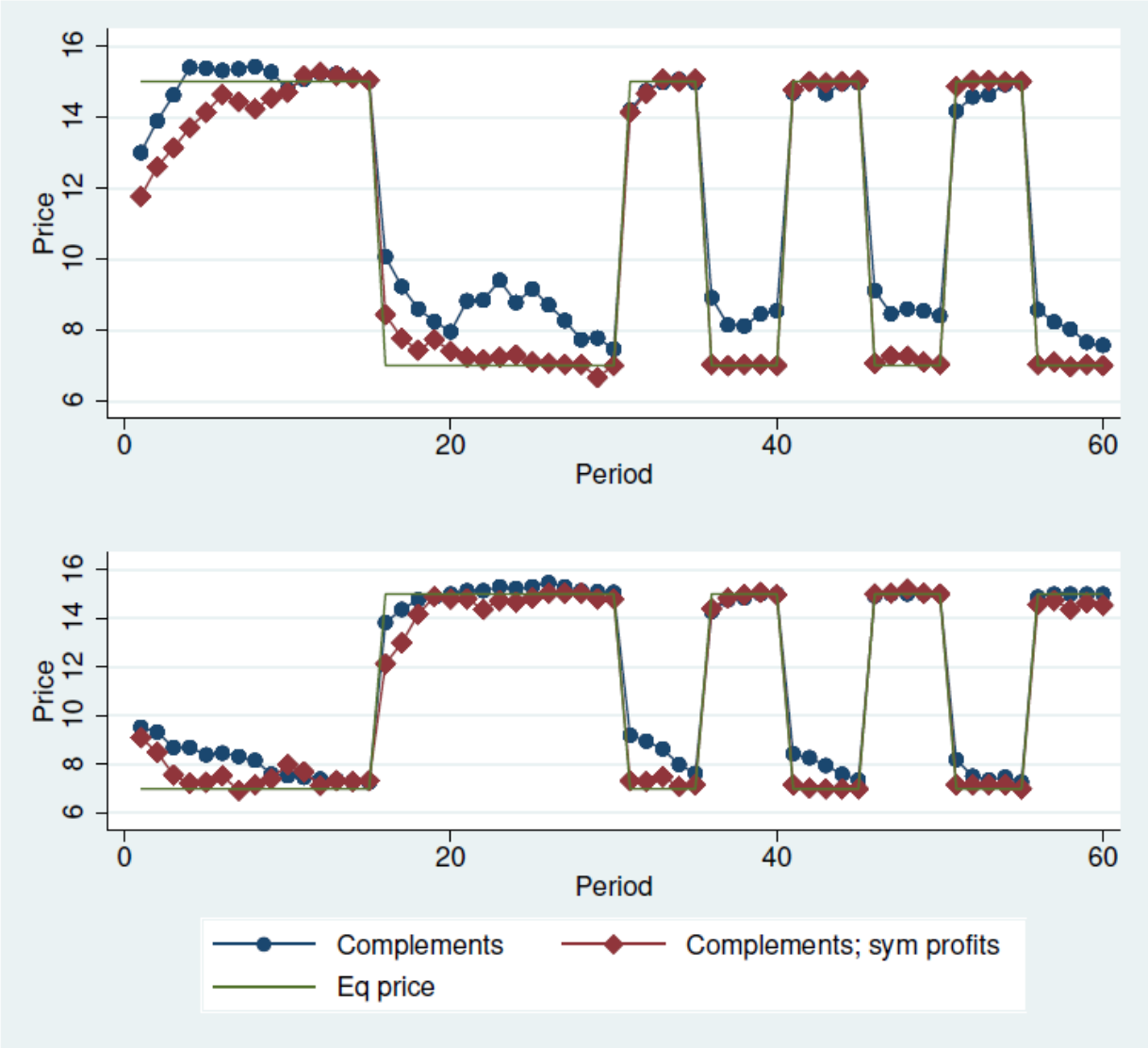
- Sluggish when str comp
  - Particularly belief



- Regression of Deviation from Best Response after Negative Cost Push Shocks under Strategic Complementarity
  - after negative cost push shocks, uncertainty (low confidence) about the other subjects' average price leads to a higher price

	Pooled	Random effects	Fixed effects	t=16 only	t=16, 31, $\cdots$
Confidence	-0.109***	-0.095**	-0.065	-0.288*	-0.194**
	(0.039)	(0.042)	(0.051)	(0.146)	(0.092)
Constant	1.166***	1.089***		0.978**	1.074***
	(0.153)	(0.167)		(0.436)	(0.324)
Observations	1,575	1,575	1,575	75	316
R-squared	0.005		0.001	0.051	0.014
Hausman test p-value	–	0.296		–	–

- Case of symmetric payoff



Implications

- Level-k
  - maybe not
  - Initially no change, but we observe a significant change in prices
- Quantal response equilibrium (QRE)
  - Players make a mistake
  - Does this explain sluggish price setting?

Summary

- Price stickiness because of strategic complementarity
  - No need for money illusion, cognitive inability, explicit price rigidity
  - But asymmetry seems to be important.
  - Less sticky by repetition