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Price competition in an inflationary environment☆

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ABSTRACT

In an experimental study with price-setting firms we find that inflation significantly reduces real prices (by lowering price markups) and significantly raises welfare compared to the treatment with a constant overall price level. Money illusion and a reduced ability to collude in an environment with a constantly changing, i.e., increasing, price level drive this result. In a third treatment with deflation, collusion is somewhat reduced as well, but money illusion pushes prices up so that welfare is lower than under inflation.

1. Introduction

Does a constant price level facilitate price-collusion among firms? And is a steadily increasing nominal price level sufficient to reduce markups and thus real prices? In an experimental study with price-setting firms, we find the answers to these questions to be yes and yes. A slowly increasing nominal price level appears to be enough to reduce collusion among firms. This and the effect of money illusion mean that real prices are significantly lower under inflation and welfare is significantly higher. Under deflation, collusion appears slightly more difficult as well, but money illusion combined with the steadily decreasing overall nominal price level mean that real prices are higher than under inflation. Welfare under deflation is thus lower than under inflation and comparable to the level under constant prices.

This paper contributes to the discussion about the optimal inflation rate by providing an additional and (we believe) new argument in favor of positive inflation. See, for example, Woodford (1990) for an overview of this literature and Brunnermeier and Sannikov (2016) for a recent contribution. The causal relationship between inflation and markups we document here provides an explanation for the negative correlation between these two variables found in the data. Banerjee and

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Russel (2001) and Banerjee et al. (2001), for example, argue that inflation is associated with a lower markup. Since inflation is "strongly procyclical" (Watson and Stock, 1999), countercyclical markups would produce the negative correlation between inflation and markups we observe in the experiment, and indeed, markups are countercyclical. Rotemberg and Woodford (1999), for example, argue that there is a "great deal of evidence in support of the view" that during economic expansions "the markup declines for the typical firm". Galí et al. (2007) and Enders (2017) report similar findings in different frameworks.

The specific environment we consider is Dixit (1979)'s classic model of Bertrand competition with differentiated products in a duopoly. Dixit's model has a second, perfectly competitive sector whose price we use as numéraire and, by varying the value of this numéraire over time, we introduce inflation in the model. Our measure of welfare is the utility of the representative agent who generates the demand system.

We consider three treatments. All treatments are identical in real terms but differ in nominal terms. In the baseline treatment, the overall price level is constant. In the inflation treatment, the price level steadily increases over time, and in the deflation treatment, the price level steadily decreases over time. There are no inflation surprises; subjects know all future price levels in advance and the inflation rate is constant during the experiment. Nonetheless, we expect inflation to affect firms' price-setting. First, subjects may be prone to money illusion (Fisher, 1928), and may fail to account for nominal changes of the price level. Second, a constantly changing price level makes cooperation arguably more difficult as firms need to adjust their prices periodically.

As an example, consider the situation of two firms in the inflation treatment that happen to coordinate on the collusive price (the price a monopolist would set), and suppose that one of the firms then fails to adjust its nominal price over time. Since this is in effect a real price decrease, such a behavior can be interpreted as an attempt to undermine the collusion, in which case punishment may be justified. However, the behavior may as well be interpreted as a sign of money illusion, in which case punishment is less appropriate. Studying this additional complexity that a non-constant nominal price-level imposes on firms' ability to cooperate is the purpose of this experiment.

Money illusion and price cooperation have been studied in the experimental literature before, albeit separately. There is a large literature on Bertrand competition to which we contribute by introducing inflation and deflation. Potters and Suetens (2013) and Engel (2007) survey this literature and Duffy (2012) is a good survey of the experimental macroeconomic literature in general. Abbink and Brandts (2009) study a duopoly where demand increases or decreases over time and, similar to our design, the changes are implemented gradually from round to round. The authors find that shrinking markets lead to higher prices and conclude that this is driven by increased cooperation in shrinking markets, where profit opportunities become sparse.

With respect to money illusion, the seminal contribution is Fehr and Tyran (2001), who implement an experimental market with a large nominal shock (e.g., a doubling of nominal prices) and find that such a shock can lead to a lengthy period of adjustments before equilibrium is reached again. There are two main differences between (Fehr and Tyran, 2001) and our experiment. First, as mentioned above, the nominal "shock" in our experiment is a constant and steady increase of the aggregate price level rather than the one-time doubling in Fehr and Tyran (2001). Second, while markets are duopolies in both experiments, Fehr and Tyran (2001) use a payoff function that prevents subjects from coordinating on non-equilibrium (i.e., stage-game Nash) prices. This is a non-standard market structure without a well defined notion of welfare. By turning off any rationale for cooperative behavior the authors are able to isolate the effect of money illusion. In contrast, we deliberately allow for cooperation between firms and for money illusion to study how price-setting firms compete in an inflationary environment and how this affects consumers' welfare.

The experimental method allows us to overcome one of the limitations of studies on price-setting that use "micro data" (i.e., the firm-level data underlying the consumer price indices).[1] Micro data permit a detailed analysis of how, for example, price-setting changes with the business cycle, and how the level of inflation affects the frequency and the size of price changes. A serious drawback of the data used in this literature is that no information is available about the structure of the markets. Since there is no information and no model-free way of interpreting the data, it is typically assumed that firms operate under monopolistic competition where the firm's price is independent of its competitors' prices and is only influenced by aggregate variables such as GDP, overall inflation, and input costs.

The literature pioneered by Blinder (1991), who uses surveys to explore price-setting behavior of firms, illustrates the problem of this assumption. Blinder finds strong support that firms hesitate to raise or lower prices until other firms move first. Fabiani et al. (2006), summarizing more recent surveys conducted in nine European countries, report that the single most important factor influencing the decision to lower a price are a firm's competitors' prices. In the case of price increases, competitors' prices come third after labor and other input costs. These surveys strongly support the notion that firms find themselves somewhere in between the two extremes of a perfectly competitive market and a pure monopoly, and that they do not operate in a world in which the firm's competitors' prices are negligible. The surveys thus support Kreps' (1990, Chapter 10.2) forceful critique of the model of monopolistic competition, which is standard in the monetary economics literature because of its elegant predictions, but which typically assumes the independence of a firm's price from

[1] See for example Bils and Klenow (2004), Angeloni et al. (2006), Dhyne et al. (2006), Nakamura and Steinsson (2008), and Gagnon (2009). The main findings of this literature support the notion of earlier papers by Cecchetti (1985) and Lach and Tsiddon (1992), that firms are reluctant to change prices often. Typically, retail prices change about once a year and services prices about once every two years. Price increases are more common than price decreases, but this depends on the overall inflation rate and on the sector.

its competitors' prices. This independence assumption is not innocuous. Inflation affects a firm's price-setting decision directly (e.g., via costs) but also indirectly through the actions of other firms. This latter effect can only be detected in models that allow for interaction between firms. In an experiment, one can fix the structure of the market and thus reveal insights that remain hidden in the firm-level data of the statistical offices.

In the following sections we describe the setting (Section 2) and the experimental design and the procedures (Section 3). Our predictions are discussed in Section 4, and Section 5 presents and discusses the results. Section 6 concludes.

2. Setting

The setting is a differentiated Bertrand duopoly as proposed by Dixit (1979) with a linear demand structure. The two firms are symmetric, have zero marginal costs, zero fixed costs, no capacity limits, and each produces a single good. The quantities of the goods are denoted by q_1, q_2 and nominal prices by n_1, n_2. There is a competitive numéraire sector whose output is q_0 and whose price is P. Since the two firms are assumed to be small relative to the overall economy, we sometimes refer to P as the *aggregate price level*. By varying the value of P over time, we introduce inflation and deflation in the model. The demands arise from the utility function of a representative consumer

$$U = u(q_1, q_2) + q_0. \tag{1}$$

Since this utility leads to zero income effects on the duopoly industry, we can consider it in isolation. The inverse demand functions are partial derivatives of the function u, thus

$$p_i = \frac{n_i}{P} = \frac{\partial u(q_1, q_2)}{\partial q_i}, \qquad i = 1, 2, \tag{2}$$

where p_i is firm i's real price. We make all standard assumptions that yield downward-sloping reaction functions with a stable intersection. In particular, we assume that utility is quadratic,

$$u(q_1, q_2) = a(q_1 + q_2) - \frac{1}{2}\left(q_1^2 + 2\theta q_1 q_2 + q_2^2\right),$$

where $\alpha > 0$, $\theta \in (0, 1)$, and we restrict prices and quantities to be nonnegative. This utility function generates linear demand and linear inverse demand functions of the form:

$$q_i = \frac{1}{1+\theta}\left(a - \frac{1}{1-\theta}p_i + \frac{\theta}{1-\theta}p_j\right)$$
$$p_i = a - q_i - \theta q_j, \qquad i, j = 1, 2 \qquad i \neq j.$$

Firms choose their prices given these demand functions. The parameter θ measures the cross-price effects and is a measure of the degree of product differentiation. When $\theta \to 0$, the goods are completely differentiated and the firms are in effect monopolists in two separate markets. This linear demand system has been used in experiments before, for example, by Dolbear et al. (1968) or, more recently, by Huck et al. (2000). Under the assumption of zero marginal costs, the profit functions are

$$\pi_i = q_i\left(a - q_i - \theta q_j\right), \qquad i, j = 1, 2 \qquad i \neq j \tag{3}$$

and the real Nash price and the real collusive price are

$$p^{Nash} = \frac{1-\theta}{2-\theta}a \tag{4a}$$

$$p^{coll} = \frac{1}{2}a. \tag{4b}$$

A natural measure of the household's welfare is its utility. We assume in particular that the representative household owns the two firms and that the firms' profits are the household's only source of income. The budget constraint in this case is

$$\pi_1 + \pi_2 = q_0 + p_1 q_1 + p_2 q_2,$$

and profits equal $\pi_i = p_i q_i$. Combining this with utility (Eq. (1)), our measure of welfare is

$$V = u(q_1, q_2).$$

Since quantities are monotone in prices and utility is monotone in quantities, lower prices increase the representative household's welfare by increasing the quantities traded in the economy. In the experiment we set $a = 30$ and $\theta = 0.95$.

3. Experimental design

The setting is implemented in a computerized laboratory experiment. We use payoff tables depicting the payoff resulting from any price combination of the two duopolists. Gürerk and Selten (2012) show that subjects tend to be more cooperative in the presence of payoff tables. Since we are interested in the effect of inflation on cooperative behavior, this is advantageous. Since the payoff tables show nominal values and nominal values grow (inflation) or diminish (deflation) over time, the tables have to be large to avoid that subjects infer the length of the game from the permitted price range. In every period, subjects can choose any integer price in the range $[1, 900]$. In order to address possible difficulties with reading the payoff tables, we add several control questions between the instructions and the start of the experiment.[2] In addition to the control questions, we add a checker-board shading to the payoff table, which makes it easier to spot the payoffs of symmetric strategy choices, without highlighting these over other strategy combinations (see supplementary material).[3]

Each market has two parts. The first part is open-ended with a 5% probability that the part ends and subjects enter the second part. The second part has a fixed duration of 20 periods. With a 5% cut-off probability, the expected length of the open-ended part is 20 periods as well. Our main focus is on the open-ended part where cooperation can be rationalized by the threat of future punishment (see Appendix A). We add the second part because the uncertainty that comes with an open-ended design may prevent subjects from establishing cooperation. This conjecture was confirmed when we asked subjects in a questionnaire for a point estimate of the length of the open-ended part. The average prediction was 10.25, and almost a third of the subjects predicted five periods or less. Given these short estimates and given that the end-game effect often sets in 5 or 6 periods before the actual end, it is unlikely that subjects would try to establish cooperation in an open-ended part alone. The fixed 20 periods of the second part provide subjects with some certainty regarding the run-time of the experiment and ensures that the end of the game in the open-ended part is always far enough away to avoid triggering an end-game effect.

We observe that in the second part of the experiment, subjects continue cooperating even though cooperation cannot be rationalized by the threat of future punishment. One explanation for this is that the players are boundedly rational and consider the end of the game only when the end is "close", while treating the game as infinite otherwise (see also Kreps et al., 1982).

Subjects are partner matched, that is, the same pair of subjects play together during the entire experiment. The actual durations of the open-ended part was drawn prior to the experiment and used in three sessions per treatment (for a total of 30 groups in each treatment). The sample drawn is {2, 2, 4, 10, 11, 25, 26, 29, 41, 56}, so that the longest-playing group plays for 76 periods (56 open-ended plus 20 fixed) and the two shortest groups for 22 periods (2 open-ended plus 20 fixed). There is no restart; periods are consecutively numbered. All this, including the constant rate of inflation and deflation, is known to subjects beforehand. Subjects can assess payoff tables for all periods before making their first decision and during the entire experiment. After each period, subjects receive the following feedback: their own chosen price, the price chosen by the other firm, their own nominal payoff, and the nominal payoff of the other firm. The instructions use firm-framing, but are neutral with respect to the matched partner (i.e., we avoid words such as "opponent" or "competitor").

There are three treatments, inflation (INF), deflation (DEF), and the baseline with a constant price level (NOINF). While the underlying *real* market is the same in all treatments and all periods, its nominal representation varies with the value of the numéraire (the aggregate price level, P_t). We normalize the aggregate price level in the first period of the inflation treatment to one ($P_1^{INF} = 1$). For a constant inflation of 5 percent, we multiply P_t^{INF} in each period by a factor of 1.05. The aggregate price level in period t of the inflation treatment equals, therefore,

$$P_t^{INF} = P_1^{INF} \times (1.05)^{t-1}. \tag{5}$$

The payoff tables are in nominal terms so that each period has a different payoff table. The relationship between real and nominal prices is

$$n_{it} = p_{it} \times P_t, \tag{6}$$

where n_{it} is firm i's nominal price in period t, p_{it} is firm i's real price in period t, and P_t is the aggregate price level in period t. Whereas the real stage-game Nash equilibrium and the real collusive price are functions of the parameters θ and a, and thus constant (see Eq. (4)), the two vary in nominal terms with P_t according to

$$n_t^{coll} = p^{coll} \times P_t$$
$$n_t^{Nash} = p^{Nash} \times P_t.$$

The deflation treatment uses the payoff tables from the inflation treatment in reversed order so that, here, the aggregate price level equals one in the *last* period of the open-ended part. The rate of deflation equals, therefore, $1 - 1/1.05 \approx 0.048$.

[2] The experiment started when all subjects in a session had correctly answered the control questions. In the rare case that a subject could not answer correctly after additional explanations from the experimenters, the subject had to leave the experiment.

[3] Payoff formulas and profit calculators are two possible alternatives to payoff tables that we took into consideration initially but that we eventually discarded. Payoff formulas require a certain amount of math skills that many subjects may not have. A profit calculator is relatively easy to handle but, given the large strategy space (the large range of prices subjects can choose from), would add implicit restrictions on the information intake by subjects because of the effort to calculate price combinations.

In period 10 of the inflation treatment, the aggregate price level equals 1.55 $\left(\approx (1.05)^9 = P_{10}^{INF}\right)$. We normalize the aggregate price level in the baseline treatment to this value ($P^{NOINF} = P_{10}^{INF}$), so that in all treatments, the ex-ante expected median of the nominal price level in the open-ended part of the experiment is approximately the same.[4]

3.1. Procedures

The experiment had ten sessions and was conducted at the laboratory of the Karlsruhe Institute of Technology in November and December 2015. All recruitment was done via ORSEE (Greiner, 2004). In total, 180 subjects took part in our experiment, 60 per treatment. 140 subjects were male and 40 female. There were eight sessions with 20 participants each, one with 16, and one with 4 (to make up for no-shows, since randomization worked on groups of 20).

Subjects waited in a separate room until the experiment started, where they also signed the informed consent forms. While entering, subjects randomly drew a table tennis ball which assigned them their seat number. Matching in the experiment was tied to seat numbers. Subjects then received the instructions and, after time for individual questions, the sheet with test questions. The experiment did not proceed until all subjects had correctly answered the test questions. The experiment itself, as well as a final questionnaire, were programmed in z-Tree (Fischbacher, 2007). At the end of the experiment, all subjects were called according to their seat number and paid their earnings in private and in cash. Subjects earned on average 15.21 EUR for roughly 75 min in the lab.

4. Predictions

A selfish, money-maximizing prediction is that both firms play the subgame perfect Nash equilibrium strategies of setting the price equal to the Nash equilibrium price of the stage-game. This price equals $p^{Nash} = \frac{1-\theta}{2-\theta} a$ (in real terms) in all periods in all treatments. However, it comes as no surprise that subjects try to achieve higher payoffs by cooperating with each other. Cooperation leads to higher profits for both parties, but is susceptible to deviations (see Appendix A). Both firms playing the collusive price is the Pareto-efficient symmetric outcome. The collusive price equals the price a monopolist would set, and equals $p^{coll} = \frac{1}{2} a$ (in real terms). We therefore expect that in all treatments some subjects will try to establish cooperation on the collusive price, but that they will not always succeed.

Under inflation and deflation, collusion requires subjects to frequently change their nominal price to match the real collusive price. These required nominal adjustments make collusion and cooperation more complex.[5] We therefore predict a lower rate of cooperation in INF and DEF compared to NOINF. Inflation and deflation may also affect subjects regardless of coordination. Following (Fisher, 1928), we call this effect money illusion. If subjects use nominal prices as a proxy for real prices, their (real) choices should have a downward bias in the INF treatment and an upward bias in the DEF treatment. Since the effects of money illusion and cooperation point in the same direction in the INF treatment, we obtain a clear hypothesis of lower prices compared to NOINF. In DEF, both effects act in opposite directions. As a consequence, there is no clear hypothesis for prices in this treatment.

5. Data analysis

In order to get a first impression of how inflation and deflation affect firms' price-setting, consider the examples in Fig. 1. The figure shows nominal prices for six groups of firms over time, three from the inflation treatment (upper panels) and three from the deflation treatment (lower panels). The lengths of play vary according to the random draws. The shaded areas indicate the second part of the experiment where subjects know when exactly the experiment will end and dashed lines indicate Nash price and collusive price (i.e., the price a monopolist would set). The group in panel 1 manages to coordinate on the collusive price after some time but fails to update prices for inflation. The group in panel 2 uses a linear strategy to approximate the (exponentially) increasing nominal price level. The group makes two large upward jumps and changes slopes twice but prices remain consistently below the collusive price. In panel 3, we see an example of almost perfect Nash play with three large outliers. Panel 4 is an example of almost perfect collusion (over more than 60 periods) and panel 5 is an example of asymmetric cooperation where firms set prices consistently above the Nash price but fail to agree on a symmetric price. Finally, panel 6 is an example of money illusion where one of the firms keeps its nominal price constant for the larger part of the experiment despite the fact that it would be Pareto-efficient to move towards the collusive price.

Fig. 2 gives an overview of the main results of the experiment. The upper panels show median real prices over time for all three treatments.[6] The horizontal dashed lines indicate the real Nash price and the real collusive price. Real prices in the inflation treatment are lower than in the other two treatments. Real prices in the deflation treatment are higher than in the

[4] In order to make the payoff tables easier to read, we multiplied all entries by 10 and then rounded to the nearest integer. There are periods where, because of rounding, n_t^{coll} and n_t^{Nash} are not unique. Multiplying by a factor of 10 considerably reduces these cases.

[5] We use coordination and cooperation interchangeably. Collusion refers to the special case of cooperation on the price a monopolist would set (the "collusive" price).

[6] In the analysis, we use the price level of the baseline treatment (NOINF) as our reference level and normalize prices in the other two treatments (INF and DEF) accordingly. That is, after converting nominal into real prices (Eq. (6)), we multiply them by P^{NOINF} (see Section 3). The real Nash price and the real collusive price, thus, equal 2 and 23 after rounding to the next integer.

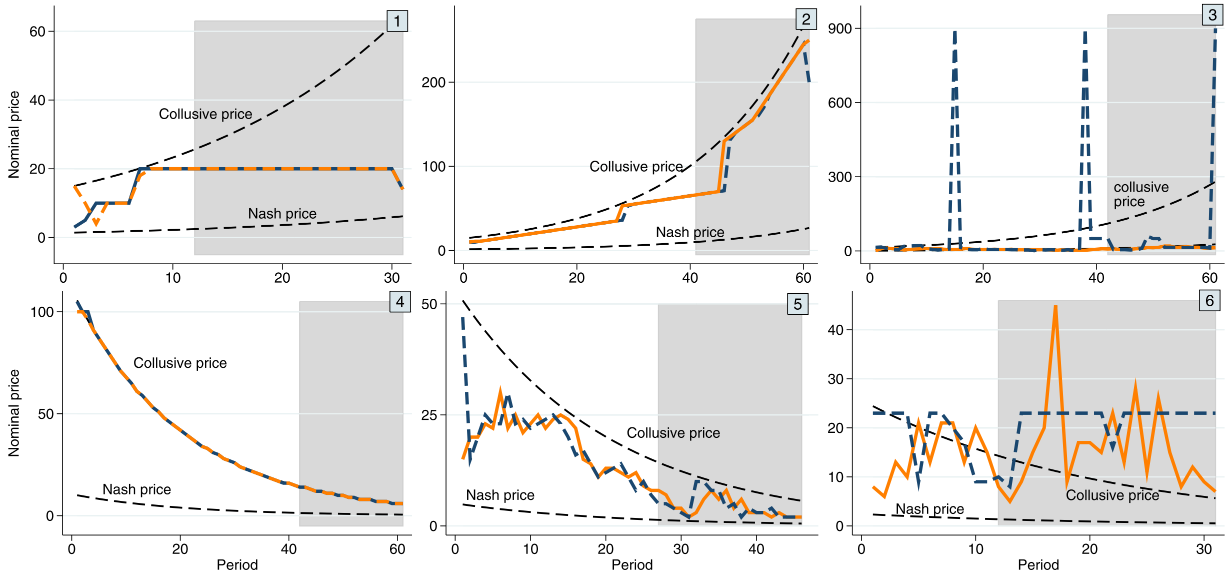

Fig. 1. Examples of play in the inflation and deflation treatments. Shown are nominal prices over time (solid orange and dashed blue lines). The lengths of play vary with the random draws. Dashed black lines denote Nash price and collusive price. The grey areas indicate the second part of the experiment where subjects know when exactly the experiment will end. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

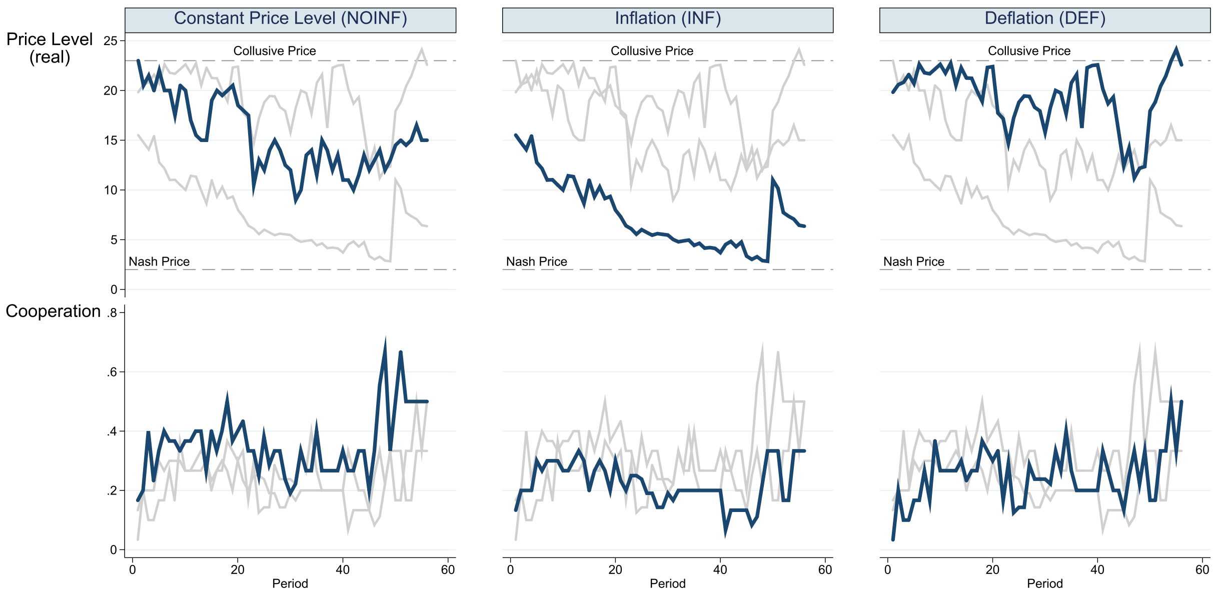

Fig. 2. Median real prices over time (upper panels) and cooperation over time (lower panels), by treatment. Horizontal dashed lines in the upper panels indicate Nash price and collusive price. Measure of cooperation: $C1_{it}$. Data from the first part of the experiment.

other two treatments. The downward trend we observe under constant prices and under inflation is absent under deflation. The lower panels of Fig. 2 show how our main measure of cooperation varies by treatment. According to this measure, firms cooperate in more than 30 percent of the periods under constant prices. Under inflation and deflation, cooperation appears to be more difficult. We discuss this measure of cooperation in more detail in Section 5.3 below where we also consider two alternative measures.

Table 1
Real prices. Descriptive statistics by treatment and non-parametric tests of treatment differences.

		Treatment		
		NOINF	INF	DEF
First part of the experiment	Mean	16.57	12.62	24.78
	Median	15.00	7.76	19.88
Entire experiment	Mean	16.76	11.17	28.01
	Median	15.00	7.39	20.17

	Treatment effects[a]		
	NOINF vs INF	NOINF vs DEF	INF vs DEF
First part of the experiment	**(p = 0.0290)	(p = 0.1930)	***(p = 0.0008)
Entire experiment	***(p = 0.0001)	***(p = 0.0035)	***(p = 0.0000)

[a] Wilcoxon-Mann-Whitney Test on subject averages, 120 observations, two-sided. * Significant at the 0.1 probability level. ** Significant at the 0.05 probability level. *** Significant at the 0.01 probability level.

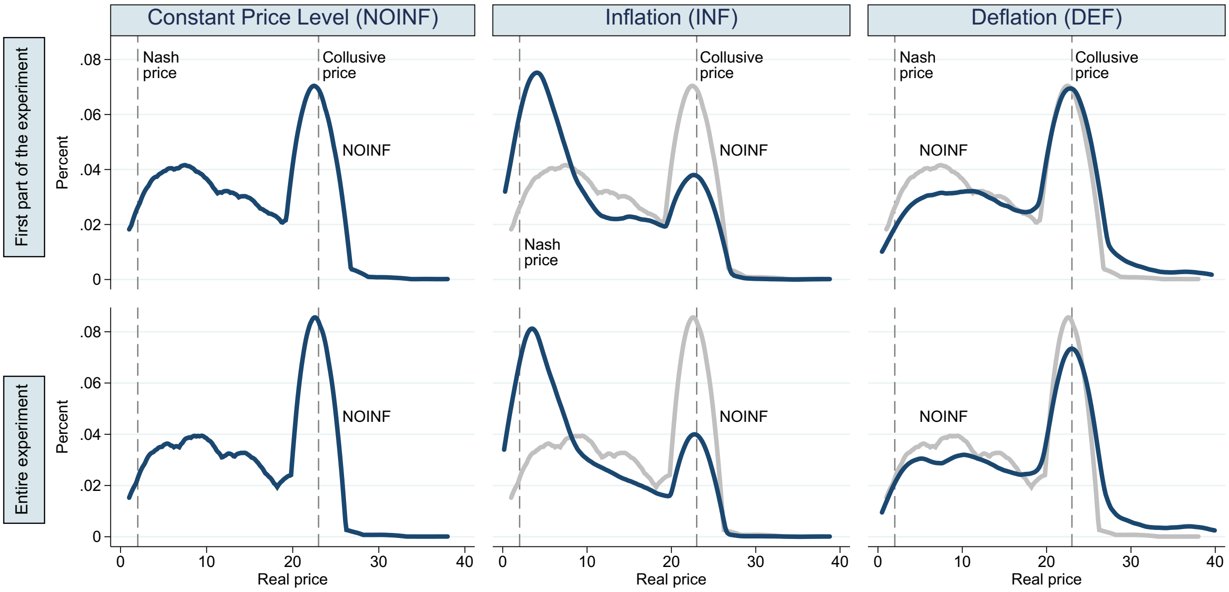

Fig. 3. Distributions of real prices by treatment. Vertical lines indicate Nash price and collusive price. Kernel density estimates, Epanechnikov kernel with $n = 50$, we exclude outliers above 40 for this figure.

In the next sections we discuss the effect of inflation on prices (Section 5.1), on welfare (Section 5.2), and on cooperation (Section 5.3).[7] Section 5.4 discusses money illusion. In what follows, we sometimes refer to the real price simply as "price". Nominal prices are always stated as such.

5.1. Prices

Real prices in the inflation treatment are significantly lower than in the other two treatments (see Table 1). In the first part of the experiment, the average price under inflation is 12.62, and under a constant price level, the average is 16.57. Under deflation, the average price rises to 24.78, which is above the collusive price of 23. A number of larger outliers move the average price up. The median price under deflation is 19.88. This is almost three times as high as the median price under inflation. A two-sided Wilcoxon-Mann-Whitney test on subject averages for the first part of the experiment suggests that the differences between NOINF and INF and between INF and DEF are significant. Using data from both parts of the experiment, all treatment differences are significant.

The distribution of prices in the three treatments is revealing and deserves some discussion. Real prices in all treatments follow a bimodal distribution with a prominent mode at around the collusive price and a second mode somewhere above the Nash price (see Fig. 3). Rather than moving the entire distribution, inflation seems to shift observations from the

[7] Sections 5.1 to 5.3 report statistics and test results for the open-ended part of the experiment and for both parts combined. Appendix B presents the results for the second part of the experiment on its own.

Table 2
Price regressions. Dependent variable p_{it}: firm *i*'s (real) price in period *t*. OLS regressions (except column 7) on treatment dummies, their period-interactions, indicator variables for cooperation in the previous period ($C1_{it-1}$), gender (*male*), and acquaintance with formal game theory (*GameTheory*). Robust standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Column 5: Including outliers. Column 6: Data from the entire experiment. Column 7: Median regression to account for outliers. All regressions clustered over subjects.

Variables	(1) p_{it}	(2) p_{it}	(3) p_{it}	(4) p_{it}	(5) p_{it} (incl. outlier)	(6) p_{it} (all *T*)	(7) p_{it} (median)
INF	−3.769**	−4.213***	−4.116***	−4.005***	−6.962*	−4.441***	−8.225***
	(1.546)	(1.383)	(1.148)	(1.147)	(4.116)	(1.281)	(2.802)
DEF	4.122**	0.608	2.186	2.101	5.946	2.906*	0.199
	(1.616)	(1.837)	(1.783)	(1.771)	(6.029)	(1.638)	(2.974)
Period		−0.176***	−0.174***	−0.176***	−0.349***	−0.106***	−0.269***
		(0.0300)	(0.0236)	(0.0238)	(0.115)	(0.0228)	(0.0661)
PeriodINF		0.0193	0.0249	0.0217	0.169	−0.0108	0.0441
		(0.0790)	(0.0543)	(0.0554)	(0.162)	(0.0527)	(0.0785)
PeriodDEF		0.215***	0.177**	0.178**	0.114	0.0839*	0.234**
		(0.0774)	(0.0700)	(0.0697)	(0.205)	(0.0490)	(0.0916)
male		3.037**	2.096*	1.745	−7.464	2.737**	4.691***
		(1.297)	(1.149)	(1.186)	(4.617)	(1.057)	(1.665)
$C1_{it-1}$			8.754***	8.597***			
			(0.955)	(0.988)			
GameTheory				0.873			
				(1.089)			
Constant	14.53***	15.18***	13.43***	13.36***	29.04***	15.39***	16.39***
	(1.028)	(1.537)	(1.315)	(1.305)	(6.091)	(1.290)	(2.464)
Observations	3674	3676	3502	3499	3708	7262	3708
R^2	0.091	0.130	0.254	0.256	0.023	0.124	0.010

higher to the lower mode. The distribution of prices under deflation and under constant prices is similar with slightly less observations at the lower mode under deflation.

Table 2 shows regression results. The dependent variable is firm *i*'s real price in period *t*. All specifications are clustered over subjects. Specifications (1)–(4) use Cook's distance (Cook, 1977) to identify and exclude influential outliers.[8]

Prices in INF are significantly lower than those in NOINF, consistent with our hypothesis. Prices in DEF are higher. When we allow for different price trends (in specifications (2)–(4)), the level effect of DEF becomes weaker and turns into a positive trend. We discuss the effect of inflation and deflation on price levels and on price trends in detail in Section 5.4 when we turn to money illusion. There is a positive gender effect of males on prices, which almost disappears once a cooperation dummy ($C1_{it-1}$) is introduced in specifications (3) and (4). Cooperation in the previous period leads to significantly higher prices in the current period. Having participated in a formal course on game theory does not influence prices. We run three robustness checks (columns (5)–(7) of the table). Specification (5) includes all observations from the first part of the experiment, including the ones identified as outliers before. Specification (6) uses data from both parts of the experiment and specification (7) uses a median regression instead of OLS.[9]

5.2. Welfare

Table 3 shows descriptive statistics and test results for the second variable of interest, welfare. Welfare is lowest under deflation and highest under inflation. The treatment differences between inflation and the other two treatments are significant; inflation leads to significantly higher welfare. There does not seem to be a significant difference between deflation and constant prices.

Table 4 shows regression results. The dependent variable is welfare. Specifications (1)–(4) use Cook's distance to identify and exclude influential outliers. When we allow for time trends (specifications (2)–(4)), inflation has a significant positive effect on the level and deflation has a very weak negative effect on the time trend. This is in line with the non-parametric tests where welfare under deflation was not significantly different to welfare under a constant price level. The positive trend in welfare mirrors the negative trend in real prices in Table 2. There is a significant negative gender effect and having participated in a formal course on game theory does not influence welfare. Cooperation in the previous period leads to significantly lower welfare in the current period.

[8] Panel 3 of Fig. 1 shows an example with large outliers. Outliers are not necessarily a sign of irrational behavior as subjects may use them as a signal to communicate with each other.

[9] We follow (Parente and Santos Silva, 2015) when calculating the clustered standard errors for the median regression. In Appendix C, we allow for a non-linear time trend.

Table 3
Welfare. Descriptive statistics by treatment and non-parametric tests of treatment differences.

		Treatment		
		NOINF	INF	DEF
First part of the experiment	Mean	407.21	424.64	384.53
	Median	420.38	445.24	403.73
Entire experiment	Mean	404.38	426.92	381.67
	Median	414.91	446.51	400.59

	Treatment effects[a]		
	NOINF vs. INF	NOINF vs. DEF	INF vs. DEF
First part of the experiment	$^{**}(p = 0.0345)$	$(p = 0.5543)$	$^{***}(p = 0.0047)$
Entire experiment	$^{***}(p = 0.0050)$	$(p = 0.1171)$	$^{***}(p = 0.0000)$

[a] Wilcoxon–Mann–Whitney Test on group averages, 60 observations, two-sided. * Significant at the 0.1 probability level. ** Significant at the 0.05 probability level. *** Significant at the 0.01 probability level.

Table 4
Welfare regressions. Dependent variable u_t: household's utility in period t. OLS regressions (except column 7) on treatment dummies, their period-interactions, indicator variables for cooperation in the previous period ($C1_{it-1}$), gender (*male*), and acquaintance with formal game theory (*GameTheory*). Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Regression 5: Including outliers. Regression 6: Data from the entire experiment. Regression 7: Median regression to account for outliers. All regressions clustered over groups.

Variables	(1) u_t	(2) u_t	(3) u_t	(4) u_t	(5) u_t (incl. outliers)	(6) u_t (all T)	(7) u_t (median)
INF	18.81	18.90*	22.22***	24.63***	22.26**	19.99*	26.67*
	(12.48)	(10.19)	(7.410)	(7.541)	(10.88)	(10.06)	(15.01)
DEF	−9.851	4.291	−6.273	−5.664	−0.805	−3.512	2.908
	(11.51)	(11.39)	(9.691)	(9.572)	(13.98)	(9.875)	(23.63)
Period		0.752***	0.835***	0.844***	0.827***	0.518***	0.885**
		(0.239)	(0.155)	(0.173)	(0.251)	(0.177)	(0.405)
PeriodINF		0.102	−0.317	−0.362	−0.272	0.126	−0.215
		(0.356)	(0.309)	(0.330)	(0.593)	(0.270)	(0.436)
PeriodDEF		−0.731*	−0.489	−0.456	−1.087*	−0.162	−0.957
		(0.382)	(0.348)	(0.385)	(0.588)	(0.298)	(1.172)
male		−24.65***	−13.91***	−12.53**	−21.11**	−22.74***	−19.78***
		(8.191)	(5.109)	(5.219)	(8.816)	(6.228)	(7.265)
$C1_{it-1}$			−58.71***	−57.35***			
			(6.560)	(6.743)			
GameTheory				−6.365			
				(5.184)			
Constant	407.4***	413.9***	420.4***	421.2***	409.0***	410.8***	419.5***
	(8.526)	(9.640)	(7.062)	(7.480)	(10.84)	(8.253)	(14.28)
Observations	1822	1789	1707	1706	1854	3531	1854
R^2	0.073	0.175	0.478	0.489	0.113	0.176	0.110

We run three robustness checks (columns (5)–(7) of the table). Specification (5) includes all observations from the first part of the experiment, including the ones identified as outliers before. Specification (6) uses data from the entire experiment and specification (7) uses a median regression instead of OLS (see footnote 9).

5.3. Cooperation

While there is a well-defined measure of welfare in the theoretical model, there is no obvious and clear-cut measure of cooperation between the two firms. A simple rule is to require both firms to set the same price, but cooperation may take on other forms, possibly asymmetric ones. In order to capture a wide variation of cooperation, we use three different measures. All measures are indicator variables that equal one if in a given period a specific form of cooperation is met and zero otherwise.

The first measure of cooperation ($C1_{it}$) requires firms to set the same price in a given period. We choose this as our main measure of cooperation because deviations from this rule are readily identified and because it leads to a fair 50/50 split of the gains from cooperation. Since equal prices may as well arise from selfish play of the stage-game Nash equilibrium or from mutual punishment, we additionally require prices not to be too close to the Nash price. We require in particular that

$$p_{it} > p^{Nash} + \frac{1}{3}(p^{coll} - p^{Nash}) \text{ for } i = 1, 2. \tag{7}$$

Table 5
Three measures of cooperation, averages by treatment.

	Measure of cooperation	NOINF	INF	DEF
First part of the experiment	$C1_{it}$	0.319	0.227	0.216
	$C2_{it}$	0.341	0.216	0.401
	$C3_{it}$	0.900	0.756	0.887
Entire experiment	$C1_{it}$	0.342	0.232	0.236
	$C2_{it}$	0.394	0.222	0.427
	$C3_{it}$	0.914	0.788	0.894

Bearing in mind that the lower of the two modes in the price distribution is considerably above the Nash price (see Fig. 3), we use a cut-off of 1/3. This excludes around a fifth of the lowest observations.

The strict requirement of symmetric play in measure $C1_{it}$ leaves out possible asymmetric cooperation. For example, subjects may take turns in playing high and low prices, or one of the subjects may accept an asymmetric outcome that creates an unequal split of the gains from cooperation. In order to capture these other forms of cooperation, we use two additional measures, one is based on the firms' joint profits and the other is defined as a range of prices that can be supported as "cooperative" on theoretical grounds.

To be specific, the second measure of cooperation ($C2_{it}$) requires that the firms' joint profits in a given period do not fall too far below the achievable maximum. The measure requires in particular that

$$\pi_{1t} + \pi_{2t} \geq 0.9 \times \Pi^{coll} \tag{8}$$

where Π^{coll} are the firms' joint profits in a given period when both firms play the collusive price p^{coll} (the price a monopolist would set).

According to the third measure ($C3_{it}$), a firm is cooperative when its real price falls in the range [3, 43]. Given our choice of parameters, prices within this range can be justified as being part of a symmetric or asymmetric fixed equilibrium. We exclude for this measure of cooperation the lowest such price which corresponds to the Nash equilibrium of the stage-game. Appendix A discusses the theoretical underpinnings. To compare, the real Nash price equals 2 and the real collusive price equals 23, so that this measure allows for prices well above the price a monopolist would set. With this definition, a firm may be cooperative even if its opponent is not. $C3_{it}$ is therefore subject-specific, and differs in this respect from $C1_{it}$ and $C2_{it}$, which are group-specific.

As an example, consider again panel 5 in Fig. 1 above, in which both firms set prices consistently above the Nash price, but fail to agree on a symmetric price. According to the strict cooperation measure $C1_{it}$, this behavior would not count as cooperative, but according to $C3_{it}$, the two firms are cooperative for almost all periods.

Table 5 shows averages of the three measures of cooperation for the three treatments. In the NOINF treatment, around a third of the firms are considered cooperative according to measure $C1_{it}$. According to $C2_{it}$, this fraction slightly increases, and according to $C3_{it}$, firms are cooperative in at least ninety percent of the periods. All measures of cooperation decrease in the inflation treatment. Under deflation, $C1_{it}$ and $C3_{it}$ are lower than under constant prices and $C2_{it}$ is higher.

The distributions of the subject-averages of the three measures of cooperation are bimodal, indicating that most subjects either cooperate in almost all periods or in only very few periods. The violin plots in Fig. 4 reflect this bimodal behavior.[10] The stars above the plots show test results from non-parametric (Wilcoxon-Mann-Whitney) tests to indicate treatment differences. For all three measures of cooperation, the mass of observations in the INF treatment appears lower than under constant prices. Using data from the entire experiment, these treatment effects are significant. For the smaller sample of the open-ended part, only $C2_{it}$ indicates a treatment effect. The tests do not indicate that cooperation under deflation is different than under constant prices.

Table 6 shows probit regressions with the three measures of cooperation as dependent variables. The explanatory variables are the treatment dummies, a time trend with treatment interactions, and an indicator for the subject's gender. When considering both parts of the experiment, we find a significant negative effect of INF on the level of all three measures of cooperation. When considering only the first part of the experiment, this effect becomes weaker and is not always significant. When we allow for a time trend and interaction terms, the level effect turns into a negative trend for $C1_{it}$ and $C3_{it}$, whereas for $C2_{it}$ all treatment effects disappear. With respect to deflation, there is a very weak treatment effect on $C1_{it}$ and no effect on the other two measures.

The fact that we do not observe any treatment effect of deflation on $C2_{it}$ and $C3_{it}$ may hint at a fundamental difference in how inflation and deflation affect cooperation. While it appears plausible that cooperation is more difficult in both treatments compared to the baseline treatment of constant prices, money illusion (see next section) creates an upward pressure on real prices under deflation, and, even if unintended, a price increase may be interpreted as a signal of a firm's willingness to cooperate (e.g., move away from the stage-game Nash equilibrium). It is conceivable, therefore, that deflation creates an environment that is conducive to cooperation. The situation is different under inflation where money illusion creates a

[10] Violin plots are box plots with a rotated kernel density on each side (Hintze and Nelson, 1998). The plots have markers for median and mean and the box indicates the interquartile range.

Table 6
Cooperation regressions. Dependent variables: Measures of cooperation $C1_{it}$, $C2_{it}$, $C3_{it}$. Probit regressions on treatment dummies, their period-interactions, and gender (*male*). Specifications (1)–(4) and (7)–(8): Clustered over groups. Specifications (5)–(6) and (9)–(10): Clustered over subjects. Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Uneven specifications use data from the first part of the experiment, even specifications from the entire experiment.

Variables	(1) $C1_{it}$	(2) $C1_{it}$	(3) $C1_{it}$	(4) $C1_{it}$	(5) $C2_{it}$	(6) $C2_{it}$	(7) $C2_{it}$	(8) $C2_{it}$	(9) $C3_{it}$	(10) $C3_{it}$	(11) $C3_{it}$	(12) $C3_{it}$
INF	−0.767	−0.990**	−0.184	−0.231	−1.367**	−1.247**	−1.057	−0.861	−0.312	−0.737**	0.879*	0.515
	(0.470)	(0.421)	(0.461)	(0.461)	(0.672)	(0.574)	(0.646)	(0.606)	(0.402)	(0.361)	(0.509)	(0.486)
DEF	−0.653*	−0.479	−0.765*	−0.531	0.108	0.352	−0.270	0.262	−0.227	−0.343	−0.100	−0.190
	(0.396)	(0.331)	(0.444)	(0.370)	(0.631)	(0.501)	(0.618)	(0.541)	(0.393)	(0.338)	(0.424)	(0.378)
Period			0.0266*	0.0147			−0.0252	−0.0128			−0.0141	−0.00338
			(0.0136)	(0.00997)			(0.0225)	(0.0136)			(0.0120)	(0.00610)
PeriodINF			−0.0401**	−0.0329***			−0.0138	−0.0131			−0.0635***	−0.0478***
			(0.0169)	(0.0123)			(0.0278)	(0.0182)			(0.0213)	(0.0158)
PeriodDEF			0.00419	0.00188			0.0351	0.00452			−0.0112	−0.00748
			(0.0179)	(0.0114)			(0.0267)	(0.0155)			(0.0158)	(0.00885)
male			1.227***	0.900***			1.183*	1.329***			1.149***	0.742**
			(0.452)	(0.302)			(0.650)	(0.450)			(0.414)	(0.367)
Constant	−0.796***	−0.502**	−2.165***	−1.559***	−0.184	−0.336	−0.927	−1.182**	2.138***	2.284***	1.459***	1.778***
	(0.288)	(0.248)	(0.491)	(0.359)	(0.503)	(0.402)	(0.772)	(0.557)	(0.315)	(0.268)	(0.379)	(0.422)
Observations	1854	3654	1854	3654	1854	3654	1854	3,654	1854	3654	1854	3654
Log Lik	−585	−1220	−563.5	−1191	−627.6	−1245	−611.9	−1218	−550	−1018	−485.7	-923.9

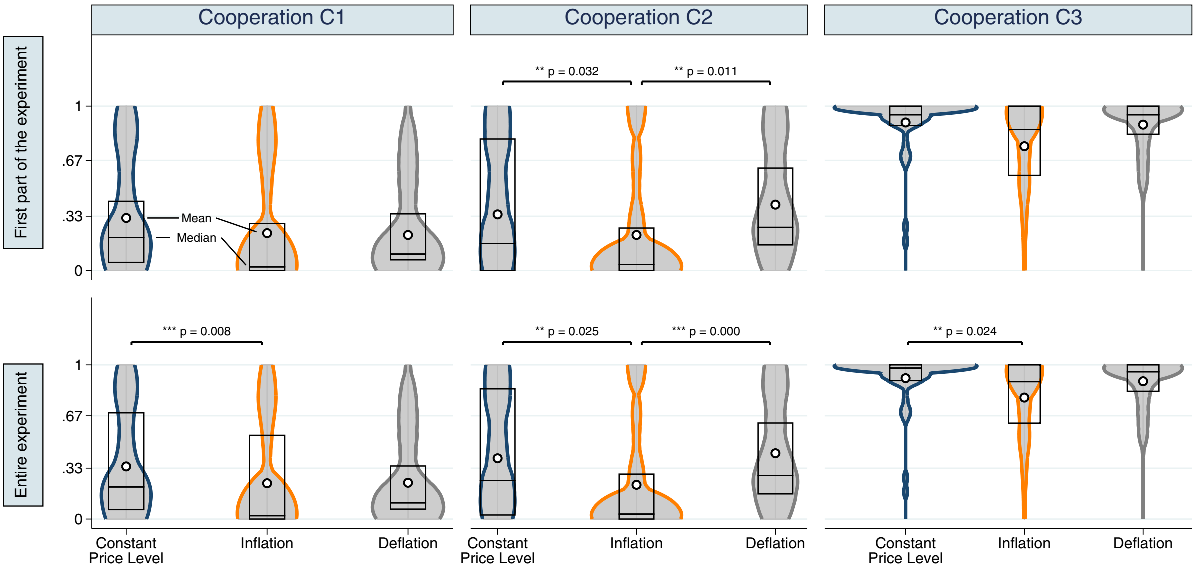

Fig. 4. Violin plots of subject-averages of $C1_i$, $C2_i$, and $C3_i$ by treatment. Hollow circles indicate means. The box indicates median (center line) and interquartile range. Stars above the plots indicate test estimates from Wilcoxon-Mann-Whitney tests ($C1_i$ and $C2_i$: two-sided, on group-averages, 60 observations; $C3_i$: two-sided, on subject-averages, 120 observations. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$).

downward pressure on prices. Price decreases, whether intended or unintended, are likely to be interpreted as a signal of a firm's unwillingness to cooperate. An inflationary environment may therefore be less accommodating to cooperation than a deflationary environment.

Since both $C2_{it}$ and $C3_{it}$ are defined over prices ($C3_{it}$ directly via a range of prices and $C2_{it}$ indirectly over profits), both measures may not clearly isolate the effect on cooperation from the effect on prices leading to the results in Table 6. For $C1_{it}$, which requires that both firms set the same price ($p_{1t} = p_{2t}$), it seems plausible that the price level itself should not affect this measure much.[11]

Summing up and restricting attention to measure $C1_{it}$, the regressions and the non-parametric tests confirm the hypothesis with respect to inflation. An increasing nominal price level makes cooperation more difficult. For deflation we observe the expected decline in cooperation, but the treatment effects are not always significant.

5.4. Money illusion

Money illusion will convey itself in the experiment in two ways that one may call the short-run and the long-run effects. In the short-run, when firms fail to adjust prices for inflation and deflation, money illusion leads to a negative price trend under inflation and a positive price trend under deflation. Panels 1 and 6 of Fig. 1 are examples of this behavior. Even if individual behavior is difficult to predict, there are two natural boundaries at which the trends are likely to be disrupted, a lower boundary at the Nash price and an upper boundary at the collusive price. These short-run trends will lead to differences in price *levels* in the long-run, with lower price levels under inflation and higher price levels under deflation. In practice, the distinction between the long-run and the short-run may be blurred by the randomized length of the experiment and when forward-looking subjects anticipate the long-run effects.

Whether one observes these effects in the experiment as treatment effects depends, obviously, on the baseline treatment (NOINF). If, for example, prices in the NOINF treatment are already close to the Nash price (the lower boundary), there is little room for inflation to decrease them further. Likewise, if prices in the NOINF treatment are already close to the collusive price (the upper boundary), there is little room for deflation to increase them further.

In our experiment, inflation has a significant negative effect on the level of prices and in the case of deflation, we observe a significant positive price trend. The fact that both treatment effects remain large and significant when we add lagged cooperation in specifications (3) and (4) in Table 2 is an indication of money illusion.

In order to quantify how much of the total effect on prices is due to money illusion and how much is due to lower cooperation, we can construct the hypothetical prices we would observe under NOINF if cooperation would be as low as under INF or DEF. The average price of 14.99 under NOINF reduces to 13.44 if cooperation would be as low as under INF. Given the average price under INF of 10.10, we find that, of the total effect on prices, a share of 0.317 is due to lower

[11] Relaxing this definition and requiring that, for example, $p_{1t} = p_{2t} \pm 1$ leaves the results almost unchanged.

cooperation and the rest is due to money illusion. For deflation, this share is 0.213, and thus somewhat lower than under INF.[12]

6. Conclusion

This paper describes an experimental study that analyses how inflation and deflation affect the behavior of price-setting firms. The results show that inflation leads to lower real prices (by reducing firms' markups) and higher welfare. Money illusion and a reduced ability to collude in an environment with a constantly changing price level drive this result. Deflation, on the other hand, leads to higher real prices (by raising firms' markups) and welfare is thus lower than under inflation and comparable to the level under constant prices. One interpretation of the results on cooperation is that inflation may create an environment that is much less accommodating to collusive behavior than the environment created by deflation or constant prices. Under inflation, money illusion exerts a steady downward pressure on (real) prices and this makes collusive behavior more difficult. Summing up, the experiment contributes to the discussion about the optimal inflation rate by arguing in favor of positive inflation and against constant prices or deflation. The argument that inflation may cause lower real prices by reducing firms' markups is, we believe, new in the literature.

Appendix A. Equilibria of the game

Here, we calculate some prominent subgame-perfect equilibria of the game as described in Sections 2 and 3. The game is formed by repeating the stage-game as described in Section 2. To make the game tractable for subjects, strategies are restricted to integer values and profits rounded to the nearest integer (compare the payoff table in the supplementary material). The Nash equilibrium of this stage-game is (2,2), with profits $\pi^{Nash} = 294$.[13] The symmetric profit maximizing strategies are (23, 23), with profits $\pi^{coll} = 1790$.

As pointed out in Section 3, this stage-game is repeated, first with a continuation probability $\delta = 0.95$, and then, after continuation failed, by an extra 20 rounds. In these last 20 rounds, the ending round is known. As such, any subgame-perfect equilibrium of a subgame starting at any point during the last 20 rounds can only consist of using the stage-game Nash equilibrium strategy as an action in any round. No future punishment is credible. Therefore, the addition of 20 extra rounds after the open-ended part of the game has no strategic impact on play in the open-ended part.

In the open-ended part, a subgame-perfect equilibrium that consists of always playing the stage-game Nash equilibrium exists since no deviation is profitable. However, other cooperative equilibria can be sustained as well.

A1. Collusive equilibrium

We will first focus on the symmetric cooperative equilibrium with the highest payoff, π^{coll}. Playing (23, 23) can be sustained by using a grim trigger strategy, threatening punishment with playing the stage-game Nash equilibrium forever on deviation from (23, 23).

The present value of sustaining cooperation is $\frac{\pi^{coll}}{1-\delta} = 35800$. The present value of eternal play of the stage-game Nash equilibrium is $\frac{\pi^{Nash}}{1-\delta} = 5880$. The one-time deviation profit is given by the best reaction to the cooperation strategy, which is undercutting with $p = 21$, leading to a one-time deviation profit of 3457. Since grim trigger punishment starts in the first round after the deviation, profits need to fulfill

$$\frac{1}{1-\delta}\pi^{coll} \geq 3457 + \frac{\delta}{1-\delta}\pi^{Nash} \tag{A.1}$$

for cooperation to be sustainable. With the continuation probability being $\delta = 0.95$, this condition is met.

A2. Other symmetric equilibria

Given the severity of the threatened punishment, other cooperative subgame perfect equilibria can also be sustained. In fact, any symmetric strategy pair (x, x), $x \in \{2, \ldots, 43\}$, is sustainable using the above punishment strategy:

$$\frac{1}{1-\delta}\pi^{sym} \geq dev + \frac{\delta}{1-\delta}\pi^{Nash} \tag{A.2}$$

where dev is the one time deviation profit obtained by deviating from x to the best response to x.

[12] We regress p_{it} on a constant and $C1_i$, the subject-average cooperation shown in Fig. 4 using the entire data set. Then, using the point estimates from this regression and the average cooperation from Table 5 gives hypothetical prices of 13.44 (INF) and 13.49 (DEF). The average prices reported here differ slightly from the numbers reported in Table 1 because here we exclude outliers (as in the regressions of Table 2). Using data from solely the first part of the experiment, gives almost identical shares.

[13] All strategies in this section refer to choice of real prices in NOINF. In case of multiple Nash equilibria of the stage-game, the profit refers to the lower payoff Nash equilibrium.

A3. Asymmetric equilibria

There are many asymmetric equilibria. Since the inequality for the collusive equilibrium is fulfilled with considerable slack, asymmetric equilibria can be constructed by starting from the collusive equilibrium with grim trigger strategies and adding a requirement of other stage-game actions. For example, requiring players to play the highest stage-game price of 900 in the first round and then playing the collusive price in all following rounds can be sustained by grim trigger strategies. In the same fashion, any price in one specific round can be part of an asymmetric equilibrium sustained by grim trigger strategies.

Since virtually any price can be justified theoretically by the general asymmetric strategies discussed in the previous paragraph, asymmetric *fixed* equilibria may be of specific interest. These are equilibria where both players use different strategies and each plays the same action in all stage-games on the equilibrium path (observed play is, therefore, fixed). To be sustainable by grim trigger strategies, any such asymmetric fixed equilibrium (x, y), without loss of generality we assume $x > y$, has to fulfill the equations

$$\frac{1}{1-\delta}\pi^{x} \geq dev^{x} + \frac{\delta}{1-\delta}\pi^{Nash} \tag{A.3}$$

and

$$\frac{1}{1-\delta}\pi^{y} \geq dev^{y} + \frac{\delta}{1-\delta}\pi^{Nash} \tag{A.4}$$

where π^x and π^y are the payoffs from playing x and y and dev^x and dev^y the respective one time deviation profits. Asymmetric fixed equilibria exist for $x \in \{4, \ldots, 21\}$ and $y = x - 1$. Summing up, the individual prices observable under asymmetric fixed equilibria are a subset of the prices observable under symmetric equilibria so that we restrict attention to the latter in the definition of $C3_{it}$.

Appendix B. Data analysis for the final 20 periods

This appendix presents descriptive statistics and regression tables for the second part of the experiment, in which subjects are informed about the number of remaining periods.

We report statistics for both parts of the experiment, the open-ended first part and the second part where subjects know when exactly the experiment will end. Overall, the treatment differences for the second part are somewhat more pronounced. That is, once subjects know how long the experiment lasts, they seem more willing to cooperate and, with the exception of the inflation treatment, prices are slightly higher. This could reflect subjects' difficulties with the uncertainty of an open-ended game (see the discussion in Section 3).

Tables B.7–B.9 show that the direction of treatment effects carries over to the second part of the experiment. In the case of prices and welfare, the treatment effects become more pronounced in the second part. Prices under inflation are

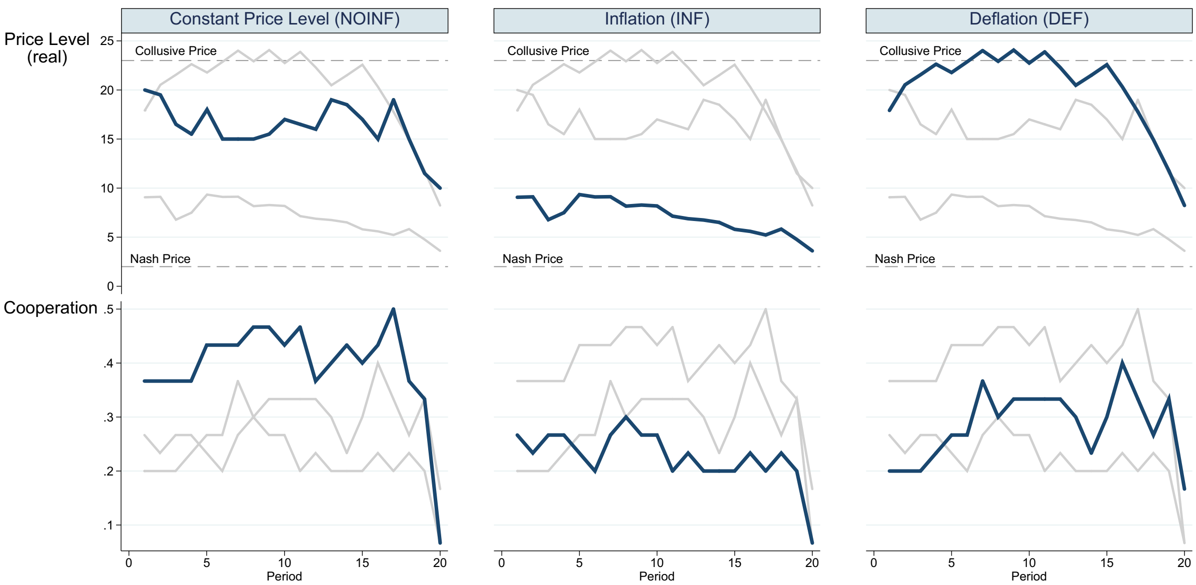

Fig. B5. Median real prices over time (upper panels) and cooperation over time (lower panels), by treatment. Horizontal dashed lines in the upper panels indicate Nash price and collusive price. Measure of cooperation: $C1_{it}$. Data from the second part of the experiment.

Table B.7
Real prices. Descriptive statistics by treatment and non-parametric tests of treatment differences.

		Treatment		
		NOINF	INF	DEF
First part of the experiment	Mean	16.57	12.62	24.78
	Median	15.00	7.76	19.88
Second part of the experiment	Mean	16.96	9.68	31.50
	Median	16.00	6.81	20.48
Entire experiment	Mean	16.76	11.17	28.01
	Median	15.00	7.39	20.17

	Treatment effects[a]		
	NOINF vs INF	NOINF vs DEF	INF vs DEF
First part of the experiment	**($p = 0.0290$)	($p = 0.1930$)	***($p = 0.0008$)
Second part of the experiment	***($p = 0.0000$)	***($p = 0.0006$)	***($p = 0.0000$)
Entire experiment	***($p = 0.0001$)	***($p = 0.0035$)	***($p = 0.0000$)

[a] Wilcoxon-Mann-Whitney Test on subject averages, 120 observations, two-sided. * Significant at the 0.1 probability level. ** Significant at the 0.05 probability level. *** Significant at the 0.01 probability level.

Table B.8
Welfare. Descriptive statistics by treatment and non-parametric tests of treatment differences.

		Treatment		
		NOINF	INF	DEF
First part of the experiment	Mean	407.21	424.64	384.53
	Median	420.38	445.24	403.73
Second part of the experiment	Mean	401.46	429.27	378.73
	Median	413.60	447.72	395.92
Entire experiment	Mean	404.38	426.92	381.67
	Median	414.91	446.51	400.59

	Treatment effects[a]		
	NOINF vs INF	NOINF vs DEF	INF vs DEF
First part of the experiment	**($p = 0.0345$)	($p = 0.5543$)	***($p = 0.0047$)
Second part of the experiment	***($p = 0.0020$)	*($p = 0.0089$)	***($p = 0.0000$)
Entire experiment	***($p = 0.0050$)	($p = 0.1171$)	***($p = 0.0000$)

[a] Wilcoxon-Mann-Whitney Test on group averages, 60 observations, two-sided. * Significant at the 0.1 probability level. ** Significant at the 0.05 probability level. *** Significant at the 0.01 probability level.

Table B.9
Three measures of cooperation. Descriptive statistics by treatment. Medians reported are medians of subject-averages.

	Measure of Cooperation	Statistics	NOINF	INF	DEF
First part of the experiment	Cooperation $C1_{it}$	Mean	0.319	0.227	0.216
		Median	0.200	0.022	0.100
	Cooperation $C2_{it}$	Mean	0.341	0.216	0.401
		Median	0.164	0.037	0.262
	Cooperation $C3_{it}$	Mean	0.900	0.756	0.887
		Median	0.947	0.857	0.974
Second part of the experiment	Cooperation $C1_{it}$	Mean	0.364	0.238	0.256
		Median	0.219	0.034	0.117
	Cooperation $C2_{it}$	Mean	0.448	0.228	0.337
		Median	0.345	0.032	0.247
	Cooperation $C3_{it}$	Mean	0.927	0.821	0.883
		Median	1.000	0.953	0.970
Entire experiment	Cooperation $C1_{it}$	Mean	0.342	0.232	0.236
		Median	0.208	0.022	0.105
	Cooperation $C2_{it}$	Mean	0.394	0.222	0.427
		Median	0.250	0.032	0.283
	Cooperation $C3_{it}$	Mean	0.914	0.788	0.894
		Median	0.980	0.891	0.955

Table B.10
Price regressions for the second part of the experiment. Dependent variable p_{it}: firm1's (real) price in period t. OLS regressions (except column 7) on treatment dummies, their period-interactions, indicator variables for cooperation in the previous period ($coop_{t-1}$), gender (*male*), and acquaintance sformal game theory (*GameTheory*). Robust standard errors in parentheses, *** p < 0.01, ** p < 0.05, * p < 0.1. Regression 5: including outliers. Regression 6: all periods. Regression 7: median regression to account for outliers. All regressions clustered over subjects. The time variables Period, PeriodINF, PeriodDEF are re-set to start with 1 in the first period of the second part of the experiment (except specification (5) which uses data from the entire experiment).

Variables	(1) p_{it}	(2) p_{it}	(3) p_{it}	(4) p_{it}	(5) p_{it} (incl. outliers)	(6) p_{it} (all T)	(7) p_{it} (median)
INF	−5.917***	−5.988***	−5.285***	−5.621***	−11.25**	−4.441***	−9.339***
	(1.188)	(2.259)	(1.483)	(1.527)	(4.392)	(1.281)	(3.093)
DEF	4.516***	4.267*	4.571**	4.268**	26.73**	2.906*	1.544
	(1.432)	(2.371)	(2.170)	(2.067)	(11.48)	(1.638)	(2.343)
Period		−0.115***	−0.113***	−0.116***	−0.189**	−0.106***	−0.169*
		(0.0361)	(0.0214)	(0.0217)	(0.0844)	(0.0228)	(0.0891)
PeriodINF		0.0101	0.0266	0.0350	0.118	−0.0108	−0.0129
		(0.0697)	(0.0468)	(0.0472)	(0.107)	(0.0527)	(0.101)
PeriodDEF		0.0234	0.0411	0.0467	−0.398	0.0839*	0.0138
		(0.0608)	(0.0511)	(0.0506)	(0.264)	(0.0490)	(0.123)
male		2.559**	1.839*	2.025*	−2.998	2.737**	2.518*
		(1.143)	(0.974)	(1.061)	(4.708)	(1.057)	(1.521)
C_{it-1}			7.340***	7.622***			
			(0.866)	(0.796)			
GameTheory				−1.481			
				(0.974)			
Constant	15.60***	17.06***	14.57***	15.20***	25.33***	15.39***	20.36***
	(0.763)	(1.656)	(1.126)	(1.145)	(5.244)	(1.290)	(2.701)
Observations	3578	3580	3580	3560	3600	7262	3600
R^2	0.125	0.142	0.209	0.211	0.022	0.124	0.014

Table B.11
Welfare regressions for the second part of the experiment. Dependent variable u_t: household's utility in period t. OLS regressions (except column 7) on treatment dummies, their period-interactions, indicator variables for cooperation in the previous period ($C1_{it-1}$), gender (*male*), and acquaintance with formal game theory (*GameTheory*). Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Regression 5: Including outliers. Regression 6: Data from the entire experiment. Regression 7: Median regression to account for outliers. All regressions clustered over groups. The time variables Period, PeriodINF, PeriodDEF are re-set to start with 1 in the first period of the second part of the experiment (except specification (5) which uses data from the entire experiment).

Variables	(1) u_t	(2) u_t	(3) u_t	(4) u_t	(5) u_t (incl. outliers)	(6) u_t (all T)	(7) u_t (median)
INF	27.81***	26.44**	20.12***	20.41***	26.69***	19.99*	38.05*
	(9.598)	(10.05)	(7.093)	(7.050)	(10.10)	(10.06)	(20.38)
DEF	−5.215	−7.621	−18.32**	−18.75**	−33.63**	−3.512	−28.35
	(9.305)	(10.94)	(7.940)	(8.044)	(16.48)	(9.875)	(31.89)
Period		0.589*	0.719**	0.718**	0.550	0.518***	1.146
		(0.351)	(0.305)	(0.305)	(0.373)	(0.177)	(0.981)
PeriodINF		−0.0998	−0.327	−0.353	−0.145	0.126	−0.607
		(0.402)	(0.365)	(0.366)	(0.422)	(0.270)	(1.012)
PeriodDEF		0.239	0.635	0.623	1.038	−0.162	1.088
		(0.584)	(0.501)	(0.498)	(1.111)	(0.298)	(1.586)
male		−19.73***	−8.302	−8.282	−19.85***	−22.74***	−11.18
		(6.713)	(5.364)	(5.540)	(7.354)	(6.228)	(7.919)
$C1_{it-1}$			−59.86***	−58.80***			
			(4.862)	(4.980)			
GameTheory				−4.897			
				(4.410)			
Constant	401.5***	411.9***	425.7***	428.0***	412.2***	410.8***	409.5***
	(6.768)	(8.620)	(7.279)	(7.577)	(9.003)	(8.253)	(19.17)
Observations	1764	1758	1750	1730	1800	3531	1800
R^2	0.103	0.143	0.512	0.512	0.132	0.176	0.125

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Table B.12

Cooperationregressions for the second part of the experiment. Dependent variables: Measures of cooperation $C1_{it}$, $C2_{it}$, $C3_{it}$. Probit regressions on treatment dummies, their period-interactions, and gender (*male*). Specifications (1)–(4) and (9)–(12): Clustered over groups. Specifications (5)–(9): Clustered over subjects. Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Uneven specifications use data from the second part of the experiment, even specifications from the entire experiment. The time variables Period, PeriodINF, PeriodDEF are re-set to start with 1 in the first period of the second part of the experiment (except all even specifications that use data from the entire experiment).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Variables	$C1_{it}$	$C1_{it}$	$C1_{it}$	$C1_{it}$	$C2_{it}$	$C2_{it}$	$C2_{it}$	$C2_{it}$	$C3_{it}$	$C3_{it}$	$C3_{it}$	$C3_{it}$
INF	−1.347***	−0.990**	−0.811	−0.231	−2.043*	−1.247**	−2.405*	−0.861	−1.524***	−0.737**	0.663	0.515
	(0.516)	(0.421)	(0.937)	(0.461)	(1.058)	(0.574)	(1.433)	(0.606)	(0.574)	(0.361)	(1.010)	(0.486)
DEF	−0.400	−0.479	−1.389*	−0.531	0.423	0.352	−0.0303	0.262	−0.713*	−0.343	−1.653*	−0.190
	(0.454)	(0.331)	(0.801)	(0.370)	(1.082)	(0.501)	(1.311)	(0.541)	(0.388)	(0.338)	(0.943)	(0.378)
Period			−0.0250*	0.0147			−0.0438	−0.0128			−0.0231	−0.00338
			(0.0138)	(0.00997)			(0.0297)	(0.0136)			(0.0197)	(0.00610)
PeriodINF			−0.0156	−0.0329***			0.0202	−0.0131			−0.0655**	−0.0478***
			(0.0253)	(0.0123)			(0.0385)	(0.0182)			(0.0291)	(0.0158)
PeriodDEF			0.0328	0.00188			0.0129	0.00452			0.0287	−0.00748
			(0.0227)	(0.0114)			(0.0361)	(0.0155)			(0.0249)	(0.00885)
male			0.786**	0.900***			1.462**	1.329***			0.591	0.742**
			(0.381)	(0.302)			(0.584)	(0.450)			(0.495)	(0.367)
Constant	−0.565*	−0.502**	−0.463	−1.559***	−0.516	−0.336	−0.347	−1.182**	3.186***	2.284***	3.419***	1.778***
	(0.343)	(0.248)	(0.531)	(0.359)	(0.958)	(0.402)	(1.147)	(0.557)	(0.505)	(0.268)	(0.865)	(0.422)
Observations	1800	3654	1800	3654	1800	3654	1800	3,654	1800	3654	1800	3654
Log Lik	−592.3	−1220	−584	−1191	−574	−1245	−561.2	−1218	−410.1	−1018	−389.5	−923.9

significantly lower than prices under constant prices or under deflation. Prices under deflation are significantly higher than in the other two treatments. A similar picture arises in the case of welfare. Welfare is highest under inflation and lowest under deflation. Average cooperation $C1_{it}$ is somewhat higher in the second part of the experiment. The other two measures are roughly the same in both parts.

In Tables B.10– B.12, we repeat the regression specifications used in Tables 2–6 for the data from the second part of the experiment. The effect on price trends we found in the case of DEF in the first part of the experiment turns into an effect on levels in the second part. This is in line with the discussion in Section 5.4. Fig. B.5 shows median real prices and average cooperation for the final 20 periods by treatment. Ignoring the "endgame effect" (the final 5–6 periods), the price levels in all three treatments are fairly constant.

Appendix C. Non-linear price regressions

Table C.13
Non-linear price regressions. Dependent variable p_{it}: firm i's (real) price in period t. OLS regressions (except column 7) on treatment dummies, their period-interactions (both linear (Period) and squared (Period2)), indicator variables for cooperation in the previous period ($C1_{it}$), gender (*male*), and acquaintance with formal game theory (*GameTheory*). Robust standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Column 5: Including outliers. Column 6: Data from the entire experiment. Column 7: Median regression to account for outliers. All regressions clustered over subjects.

Variables	(1) p_{it}	(2) p_{it}	(3) p_{it}	(4) p_{it}	(5) p_{it} (incl. outlier)	(6) p_{it} (all T)	(7) p_{it} (median)
INF	−3.769**	−2.714*	−2.746**	−2.745**	−8.354***	−1.741	−2.746**
	(1.546)	(1.379)	(1.232)	(1.226)	(1.898)	(1.380)	(1.232)
DEF	4.122**	−2.227	−0.0265	0.120	−2.215	−0.805	−0.0265
	(1.616)	(1.445)	(1.487)	(1.489)	(1.554)	(1.517)	(1.487)
Period		−0.306***	−0.325***	−0.325***	−0.715***	−0.132**	−0.325***
		(0.110)	(0.0653)	(0.0660)	(0.189)	(0.0668)	(0.0653)
PeriodINF		−0.188	−0.134	−0.137	0.206	−0.277***	−0.134
		(0.157)	(0.107)	(0.107)	(0.212)	(0.0951)	(0.107)
PeriodDEF		0.611***	0.440**	0.412**	0.643*	0.439***	0.440**
		(0.205)	(0.174)	(0.171)	(0.345)	(0.144)	(0.174)
male		2.997**	1.855	1.591	3.946**	2.684**	1.855
		(1.300)	(1.133)	(1.164)	(1.754)	(1.070)	(1.133)
$C1_{it-1}$			8.756***	8.595***			8.756***
			(0.937)	(0.969)			(0.937)
GameTheory				1.013			
				(1.055)			
Period2		0.00275	0.00307**	0.00304**	0.00966***	0.000415	0.00307**
		(0.00215)	(0.00121)	(0.00124)	(0.00366)	(0.00109)	(0.00121)
Period2INF		0.00438	0.00318	0.00326	−0.00437	0.00424**	0.00318
		(0.00348)	(0.00224)	(0.00226)	(0.00410)	(0.00178)	(0.00224)
Period2DEF		−0.00846*	−0.00547	−0.00487	−0.00885	−0.00562**	−0.00547
		(0.00454)	(0.00384)	(0.00379)	(0.00711)	(0.00240)	(0.00384)
Constant	14.53***	16.16***	14.82***	14.60***	19.76***	15.70***	14.82***
	(1.028)	(1.479)	(1.303)	(1.296)	(1.961)	(1.288)	(1.303)
Observations	3674	3676	3501	3497	3708	7261	3501
R^2	0.091	0.141	0.268	0.276	0.013	0.140	0.268

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jmoneco.2018.09.004.

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