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Abstract

We study how inflation and deflation affect firms' ability to cooperate in an experimental Bertrand duopoly with differentiated products. We find that there is significantly less cooperation in the treatments with inflation and deflation compared to the no-inflation treatments. The difficulties to cooperate affect prices and welfare: Depending on the market structure, inflation and deflation lead to significantly lower (real) prices and higher welfare.

Keywords: Bertrand Duopoly, Inflation, Experiment, Money Illusion

JEL-Codes: C9, E31, E42

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1 Introduction

Price setting firms typically operate somewhere between the two extremes of a perfectly competitive market on the one side and a monopoly on the other. Firms benefit from achieving cooperation with the other firms in the market, that is, to set prices above the Nash equilibrium. In laboratory markets, this type of cooperation is typically found even in the absence of enforceable contracts and without explicit communication, especially once the firms interact in a repeated setting. We study how inflation and deflation affects firms' ability to cooperate. The specific environment we consider is the classical model of (repeated) Bertrand competition with differentiated products in a duopoly. Here, each firm needs to take into account the price set by the other firm when evaluating the most profitable own price. Cooperation (i.e. pricing above the Nash equilibrium) leads to higher profits, but is susceptible to deviations. Firms try to prevent deviations by the threat of punishment, that is by lowering prices in future rounds.[1]

Critical to sustaining cooperation via the threat of punishment is the ability of firms to detect deviations. If, for example, a firm's competitors' prices are not known or known only with uncertainty, sustaining cooperation becomes difficult. In our setup, there is no uncertainty; prices are common knowledge. But we introduce inflation so that the overall price level changes over time. The inflation rate is constant and there are no inflation surprises. Nonetheless, we expect inflation to affect a firm's price setting. In an environment without inflation, the cooperative status quo is to not change prices. In an environment with inflation, the cooperative status quo is to change prices regularly. In order to stay at a cooperative real price, firms need to periodically raise their nominal price. Staying at the old nominal price is in effect a real price deviation. The task of sustaining cooperation becomes harder. The same is true for achieving coordination in the first place. Without inflation, coordination can follow a simple rule of thumb: If both firms play a cooperative

[1]Cooperation, in a finitely repeated market, is not a Nash-Equilibrium, since there is no incentive to punish in the last round. Nonetheless, previous experiments have shown that subjects are willing to spend money on punishment, when there is no future interaction, and even more so in early rounds of finitely repeated games.

price, continue playing this price from now on. Even if non-coordinated firms played completely randomly, they would eventually, by chance, play the same price, creating a natural focal point to start coordinating on. Under inflation, no focal point exists since coordination (at the same real level) requires firms to adjust prices regularly. Given that the opponent did not raise his price by the same amount as I did, was he deviating? Or was he trying to coordinate on a nominal price instead of a real price? Did he fail to calculate the correct new nominal cooperative price? So, should I immediately start punishing, knowing that this could lead to a price war we will both suffer in, or should I allow for some mistakes by my opponent? If firms hesitate to punish a real deviation under inflation as strongly as they would punish a real (and nominal) deviation in the case with no inflation then sophisticated firms might use inflation to hide some real deviations and make a higher profit that way.

We look at treatments with both positive (INF), negative (DEF) and zero inflation (NOINF). The treatments are identical in real terms but differ in nominal terms. To study how the results vary with market structure, we vary the degree of homogeneity of the product (WEAK and STRONG). This results in a 3×2 design.

Our main result is that inflation and deflation complicate cooperation. Independently of the market structure, cooperation is lower in INF and DEF compared to NOINF. Some firms cooperate in real, others in nominal terms. Nominal cooperation (i.e. playing the same (nominally) constant price for several periods) may be interpreted as a sign of money illusion. Money illusion can also explain why the real price has a slightly positive trend in DEF whereas it has a strong negative trend in INF. However, punishment does not appear to differ between treatments. One may expect that money illusion would make punishment harsher (in real terms) under inflation than under deflation when subjects focus on nominal instead of real prices but no such behaviour is observed.

Our setting allows for welfare analysis. Our measure of welfare is the utility of the representative agent that we use to generate the demand functions. Utility, of course, depends on prices but the relationship is neither linear nor monotone. Here, the main finding is that cooperation by firms lowers welfare. Depending on the market structure, inflation and deflation may significantly raise welfare. Welfare in the NOINF treatments is never above welfare in the INF and DEF treatment.

In a related line of research, Fehr and Tyran study the phenomenon of money illusion. Fehr and Tyran (2001, 2008) implement an experimental market with a large nominal shock (nominal equilibrium prices are halved in the 2008 paper and more than halved or doubled in the 2001 paper). They find that, depending on the direction of the shock and the strategic environment, a nominal shock can lead to a lengthy period of adjustment before equilibrium is reached again. In contrast to Fehr and Tyran, we implement inflation as a steady increase of the price level in each period instead of a one-off shock. Per period, the inflation rate is 5%. We use a standard differentiated Bertrand market setup, where the demand functions can be derived from the utility function of a hypothetical representative consumer Dixit (1979). Fehr and Tyran deliberately do not implement a standard market structure because they want to avoid the effect of subjects trying to coordinate on non-equilibrium prices. In contrast, the study of the impact of inflation onto this coordination is our explicit goal; therefore, we stick to a model where firms can profit from collectively playing prices above the Nash-Equilibrium. In addition, deriving demand from first principles allows us to perform standard welfare analysis.

In a separate paper by Fehr and Tyran (2007), coordination is studied in an experimental market where the individual payoff of a firm is given in nominal terms. These "nominal points" are then divided by the average price of other firms to calculate the real payoff. In this market, three Nash-Equilibria exist. Play converges to an inefficient Nash-Equilibrium instead of the efficient equilibrium. This situation can roughly be interpreted as one where all other firms are large and combined make up the whole economy.[2] Then, price changes by other firms can be interpreted as inflation. In contrast to that, our firms are large within their respective market but small relative to the economy: Inflation is exogenously given and not influenced by decisions of the firms. Since our market only features one equilibrium, our notion of

[2]This interpretation does not work perfectly, since the payoff adjustment is made for each firm. That is, for each firm, all other firms would have to form the entire economy.

coordination failure is different from Fehr and Tyran. Whereas in Fehr and Tyran (2007), coordination failure results from converging to the wrong equilibrium, we define coordination failure as both firms playing different prices.

Since we use a Bertrand setting, our research intersects with the literature on oligopoly markets. This is one of the experimentally most well studied fields of economics. A meta study by Engel (2007) lists over a hundred different experimental papers using Bertrand and Cournot settings. We want to study effects on cooperation and therefore restrict attention to the case of a duopoly where we expect cooperation to matter most. Engels reports a large impact of product heterogeneity in some cases, therefore we include treatments with different product heterogeneity.

Duffy (2012) is an excellent survey of the experimental macroeconomics literature. We contribute to this literature in two directions. First, we model inflation as a steady increase of the overall price level rather than a one-off shock that raises or lowers the value of the numeraire from one period to the next by a multiple of a typical rate of year-on-year inflation. These one-off shocks are rarely observed in practice. An example may be a currency changeover, but inflation, at least in the OECD countries during the last decades, is a steady, often small increase of the price level of around 1 to 5 percent per year. Second, we explicitly allow for cooperation between firms and find that inflation significantly affects firms ability to cooperate.

In the last ten years, the statistical offices of a number of countries published the firm-level data ("microdata") underlying the consumer price indices. See Nakamura and Steinsson (2008), Gagnon (2009), Angeloni et al. (2006), Dhyne et al. (2006) and Bils and Klenow (2004). The main findings support the notion of earlier papers by Cecchetti (1985) and Lach and Tsiddon (1992) that firms are reluctant to change prices. Typically, retail prices change about once a year and services prices once about every two years. Price increases are more common than price decreases but this depends on the overall inflation rate and on the sectors. In section 2 we will discuss how these findings influenced the design of our experiment.

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 since there is no model-free way of interpreting the data (Nakamura and Steinsson (2008)), it is typically assumed that firms operate in a monopolistic market where the firm's price is independent of its competitors' prices and only influenced by aggregate variables such as GDP, overall inflation, exchange rates and labour and other input costs. It is this drawback that motivates us to run experiments where we can control for the structure of a market and thus reveal insights that remain hidden in the firm-level data of the statistical offices.

The literature pioneered by Blinder (1991), who uses surveys to explore price setting behavior of firms, illustrates the importance of the drawback. Blinder finds strong support that firms hesitate to raise or lower prices until other firms move first. Fabiani et al. (2006) summarize more recent surveys conducted in nine European countries. The authors 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 labour and other input costs. These surveys strongly support the notion that firms find themselves somewhere in between the two extremes of a perfect 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) forceful critique of the model of monopolistic competition which is standard in the monetary economics literature and, probably for this reason, is not uncommon in the experimental macroeconomics literature. However, the assumption that a firm sets its price independently of its competitors' prices is not innocuous. Inflation affects prices directly but also indirectly through changes in the amount of cooperation by the firms. This later effect cannot be detected in models which do not allow for cooperation between firms. Even in the frictionless world of our experiment where there is no uncertainty about future inflation, no menu costs, no externally imposed staggering of prices, and no informational frictions about the behavior of a firm's competitors, inflation and deflation have a significant effect on firms' ability to cooperate and thus on how inflation of the overall price level is passed on to consumers.

The paper is organized as follows. Section 2 describes the setting, and Section 3 the experimental design and the procedure. Section 4 discusses our predictions and Section 5 presents and discusses the results. Concluding remarks in section 6 close the paper.

2 Setting

We consider a differentiated Bertrand duopoly proposed by Dixit (1979) with a linear demand structure. Firms are symmetric, have zero marginal costs, zero fixed costs, and no capacity limits. The quantities of the products are q_1, q_2 and nominal prices are p_1, p_2. There is a competitive numeraire sector whose output is q_0 and whose price is P. Inflation is introduced by varying the value of the numeraire good. P is normalized to 1 in the first period of the inflation treatment. The demands are assumed to arise from the utility function of a representative consumer

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

Since this has 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

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

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:

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

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 $\theta = 0$, the goods are completely differentiated and the firms are in effect monopolists in two separate markets. As θ increases, the consumer is willing to substitute one good for the other. This is a standard linear demand system that has been used in experiments before, for example, by Dolbear et al. (1968) or, more recently, Huck et al. (2000). Since marginal costs are assumed to be zero, the profit functions are

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

and the real Nash price and the real perfect collusive price are given by

$$
\begin{aligned}
\frac{p_i^{Nash}}{P} &= \frac{1-\theta}{2-\theta}a \\
\frac{p_i^{coll}}{P} &= \frac{1}{2}a
\end{aligned}
$$

Regarding welfare, a natural measure of the household's welfare is its utility.[3] We assume in particular, that the representative household owns the two firms and that the firms' profits are his sole source of income. The budget constraint in this case can be written as

$$
\pi_1 + \pi_2 = q_0 + \frac{p_1}{P}q_1 + \frac{p_2}{P}q_2
$$

where π_i denotes firm i's profits. Profits can be simplified to $\pi_i = \frac{p_i}{P}q_i$. Combining

[3]A different measure would be the sum of the firms' and the consumer's rents in the two markets. This measure of welfare is equal to utility only if the two markets are completely separate, e.g. when $\theta = 0$.

this with utility (equation 1), our measure of welfare is given by

$$V = u\left(q_1, q_2\right).$$

3 Experimental Design

The setting is implemented in a computerized lab 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 cooperation behavior, this is advantageous. Implementing a duopoly instead of a larger market stems from the same reasoning. An additional advantage of not presenting payoff formulas is to avoid barriers to participation by subjects with low math skills.[4]

To address possible difficulties with reading the payoff tables, we add several control questions between the instructions and the start of the experiment.[5] Additionally, 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.

The market is repeated for 20 periods.[6] Subjects are partner matched, that is, the same pair of subjects plays together for all 20 periods. The instructions use a firm framing, but are neutral with respect to the matched partner. To introduce inflation, subjects are paid in "profit units" in each period. The exchange rate between profit units and Euro varies in the INF and DEF treatments. All of this, including the

[4] An alternative way of avoiding the payoff function in the instructions would have been a profit calculator. However, our strategy space, while finite, is large: Subjects could chose any integer price $p_i \in [1, 40]$. Using a profit calculator would add implicit restrictions on the information intake by subjects due to limited time available to calculate price combinations. We also wanted to avoid the implied normative effect of a payoff calculator with an automated function calculating the best response to a given strategy of the other player.

[5] The experiment started when all subjects in a session had correctly answered the control questions.

[6] More repetitions would require enlarging the payoff tables.

	$\theta = 0.75$	$\theta = 0.95$
No Inflation	NOINF WEAK (42 subjects)	NOINF STRONG (24 subjects)
Inflation	INF WEAK (36 subjects)	INF STRONG (26 subjects)
Deflation	DEF WEAK (40 subjects)	DEF STRONG (22 subjects)

Table 1: Treatments and Number of Subjects per Treatment

(constant) rate of inflation/deflation in each period is known to subjects beforehand: Subjects are handed the payoff tables for all periods before making their first decision.

To avoid corner solutions, we chose the payoff tables such that, in all periods of all treatments, the Nash equilibrium price and the collusive price are strictly larger than one and strictly lower than 40. 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.

We have six treatments. Homogeneity is either WEAK ($\theta = .75$) or STRONG ($\theta = .95$), and the market has either inflation (INF) of 5% per period, deflation (DEF) or no inflation (NOINF). Deflation is the reverse of inflation: Period 20 in INF is period 1 in DEF, period 19 in INF is period 2 in DEF and so on. Our treatments are listed in table 1.

While all periods are identical in real terms, the nominal prices that constitute the Nash equilibrium strategy vary in INF and DEF. The same holds true for the collusive price. Table 2 summarizes the Nash and collusive predictions.[7]

3.1 Procedures

The experiment consisted of fifteen sessions and was conducted at the laboratory of the University of Heidelberg from July 2012 to September 2012. All recruitment

[7] Due to rounding, the Nash equilibrium is sometimes not unique. Similarly, the perfect collusive strategy is not unique in period 3 of INF (period 18 of DEF).

		Nash-Equilibrium	Collusion
NOINF	WEAK	10	23
	STRONG	3	23
INF	WEAK	$5 \rightarrow 15$	$15 \rightarrow 38$
	STRONG	$2 \rightarrow 4$	$15 \rightarrow 38$
DEF	WEAK	$15 \rightarrow 5$	$38 \rightarrow 15$
	STRONG	$4 \rightarrow 2$	$38 \rightarrow 15$

Nash Equilibrium and collusive prices for each treatment.
The arrows $(\rightarrow)$ indicate movements of the nominal values from period 1 to period 20.

Table 2: Equilibria and Collusion in Nominal Terms

was done via ORSEE (Greiner (2004)). In total, 190 subjects took part in our experiment, 109 male and 81 female.

Subjects waited in front of the laboratory till the experiment started. 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, the profit tables, 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.[8] 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 9.18 EUR for roughly 75 minutes in the lab.

4 Predictions

The selfish, money-maximizing prediction is playing the Nash equilibrium price of the stage game in all 20 periods. However, it comes at no surprise that subjects try to beat the Nash profit by cooperating with each other. Cooperation leads to higher

[8]In some sessions, we had replacement subjects, who also read the instruction and answered the test questions and were to be substituted in for any subject not answering the test questions correctly. However, this never happened. All subjects answered correctly.

profits for both parties, but is susceptible to deviations. Therefore, we expect that, in all treatments, some subjects will try to establish cooperation on the collusive price, but that they will not always succeed. We predict a lower rate of cooperation in INF and DEF compared to NOINF. In NOINF, optimal cooperation is achieved by a pair of firms coordinating to play the collusive price of 23 for all 20 periods. It is also possible to coordinate on values between the collusive price and the Nash-equilibrium price.[9] In INF and DEF, collusion requires subjects to frequently change their nominal price to match the real collusive price of 23. These required nominal price adjustments make collusion more complex. As a primary effect, cooperation could be lower because some subjects fail to realize that adjustments are needed. As a secondary effect, punishment might be less prevalent: Since it is not clear whether a failure to adjust is a deliberate deviation, or a mistake due to complexity, subjects might punish less, thus opening the door to deliberate deviations.

A slightly less profitable, but perhaps easier, way to coordinate is for both firms to coordinate on a (nominally) constant price for several periods. To distinguish the two, we call continued cooperation on a real price "real cooperation" and continued cooperation on a nominal price "nominal cooperation". Figure 1 shows some extreme examples of real cooperation (right hand panels) and nominal cooperation (left hand panels) from the inflation treatment. Nominal cooperation over many rounds reduces the gains from cooperation considerably. Group 405 in the upper left panel starts playing the collusive price and nominally coordinates on this price for most of the experiment. Two attempts to coordinate on a higher nominal price fail, and by period 20, they play the Nash equilibrium and achieve zero gains from cooperation.

Inflation and deflation may also affect subjects regardless of coordination. Following Fehr and Tyran (2001), we call this effect money illusion. If subjects use nominal prices as a proxy for real prices, their (real) choices should have an upward bias in the DEF treatments and a downward bias in the INF treatments.

Engel (2007) finds, for fixed partner matching, lower prices in a market with

[9] In principle, subjects could also coordinate to play asymmetric price combinations. However, these lead to unequal outcomes. Given the symmetric setup of the game, a 50-50 split is a clear focal point. Therefore we disregard the possibility of coordinated asymmetric play.

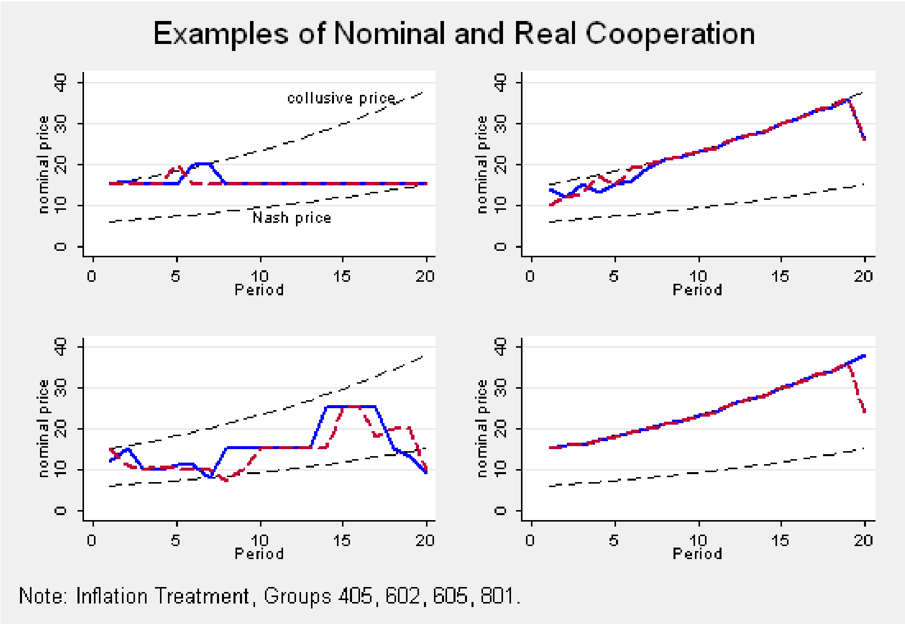

Figure 1: Examples of play in INF

homogeneous products compared to a market with heterogeneous products. Since we have higher homogeneity in STRONG, compared to WEAK, we expect overall higher prices in the WEAK treatments, at least in the case of no inflation. Engel's results do not include inflation and deflation, but we can search for a similar difference in our INF and DEF treatments.[10]

5 Results

To structure the results, we will divide our analysis into four parts. First, we will look at cooperation between the subjects in our treatments. Here we answer the question whether introducing inflation or deflation leads to lower cooperation. Second, we investigate whether the price *level* differs between treatments, and third whether price *changes* differ between treatments. There, were are especially interested in how subjects react to price decreases by their partners, i.e. whether and how subjects punish

[10]There certainly will be many reasons for subjects to set a specific price that are common to all our treatments: E.g. some subjects might be more altruistic, some might even play randomly, and there is a large endgame effect. When possible, we control for these in our regressions, but they are not the main focus of our study.

firms that deviate towards lower prices. Finally, we study whether the differences we find for prices and cooperation affect the utility of the representative agent that we use to construct the market demand.

We call all subjects who play an equal price *coordinated* on this price. However, coordination on some price levels does not qualify as *cooperation*. E.g. playing the Nash-equilibrium of the stage game is a sign of coordination, does, however, not require any cooperation with the other firm, since playing the Nash price follows already from pure self-interest. To differentiate cooperation from coordination, we define cooperation as both firms playing the same price above the Nash price:

$$coop_t = \begin{cases} 1 & \text{if } p_{1t} = p_{2t} > p_t^{Nash} \\ 0 & \text{otherwise} \end{cases}$$

where p_{it} is firm i's price in period t and $i = 1, 2$. *Collusion* is cooperation on the most profitable price, the collusive price. Additionally, we use the dummy variable $coll\_first3$ to describe attempted collusion. $coll\_first3$ is equal to one if a subject plays the collusive price at least once during the first three periods, and zero otherwise.

5.1 The Effect of Inflation on Cooperation

Figure 2 shows the levels of cooperation in our treatments over time. While the overall rate of cooperation is 25.6%, we find considerable differences between our treatments. In almost all periods, cooperation in our NOINF treatments is higher than in the INF and DEF treatments. There also appears to be a strong endgame effect, particularly in the STRONG treatments.

Table 3 shows six probit regressions. Specification (4a) is our baseline model. In specifications (1) - (3) we look at levels alone, and then add period and period interaction terms in specifications (4a) - (5). In specification (3) and (5) the first three and last three periods are left out to control for possible endgame and starting effects. In specification (4b), we change the omitted category from NOINFweak to

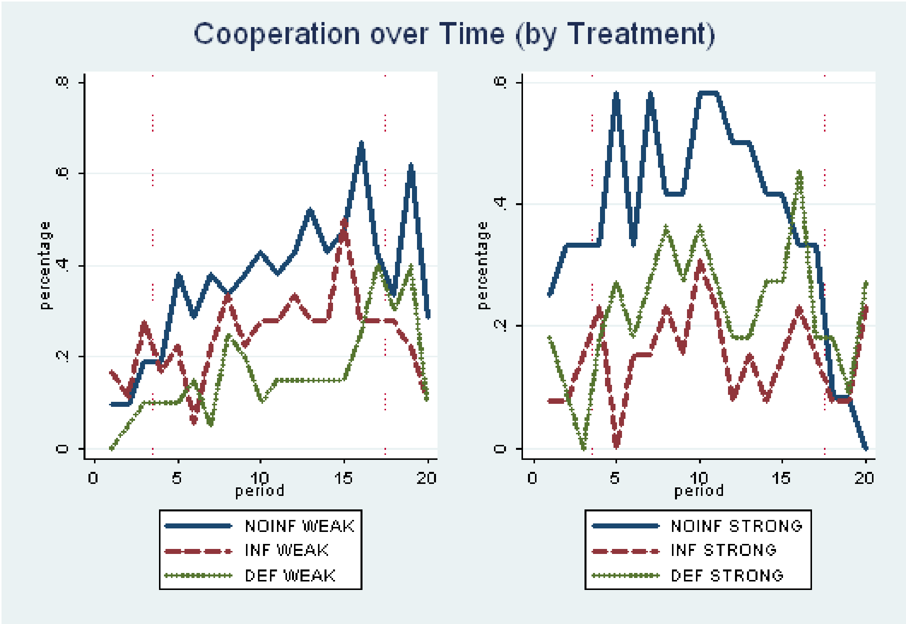

Figure 2: Cooperation over time

NOINFstrong to allow for easier comparisons among the STRONG treatments.

In specifications (1) - (3), we find that cooperation is significantly lower in the INF and DEF treatments when the homogeneity of products is WEAK. The direction of the effect is the same with STRONG homogeneity, however, here it is only strongly significant for the INF treatment.[11] Cooperation in t predicts cooperation in $t+1$ ($coop_{t-1}$), as does being male, although this effect goes away when concentrating on the middle periods. Cooperation in t is higher when a firm's price in $t-1$ is high (p_{1t-1}). Taking time trends into account (specifications 4a, 4b, and 5) we find that some of the significant differences between the cases with no inflation and those with inflation or deflation are due to different trends in cooperation. INFweak has decreasing cooperation, compared to the case without inflation, while the time trend is more positive for INFstrong and DEFstrong. Some of the differences between NOINF, INF and DEF are due to different time trends, confirming the impressions from figure 2.

Looking at the comparison between STRONG and WEAK homogeneity, we find

[11] DEFstrong differs from NOINFstrong at 10% in levels in specifications (1) and (3), and does not significantly differ in specification (2).

	(1) period 1-20	(2) period 1-20	(3) period 4-17	(4a) period 1-20	(4b) period 1-20	(5) period 4-17
VARIABLES	$coop_t$	$coop_t$	$coop_t$	$coop_t$	$coop_t$	$coop_t$
NOINFweak					-0.233***	
					(0.0420)	
INFweak	-0.123***	-0.113***	-0.156***	-0.0353	-0.241***	-0.154*
	(0.0374)	(0.0343)	(0.0520)	(0.0639)	(0.0374)	(0.0918)
DEFweak	-0.133***	-0.113***	-0.210***	-0.112**	-0.286***	-0.0461
	(0.0360)	(0.0339)	(0.0460)	(0.0538)	(0.0355)	(0.118)
NOINFstrong	-0.0729	-0.0602	-0.0188	0.390***		0.520***
	(0.0464)	(0.0425)	(0.0775)	(0.104)		(0.161)
INFstrong	-0.172***	-0.153***	-0.254***	-0.0791	-0.241***	-0.121
	(0.0298)	(0.0304)	(0.0356)	(0.0619)	(0.0301)	(0.107)
DEFstrong	-0.141***	-0.123***	-0.131**	-0.0589	-0.226***	0.0351
	(0.0348)	(0.0349)	(0.0581)	(0.0691)	(0.0300)	(0.157)
periodNOINFweak					0.0345***	
					(0.00542)	
periodINFweak				-0.00856*	0.0259***	-0.00297
				(0.00443)	(0.00559)	(0.00964)
periodDEFweak				-0.000639	0.0338***	-0.0195**
				(0.00436)	(0.00561)	(0.00977)
periodNOINFstrong				-0.0345***		-0.0433***
				(0.00542)		(0.0114)
periodINFstrong				-0.0100*	0.0244***	-0.0184
				(0.00513)	(0.00612)	(0.0113)
periodDEFstrong				-0.00788	0.0266***	-0.0207*
				(0.00527)	(0.00626)	(0.0114)
period				-0.153***	-0.187***	0.0656
				(0.0463)	(0.0469)	(0.0510)
p_{1t-1}		0.00601***	0.00265	0.00540***	0.00540***	0.00441
		(0.00170)	(0.00279)	(0.00176)	(0.00176)	(0.00286)
$coll\_first3$		0.0461	0.0835	0.0528	0.0528	0.0905
		(0.0376)	(0.0620)	(0.0401)	(0.0401)	(0.0674)
$male$	0.0904***	0.0687**	0.0456	0.0728**	0.0728**	0.0886*
	(0.0330)	(0.0286)	(0.0474)	(0.0301)	(0.0301)	(0.0488)
$coop_{t-1}$		0.187***	0.0922***	0.155***	0.155***	0.0847**
		(0.0258)	(0.0351)	(0.0258)	(0.0258)	(0.0355)
Observations	3,800	3,610	2,280	3,610	3,610	2,280
Log Lik	-1606	-1515	-926.9	-1489	-1489	-928.4

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 3: Cooperation

a difference in the time trend for the case of no inflation, but no significant differences for the cases of inflation and deflation.[12] Overall, there is strong evidence for lower cooperation under inflation and deflation.

Result 1a: *Cooperation* Inflation and deflation reduce cooperation between firms in the experiment.

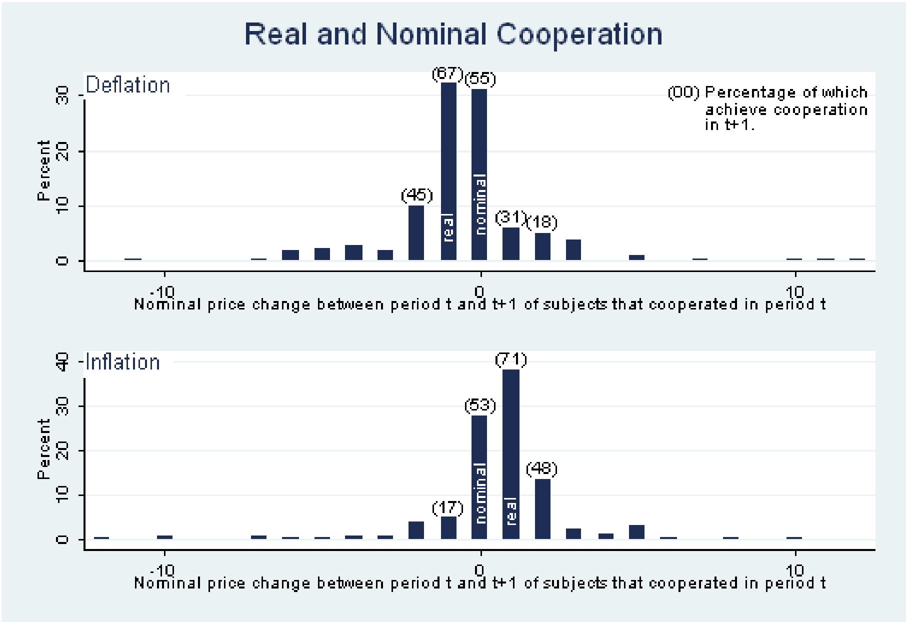

Figure 3: Real and nominal cooperation

Up until now, we considered real and nominal cooperation equally. Figure 3 shows the nominal price change between period t and period $t + 1$ for groups that achieved cooperation in period t.[13] We see that subjects are most likely to go for real cooperation, that is, to adjust their price such that the real price stays the same. However, a sizable share in both the DEF and the INF treatments keeps their nominal price the same. The numbers above the bars show the percentage of

[12]Performing WALD tests in (4a), we find no significant difference between: DEFweak & DEFstrong; INFweak & INFstrong; periodDEFweak & periodDEFstrong; periodINFweak & periodINFstrong.

[13]Since nominal prices are equal to real prices in NOINF, we exclude this treatment from the figure.

groups that achieve cooperation again in period $t+1$. We see that real cooperation leads to a high rate of cooperation in the next period.[14] Nominal cooperation works less well, especially under inflation. While, over time, both forms of cooperation can be achieved between the two firms in a market, the fact that both nominal and real cooperation are chosen by subjects implies that coordination is initially harder: Firms in a market not only have to find out whether their opposing firm will cooperate, but also have to find out whether it will cooperate in nominal or real terms. This additional complication can explain the lower rates of overall cooperation we find in INF and DEF. This complication is closely related to what Fehr and Tyran (2008) call money illusion. It is not necessary that subjects suffer from money illusion ("individual level money illusion") but it suffices that subjects are not sure about whether their opponent suffers from money illusion.

Result 1b: *Nominal versus Real Cooperation* Under inflation and deflation subjects cooperate both on nominal and on real prices.

5.2 The Effect of Inflation on the Price Level

Figure 4 shows the average real price of all six treatments over the 20 periods of the experiment. We see, again, a clear endgame effect and a strong effect of the first few periods of play. Under WEAK homogeneity, we see a similar downward trend for NOINF and INF, with lower prices in INF. DEF, on the other hand, displays a positive trend in the central periods of the experiment. This positive trend in DEF is repeated in the STRONG treatments but there, no obvious difference between DEF and NOINF appears. INF, on the other hand, displays a strong downward trend.

The mean price levels shown in figure 4 disguise the underlying heterogeneity of prices. Figure 5 plots the distributions of prices in our six treatments. The distributions typically have two modes: one close to the Nash equilibrium and one around the collusive (monopoly) price. In the WEAK treatments, inflation and

[14] Given that play goes over 20 periods, a likelihood of failure of 20-27% per period could also be regarded as high.

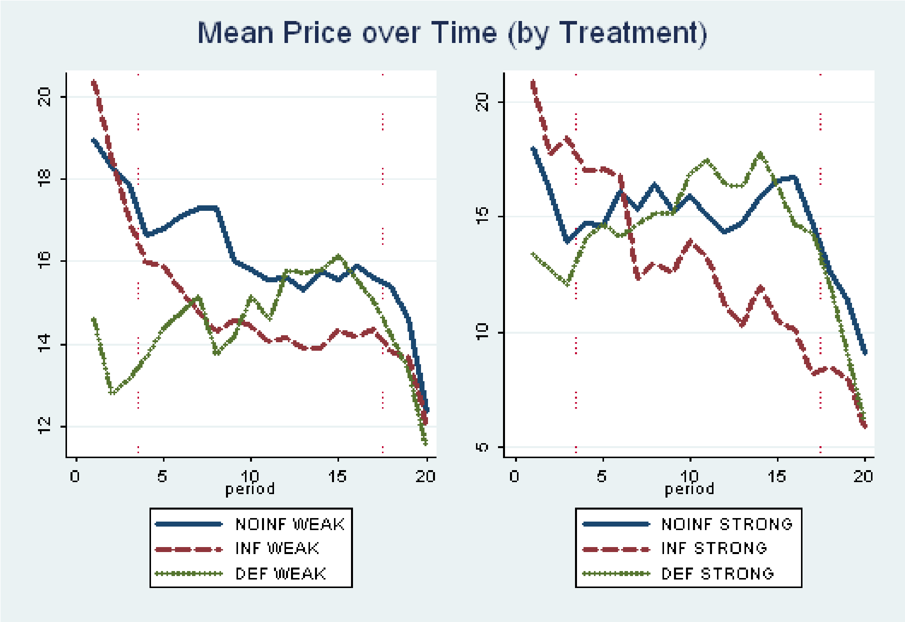

Figure 4: Real price over time

deflation reduce the mass around the higher mode - confirming the impressions from figure 4. A similar picture appears in the STRONG treatments though there the bimodality is less pronounced. It is interesting how the distributions shift over time. Comparing the first 10 with the last 10 periods, we see slight leftward shifts of the distributions in INF and NOINF but a slight rightward shift in DEF. This pattern is even stronger in the STRONG treatments. In the regressions below, the residuals inherit to some extent the bimodality of the regressand.

In table 4, we present the regression on the price level. Specification (4a) is our baseline model. We start with describing the non-treatment variables, which have clear results in all specifications. Male subjects set higher prices, as do subjects who played the collusive price during the first three periods ($coll\_first3$). Subjects who are in a group that cooperated in t set considerably higher prices in $t+1$ ($coop_t$).

Regarding the difference between NOINF, INF and DEF, we find a negative price effect when moving from NOINFweak to DEFweak. In later rounds, this is counteracted by the positive time trend in DEFweak. INFweak and NOINFweak are never significantly different at the 5% level in levels or trends. With STRONG homogeneity, the picture is reversed. DEFstrong is never different from NOINFstrong, but

	(1)	(2)	(3)	(4a)	(4b)	(5)	(6)
	period 1-20	period 4-17	period 1-20	period 1-20	period 1-20	period 1-20	period 4-17
VARIABLES	p_{1t}	p_{1t}	p_{1t}	p_{1t}	p_{1t}	p_{1t}	p_{1t}
NOINFweak					3.481***		
					(1.179)		
INFweak	-0.768	-1.090	-0.285	-1.346*	2.135*	-1.346	-1.537
	(0.951)	(1.058)	(0.897)	(0.797)	(1.240)	(1.020)	(0.955)
DEFweak	-1.799**	-1.268	-4.277***	-3.136***	0.345	-3.136**	-3.355***
	(0.896)	(1.017)	(0.889)	(0.929)	(1.297)	(1.246)	(1.125)
NOINFstrong	-1.422	-0.823	-1.703	-3.481***		-3.481**	-4.145***
	(1.145)	(1.284)	(1.415)	(1.179)		(1.596)	(1.375)
INFstrong	-3.096***	-3.198***	1.532	0.990	4.471***	0.990	1.328
	(0.896)	(1.028)	(1.022)	(1.036)	(1.404)	(1.300)	(1.434)
DEFstrong	-1.711	-0.238	-2.819*	-2.310	1.171	-2.310	-2.730
	(1.125)	(1.302)	(1.511)	(1.466)	(1.728)	(1.990)	(1.958)
periodNOINFweak					-0.158**		
					(0.0772)		
periodINFweak			-0.0460	0.0500	-0.108	0.0500	0.0532
			(0.0615)	(0.0583)	(0.0839)	(0.0754)	(0.0700)
periodDEFweak			0.236***	0.259***	0.101	0.259***	0.344***
			(0.0661)	(0.0651)	(0.0895)	(0.0888)	(0.0878)
periodNOINFstrong			0.0268	0.158**		0.158	0.272***
			(0.0808)	(0.0772)		(0.0994)	(0.0935)
periodINFstrong			-0.441***	-0.328***	-0.486***	-0.328***	-0.361***
			(0.0861)	(0.0826)	(0.104)	(0.107)	(0.121)
periodDEFstrong			0.105	0.137	-0.0211	0.137	0.301*
			(0.110)	(0.111)	(0.126)	(0.150)	(0.173)
period			-0.215***	-0.297***	-0.139*	-0.297***	-0.236***
			(0.0371)	(0.0341)	(0.0711)	(0.0448)	(0.0426)
male	2.490***	2.809***	2.490***	1.775***	1.775***	1.775***	2.023***
	(0.573)	(0.648)	(0.573)	(0.523)	(0.523)	(0.472)	(0.580)
$coop_{t-1}$				4.152***	4.152***	4.152***	4.031***
				(0.492)	(0.492)	(0.652)	(0.518)
$coll\_first3$				1.978***	1.978***	1.978***	1.959***
				(0.633)	(0.633)	(0.632)	(0.718)
Constant	14.65***	14.43***	16.90***	16.11***	12.63***	16.11***	15.25***
	(0.755)	(0.835)	(0.673)	(0.621)	(1.150)	(0.750)	(0.699)
Observations	3,800	2,660	3,800	3,610	3,610	3,610	2,660
R^2	0.060	0.076	0.130	0.222	0.222	0.222	0.204

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.
Regressions 1, 2, 3, 4a, 4b, and 6: clustered over Subjects. Regression 5: clustered over Groups.
Regressions 1, 3, 4a, 4b, and 5 : full sample. Regressions 2 and 6 : periods 4 - 17.

Table 4: Price Levels

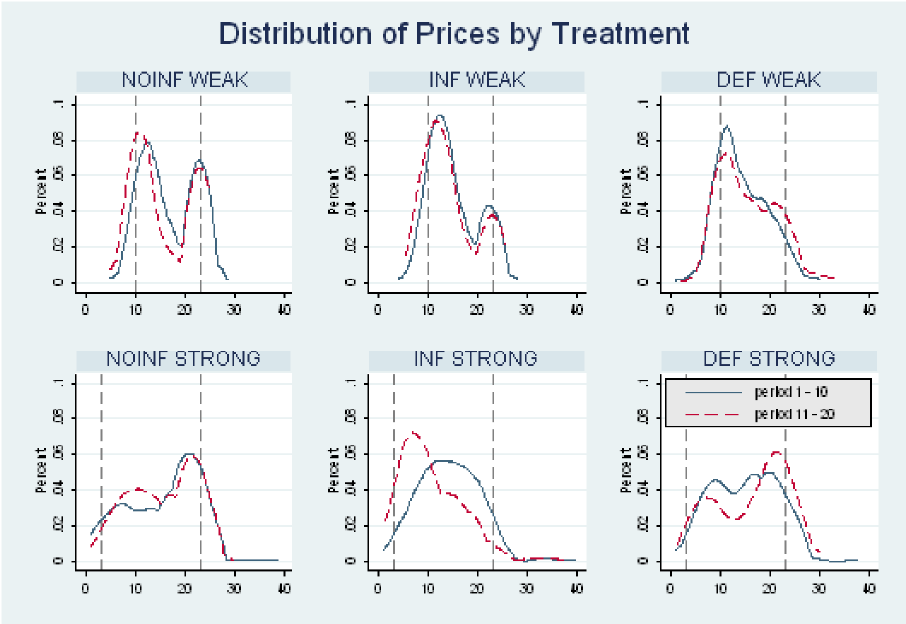

Figure 5: Distribution of prices by treatment

INFstrong is in most specifications.[15]

What about the differences between STRONG and WEAK, holding the inflation regime constant? Without inflation, we find a significant difference only when taking the time trend into account and controlling for cooperation ($coop_t$) and for subjects that played the collusive price in the first 3 periods ($coll\_first3$). Under deflation, we never find any significant difference between WEAK and STRONG, however, we do find a difference for the inflation treatments, mostly due to a more negative time trend in STRONG.[16] That is, we find some evidence for the predicted higher price level in WEAK, but not for our deflation treatments.

Result 2a: *Inflation/deflation.* Prices in the experiment are significantly higher under deflation and weak homogeneity of products, and under inflation and strong homogeneity of products than in the case without inflation.

[15]Specification (4b) is shown with NOINFstrong omitted. Results from Wald tests on NOINFstrong=INFstrong for the other specifications are: (1) n.s.; (2) 10% ; (3) 5% in levels and 0.1% in trends; (5) 1% in levels and 0.1% in trends.

[16]WALD test results for INFweak=INFstrong are: (1) 1% in levels; (2) 5% in levels; (3) 10% in levels and 0.1% in trends; (4) 5% in levels and 0.1% in trends; (5) 10% in levels and 1% in trends; (6) 10% in levels and 1% in trends.

Result 2b: *Weak/strong homogeneity.* Prices in the experiment are significantly higher under weaker homogeneity of products in the case of inflation, and, less robustly, under no inflation, but not under deflation.

5.3 The Effect of Inflation on Price Changes

What influences the decision to change a price? In regression 5, we look at price changes. Our main variable of interest here is Δp_{2t-1}, the price change of the other player in the previous period. An increase, after observing an increase by the other player, can be interpreted as a reward (since a higher price raises the payoff of the other player). Similarly, a decrease, after seeing a decrease in price by the other player, can be seen as a punishment.

There is a significant punishing/rewarding effect in all our specifications which does not depend on the treatment: The treatment interaction terms are never significant at the 10% level with one exception (the interaction with DEFweak is significant at 5% in specification 5b).[17] The regressor Δp_{2t} measures a similar, but different effect: Punishment or reward of *expected* price changes. Of course, here the measurement could be very noisy, since we do not know how well subjects' expectations of the opponent's choice align with real choices. What we find is an effect of much smaller magnitude, but in the different direction: Subjects reward price raises in the previous period, but do not reward expected price raises in this period.[18] For Δp_{2t}, too, there are no treatments effects (not shown).

The results for the treatment dummies confirm the impression provided by regression 4: Price trends are measured by treatment dummies here, whereas they were measured by treatment-period interaction dummies in the regression on price levels.

[17]NOINFweak is the omitted category, but there is no difference in punishment among the STRONG treatments as well. Nor is there a significant difference between the $\Delta p_{2t-1} \times INFweak$ and $\Delta p_{2t-1} \times INFstrong$ dummies, or $\Delta p_{2t-1} \times DEFweak$ and $\Delta p_{2t-1} \times DEFstrong$.

[18]A different explanation of the result would be that subjects want to reward, but have systematically wrong beliefs.

VARIABLES	(1) Δp_{1t}	(2) Δp_{1t}	(3) Δp_{1t}	(4) Δp_{1t}	(5a) Δp_{1t}	(5b) Δp_{1t}	(6) Δp_{1t}
NOINFweak						0.263	
						(0.248)	
INFweak	-0.00889	0.137	-0.0239	0.128	-0.0817	0.182	-0.0817
	(0.0806)	(0.115)	(0.0856)	(0.117)	(0.249)	(0.267)	(0.334)
DEFweak	0.227***	0.348***	0.287***	0.354***	0.280	0.543**	0.280
	(0.0717)	(0.101)	(0.0792)	(0.101)	(0.225)	(0.262)	(0.304)
NOINFstrong	-0.0319	0.0847	-0.0470	0.0792	-0.263		-0.263
	(0.127)	(0.174)	(0.131)	(0.175)	(0.248)		(0.309)
INFstrong	-0.235**	-0.445***	-0.276**	-0.439***	-0.992***	-0.729**	-0.992***
	(0.0936)	(0.138)	(0.114)	(0.152)	(0.270)	(0.289)	(0.347)
DEFstrong	-0.0403	0.0460	-0.0168	0.0714	-0.0112	0.252	-0.0112
	(0.117)	(0.128)	(0.121)	(0.125)	(0.265)	(0.292)	(0.359)
$\Delta p_{2t-1}\times$NOINFweak						0.0117	
						(0.0660)	
$\Delta p_{2t-1}\times$INFweak			0.00236	-0.0199	-0.0165	-0.00485	-0.0165
			(0.0776)	(0.0674)	(0.0622)	(0.0662)	(0.0709)
$\Delta p_{2t-1}\times$DEFweak			0.0981	0.107	0.106	0.118*	0.106
			(0.0599)	(0.0679)	(0.0644)	(0.0677)	(0.0733)
$\Delta p_{2t-1}\times$NOINFstrong			0.0156	-0.0121	-0.0117		-0.0117
			(0.0776)	(0.0696)	(0.0660)		(0.0593)
$\Delta p_{2t-1}\times$INFstrong			0.0710	0.0365	0.0304	0.0420	0.0304
			(0.0703)	(0.0655)	(0.0617)	(0.0660)	(0.0643)
$\Delta p_{2t-1}\times$DEFstrong			0.113	0.119	0.116	0.127	0.116
			(0.0813)	(0.0854)	(0.0798)	(0.0827)	(0.0843)
Δp_{2t-1}		-0.0613***	-0.135***	-0.0620***	-0.0762***	-0.0762***	-0.0762***
		(0.0207)	(0.0242)	(0.0202)	(0.0190)	(0.0190)	(0.0254)
$male$	-0.0336	-0.0846	-0.0257	-0.0842	0.369**	0.369**	0.369**
	(0.0568)	(0.0827)	(0.0603)	(0.0821)	(0.160)	(0.160)	(0.152)
p_{1t}					-0.231***	-0.231***	-0.231***
					(0.0211)	(0.0211)	(0.0242)
Δp_{1t-1}		-0.405***		-0.405***	-0.257***	-0.257***	-0.257***
		(0.0323)		(0.0320)	(0.0297)	(0.0297)	(0.0336)
Δp_{1t-2}		-0.214***		-0.216***	-0.131***	-0.131***	-0.131***
		(0.0310)		(0.0310)	(0.0307)	(0.0307)	(0.0253)
$coll\_first3$		-0.570***		-0.571***	-0.0129	-0.0129	-0.0129
		(0.102)		(0.102)	(0.197)	(0.197)	(0.192)
$coop_{t-1}$		0.681***		0.679***	1.432***	1.432***	1.432***
		(0.145)		(0.143)	(0.191)	(0.191)	(0.239)
Δp_{2t-2}	0.208***	0.155***	0.107**	0.118**	0.107**	0.0952*	0.107**
	(0.0264)	(0.0274)	(0.0447)	(0.0475)	(0.0448)	(0.0523)	(0.0481)
Constant	-0.261***	-0.504***	-0.335***	-0.512***	2.513***	2.250***	2.513***
	(0.0671)	(0.0870)	(0.0757)	(0.0891)	(0.310)	(0.328)	(0.371)
Observations	3,420	3,230	3,420	3,230	3,230	3,230	3,230
R^2	0.047	0.209	0.065	0.211	0.269	0.269	0.269

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Price Changes

Regarding the other control variables, we find a downward trend when play is at higher levels (p_{1t-1}) - this is not surprising, since the Nash price forms a natural selfish lower bound on declining prices. Playing the collusive price ($coll\_first3$) during the first three periods is significant, but only when not controlling for the price level directly. Also unsurprisingly, cooperation has a strong positive effect on the price trend. The result for the lagged own price changes (Δp_{1t-1} & Δp_{1t-2}) is interesting. Price paths are not monotone, but "oscillate": Having raised the price in one of the previous two periods predicts not another increase but a reduction.

Result 3a: *Reward and Punishment* Subjects reward price increases by their opponents and punish price decreases. This rewarding and punishing behavior does not differ across treatments.

Result 3b: *Price Paths* Price paths in the experiment are not monotone, but have a tendency to oscillate.

5.4 The Effect of Inflation on Welfare

Since we derive our market demands from a representative agent model, we can calculate welfare as the utility of this representative agent. Naturally, utility is correlated with pricing by individual firms but it is neither linear nor monotone in prices. Utility is not the same as consumer surplus. Since the agent owns all firms, firm profits relax the agent's budget constraint and therefore his utility. What is "good" for firms, namely coordinating on high prices, is often "bad" for welfare. For the consumer, anything that stops firms from coordinating on high prices is good.

Figure 6 depicts the utility levels in all six treatments over time. By construction ($du/d\theta < 0$) utility is lower in the STRONG treatments. We, therefore, restrict our discussion to comparisons between NOINF, INF and DEF within each level of homogeneity. The picture is mostly the reverse of what we saw in figure 4.

	(1)	(2)	(3)	(4a)	(4b)	(5)	(6)
	period 1-20	period 4-17	period 1-20	period 1-20	period 1-20	period 1-20	period 4-17
VARIABLES	u_t	u_t	u_t	u_t	u_t	u_t	u_t
NOINFweak					13.40*		
					(7.156)		
INFweak	7.640	9.623	3.843	12.73**	26.14***	12.73	10.71
	(7.497)	(8.415)	(6.751)	(6.309)	(7.556)	(8.676)	(7.645)
DEFweak	14.18**	9.348	34.09***	25.81***	39.21***	25.81***	24.45***
	(6.994)	(7.999)	(6.524)	(6.863)	(8.010)	(9.546)	(8.086)
NOINFstrong	-31.15***	-35.38***	-24.19**	-13.40*		-13.40	-14.33**
	(8.173)	(9.105)	(9.561)	(7.156)		(9.906)	(6.830)
INFstrong	-17.75***	-16.52**	-27.98***	-23.37***	-9.972	-23.37***	-25.63***
	(6.083)	(6.797)	(6.900)	(6.239)	(7.566)	(8.489)	(6.764)
DEFstrong	-30.25***	-39.74***	-11.82	-16.00*	-2.601	-16.00	-18.11
	(7.666)	(8.752)	(9.233)	(8.510)	(9.492)	(11.82)	(12.21)
periodNOINFweak					1.478***		
					(0.402)		
periodINFweak			0.362	-0.443	1.035**	-0.443	-0.203
			(0.436)	(0.419)	(0.432)	(0.593)	(0.521)
periodDEFweak			-1.896***	-2.063***	-0.585	-2.063***	-2.525***
			(0.474)	(0.471)	(0.496)	(0.668)	(0.613)
periodNOINFstrong			-0.663	-1.478***		-1.478**	-1.677***
			(0.463)	(0.402)		(0.568)	(0.389)
periodINFstrong			0.975**	0.0828	1.561***	0.0828	0.323
			(0.464)	(0.427)	(0.457)	(0.605)	(0.509)
periodDEFstrong			-1.755***	-1.959***	-0.481	-1.959**	-2.538**
			(0.602)	(0.598)	(0.617)	(0.848)	(1.061)
period			1.793***	2.386***	0.908***	2.386***	1.763***
			(0.285)	(0.265)	(0.312)	(0.375)	(0.310)
$male$	-15.91***	-18.60***	-15.91***	-10.87***	-10.87***	-10.87***	-12.67***
	(4.104)	(4.662)	(4.107)	(3.657)	(3.657)	(3.297)	(4.089)
$coop_{t-1}$				-31.24***	-31.24***	-31.24***	-31.07***
				(3.555)	(3.555)	(4.857)	(3.759)
$coll\_first3$				-13.45***	-13.45***	-13.45***	-13.88***
				(4.568)	(4.568)	(4.473)	(5.184)
Constant	450.2***	452.8***	431.3***	437.4***	424.0***	437.4***	446.7***
	(5.807)	(6.570)	(5.186)	(4.750)	(6.302)	(6.234)	(5.214)
Observations	3,800	2,660	3,800	3,610	3,610	3,610	2,660
R^2	0.196	0.237	0.247	0.364	0.364	0.364	0.372

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.
Regressions 1 2 3 4a 4b 6: clustered over Subjects Regression 5: clustered over Groups
Regressions 1 3 4a 4b 5 : full sample Regressions 2 and 6 : periods 4-17

Table 6: Utility

The utility regressions are presented in table 6. Our main specification is (4a). As above, we change the omitted category in (4b). (5) and (6) are robustness checks, with clustering on group instead of subject level and only the middle periods respectively. In the control variables, we see a clear effect for male firms (*male*), cooperating firms ($coop_t$) and firms who initially play the collusive price ($coll\_first3$). All three lower utility.

In the WEAK treatments, we find a mostly significant higher utility for the case of deflation. This effect is significant in all specifications apart from (2) and, due to the negative time trend, especially strong in the initial periods. The effect for inflation is less robust. We do find a significantly (5%) lower utility in our main specification, but not in specifications (1) and (2) nor in specifications (5) and (6). The picture is similar in the STRONG treatments. There, however, it is the INFstrong treatment that is significantly different from the NOINF case, due to its positive time trend.[19] DEFstrong, on the other hand does not significantly differ from NOINFstrong.

Result 4a: *Welfare* Deflation coupled with weak homogeneity of products, and inflation, coupled with strong homogeneity, raise welfare in the experiment compared to no inflation.

Result 4b: *Welfare and Cooperation* Successful cooperation by firms lowers welfare in the experiment.

6 Conclusion

We report results from an experimental Bertrand duopoly with differentiated products where firms are exposed to inflation and deflation. Our main result is that infla-

[19] Wald tests for INFstrong = NOINFstrong in levels and trends in specifications: (1) 5% in levels; (2) 5% in levels; (3) n.s. in levels, 1% in trends; (4) n.s. in levels, 1% in trends; (5) n.s. in levels, 5% in trends; (6) n.s. in levels, 1% in trends.

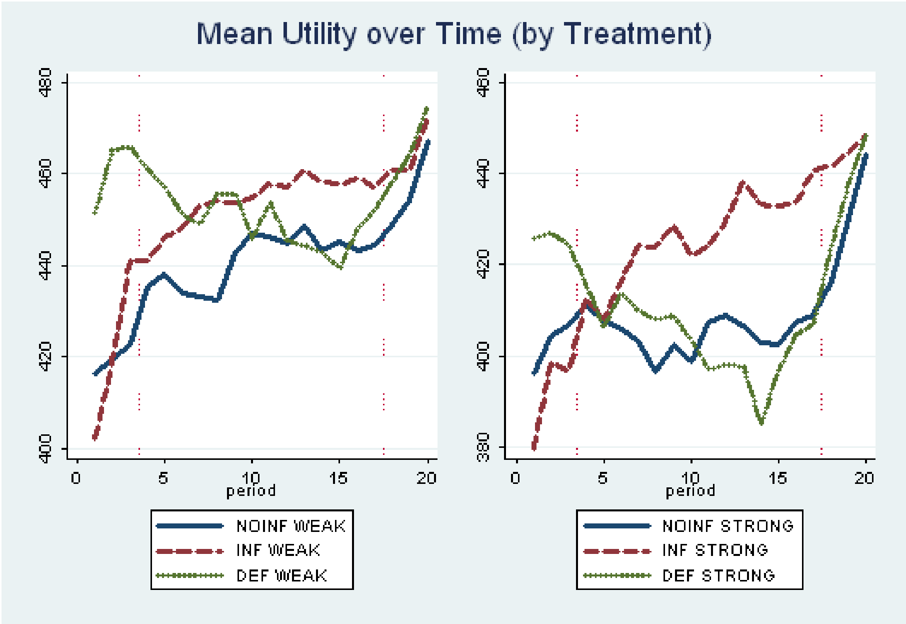

Figure 6: Utility over time

tion complicates cooperation. Independently of the market structure, cooperation is lower in INF and DEF compared to NOINF. Interestingly, some firms cooperate in nominal instead of real terms. This may be interpreted as a sign of money illusions. Money illusion can also explain why real prices have a slightly positive trend in DEF whereas they have a strong negative trend in INF. Punishment does not appear to differ between treatments. Using utility as a measure of welfare, we find that cooperation by firms lowers welfare. Depending on the market structure, inflation and deflation may significantly raise welfare. Welfare in the NOINF treatments is never above welfare generated in the INF and DEF treatment.

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