Money Illusion and Coordination Failure

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Abstract: Economists long considered money illusion to be largely irrelevant. Here we show, however, that money illusion has powerful effects on equilibrium selection. If we represent payoffs in nominal terms, choices converge to the Pareto inefficient equilibrium; however, if we lift the veil of money by representing payoffs in real terms, the Pareto efficient equilibrium is selected. We also show that strategic uncertainty about the other players' behavior is key for the equilibrium selection effects of money illusion: even though money illusion vanishes over time if subjects are given learning opportunities in the context of an individual optimization problem, powerful and persistent effects of money illusion are found when strategic uncertainty prevails.

Keywords: money illusion, coordination failure, equilibrium selection, multiple equilibria, coordination games.

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1. Introduction

The rational expectations revolution in the 1970's eradicated the study of money illusion, and its implications, from economists' research agenda for a long time. The rational expectations approach assumes that people are rational; and since rational individuals do not exhibit illusions there is nothing to study. Money illusion was a concept to be mentioned in courses about the history of economic thought but not in actual research endeavors (Howitt 1989). In fact, a good recipe to get theory papers rejected by leading journals was to assume that money illusion affected individuals' behavior (Tobin 1972).[1] More recently, however, some economists seem to be willing to reconsider the relevance of money illusion in economics, partly because of evidence that nominal wages and prices seem to be rigid (Agell and Bennmarker 2002; Akerlof 2002; Bewley 1999; Blinder et al. 1998; Campbell and Kamlani 1997; Fehr and Tyran 2001; Howitt 2002; Kahn 1997; Kahneman, Knetsch and Thaler 1986; Shafir, Diamond and Tversky 1997).

A powerful intuitive argument supports the view that money illusion is largely irrelevant for economics, however: the illusion has detrimental effects on peoples' economic well-being and they thus have a strong incentive to make illusion-free decisions. Therefore, people will ultimately make illusion-free decisions, implying that money illusion has little or no impact on aggregate outcomes – at least in the long run. It is the purpose of this paper to show that this argument can be seriously misleading because it neglects the strategic repercussions of money illusion. We show experimentally that even if learning in the context of an individual optimization problem does eventually remove individuals' money illusion, there can be large permanent effects of money illusion in a strategic environment. These effects arise because money illusion induces individuals to coordinate on inferior equilibria. Once individuals are locked in a bad equilibrium there is no escape, meaning that they experience permanent economic losses relative to the efficient equilibrium. Thus, even if individual-level money illusion is only a temporary phenomenon in an individual optimization task, it can cause permanent real effects in a strategic setting by coordinating people on inefficient equilibria.

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[1] James Tobin (1972: 3) nicely described this situation: "An economic theorist can, of course, commit no greater crime than to assume money illusion". Tobin himself believed that money illusion is relevant.

A large literature now indicates that a non-negligible share of individuals is typically prone to certain forms of bounded rationality (Camerer 1995; Costa-Gomes, Crawford and Broseta 2001; Crawford 1997; Goeree and Holt 2001; Kahneman 2003; Stahl and Wilson 1995; Weizsäcker 2003). By definition, boundedly rational behavior is suboptimal behavior, i.e., an agent with a suboptimal response earns less than a fully rational agent for the other players' given actions. Thus, the intuitive argument that speaks against the relevance of money illusion also speaks against the relevance of any other form of bounded rationality. Our results suggest, however, that the existence of boundedly rational agents may have strategic repercussions that may, in turn, render bounded rationality relevant for aggregate outcomes, even if individual learning in a non-strategic context could, in principle, remove the suboptimality of individuals' choices. Claims about the relevance or irrelevance of suboptimal behaviors for aggregate outcomes therefore require a careful analysis of the agents' strategic interactions and cannot solely be made on the basis of intuitions about the suboptimality of individual behaviors.

Our results are based on a series of experiments that implemented a strategic pricing game with 3 Pareto-ranked equilibria. The experimental design is based on the characterization of money illusion as a framing effect (Shafir, Diamond and Tversky 1997; Fehr and Tyran 2001). Money illusion occurs when objectively identical situations cause different behavioral patterns depending on whether the situation is framed in nominal or in real terms. Accordingly, we capture the impact of money illusion by comparing behavior in a condition in which payoff information is provided in real terms to behavior in a condition in which payoff information is provided in nominal terms. In the Pareto-dominant equilibrium, each subject earns the highest *real* payoff but the *nominal* payoff is highest for each subject in a different equilibrium. Thus, if we give subjects payoff information in nominal terms they may exhibit money illusion by taking nominal payoffs as a proxy for real payoffs and coordinate on the equilibrium with highest nominal payoffs. In contrast, if we give subjects payoff information in real terms, the situation is transparent and it is clear that they earn the most in the Pareto-dominant equilibrium. This means that money illusion is ruled out under the real payoff representation while money illusion can play a role under the nominal payoff representation by coordinating subjects on a Pareto-inferior equilibrium. Therefore, if money illusion has no or little relevance, subjects should play the Pareto-dominant equilibrium both under the nominal and the real representation of payoffs.

The actual behavior of experimental subjects contrasts sharply with this prediction. Under the real payoff representation, most subjects start to play at or close to the Pareto-dominant equilibrium and nearly all subjects quickly converge to this equilibrium. In contrast, not a single subject plays this equilibrium under the nominal payoff representation. In this condition, the vast majority of subjects start to play far away from the Pareto-dominant equilibrium and they then converge to the inefficient equilibrium with high nominal payoffs. As a consequence, subjects' real earnings under the nominal payoff representation are on average almost 50 percent lower than under the real payoff representation. These results illustrate that money illusion may be a powerful source of coordination failure, causing permanent real effects.

In a next step, we examined the extent to which individual-level money illusion causes the failure to coordinate on the efficient equilibrium. This question is interesting because coordination failure in a strategic setting may also arise from the belief that the other players have money illusion. If everyone believes that the other players have money illusion and that, therefore, the others coordinate on a Pareto-inferior equilibrium with high nominal payoffs, it is in everyone's interest to play this equilibrium as well.[2] To isolate these (indirect, expectations-driven) effects of strategic interaction from the (direct) effects of individual-level money illusion, we transformed the strategic game into an individual optimization task. We implemented a treatment in which each subject plays against pre-programmed computers who play a best reply to whatever the human player chooses. In addition, subjects are informed about the computers' response to each of their feasible choices. This means that subjects are no longer in a truly strategic situation because no strategic uncertainty exists with regard to the other players' choices. Subjects can maximize their payoffs by unilaterally choosing the Pareto-dominant equilibrium, taking the computers' responses into account. If subjects are able to solve this optimization problem better under the real payoff representation than under the nominal payoff representation, we have evidence for individual-level money illusion.

The data indicates that a considerable number of subjects indeed suffer from individual-level money illusion during the first half of the experiment. Towards the end of the experiment, most subjects learn to make the optimal decision by choosing the efficient equilibrium. This observation shows that money illusion indeed vanishes at the individual

[2] This might under some conditions even happen if all agents are fully rational (see Chwe 1999 discussion).

level if subjects repeatedly face the individual optimization task. However, repeatedly making the same decision in a strategic setting, where subjects face other human players whose actions have to be predicted, does not prevent the vast majority of subjects from coordinating on an inferior equilibrium. Apparently, it is one thing to pierce the veil of money in an individual optimization problem and another thing to escape the impact of money illusion in a strategic setting.

A few other papers have examined the role of money illusion in recent years. Shafir, Tversky and Diamond (1997) provided interesting questionnaire evidence indicating that money illusion affects both people's preferences as well as their perceptions of the constraints they face. More recently, field evidence has provided empirical support for the effects of money illusion on donations (Kooreman, Faber and Hofmans 2004; Cannon and Cipriani 2004), housing markets (Genesove and Mayer 2001, Brunnermeier and Julliard 2005) and stock markets (Cohen, Polk and Vuolteenaho 2005).

Fehr and Tyran (2001) have shown that money illusion causes asymmetric price adjustment in response to anticipated negative and positive monetary shocks. Money illusion strongly retards the adjustment of nominal prices to a unique equilibrium after a negative monetary shock, while prices quickly adjust to the new unique equilibrium after a positive shock. However, none of the previous papers has considered the effects of money illusion on coordination failure, i.e., they did not examine whether money illusion has permanent effects on subjects' behavior. In addition, we go beyond previous work by showing that, despite a substantial level of initially prevailing money illusion, this illusion indeed vanishes if the decision about equilibrium selection is transformed to a repeated individual optimization problem. However, as our results on coordination failure show, this fact is fully compatible with powerful and persistent effects of money illusion in a strategic setting.

We believe that our paper contributes to the debate about equilibrium selection principles in games with multiple equilibria. This debate has a strong focus on the principles of payoff dominance and risk dominance (Harsanyi and Selten 1988; Cooper et al. 1990; van Huyck, Battalio and Beil 1991; Cooper 1999; Anderson, Goeree and Holt 2001; Camerer 2003; Heinemann, Nagel and Ockenfels 2004). The principle of payoff dominance is typically interpreted as implying that equilibria, which dominate in terms of *real* payoffs, may have a particular attraction power. To our knowledge, no contributor in this debate has yet explicitly differentiated between nominal payoff dominance and real payoff dominance. The evidence presented in this paper shows, however, that this distinction is crucial. High nominal payoffs, even though associated with low real payoffs, seem to attract a considerable number of subjects. This suggests that the principle of *nominal* payoff dominance should also be taken into account in future discussions about equilibrium selection. Equilibria with high nominal payoffs may be focal points with a strong attraction power.

In the next section we describe the experimental design in more detail. Section 3 reports the results of our experiments. Section 4 presents the results of a robustness check where we examine whether strategic teaching mitigates coordination failure due to money illusion. Section 5 summarizes our results and concludes the paper.

2. Experimental Design

To study the effects of money illusion on equilibrium selection, we designed a symmetric n-player pricing game with three Pareto-ranked equilibria. In this game, each subject simultaneously chose a price $P_i \in \{1, 2, \ldots, 30\}$. We implemented a symmetric game because we thought that this would simplify equilibration. In addition, we also chose a simple payoff structure where each subjects' real payoff depended only on the subject's own price and on the average price $\bar{P}_{-i}$ of the *other* n-1 players. This was convenient as it allowed us to represent each subject's payoff in a payoff matrix (see Appendix A). The payoff matrix showed the subject's payoff for any combination of the own price P_i and the others' average price $\bar{P}_{-i}$. Since the game was symmetric, each of the n players in the group had the same payoff table, which was common knowledge among the players.

The three equilibria of the game are described in Table 1 below. Equilibrium A arises when each subject chooses $P_A = 4$, leading to a real payoff of $\pi_A = 28$ for each player. In equilibrium B, the price is $P_B = 10$ causing a real payoff of 5. Equilibrium C arises when each subject chooses $P_C = 27$, leading to a real payoff $\pi_C = 21$. The players' best reply functions had a non-negative slope: if $\bar{P}_{-i}$ increased it was, in general, also in the interest of player i to increase his price. For every given level of $\bar{P}_{-i}$ player i had a unique best reply. Since the game is symmetric, the equilibria in this game in $(P_i, \bar{P}_{-i})$ space are located at the intersection of the best reply function with the 45-degree line. If subjects have adaptive expectations and play a best reply to their expectation, equilibrium A and C are stable, and equilibrium B is unstable.

***Table 1*:** The equilibria in the price-setting game

Equilibrium	Equilibrium price level	Real equilibrium payoff	Nominal equilibrium payoff
A	$P_A = 4$	$\pi_A = 28$	$P_A\pi_A = 112$
B	$P_B = 10$	$\pi_B = 5$	$P_B\pi_B = 50$
C	$P_C = 27$	$\pi_C = 21$	$P_C\pi_C = 567$

Our price-setting game was implemented in four different treatment conditions (see Table 2).[3] The treatments differed only with respect to the presentation of the payoffs and whether subjects played against other subjects or against *n*-1 pre-programmed computers. The real payoff functions were identical across treatments, i.e. the subjects earned the same real payoff for any combination of P_i and $\overline{P}_{-i}$, regardless of the treatment condition. Subjects' payoff matrix under the real payoff representation showed their payoff in real terms, while their payoff matrix showed their nominal payoff under the nominal payoff representation.[4] To compute the real payoff under the nominal representation, subjects had to deflate their nominal payoff by the prevailing level of $\overline{P}_{-i}$.[5] This was explained to the subjects in detail in the experimental instructions (see appendix A).

The behavioral differences across treatments with a nominal and a real payoff representation capture the effects of money illusion. Historically, economists have defined money illusion as a violation of the homogeneity postulate. According to this definition, money illusion prevails if demand and supply functions are not homogeneous of degree zero in all nominal prices (Leontief 1936). If all nominal prices change by the same percentage, people's opportunity set remains constant, so that rational individuals will make the same decisions as before the price change. Therefore, the historical definition is based on the

[3] The results of an additional treatment are reported in section 3.1.

[4] Appendix A presents the payoff matrix for the real and the nominal case.

[5] We chose the average price of the other *n* -1 players as the deflator to make the subjects' task easier compared to the case where the overall average price of the group is the deflator. To be able to play a best reply, subjects have to predict $\overline{P}_{-i}$. Therefore, they have to deflate their nominal payoff with the predicted value of $\overline{P}_{-i}$ to compute their expected real payoff.

intuition that rational individuals will make identical choices in objectively identical situations (when the objective consumption opportunities remain constant), regardless of the fact that nominal prices have changed: The nominal representation of a situation does not affect the behavior of rational individuals; if it does, individuals suffer from money illusion. In terms of our treatment conditions, this means that money illusion is absent if there are no behavioral differences across the nominal and the real payoff representation.

The main purpose of our pricing game was to create a conflict between two potentially important equilibrium selection principles – the principle of real payoff dominance and the principle of nominal payoff dominance. This conflict between nominal and real payoff dominance is illustrated in Table 1, where the real payoff is highest for every player in equilibrium A but the nominal payoff is highest in equilibrium C. In fact, the payoff vector in equilibrium A is the only Pareto efficient point in the payoff space which renders equilibrium A particularly attractive. The principle of real payoff dominance predicts that equilibrium A is selected regardless of whether payoffs are represented in nominal or in real terms because the principle assumes that subjects can pierce the veil of money under the nominal representation. In contrast, the principle of nominal payoff dominance predicts that equilibrium A is selected when payoffs are represented in real terms while equilibrium C is selected under the nominal payoff representation. If we indeed observe that players permanently coordinate on equilibrium A under the real representation and on equilibrium C under the nominal representation, we not only have evidence for the principle of nominal payoff dominance but also for the striking claim that money illusion may have permanent real effects.

It should be noted that we chose the details of our pricing game with the pupose of creating a tension between nominal and real payoff dominance. This tension results from the fact that the price level is an (endogenous) nominal variable, and increases by more from equilibrium A to C than the real payoff falls. We do not claim that the details of our pricing game capture common features of oligopolistic pricing games. For example, multiple equilibria do not necessarily occur in pricing games and, if they do, a low-price equilibrium does not necessarily pareto-dominate other equilibria.[6] Therefore, our design should be seen

[6] However, it should be noted that such a situation is possible in principle. For example, Adriani et al. (2003) claim that the introduction of the Euro (a type of nominal framing that differs from ours) has served as a coordination device, inducing a shift of the EU-restaurant industry to a high-price equilibrium.

as a clear-cut testing ground for whether money illusion is a coordination device when coordination is the main issue.

When the subjects faced pre-programmed computers, we told them the computers' aggregate reply, i.e., the level of $\bar{P}_{-i}$ the computers choose for each of their feasible price choices. Thus, each subject was a "Stackelberg-leader" vis à vis the *n*-1 computers. Each computer was programmed to play a best reply to the subject's choice and to the other computers' choices. Note that since subjects' knew the computers' response to each of their feasible price choices they faced no strategic uncertainty.[7] To maximize their payoff, they had to solve an individual optimization problem taking the computers' aggregate response into account. The treatments with computerized opponents therefore measure the extent to which subjects can solve this individual optimization problem by choosing the efficient equilibrium A.[8]

Table 2: Experimental Design

	Payoff representation in real terms	**Payoff representation in nominal terms**
Human opponents	Real treatment with human opponents (**RH**): 13 groups with *n* human players	Nominal treatment with human opponents (**NH**): 26 groups with *n* human players
Pre-programmed computerized opponents	Real treatment with computerized opponents (**RC**): 23 groups with 1 human and *n*-1 computerized players in each group	Nominal treatment with computerized opponents (**NC**): 22 groups with 1 human and *n*-1 computerized players in each group

[7] The absence of strategic uncertainty implies that the outcome space is larger in the strategic game than in the individual optimization task. While the outcome space is 30 price choices of *i* x 30 average price choices by – *i* in the strategic game, it is only 30 price choices by *i* x 1 best reply by –*i*.

[8] In standard oligopolistic pricing games, the Stackelberg and Cournot solutions do not coincide. We have designed the pricing game in such a manner that they do coincide. It is precisely this design feature that

Table 1 shows that equilibrium A dominates the other two equilibria in real terms. However, subjects may not be able to play the best equilibrium immediately. They may have to discover the best equilibrium when facing human opponents, or their optimal strategy when facing computerized opponents. For this reason, we repeated the same game for 30 periods in each treatment condition. When subjects faced human opponents, the group composition remained constant throughout the 30 periods. In all conditions, subjects were informed about the actual average price of the other players, $\bar{P}_{-i}$, and about their own real payoff at the end of each period. Then they entered the next period where they again chose their prices simultaneously.

An important purpose of our treatment conditions was to isolate the role of money illusion as an equilibrium selection device from other boundedly rational forms of equilibrium selection. The two major conditions in our design are the Real treatment with human opponents (RH) and the Nominal treatment with human opponents (NH). The difference between these two conditions demonstrates the overall effect of money illusion on equilibrium selection. Money illusion can play no role in the RH because by representing payoffs in real terms the veil of money is already lifted. Money illusion could cause behavioral effects in the NH if, for example, subjects take nominal payoffs as a proxy for real payoffs. Thus, if significantly more subjects play the efficient equilibrium in RH compared to NH, we have evidence that money illusion affects equilibrium selection.

The next task then is to examine the mechanism that leads to the selection effects of money illusion. In principle, money illusion can effect equilibrium selection in two ways. First, there may be direct effects of money illusion on equilibrium selection: subjects may play the inefficient equilibrium C because they exhibit individual-level money illusion. Second, there may be indirect effects arising from subjects' expectations about other players' money illusion. Even if no player exhibits individual-level money illusion, most subjects may nevertheless have an incentive to play the inefficient equilibrium C if they believe that a sufficient number of other players exhibit money illusion and will, therefore, play equilibrium C. Our treatments with computerized opponents enable us to isolate the extent to which individual-level money illusion directly affects equilibrium selection.

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enables us to isolate the direct and indirect (i.e. expectations-driven) effects of money illusion on coordination.

In the RC, the real treatment with computerized opponents, we measure the extent to which individual-level irrationality other than money illusion affects equilibrium selection. In the RC, any deviation from the efficient equilibrium A denotes a non-optimal individual choice. In the NC, subjects face an individual optimization problem under the nominal payoff representation. The difference in subjects' price choices between the RC and the NC treatment informs us to what extent individual-level money illusion contributes to mis-coordination. If fewer subjects are able to coordinate on the efficient equilibrium in the NC than in the RC, we have evidence that individual-level money illusion is a source of mis-coordination.

Finally, our design allows for two other important comparisons: first, the comparison between the RC and the RH and, second, the comparison between the NC and the NH. The difference between RC and RH measures whether individual irrationality other than money illusion is magnified or mitigated by strategic interaction with human players. If, for example, subjects play the efficient equilibrium more often in the RH than in the RC, we can conclude that strategic interaction with human players weakens the impact of individual irrationality other than money illusion on equilibrium selection.

A particularly interesting result would be obtained if individual irrationality other than money illusion played no or almost no role in RH. In this case, the total amount of mis-coordination in the NH could be attributed to the direct and indirect effects of money illusion. Moreover, the difference between NC and NH in this case can be attributed to the indirect effects of money illusion arising solely through strategic interaction with human players.[9]

The experiments were conducted with the software Z-tree (Fischbacher 1999). A total of 174 undergraduate students from the Universities of Zürich, St. Gallen, and Innsbruck participated in the treatments described in Table 2. On average, an experimental session lasted

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[9] More generally, the indirect effects of money illusion can be measured by comparing the price difference between RH and RC with the price difference between NH and NC. The difference between NH and NC measures the indirect effects of all individual irrationalities because both money illusion and other individual irrationality can play a role in the nominal treatments. The difference between RH and RC measures only the indirect effects of individual irrationality that have nothing to do with money illusion. Thus, by subtracting the price difference between RH and RC, $P^{RH} - P^{RC}$, from the price difference between NH and NC, $P^{NH} - P^{NC}$, we isolate the indirect effects of money illusion on prices. Note, that if $P^{RH} - P^{RC} \leq 0$, the indirect effects of money illusion are given by $(P^{NH} - P^{NC}) - (P^{RH} - P^{RC})$ which is greater than or equal to $P^{NH} - P^{NC}$. Therefore, the whole difference between P^{NH} and P^{NC} can be attributed to the indirect effects of money illusion.

45 minutes and subjects earned CHF 31.20 (≈ US $ 25). Subjects were randomly allocated to groups of $n = 5$ or $n = 6$ players. They received written instructions explaining the procedures of the experiment, and nominal or real payoff matrices depending on the treatment condition (see Appendix A). The calculation of real payoffs based on the nominal payoffs shown on the payoff matrix was carefully explained in the NC and the NH. Subjects were allowed to ask questions before the experiment started. In each period they had to simultaneously choose a price $P_i \in \{1, 2, \ldots, 30\}$. In addition, they had to indicate their expectation of $\bar{P}_{-i}$ in the treatments with human opponents in each period.

3. Results

We start our discussion of results with the comparison of the NH and the RH. We summarize this comparison in

Result 1: In the Nominal treatment with human opponents (NH), initially chosen prices are high and all groups eventually converge to the inefficient equilibrium C, whereas initially chosen prices are low and all groups converge to the efficient equilibrium A in the Real treatment with human opponents (RH).

Figure 1 and Tables 3 and 4 provide support for Result 1. Figure 1 and Table 3 show the evolution of average prices across NH and RH. The figure illustrates that a large gap in average prices across treatments already arises in period 1 – the average price in the NH is 20.1 in the first period whereas it is 8.4 in the RH. This difference is highly significant ($p <$ .0001) according to a Mann-Whitney test using individual prices as a unit of observation. It is noteworthy that in RH almost two thirds (63.5 percent) of all subjects chose exactly $P_A = 4$ in the first period while not a single subject chose this price in NH (see first line of Table 4).

Moreover, the average price quickly converges towards the efficient equilibrium $P_A = 4$ in the RH whereas a steady convergence to the inefficient equilibrium $P_C = 27$ occurs in the NH.[10] From period 4 onwards, the average price in the RH is always extremely close to $P_A =$

[10] Period-wise Mann-Whitney tests with group average prices as the units of observation indicate significant

4 and the hypothesis that subjects play the efficient equilibrium can only be rejected (at the 10 percent significance level) in periods 1 and 2.[11]

Table 4 presents the percentage of subjects who play the efficient equilibrium. This table makes clear how radically different individuals' price choices in the NH and the RH are. Throughout the 30 periods, there is not a single case in which a subject chose the efficient equilibrium in the NH, while 64 percent of the subjects already opted for $P_A = 4$ in period 1 in the RH. From period 7 onwards more than 90 percent of the subjects chose the efficient equilibrium in the RH. In contrast, a relatively slow convergence to the inefficient equilibrium $P_C = 27$ occurs in the NH. Initially, only 18 percent of the subjects chose $P_C = 27$ but 38 percent already played this equilibrium in period 10, and reaching 68 percent in period 20 and 84 percent in period 30. The reason for the slower equilibration in the NH is that some subjects seem to have understood that there is a better equilibrium. These subjects deliberately chose occasionally very low prices to induce the other group members to also choose low prices (see section 3.1. for a discussion of strategic teaching).

Naturally, the divergence between the NH and the RH is reflected in the real payoffs the subjects earned. Columns 5 and 6 of Table 3 show that subjects earn considerably less in the NH than in the RH in all periods. Recall from Table 1 that the real equilibrium payoff in the efficient equilibrium is 28, while if subjects play the inefficient equilibrium C they only earn 21. There is rarely a period in which subjects do not earn at least 10 units more on average in the RH. This indicates that the mis-coordination in the NH goes beyond the fact that subjects coordinated on an inefficient equilibrium. The large payoff difference is partly caused by the slower convergence towards the equilibrium, i.e., by the larger incidence of disequilibrium play in the NH.

The striking price divergence across the NH and the RH suggests that money illusion has powerful effects on equilibrium selection. The mere fact that payoffs are represented in nominal terms induces subjects to predominantly choose the equilibrium with the higher nominal but the lower real payoff. How can this fact be explained? The movement of price

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differences ($p < .001$) between RH and NH in every period.

[11] This is indicated by period-wise t-tests with group average prices as the units of observation. From period 3 onwards the p-values for the null hypothesis of equilibrium play exceed the 10 percent level.

expectations across treatments provides a first hint (see the graphs with empty circles and diamonds in Figure 1). Average price expectations were clearly different in RH and NH already in the first period, and the average price path in both the RH and the NH closely tracks subjects' average expectations of $\overline{P}_{-i}$. Since most subjects played a best reply to their expectation about $\overline{P}_{-i}$ this expectation is a decisive determinant of subjects' price choices.[12] Therefore, the strong divergence of the subjects' price expectations, which was already apparent in period 1, is of great interest – they expected on average a value of 20.0 for $\overline{P}_{-i}$ in the NH, whereas they expected a value of 8.2 in the RH. Not a single subject (out of 77) expected $\overline{P}_{-i}$ = 4 in period 1 in the NH and only 1 subject expected $\overline{P}_{-i}$ = 5. In contrast, 48.1 percent (25 out of 52) held equilibrium expectations of $\overline{P}_{-i}$ = 4 in the RH and an additional 11.5 percent (6 out of 52) expected $\overline{P}_{-i}$ = 5 in period 1. These differences in expectations are highly significant (Mann-Whitney test, $p < .0001$).

We may consider the within-group variance of prices, expectations and expectation errors as proxies for strategic uncertainty in a group. The reason is that if a group is perfectly coordinated, i. e., if subjects have equilibrium expectations and play best replies to their expectations, , the respective variances will be zero. Note that these proxies converge to zero when individual expectations and actions converge, which holds irrespective of which equilibrium a group coordinates on. Indeed, all three proxies converge to zero in the RH, and all proxies tend to be higher in NH than in RH. For example, the variance of price choices (averaged over all groups) is 59.5 in NH and 46.6 in RH in period 1, falls to 25.7 in NH and 4.0 in RH in period 3, and is still at 18.1 in NH but is close to zero (0.8) in RH after 5 periods. Similarly, the variance of expectations (averaged over all groups) is 42.6 and 37.5 in period 1, 19.1 and 5.2 in period 3, and 10.0 and 6.2 in period 5 in NH and RH, respectively. The variance of expectation errors is 66.7 and 60.0 in period 1, 29.6 and 5.3 in period 3, and 16.4 and 5.6 in period 5 in NH and RH, respectively.

So far our analysis suggests that the nominal representation of payoffs causes significantly higher price expectations which in turn induce subjects to choose significantly higher prices in the NH. This raises the question whether there were indeed subjects who

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[12] If a subject is uncertain about the true value of $\overline{P}_{-i}$ the calculation of the best reply requires, of course, taking the subjective distribution of $\overline{P}_{-i}$ and not only the expectation of $\overline{P}_{-i}$ into account. However, for simplicity, in the following we will use the term "best reply" in the sense of a best reply to the expectation of $\overline{P}_{-i}$.

failed to see through the veil of money or whether the higher expectations in the NH were solely rooted in subjects' beliefs about other players' money illusion. To examine the existence of individual-level illusion we turn to

Result 2: Only a minority of subjects initially plays the efficient equilibrium in the Nominal treatment with computerized opponents (NC), whereas a large majority of subjects plays the efficient equilibrium from the beginning in the Real treatment with computerized opponents (RC). However, the differences between the NC and the RC become small and insignificant over time.

We provide support for Result 2 by means of Figure 2 and Tables 3 to 5. In Figure 2, we depict the evolution of average prices in the RC and the NC. To facilitate comparison with the previously discussed treatments, we also included the average prices of the RH and the NH. Figure 2 and Table 3 show that the average price in the NC in the first 15 periods lies between 4 and 12 units higher than in the RC. Yet, the price difference diminishes to only 2-3 units from period 16 onwards. A similar picture emerges if we look at the frequency with which the efficient equilibrium is played (see Table 4). Almost two thirds of all subjects already play the efficient equilibrium in period 1 of the RC and the frequency of equilibrium play from period 10 onwards is rarely below 80 percent. In the NC, only 22.7 percent of the subjects play the efficient equilibrium in period 1 and it takes 16 periods until roughly two-thirds of the subjects play $P_A = 4$. Finally, we also conducted period-wise Mann Whitney tests of the null hypothesis that subjects' price choices are identical across the RC and the NC. Table 5 indicates that the null hypothesis can be rejected for the majority of the first 15 periods. From period 16 onwards, the null hypothesis can no longer be rejected.

Because conditions NC and RC are individual optimization tasks, it is costless for subjects to "jump" from one equilibrium to the other across periods. A sequence of choices close to or at equilibrium C followed by a jump to equilibrium A in period $t + 1$ can be taken as an indication that the subject learned about the existence of the Pareto-dominant equilibrium A in period t. To test, we only consider subjects who are likely to have been prone to money illusion in the first period (i.e. they chose prices of at least 20), and count instances in which subjects jump from P_C to P_A. We obtain the following: In NC, there are 10 (out of 22) subjects who jump to equilibrium A. Six of these jumps occur before period 10, the last jump is observed in period 21. In RH, there are only 3 (out of 23) subjects who jump, and all jumps occurred before period 7. There are only a few cases in which subjects seem to "search" the payoff table (i.e. chose disequilibrium prices), and the incidence of such disequilibrium behavior is larger in NC than in RC. In NC, 3.4 percent of all choices are in disequilibrium in the first 10 periods, and this percentage falls to 1.0 in the last 10 periods. In contrast, the corresponding number is 1.5 percent in the first 10 periods and drops to 0.3 percent for the last ten in RC.

Taken together, the evidence suggests that the nominal representation causes significantly more problems for the subjects in solving the individual optimization problem. This provides direct evidence for individual-level money illusion. Yet, over time subjects increasingly learn to see better through the veil of money and solve the optimization problem in the NC roughly in the same way as in the RC. This result seems to provide a justification for economists' reluctance to take money illusion seriously because if subjects have inexpensive individual learning opportunities, individual-level money illusion largely disappears over time. We show, however, that even if individual-level money illusion only exists temporarily it may nevertheless contribute to the selection of inefficient equilibria or it may strongly retard adjustment towards a unique equilibrium as shown in Fehr and Tyran (2001). The reason why the conclusion that money illusion is irrelevant is premature is that strategic interaction with human players may magnify individual-level irrationality. For this reason we next examine how strategic interaction in the RH affects individual irrationality other than money illusion.

Result 3: Strategic interaction with human players in the treatments with a real payoff representation increases the frequency with which the *efficient* equilibrium is played and, eventually, removes almost all inefficiencies.

Figure 2 and Table 3 show that the average price in the RC and the RH in period 1 is almost identical. After period 1, the average price quickly converges to the efficient equilibrium in the RH while it fluctuates between 2 and 4 units above the efficient equilibrium in the RC. In Table 5, we have conducted period-wise Mann Whitney tests of the null hypothesis of equal average group prices across the RC and the RH. Occasionally, the difference is significant (e.g. in periods 2, 10, and 15) but the null hypothesis cannot be rejected in most periods. Nevertheless, the relative frequency with which the efficient equilibrium is played is higher in the RH than in the RC in most periods (see Table 4). In period 1, 65.2 percent of the individuals in the RC and 63.2 percent of subjects in the RH play the efficient equilibrium but from period 5 onwards the frequency of efficient equilibrium play is always higher in the RH, reaching 98 percent in the final 4 periods. Thus, although the difference between the RC and the RH is small, it persists over time. This indicates that there is a small amount of individual-level irrationality in the RC, which is caused by 10-15 percent of the subjects. This irrationality in behavior is largely removed in the RH.

The discussion above suggests that when payoffs are represented in real terms, strategic interactions with human players do not magnify but remove the impact of individual-level bounded rationality on mis-coordination. A possible interpretation of this result is that the imitation of other human players enhances adjustment towards the equilibrium in the RH. Recall that in the RH, most players quickly play the Pareto-efficient equilibrium. This information is transmitted to the subjects at the end of each period, so that the less than fully rational subjects can easily imitate the others' behavior. Such imitation is not possible in the RC where each subject has to calculate the response of the computerized players to his or her own choice. An alternative interpretation is that rational play is easier in the RH than in the RC if the vast majority of human opponents plays the Pareto efficient equilibrium. In this case, strategic uncertainty about the others' behavior is virtually absent and it is, therefore, easy for the less intelligent players to best reply to the “given” average price of the others. Since the average price of the other (computerized) players in the RC cannot be taken as given, no such easy solution exists for the less intelligent players. In view of the fact that strategic interaction in the RH facilitates full adjustment towards the efficient equilibrium relative to the RC, a comparison of people's behavior in the NC and the NH is of interest:

Result 4: Under the nominal payoff representation, strategic interaction with human players causes a large increase in the frequency with which the *inefficient* equilibrium C is played, and it completely eliminates play of the efficient equilibrium from the beginning.

We again refer to Figure 2 and Tables 3 to 5 to support this result. Figure 2 and Table 3 indicate that the average price in the NC and the NH are relatively close together in the first two to three periods. However, whereas the average price rises steadily in the NH, it falls in the NC, generating a sharply increasing price difference. This gradual divergence in average prices is reflected in period-wise Mann Whitney tests presented in Table 5. During the first 8 periods, the null hypothesis of equal average group prices across NC and NH cannot be rejected but afterwards prices are always significantly different. The reason for the diverging price movements is that subjects learn to choose the efficient equilibrium in the NC whereas groups increasingly coordinate on the inefficient equilibrium in the NH. In the NC, the frequency of playing the *efficient* equilibrium rises from 22.7 percent in period 1 to 81.8 percent in period 30, while the frequency of playing the *inefficient* equilibrium C in the NH rises from 18.2 percent in period 1 to 84.4 percent in period 30.

In our view, the comparison between the NC and the NH is exciting because it suggests that most subjects do learn to play the efficient equilibrium when they are provided with individual learning opportunities and when they are not entrapped in the attraction power of an inefficient equilibrium (see also our discussion of "jumping" behavior following Result 2). Thus, individual learning largely removes the power of the veil of money over subjects' behavior in an environment where beliefs about the opponents' money illusion are rendered irrelevant. However, when subjects play the pricing game with other humans, the initially prevailing level of money illusion throws subjects in the basin of attraction of the inefficient equilibrium from which no escape seems possible. The inefficient equilibrium slowly but relentlessly attracts the subjects' behavior. This development is also associated with a shift in the relative importance of the direct and the indirect effects of money illusion. Initially, during the first few periods, the difference in prices between the NC and the NH is small, suggesting that individual-level money illusion initially dominates subjects' behavior in both treatments. Over time, individual-level illusion declines in the NC but the overall effect of money illusion nevertheless increases as indicated by the rising frequency with which the inefficient equilibrium is played in the NH. This suggests that the indirect effects of money illusion, which operate via subjects' price expectations, become increasingly important over time.

4. Strategic teaching and coordination failure – a robustness check

Our results in the NC show that roughly one fifth of the players played the efficient equilibrium from the beginning. Moreover, over time this percentage increases – in period 8, for example, already 55 percent of all players play the efficient equilibrium in the NC. These findings suggest that there were also some players in the NH who knew that C is the Pareto-dominated equilibrium. If this is correct, one would expect to observe some attempts at "strategic teaching", which means that the sophisticated players tried to motivate the unsophisticated (still illuded) players to coordinate on the Pareto-dominant equilibrium A. According to Camerer, Ho and Chong (2002: 139) "Sophisticated players matched with the same players repeatedly usually have an incentive to ''teach'' adaptive players, by choosing strategies with poor short-run payoffs which will change what adaptive players do, in a way that benefits the sophisticated player in the long run."

We indeed observe some attempts at strategic teaching in NH, but these attempts were all unsuccessful. One might speculate that these attempts were unsuccessful because strategic teaching is impeded by the fact that players could only observe the average (i.e. aggregated) price choices of other players, but not their individual price choices. In this section, we report the results from a control treatment NH in which subjects are given *disaggregated* information about price choices (i.e. each subject is informed about all individual price choices). This treatment is henceforth called "NH(disaggregated)".

To illustrate the hypothesis that aggregated information (i.e. players only know the average of others' price choices) limits the incentives for strategic teaching, suppose a group is coordinated on the Pareto-dominated equilibrium C in period t. Suppose the group (with n = 6) consists exclusively of players who have learned that equilibrium A is Pareto-dominant. Suppose an illusion-free player i chooses $P_A = 4$ in $t + 1$. In NH with aggregated information, the other $-i$ players only observe that the average price has fallen from $P_C = 27$ in t to 22 in $t + 1$ but they do not know why it has fallen. They are uncertain about whether, for example, all other players have chosen $P_i = 22$ or whether one has chosen P_A and the others P_C. In NH, an illusion-free player can therefore not effectively signal to other players that he in fact is illusion-free, and this might reduce the incentives for this player to send this (costly) signal. In NH(disaggregated), in contrast, the illusion-free players will realize that there is (at least one) other illusion-free player upon observing the choice of P_A which might motivate them to choose P_A, too.

In fact, the slow convergence to equilibrium C observed in NH is to some extent due to fruitless attempts of illusion-free agents to induce other group members to select equilibrium A. To illustrate, consider the extreme example of group 10 in NH. This group had an average price of 15.6 in period 1 and converged slowly towards equilibrium C by approximate best-reply dynamics. In period 8, the average group price was 21.4. For the next 6 periods, player number 5 choose $P_5 = 1$, inducing the rest of the group to choose lower prices. By period 16, the group average price had fallen to 3.8, but the group was still not coordinated on equilibrium A (in fact, player #5 was the only player who chose $P_5 = 4$ in this period). In period 17, player #4, perhaps frustrated from a long streak of low disequilibrium payoffs, chose a price of 29. The group then seems to have responded to his "teaching" since the average group price eventually converged to the bad equilibrium C (however, the group failed to fully coordinate even in period 30). This somewhat extreme example illustrates that there were occasional attempts of strategic teaching in NH but these attempts were not successful since all groups eventually converged to the Pareto-dominated equilibrium C. We now discuss whether providing players with disaggregated information about price choices in NH(disaggregated) makes strategic teaching more successful.

The treatment NH(disaggregated) was run with additional 36 subjects in 6 groups of n = 6 (undergraduates at the University of Copenhagen) under otherwise identical conditions as in NH. Figure 3 shows average prices for each group in NH(disaggregated). As can be seen from the figure, average group prices were relatively high in the first period and not much dispersed (group averages range from 17.3 to 23.3, and the overall average price of 19.7 was very close to the average in NH of 20.1). Four groups then converge quite quickly, and 2 groups converge rather slowly, to the Pareto-dominated equilibrium C.

Group 3 is particularly interesting from the perspective of strategic teaching (see bold line in Figure 3). This group was perfectly coordinated on equilibrium C in periods 8 to 10. In period 11, however, player #6 chose $P_6 = 4$ while the other players continued to choose high prices. In period 12, the teaching of player #6 (who again chose 4) seems to have induced player #1 to also choose a price of 4. In period 13, already 4 players chose $P_i = 4$ while the remaining two players chose best replies to their (now low) expectations. That is, in period

13, there apparently were at least 4 illusion-free players in the group. Period 14 is then the first period in which perfect coordination on the Pareto-dominant equilibrium A was achieved in this group.

While the previous paragraph documents an exciting example of successful strategic teaching, it should be clear from the Figure 3 that this is an exceptional case. Strategic teaching was successful only in 1 out of 6 groups in NH(disaggregated). In the two groups that eventually converged to equilibrium C (see groups 5 and 6 in Figure 3) there were some players who repeatedly chose $P_i = 4$ (i.e., they chose actions that were not best replies to their short-run beliefs) in attempting to teach the group, but their efforts were in vain. For example, in group 5, there were two illusion-free players choosing $P_A = 4$ in periods 3 and 4, but this was not sufficient to induce the other, probably illuded, players to coordinate on the Pareto-dominant equilibrium A. Instead, the group perfectly coordinated on the Pareto-dominated equilibrium C from period 16 on.

Overall, lock-in was strong and strategic teaching mostly unsuccessful in our setting even when subjects were provided with disaggregated information about other players' price choices. We believe that it would be interesting for further research to investigate the effects of playing the game for more periods (increasing the benefits from strategic teaching because there are more periods left in which on is coordinated on the Pareto-dominant equilibrium). In addition, we think that communication (which could be an alternative to strategic teaching, see Brandts and Cooper 2005) or collective action (which would enable a majority of sophisticated players to overrule the illuded players and directly "jump" to Pareto-dominant equilibrium, see Capra et al. 2005) are potentially promising institutions to break the persistent lock-in on the Pareto-dominated equilibrium we observe.

5. Concluding remarks

This paper shows that seemingly innocuous differences in the payoff representation have powerful effects on equilibrium selection. When payoffs are represented in nominal terms, 84 percent of the subjects eventually converge to a Pareto inferior equilibrium while 98 percent of the subjects finally play the Pareto efficient equilibrium under the real payoff representation. This constitutes clear and powerful evidence for the behavioral relevance of money illusion. In particular, our results suggest that nominal payoff dominance is an equilibrium selection principle which drives behavior in strategic settings. We also show that persistent effects of money illusion occur despite the fact that most individuals are eventually able to pierce the veil of money when they are given repeated individual learning opportunities. Thus, the argument that the impact of money illusion on aggregate outcomes will eventually vanish through learning, can be seriously misleading. In our context, it is misleading because learning in strategic environments with multiple equilibria may be difficult or impossible or, if it occurs, it may be too late to have much impact on the aggregate outcome.

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Appendix A: Instructions

[The original instructions were in German. The instructions below refer to the nominal treatment with human players (NH). The subjects received the instruction below and the nominal payoff matrix.]

Welcome to the experiment. Please read these instructions carefully. You can earn money in this experiment. During the experiment, we calculate your income in points. All points you earn during the experiment will be converted into Swiss Francs according to the exchange rate: 10 points = 0.40 Francs.

Please **do not communicate** with other participants during the experiment. Please ask us if you have questions.

This experiment has 30 periods. All participants are members of a group. Your monitor indicates the number of people in your group. You do not know who is in your group but the composition of the group remains stable throughout the experiment. Only the decisions in your group are relevant for your earnings. Decisions by other groups are irrelevant for you.

All group members are in the role of firms. In each period, all firms must **simultaneously** set a price from 1 to 30 (1 and 30 included). How much a firm earns depends on the price it chooses and on the average price all **other** firms in the group choose.

The income table shows your **nominal point income**. All firms have the same tables. *Example*: Suppose you choose a price of 15 and the other firms choose prices of 16 on average. In this case your *nominal* point income is 48 points.

For the determination of your earnings at the end of the experiment, only the real point income is relevant. This holds for all firms. To calculate your real point income from your nominal point income, you have to divide the nominal point income by the average price of other firms. Therefore, the nominal and the real point income are related as follows:

Real point income = Nominal point income / Average price of other firms

In the example above, your nominal point income is 48 points, but you **real** point income is 3 points (= 48 points / 16).

Here is how the experiment proceeds: At the beginning of each period, you choose a selling price (a number from 1 to 30) and indicate which average price of other firms you expect. At the end of each period you are informed about the actual average price of the other firms and about your actual real point income.

Do you have any questions?

The decisions of other firms

[This decision sheet was only given to subjects in the NC and the RC] In this experiment, the decisions of other firms will not be taken by other participants but by *pre-programmed computers*. These **computers choose their prices depending on your choice**. The table below shows how the computers respond to your pricing decision.

Your price choice	Average price of other (computerized) firms
1	4
2	4
3	4
4	4
5	4
6	4
7	4
8	5
9	6
10	10
11	14
12	15
13	16
14	17
15	18
16	19
17	20
18	21
19	22
20	23
21	24
22	25
23	26
24	27
25	27
26	27
27	27
28	27
29	27
30	27

Table A1: Payoff table in the nominal treatments (NH and NC)

Average price of other firms

selling price	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1	13	11	11	15	19	15	13	12	11	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	24	25	19	25	32	22	16	14	12	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
3	13	48	44	58	73	37	23	16	13	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
4	6	25	84	112	140	84	39	22	15	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
5	3	11	44	58	73	162	88	37	19	12	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
6	2	7	19	25	32	84	168	80	29	12	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
7	2	5	11	15	19	37	88	152	59	14	13	14	15	16	17	18	19	19	20	21	22	23	24	25	26	27	28	29	30	31
8	2	4	8	10	13	22	39	80	108	18	14	15	15	16	17	18	19	20	21	22	23	24	25	25	26	27	28	30	31	32
9	1	3	6	8	10	15	23	37	59	30	17	16	17	17	18	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
10	1	3	5	7	9	12	16	22	29	50	22	19	18	18	19	19	20	21	21	22	23	24	25	26	27	28	29	30	31	32
11	1	3	5	6	8	10	13	16	19	30	39	26	22	21	20	20	21	21	22	23	24	24	25	26	27	28	29	30	31	32
12	1	3	4	6	7	9	11	14	15	18	66	48	31	25	23	22	22	22	23	23	24	25	26	27	27	28	29	30	31	32
13	1	2	4	5	7	8	10	12	13	14	39	84	59	36	29	25	24	24	24	24	25	25	26	27	28	29	30	31	32	33
14	1	2	4	5	6	8	9	11	12	12	22	48	104	70	42	32	28	26	26	26	26	26	27	28	28	29	30	31	32	33
15	1	2	4	5	6	8	9	10	11	12	17	26	59	126	83	48	36	31	29	28	27	27	28	28	29	30	31	32	33	34
16	1	2	4	5	6	7	9	10	11	11	14	19	31	70	150	96	54	40	34	31	30	29	29	29	30	30	31	33	33	34
17	1	2	3	5	6	7	8	9	10	11	13	16	22	36	83	176	111	61	44	36	33	32	31	31	31	31	32	34	34	35
18	1	2	3	5	6	7	8	9	10	11	12	15	18	25	42	96	204	126	68	48	40	36	34	33	32	32	34	35	35	36
19	1	2	3	4	6	7	8	9	10	10	12	14	17	21	29	48	111	234	143	76	53	43	38	36	35	34	35	37	37	37
20	1	2	3	4	6	7	8	9	10	10	12	13	15	18	23	32	54	126	266	160	84	57	46	41	38	36	38	39	39	38
21	1	2	3	4	5	7	8	9	10	10	12	13	15	17	20	25	36	61	143	300	179	92	62	49	43	40	42	43	42	41
22	1	2	3	4	5	7	8	9	10	10	12	13	14	16	19	22	28	40	68	160	336	198	101	67	53	46	48	50	46	44
23	1	2	3	4	5	6	8	9	9	10	11	13	14	16	18	20	24	31	44	76	179	374	219	110	73	57	59	61	54	49
24	1	2	3	4	5	6	7	8	9	10	11	13	14	15	17	19	22	26	34	48	84	198	414	240	120	78	81	84	67	57
25	1	2	3	4	5	6	7	8	9	10	11	12	14	15	17	18	21	24	29	36	53	92	219	456	263	130	135	140	93	71
26	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	18	20	22	26	31	40	57	101	240	500	286	297	308	157	99
27	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	18	19	21	24	28	33	43	62	110	263	546	567	588	348	168
28	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	19	21	23	26	30	36	46	67	120	286	297	308	667	375
29	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	19	20	22	24	27	32	38	49	73	130	135	140	348	720
30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	17	18	20	21	23	26	29	34	41	53	78	81	84	157	375

Table A2: Payoff table in the real treatments (RH and RC)

Average price of other firms

selling price	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1	13	6	4	4	4	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	24	13	6	6	6	4	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	13	24	15	15	15	6	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	6	13	28	28	28	14	6	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	3	6	15	15	15	27	13	5	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	2	4	6	6	6	14	24	10	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	2	3	4	4	4	6	13	19	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	2	2	3	3	3	4	6	10	12	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	2	2	2	2	3	3	5	7	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	2	2	2	2	2	2	3	3	5	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	2	2	2	2	2	2	2	2	3	4	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	2	1	2	1	2	2	2	2	2	6	4	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	2	1	1	4	7	5	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	2	4	8	5	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	2	2	5	9	6	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	2	2	5	10	6	3	2	2	2	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	2	3	6	11	7	3	2	2	2	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	2	3	6	12	7	4	2	2	2	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	7	13	8	4	3	2	2	2	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	7	14	8	4	3	2	2	2	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	8	15	9	4	3	2	2	2	2	2	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	4	8	16	9	4	3	2	2	2	2	2	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	4	9	17	10	5	3	2	2	2	2	2
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	4	9	18	10	5	3	3	3	2	2
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	4	10	19	11	5	5	5	3	2
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	4	10	20	11	11	11	5	3
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	5	11	21	21	21	12	6
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	5	11	11	11	23	13
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	5	5	5	12	24
30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	3	3	5	13

Appendix B - Functional Specification of Payoffs

The real payoff function for all players *i* is:

$$\pi_i = 1 + \frac{H}{1 + (P_i - P_i^*)^2}$$

The table below shows the best reply P_i^* for player *i* and the parameter H for every feasible average price of the other players $\overline{P}_{-i}$. Note that P_k, $k \in$ {A, B, C}, is the price in equilibrium A, B, or C, respectively. π_k, $k \in$ {A, B, C}, is the real profit in equilibrium A, B, or C, respectively. Recall from Table 1 that $P_A = 4$, $P_B = 10$, $P_C = 27$, $\pi_A = 28$, $\pi_B = 5$ and $\pi_C = 21$. For example, if $\overline{P}_{-i}$ is below $P_A - 1$, player *i*'s best reply is given by $\overline{P}_{-i} + 1$ and H = $\pi_A - 5$. The real payoff matrix is based on the payoff function above but all numbers in the matrix are rounded to integers.

Table B1: Real payoffs

If the average price of other firms is in the range	player *i*'s best reply P_i^* is given by	and the parameter *H* is given by
$\overline{P}_{-i} < P_A - 1$	$\overline{P}_{-i} + 1$	$\pi_A - 5$
$P_A - 1 \le \overline{P}_{-i} \le P_A + 1$	P_A	$\pi_A - 1$
$P_A + 1 < \overline{P}_{-i} < P_B$	$\overline{P}_{-i} - 1$	$2 + \alpha\overline{P}_{-i}$
$\overline{P}_{-i} = P_B$	P_B	$\pi_B - 1$
$P_B < \overline{P}_{-i} < P_C - 1$	$\overline{P}_{-i} + 1$	$4 - \alpha$
$P_C - 1 \le \overline{P}_{-i} \le P_C + 1$	P_C	$\pi_C - 1$
$\overline{P}_{-i} > P_C + 1$	$\overline{P}_{-i} - 1$	$3 - \alpha$
		where: $\alpha = 10 - \overline{P}_{-i}$

Table 3**:** Evolution of Prices and Real Payoffs over Time

	Average Price				Average real payoff			
	Human opponents		Computerized opponents		Human opponents		Computerized opponents	
period	Real (RH)	Nominal (NH)	Real (RC)	Nominal (NC)	Real (RH)	Nominal (NH)	Real (RC)	Nominal (NC)
1	8.4	20.1	8.3	17.3	8.9	2.9	21.3	13.1
2	6.6	20.9	7.4	19.0	13.9	5.3	22.3	15.5
3	5.2	21.9	7.3	18.3	19.5	6.3	21.7	15.3
4	4.6	22.2	7.7	17.3	22.5	6.0	25.4	18.1
5	4.1	22.7	8.9	15.5	24.0	6.7	25.5	21.8
6	4.0	23.1	9.0	14.4	25.1	8.0	23.8	21.4
7	3.9	23.4	6.0	15.3	26.6	10.6	26.8	22.6
8	4.1	23.9	6.0	14.4	25.4	10.9	25.5	23.9
9	4.3	23.9	7.0	11.6	24.7	11.4	27.1	22.1
10	4.4	24.0	9.7	12.5	24.0	12.3	23.8	23.1
11	4.0	24.1	6.8	12.4	26.5	11.5	25.4	24.1
12	4.0	24.0	6.0	12.3	27.1	11.9	26.8	23.1
13	4.4	24.1	7.2	12.8	24.4	13.6	25.1	23.6
14	4.9	24.2	7.0	12.5	21.6	13.5	25.7	24.5
15	3.9	24.1	5.1	13.4	26.9	14.1	26.6	25.1
16	3.9	24.5	6.8	10.5	26.3	15.4	25.7	24.6
17	3.9	25.1	6.0	8.6	26.9	15.1	26.4	24.5
18	4.2	24.9	8.0	9.2	25.4	13.8	26.3	26.4
19	3.9	25.3	7.3	9.2	26.7	15.2	25.0	25.2
20	3.9	26.0	6.0	9.3	27.3	16.9	26.8	26.0
21	4.0	25.1	6.0	9.7	27.1	13.6	26.0	24.7
22	3.9	26.1	7.0	9.6	27.0	16.0	27.0	23.6
23	4.0	26.4	6.0	7.9	27.1	16.9	26.7	24.5
24	4.0	26.6	7.0	8.7	26.8	15.3	27.0	25.4
25	3.9	27.1	6.0	8.2	27.1	17.2	26.7	24.1
26	4.0	27.2	6.0	8.0	27.3	19.1	27.4	26.7
27	3.9	27.1	6.0	8.1	27.5	19.4	27.4	25.9
28	3.9	26.7	8.0	8.2	27.5	18.0	27.0	26.3
29	3.9	26.8	6.0	8.3	27.5	18.4	26.8	26.7
30	3.9	26.4	7.0	8.2	27.5	17.8	27.4	25.9

Table 4**:** Percentage of subjects choosing equilibrium action P_A (i.e. Pareto-dominant equilibrium)

period	Human opponents		Computerized opponents	
	Real (RH)	Nominal (NH)	Real (RC)	Nominal (NC)
1	63.5	0.0 (18.2)*	65.2	22.7
2	59.6	0.0 (9.1)	69.6	22.7
3	65.4	0.0 (10.4)	65.2	27.3
4	78.8	0.0 (14.3)	78.3	31.8
5	80.8	0.0 (14.3)	73.9	45.5
6	86.5	0.0 (15.6)	69.6	45.5
7	94.2	0.0 (26.0)	87.0	45.5
8	92.3	0.0 (28.6)	82.6	54.5
9	94.2	0.0 (33.8)	87.0	54.5
10	92.3	0.0 (37.7)	69.6	59.1
11	92.3	0.0 (42.9)	82.6	63.6
12	96.2	0.0 (48.1)	87.0	59.1
13	92.3	0.0 (46.8)	78.3	59.1
14	92.3	0.0 (50.6)	82.6	63.6
15	94.2	0.0 (48.1)	87.0	59.1
16	90.4	0.0 (49.4)	82.6	68.2
17	94.2	0.0 (57.1)	87.0	72.7
18	94.2	0.0 (58.4)	82.6	77.3
19	94.2	0.0 (59.7)	73.9	77.3
20	96.2	0.0 (67.5)	87.0	77.3
21	96.2	0.0 (61.0)	91.3	72.7
22	94.2	0.0 (66.2)	87.0	72.7
23	96.2	0.0 (70.1)	91.3	81.8
24	94.2	0.0 (68.8)	87.0	72.7
25	96.2	0.0 (71.4)	91.3	81.8
26	96.2	0.0 (85.7)	91.3	81.8
27	98.1	0.0 (89.6)	91.3	81.8
28	98.1	0.0 (85.7)	82.6	81.8
29	98.1	0.0 (83.1)	91.3	81.8
30	98.1	0.0 (84.4)	82.6	81.8

* Numbers in parentheses denote the percentage of subjects choosing the equilibrium action P_C (i.e., Pareto-dominated equilibrium).

***Table 5*: Statistical significance of treatment differences**

period	RC vs. NC	RC vs. RH	NC vs. NH
1	0.013	0.077	0.609
2	0.001	0.018	0.401
3	0.005	0.491	0.951
4	0.009	0.123	0.950
5	0.061	0.154	0.531
6	0.104	0.248	0.192
7	0.003	0.145	0.603
8	0.018	0.641	0.295
9	0.110	0.771	0.005
10	0.363	0.038	0.019
11	0.031	0.978	0.033
12	0.014	0.754	0.006
13	0.161	0.095	0.015
14	0.114	0.348	0.006
15	0.019	0.028	0.015
16	0.221	0.042	0.002
17	0.101	0.117	0.000
18	0.601	0.244	0.000
19	0.629	0.285	0.000
20	0.339	0.084	0.000
21	0.125	0.490	0.001
22	0.313	0.028	0.000
23	0.420	0.490	0.000
24	0.290	0.346	0.000
25	0.355	0.032	0.000
26	0.376	0.490	0.000
27	0.408	0.107	0.000
28	0.945	0.063	0.000
29	0.336	0.107	0.000
30	0.838	0.064	0.000

Table 5 reports two-tailed *p*-values of Mann Whitney tests of the null hypothesis that average prices are equal across the corresponding treatments. Average group prices are the independent units of observation.

***Figure 1*: Average prices and expectations in the treatments with human opponents**

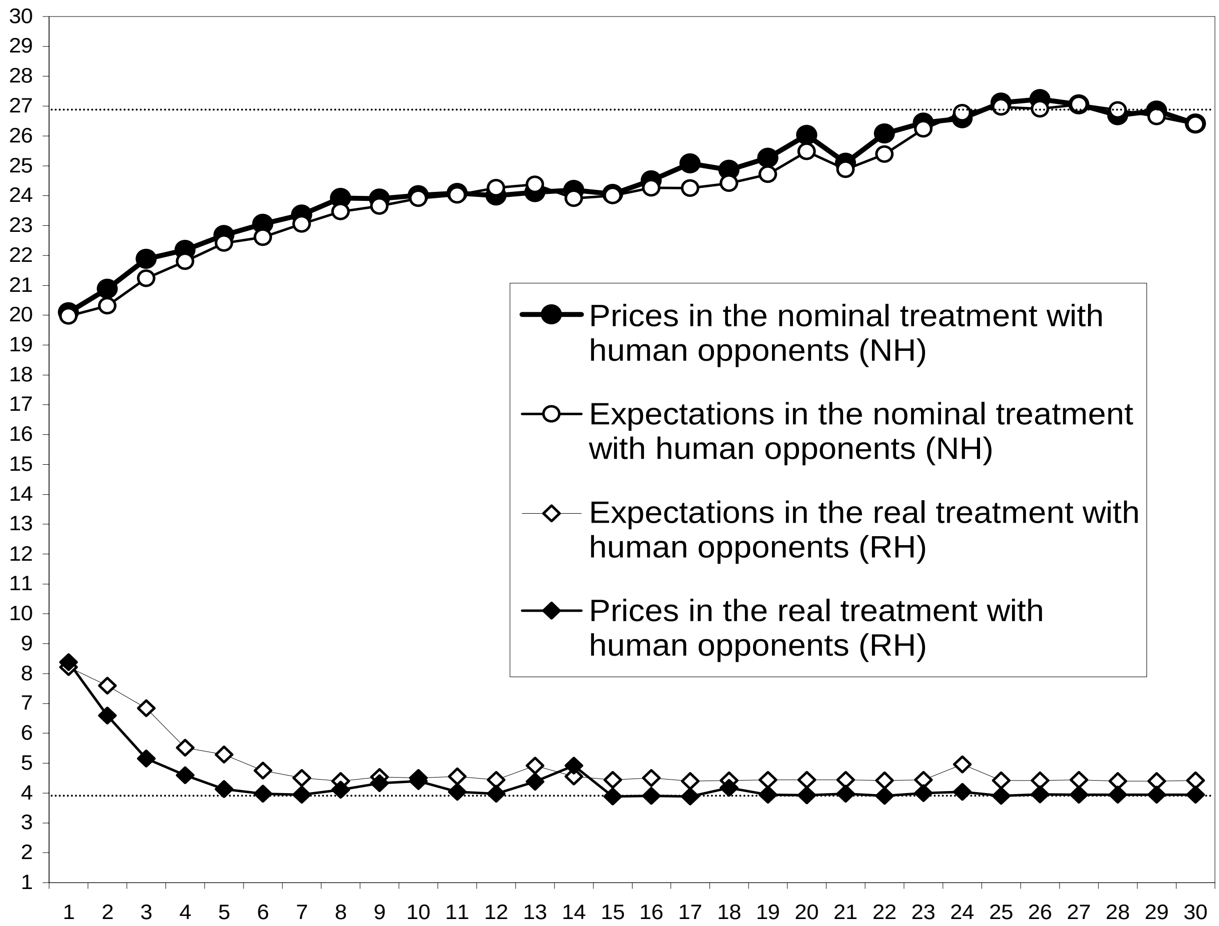

***Figure 2*:** Average prices across all treatments

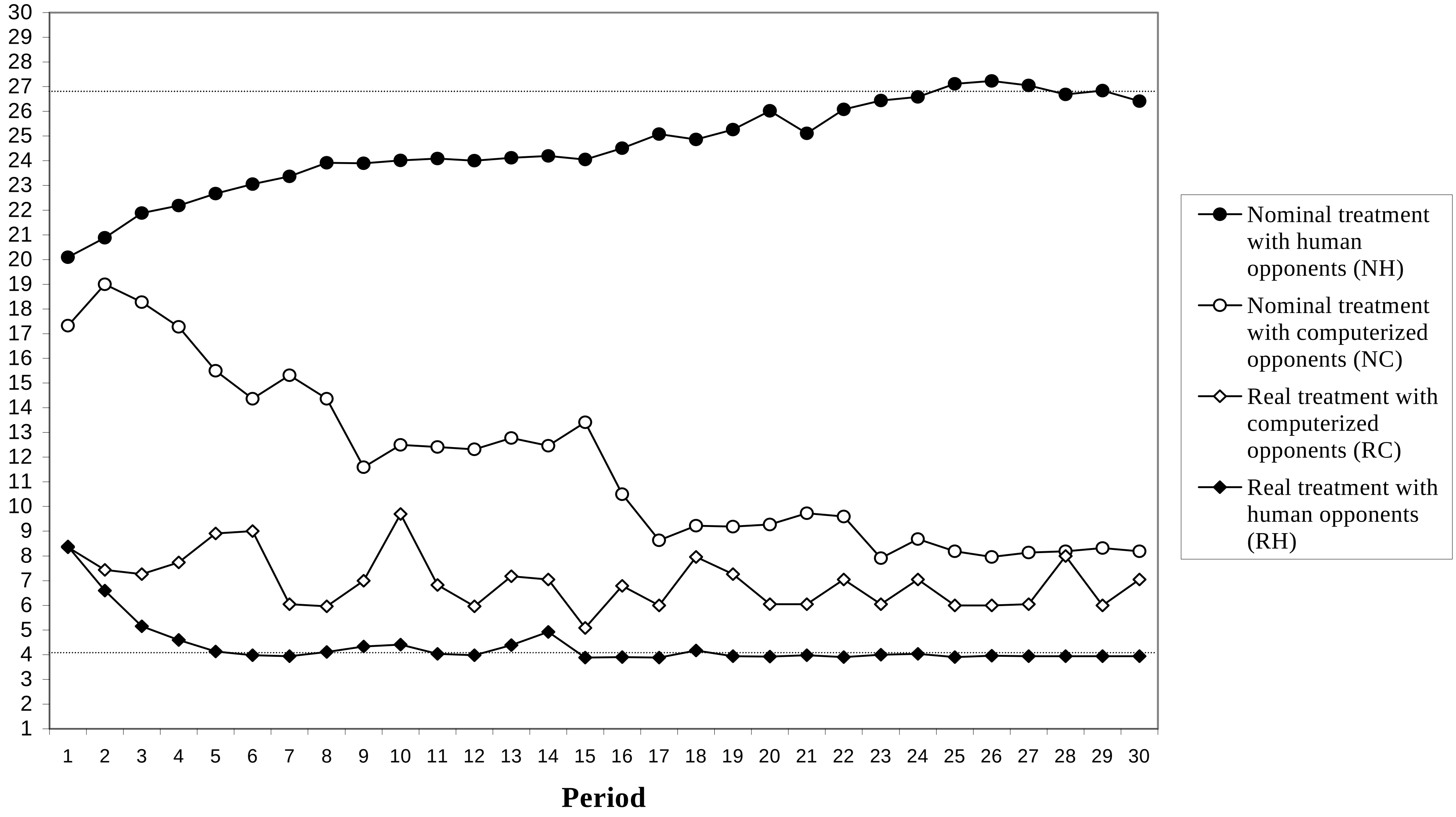

Figure 3: Average group prices (treatment NH disaggregated)