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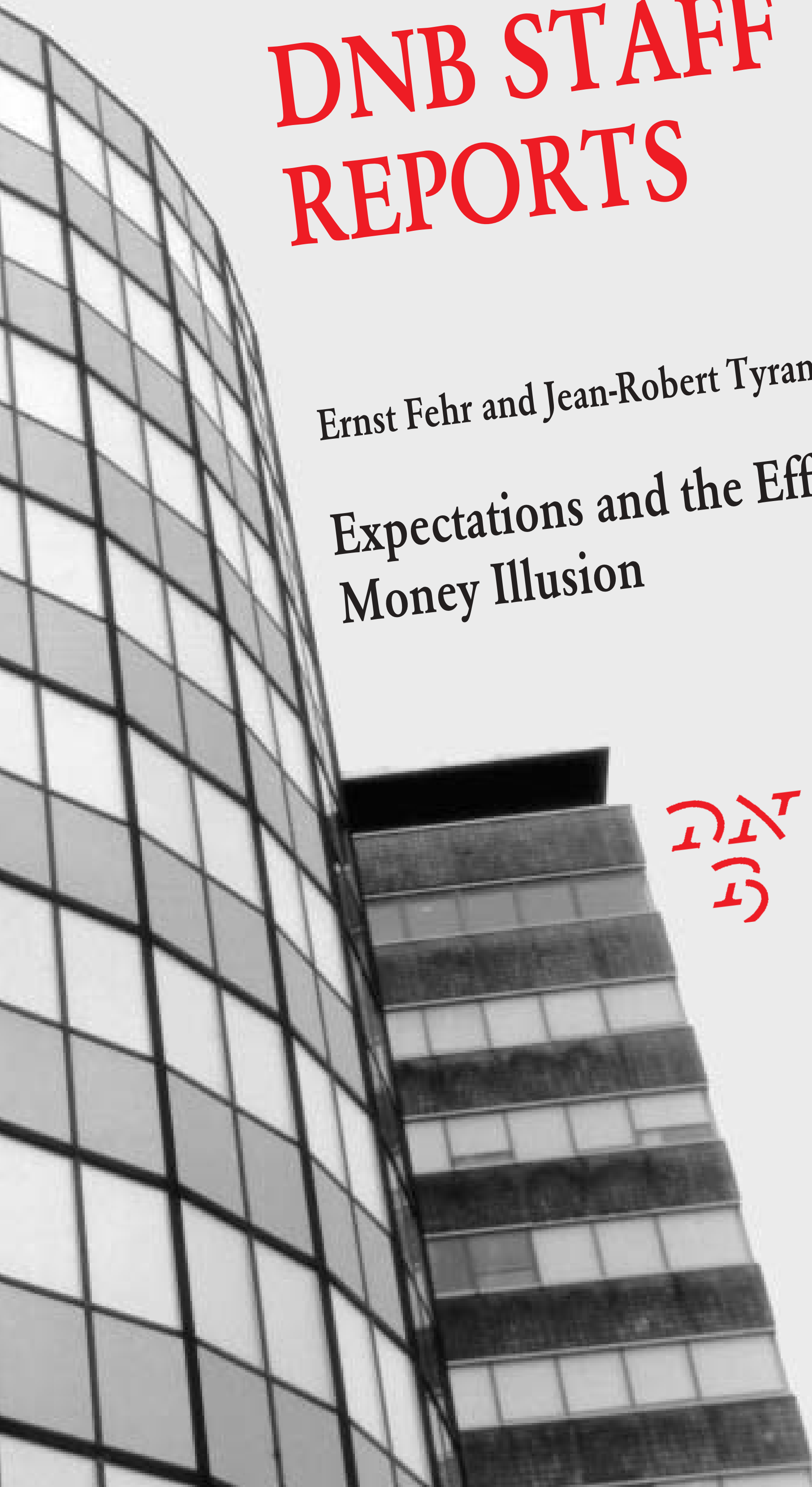
Expectations and the Effects of Money Illusion



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Expectations and the Effects of Money Illusion

Ernst Fehr[*] and Jean-Robert Tyran[**]

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Abstract

This paper analyzes the role of expectations in determining the real effects of money illusion. We argue that money illusion may cause significant but transitory nominal inertia following changes in monetary policy and that money illusion may even have permanent effects because it coordinates agents onto inferior equilibria. We provide experimental evidence for both transitory as well as permanent effects of money illusion. These effects arise mainly because money illusion shapes expectations. Forming expectations is necessary for making optimal decisions in a strategic environment. We show that strategic complementarity is a key determinant of aggregate-level effects of money illusion.

Keywords: Money illusion, rational expectations, nominal inertia, coordination failure.

JEL-Codes: C9, E32, E52.

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1. Introduction

While the debate on how economic agents form expectations and how these expectations should be modeled has been key to modern macroeconomics, money illusion has been an anathema to macroeconomists until recently. The rational expectations revolution in the 1970s thoroughly banned the study of money illusion from economists' research agendas. Rational individuals do not exhibit illusions and because, by assumption, people behave rationally, there is nothing to study. Money illusion was a concept to be mentioned in courses about the history of economic thought but not a part of actual research endeavors. In fact, a reliable method for getting leading journals to reject theory papers was to propagate that money illusion affected individual behavior.

There is an intuitively powerful argument supporting the view that money illusion is irrelevant for economics; this states that people will suffer economically from their illusion so that they have a strong incentive to make illusion-free decisions. Therefore, people will eventually learn to make illusion-free decisions, implying that money illusion has little or no impact on aggregate outcomes. The purpose of this paper is to show that this argument is seriously misleading because it neglects the indirect effects of money illusion in a strategic environment, where agents have to form expectations (including higher-order expectations i.e., expectations about expectations of others, and so on) to make optimal decisions. Such expectations are exceedingly difficult to form, and may be shaped by money illusion.

We show experimentally that even if money illusion only distorts individual decisions slightly, it can have important aggregate-level effects because money illusion can shape expectations. We analyze two types of aggregate-level effects. First, we show that money illusion is a cause of nominal inertia after an anticipated monetary shock in an economy with a unique equilibrium. Second, we show that money illusion can even have permanent effects by coordinating individuals on inferior equilibria. We begin our discussion by explaining that experimental methods are useful in investigating money illusion as a cause of nominal inertia because experimental methods provide insights that cannot be gained with other empirical approaches. We proceed by presenting an experimental design in which money illusion causes nominal inertia even if money illusion is almost absent at the individual level. The importance of expectation formation is demonstrated by comparing an experimental treatment in which experimental subjects play against other subjects with one in which subjects play against computerized (simulated) agents. Since subjects know that they play against computers that are programmed to have perfect foresight, they do not have to form expectations. Furthermore, we identify strategic complementarity as a key element of nominal inertia by showing that the standard rational expectations theory provides very accurate predictions of aggregate-level behavior in the absence of strategic complementarity.

The second type of aggregate-level effects of money illusion which we analyze concerns permanent effects. While the experimental designs for the study of nominal inertia had a unique equilibrium to which nominal prices eventually converge in all cases, the design for the examination of permanent effects has *multiple* equilibria. We experimentally show that money illusion can have powerful permanent effects in an environment with multiple pareto-ranked equilibria (arising from a locally extreme degree of strategic complementarity). These permanent effects arise because money illusion induces subjects to coordinate on inferior equilibria. Once individuals attain a bad equilibrium, they are locked in so that they experience permanent economic losses relative to the efficient equilibrium. We again compare this behavior to a treatment in which subjects play against computerized agents with perfect foresight to isolate for the role of expectations. In this case, we find that individual-level money illusion initially causes some individuals to make non-efficient choices, but behavior eventually converges to the efficient equilibrium in most cases. Thus, even if individual-level money illusion is only a temporary phenomenon in a non-strategic setting, it can cause permanent real effects in a strategic setting by coordinating people on inefficient equilibria.

We proceed as follows. Section 2 reports evidence from questionnaire studies suggesting that money illusion is an important phenomenon at the individual level. Section 3 explains why economists have been interested in nominal inertia and discusses the particular strengths of the experimental approach. We also explain why expectations can magnify the effects of money illusion. Section 4 discusses experimental studies investigating money illusion as a cause of nominal inertia. Section 5 presents an experimental design for investigating the permanent effects of money illusion and reports the main findings. Section 6 concludes.

2. Money illusion at the individual level

Various authors have used the term "money illusion" in different manners, although the foundation behind the term seems to be rather similar (see Howitt 1989). The basic intuition says that if the *real* incentive structure, i.e., the *objective* situation an individual faces, remains unchanged, the *real* decisions of an illusion-free individual also remain constant. This intuition is built on two crucial assumptions: first, the objective function of the individual does not depend on nominal but only on real magnitudes. Second, people perceive that purely nominal changes do not affect their opportunity set. For example, people have to understand that an equiproportionate change in all nominal magnitudes leaves the real constraints unaffected. Some economists suspected that these assumptions do not always hold. For example, Irving Fisher (1928: 4) was convinced that ordinary people, in general, fail "to perceive that the dollar, or any other unit of money expands or shrinks in value" after a monetary shock.

However, whether people are indeed able to "pierce the veil of money" is an empirical question. Shafir, Diamond and Tversky (henceforth SDT, 1997) conducted questionnaire studies indicating that frequently one or both preconditions for the absence of money illusion are violated. Their results suggest that nominal values affect both people's preferences as well as their perceptions of the constraints. Moreover, many people not only seem to be prone to money illusion; they also expect other people's preferences and decisions to be affected by money illusion. Problem 1 of SDT's questionnaire study neatly illustrates these claims. SDT presented the following hypothetical scenario to two groups of respondents:

> *Consider two individuals, Ann and Barbara, who graduated from the same college a year apart. Upon graduation, both took similar jobs with publishing firms. Ann started with a yearly salary of $ 30,000. During her first year on the job there was no inflation, and in her second year Ann received a 2% ($ 600) raise in salary. Barbara also started with a yearly salary of $ 30,000. During her first year on the job there was 4 % inflation, and in her second year Barbara received a 5% ($ 1500) raise in salary.*

Respondents of group 1 were then asked the happiness question: *"As Ann and Barbara entered their second year on the job, who do you think was happier?"* 36 percent thought that Ann was happier while 64 percent believed that Barbara was happier. This indicates that most subjects believed that preferences are affected by nominal variables because in real terms, of course, Ann does better.[1] Respondents of group 2 were asked the following question: *"As they entered their second year on the job, each received a job offer from another firm. Who do you think was more likely to leave the present position for another job?"* In line with the response to the happiness question 65 percent believed that Ann, who is doing better in economic terms, is more likely to leave the present job. Thus, a majority believed that other people's decisions are affected by money illusion.

Since the absence of money illusion means that purely nominal changes do not affect an individual's preferences, perceptions nor, hence, choices of real magnitudes, it is natural to view *money illusion as a framing effect*. From this viewpoint, an individual exhibits money illusion if the preferences or the perception of the constraints and the associated decisions depend on whether the same environment is represented in nominal or real terms. SDT's analysis is based on a large body of research in cognitive psychology that shows that alternative representations of the same situation may well lead to systematically different responses (Tversky and Kahneman 1981, 1986). Representation effects seem to arise because people tend to adopt the particular frame that is presented and evaluate the options within this frame. Because some options loom larger in one representation than in another, an alternative framing of the same option can give rise to different choices.

SDT argue that people tend to have multiple representations but that the nominal representation is often *simpler and more salient*. They suggest that people are generally aware of the difference between nominal and real values, but because money is a salient and *natural unit*, people often think of transactions predominantly in nominal terms.

Economists tend to question the relevance of results from questionnaire studies on two grounds. First, they suspect that there may be a considerable difference between what people say they would do in a hypothetical scenario and what they actually do when subject to economic incentives. Second, it is not sufficient to show that money illusion prevails at the individual level to conclude that money illusion will be of any importance at the aggregate level from an economic viewpoint. For example, the individual-level effects of money illusion may cancel out with interaction and may therefore be irrelevant at the aggregate level. Experimental methods enable the researcher to address these objections. The interaction

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[1] There was a third group of respondents who was asked whether Ann or Barbara is doing better in economic terms. 71 percent answered that Ann is in fact doing better in economic terms.

between economic agents which are exposed to economic incentives can be studied in experimental investigations.

3. Expectations and the aggregate effects of money illusion

In this section, we explain how expectations formation can yield large indirect effects of money illusion even if the direct (i.e., individual-level) effects of money illusion are small. If these indirect effects are important, money illusion has important aggregate-level effects. Below, we discuss two such effects: long-run effects arising from permanent miscoordination on inferior equilibria and short-run effects arising from nominal inertia.

Nominal inertia refers to a tendency of *nominal* prices and wages to adjust slowly to nominal shocks. One of the reasons why economists have been interested in nominal inertia ever since the writings of David Hume (1752) is that nominal inertia implies monetary non-neutrality, meaning that nominal inertia implies that changes in monetary policy affect real macroeconomic variables like output or employment. In principle, money illusion could provide an explanation for the inertia of nominal prices and wages; such explanations were routinely invoked before the advent of the rational expectations revolution of the 1970s.[2] However, the notion of money illusion seems to have been thoroughly discredited in mainstream economics in the meantime. Tobin (1972: 3), for example, described the negative attitude of most economic theorists towards money illusion as follows: "An economic theorist can, of course, commit no greater crime than to assume money illusion." The reason for this negative attitude is that money illusion contradicts basic rationality assumptions and does not fit nicely into the equilibrium mold of economics. As a consequence, economists have sought explanations of nominal inertia which are based on the assumption of fully rational agents holding rational expectations. For example, factors like informational frictions (Lucas 1972),

[2] Before the advent of the rational expectations revolution, the assumption of money illusion was usually not justified explicitly. Money illusion was often casually invoked, probably because it seemed such a natural assumption at the time. For example, Milton Friedman (1968) proposed a theory of monetary non-neutrality that is based on a misperception of real wages by workers. According to Friedman, when the money supply rises unexpectedly, the price level rises, pushing down the real wage. Employers hire more because the cost of labor has fallen. Employers are willing to work more because they focus on the nominal wage and infer (incorrectly) that the reward for work has risen. While Friedman did not explain this asymmetry between workers and firms, it seemed natural at the time to assume that workers at least partly ignore the effect of a price level increase on real wages. This ignorance was the centerpiece of Friedman's proposed explanation for the short-run Philips curve.

staggering of contracts (e.g., Fischer 1977, Taylor 1979) and costs of price adjustment (Mankiw 1985) have been invoked to explain nominal inertia in a fully rational framework.

The inertia of nominal prices and wages has been deemed an important phenomenon (see, e.g., Akerlof, Dickens and Perry 1996, Kahn 1997). However, despite the vast amount of empirical and theoretical literature on nominal inertia, very little is known about its *causes*. One of the reasons for this lack of knowledge is that the empirical research strategies applied to date were inept for isolating the causes of nominal inertia. For example, Alan Blinder and his colleagues (1998: 3) ask: “Why are wages and prices so ‘sticky‘? The abject failure of standard research methodology to make headway on this critical issue in the micro-foundations of macroeconomics motivated the unorthodox approach of the present study.“ The “unorthodox” approach chosen by Blinder and his colleagues is to ask managers about how and why they change prices, while our unorthodox approach is to conduct economic laboratory experiments. In the next section, we argue that experimental methods allow a new examination of this old and important issue. In section 4, we develop an experimental framework for investigating whether money illusion causes nominal inertia. We investigate the adjustment of nominal prices after an anticipated monetary shock in an environment in which firms face no exogenous obstacles to price adjustment whatsoever. Therefore, none of the rationality-based explanations for nominal inertia mentioned above apply. As a consequence, our investigation does not intend to question the potential relevance of these rationality-based explanations. However, our results do demonstrate the importance of money illusion, expectation formation, and strategic complementarity in understanding the causes of nominal inertia. The results suggest, in particular, that money illusion has been dismissed prematurely as a candidate for the explanation of nominal inertia.

A) Why use experimental methods to investigate nominal inertia?

In laboratory experiments, we observe the behavior of real people who are exposed to real economic incentives in a controlled environment. In what respect do experimental investigations have advantages over empirical investigations with field data? An obvious first advantage consists of the *correct measurement* of endogenous variables like prices and real economic activity. In contrast, the conclusions drawn from field studies investigating the real effects of monetary shocks appear to be extremely non-robust with respect to measurement problems (e.g., Belongia 1996). Second, data that is crucial for many economic theories can be gathered in the laboratory but cannot be directly observed in the field. *Expectation data* is especially valuable in our context. The third and most important advantage of the experimental method is *control over the environment and the information conditions*. The ability to control the environment has several implications. For example, truly *exogenous* monetary shocks can be implemented in the laboratory. In contrast, macroeconomic field studies are plagued by notorious causality problems. In the laboratory, the theoretical equilibrium values of the economy under study are known. Therefore, the observing experimentalist can distinguish between equilibrium and out-of-equilibrium realizations of endogenous variables. This is a crucial advantage, since nominal inertia is a disequilibrium phenomenon. In addition, we control information conditions, i.e., we control what economic agents know about their economic environment and what they know about the information available to other agents. As will be explained in section 4, this allows us to implement an anticipated monetary shock.

Finally, *causal relations* can be established in an experiment through controlled *ceteris paribus* variations in the decision environment. The causes of nominal inertia can be isolated by changing only one aspect of the environment and by comparing nominal price adjustment in the respective treatments. Our main objective is to investigate whether money illusion is a cause of nominal inertia. As explained above, money illusion implies that behavior depends on whether the same objective situation is framed in nominal or in real terms. A particularly transparent example of money illusion prevails if people behave differently when they receive payoff information in real or in nominal terms. Unfortunately, business life does not seem to provide examples where the same objective situation is sometimes represented in nominal terms and sometimes in real terms. In fact, almost all business transactions involve nominal payoff information. Therefore, a major advantage in the experimental approach to the causes of nominal inertia is that the "frame" is under the experimenter's control. In particular, we implemented a treatment condition in which payoffs were represented in nominal terms and a control condition in which payoffs were represented in real terms.

The above arguments suggest that experimental methods can be very useful for the examination of nominal inertia (see Duffy 1998 for a survey of experiments in monetary economics). We also would like to stress, however, that these methods are not a substitute for the analysis of field data. Laboratory experiments, in our view, complement the standard econometric techniques of the analysis of field data. Both methods should be used to increase our knowledge. Yet, the marginal return from experimental methods is likely to be high due to the relative lack of these investigations in the past.

B) Money illusion and expectations in a strategic environment

This section explains that money illusion can have both direct and indirect effects. The direct effects arise from individual optimization errors resulting from a confusion of nominal and real values. The indirect effects occur in a strategic environment and are shaped by expectations. To understand these indirect effects, three elements need to be introduced. First, agents are heterogeneous with respect to rationality. A large body of experimental evidence shows that the assumption of rationality does not hold equally well for all agents in a variety of contexts (see Camerer 2003 for a survey). In our context, this simply means that some agents are prone to individual-level money illusion while others are not. The second element is strategic complementarity which essentially induces an incentive to "follow the crowd". In principle, these two elements are sufficient to explain indirect effects of money illusion. However, some theoretical models using these two elements make the unrealistic assumption of perfect foresight among rational agents. We must therefore introduce a third element illustrating that expectations are uncertain and biased by money illusion, which we will explain in detail below.

Strategic complementarity means that if other agents change the value of their action variable (e.g., their prices), it is optimal for a rational agent to change the value of his action variable (e.g., his price) in the same direction. It has been argued that strategic complementarity is an important characteristic of macroeconomic relations (Cooper and Haltiwanger 1996), and it certainly is a natural property of (monopolistic) price competition. Technically speaking, strategic complementarity implies a positive slope of the reaction function. The intuition behind the concept is that rational agents have an incentive to “follow the crowd”. Yet, to be able "to follow the crowd", agents have to predict where it is going, so to speak. More generally, agents have to form expectations to make optimizing decisions in a strategic environment.

In a situation with strategic complementarity, heterogeneity of agents can multiply the effects individual-level bounded rationality. For example, Haltiwanger and Waldman (1985, 1989) show theoretically that under strategic complementarity, a *small* group of non-rational price setters can have *large* effects on the adjustment process to equilibrium because they induce rational agents to hold non-equilibrium expectations and to choose non-equilibrium actions. The intuition behind this theoretical result is that the rational agents partially imitate the behavior of the non-rational agents because of strategic complementarity and thereby multiply the effects of the latter on the aggregate price level. However, this model relaxes the rationality assumption in a specific manner. On the one hand, there are non-rational agents who do not optimally adjust their nominal prices to the monetary shock. On the other hand, the rational agents in fact are assumed to have perfect foresight. These agents surmise correctly how the presence of non-rational agents affects the economy. Note that forming higher-order expectations is a very difficult task. It requires the ability to predict other peoples' predictions about what everybody else does, for example. Therefore, the rationality requirements are unrealistically high in this model.[3]

Suppose that human decision-makers are rational but do not have perfect foresight. That is, suppose decision-makers are able to choose a rational action given that they know what everybody else does, but unable to form correct expectations. In particular, expectations are assumed to be uncertain and biased by money illusion in a strategic environment. In our context, this means that decision-makers assume with positive probability that some others suffer from money illusion (or assume that others expect again others to suffer from money illusion, and so on). As a result, they assume that this group will not fully adjust to the shock. This uncertain and biased expectation, in turn, also induces the rational agents to adjust only imperfectly to a shock. An interesting aspect of this idea is that a mere biased belief about others' money illusion may cause nominal inertia even if no single individual is in fact prone to money illusion. That is, given strategic complementarity, money illusion may cause pronounced nominal inertia even if individual-level money illusion is very small or non-existent.

The illusion-based account of nominal inertia provided above is structurally identical to an "informational friction" theory which has recently met with renewed interest. For example, Woodford (2002) as well as Mankiw and Reis (2002) impose a constraint on the information that people use when forming expectations, and, as a consequence, only a share of agents is fully informed about shocks at any time. To justify these informational constraints, the

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[3] The rationality requirements are much higher for the attainment of an equilibrium than they are for individual maximization as pointed out by Arrow (1987), for example. Attainment of the equilibrium involves "an informational burden of an entirely different magnitude than simply optimizing at known prices." (1987: 201).

authors cite work by Sims (2003) on "rational inattention".[4] However, the apparent similarity of assuming limited information processing capacity and limited rationality does not seem to be discussed in the literature[5], nor is it apparently essential to this line of research (instead, the main aim of this research is to investigate the implications of individual information constraints for optimal monetary policy. See Adam 2003 or Ball, Mankiw and Reis 2003).

4. Experiments on money illusion as a cause of nominal inertia

Section A provides a brief description of the basic design, section B explains the hypotheses, and section C presents the main results of an experimental study on money illusion as a cause of nominal inertia after a negative monetary shock. Section D briefly reports on an experiment with a positive shock, and section E investigates how strategic properties affect nominal inertia.

A) Design

In our experiment, n = 4 subjects are in the role of firms and simultaneously choose nominal prices in T consecutive periods. The firms are free to change nominal prices at no (menu) cost in any period. Price competition is characterized by strategic complementarity, i.e., if an agent expects his competitors to increase their prices, it is optimal for him to do so as well. After the simultaneous pricing decision, each firm receives information about the aggregate price level (resulting from other firms' choices) and the own payoff. Firms take their decisions in a fully stationary environment, i.e., there is no exogenous uncertainty whatsoever. The experiment has a pre-shock and a post-shock phase with a length of $T/2$ periods each. The pre-shock phase mainly serves the purpose of equilibrating the system. The post-shock phase serves to observe how nominal prices adjust to the monetary shock in various treatment conditions (for details see Fehr and Tyran 2001).

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4 Motolese (2003) provides an alternative approach in which endogenously heterogeneous beliefs can cause monetary non-neutrality.

5 See Conlisk (1996) for a more general discussion of the relation between limited rationality and limited information.

The real payoff of player *i*, π_i, depends on his own nominal price p_i, on the *average* price competing firms choose P_{-i} (i.e., the price level, excluding the choice of *i*), and on a nominal shift variable (the quantity of money *M*) in the following way: $\pi_i = \pi_i(p_i/P_{-i}, M/P_{-i})$. Thus, the real payoff remains unchanged if all prices and *M* change by the same percentage. Subjects receive information about payoffs in payoff tables (payoff matrices). This is possible because the payoff depends only on p_i and P_{-i} for a given level of *M*. The payoff table shows the nominal or the real payoffs of a player for all feasible combinations of p_i and P_{-i}. The treatment condition determines whether the payoff table shows the nominal or the real payoff (see below). All players are fully informed about their own payoff table and those of the other *n*-1 players in the group.

The monetary shock is implemented by distributing new payoff tables which are based on a smaller quantity of money. In particular, it is publicly announced at the end of period $t = T/2$ that all *n* firms receive new payoff tables. Again, each player is informed about his own new payoff table and those of the other *n*-1 players. We implement an *anticipated* monetary shock with this procedure because the firms get the new tables (with sufficient time for study) before they have to take their decisions in $T/2 + 1$, meaning that they know the other firms' new payoff tables and they know that others know this, etc. We implement a *negative* monetary shock because the new payoff tables are based on a quantity of money M_1 which is smaller than the previous quantity M_0 ($M_1 = M_0/3$). Finally, we implement an *exogenous* monetary shock because the firms get the new tables in $t = T/2$, irrespective of previous decisions. The parameters of the experiment imply a *unique* money-neutral equilibrium. Since the quantity of money falls by two-thirds, the price level should theoretically also fall by two-thirds. In particular, the average price taken over all *n* firms falls from 18 (in the pre-shock equilibrium) to 6 (in the post-shock equilibrium).

To investigate whether money illusion is a cause of nominal inertia, we chose the following design (see table 1). The first variation concerns the variation of the *representation of payoffs*. In the real representation, the payoff tables show *real* payoffs. That is, the numbers in the payoff table show how much the subjects will be paid at the end of a period for any feasible p_i-P_{-i}-combination. In the nominal representation, the payoff tables show nominal payoffs. Subjects must deflate nominal payoffs in order to determine what the corresponding real payoffs are, meaning they must divide the nominal payoff shown in the table by the prevailing level of P_{-i}. Note that, with one exception, the payoff tables are completely identical in the two representations. All real payoffs are multiplied by the relevant average price P_{-i} in the nominal representation, while this is not the case in the real representation. We instructed the subjects who participated in the nominal treatment how to calculate real payoffs from nominal payoffs before the beginning of the experiment. Subjects had to solve several control questions to make sure that they knew how to perform these computations. In addition, they received a pocket calculator to facilitate their computations. All of the subjects solved all exercises successfully.

Table 1: Treatment conditions

		Need to form expectations	
		Yes (Human opponents)	**No** (Computerized opponents)
Representation of payoffs	**Nominal**	**NH**	**NC**
	Real	**RH**	**RC**

The second variation concerns *whether subjects need to form expectations* about the price choices of other firms (i.e., whether there is strategic uncertainty). In the "human opponents" treatments, subjects know that they interact with n - 1 other human subjects (see table 1). Subjects participating in these treatment conditions have to indicate their expectations EP_{-i} about the price level P_{-i} in each period. In the "computerized opponents" treatments, subjects know that they play against n - 1 computers, and they know how these computers are programmed. In particular, the computers are programmed to simulate agents with perfect foresight. Thus, each subject i knows for certain that if i chooses price x, then the n - 1 computers are going to choose prices that result in a price level P_{-i} of y. This means that there is *no need* for subjects to form expectations in the computerized treatments. A subject's task is reduced to an individual optimization problem. The experimental parameters are such that if subject i knows where the equilibrium is, he or she has no incentive whatsoever for not choosing the unique equilibrium.

B) Hypotheses

If one neglects disequilibrium play, as is routinely done in rational expectations models[6], there should be no nominal inertia in all four cells of table 1. The reason is that these models assume money illusion and expectations formation to be irrelevant since the full rationality of all agents is assumed to be common knowledge. Therefore, nominal prices should adjust to the anticipated monetary shock instantaneously and equiproportionately. As a consequence, the anticipated monetary shock should be perfectly “neutral” (i.e., have no effect on the efficiency of the experimental economy) in all four treatments.

The deviation of post-shock nominal prices from equilibrium prices in the real representation with computerized opponents (RC) is a measure of individual-level irrationality which is unrelated to money illusion. For example, some subjects may be inattentive or confused by the monetary shock. In this case, nominal prices will not adjust to the nominal shock in cell RC instantaneously.

The effect of expectations formation is measured by the difference in adjustment speed between RH and RC. In both treatments, payoffs are represented in real terms. In RH, subjects have to form expectations about the effect of the monetary shock on other subjects' pricing decisions, whereas they do not have to do so in RC. If nominal prices are more inertial in RH than in RC, it must be because some subjects expected that other subjects would not fully adjust nominal prices or because they are confused.

The effect of individual-level money illusion is measured by the difference in adjustment speed between NC and RC. In both cases, subjects do not have to form expectations about the decisions of other firms. The only difference between these two treatments is the nominal vs. the real representation of payoffs. Therefore, the difference in adjustment speed between NC and RC measures how money illusion affects individual behavior, i.e., it measures the direct effect of money illusion.

The most interesting comparison occurs between NH and RH. Subjects have to form expectations about the pricing decisions of the other human subjects in both treatments. The only difference between these treatments is the nominal vs. real representation of payoffs. In

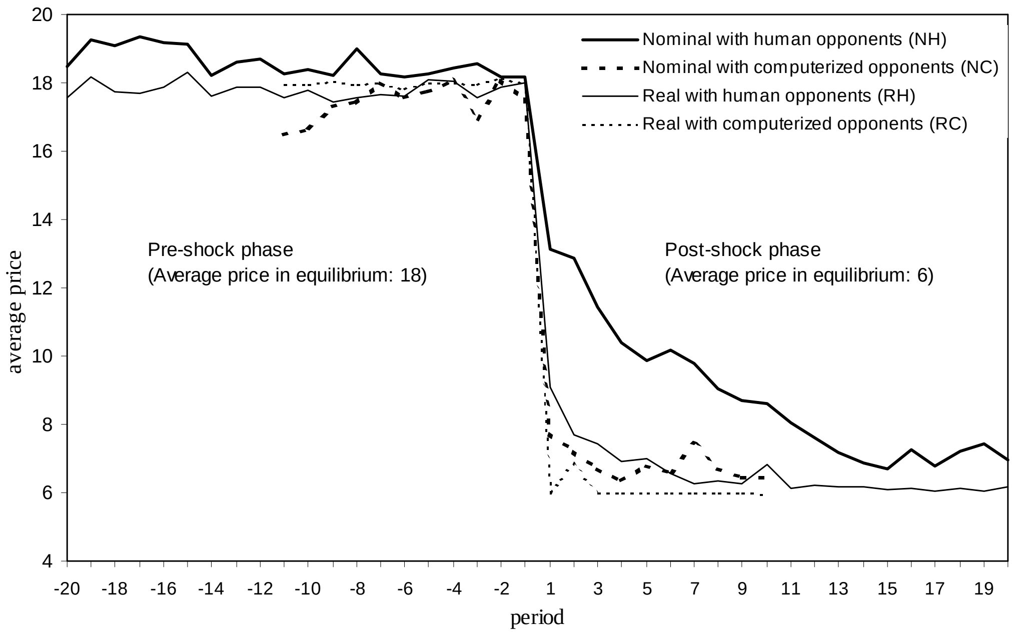
[6] According to Muth (1961: 316), rational expectations are equilibrium expectations: "I should like to suggest that expectations, since they are informed predictions of future events, are essentially the same as the predictions of the relevant theory."

particular, the difference in adjustment speed between NH and RH measures the direct and indirect effects of money illusion.

C) Results

The main results are summarized in figure 1. This figure shows average nominal prices in the four treatments. The data shown was generated by the decisions of 130 subjects who earned an average of $28. Each subject only participated in one of the four treatments. The first interesting point is that prices equilibrated quite nicely to the pre-shock equilibrium level of 18 in all four treatments.

Figure 1: Evolution of average prices



In the real representation with computerized opponents (RC), *100 percent of the subjects* (22 out of 22) *instantaneously and perfectly adjusted* prices to the shock. Therefore, the observed behavior is perfectly in line with the standard (macro-)economic theory prediction. As a consequence of this perfect price adjustment, the anticipated monetary shock is perfectly "neutral" in this case. We conclude from this observation that the shock itself results in no noticeable confusion of subjects. However, it should be noted that the laboratory environment we implement is rather simple and easy to understand for subjects.

In the real representation with human opponents (RH), only 35 percent of the subjects (14 out of 40) adjusted nominal prices to the shock instantaneously and perfectly, but most initial post-shock price choices were close to the equilibrium. The comparison of RC and RH shows that nominal prices are significantly more inertial if subjects have to form expectations than when they do not (see figure 1). A regression analysis shows that average prices in RH differ significantly from the equilibrium price level for two periods. We conclude that our human subjects are not able to solve the problem of coordinating expectations on the unique equilibrium perfectly. Put differently, the assumption of common knowledge of rationality does not seem to hold.

In the nominal representation with computerized opponents (NC), 79 percent of the subjects (19 out of 24) instantaneously and perfectly adjusted prices to the shock. Taken together, the results from the treatments with computerized opponents indicate that there is only a small amount of money illusion at the individual level, but that there is no individual-level irrationality beyond that. Since price adjustment is only slightly slower in the NC than in the RC, we conclude that individual-level money illusion does not cause pronounced nominal inertia (compare the two dotted lines in figure 1).

In the nominal representation with human opponents (NH), the adjustment of nominal prices to the monetary shock *is very inertial* (see figure 1). In particular, only 11 percent of the subjects (5 out of 44) fully adjusted nominal prices to the equilibrium level in the first post-shock period and, as a consequence, the nominal price level fell by less than half of the predicted amount. According to our regression analysis, it takes 12 periods for full price adjustment in NH, whereas nominal prices equilibrate already after 2 periods in RH. The observed differences in adjustment speed in NH and RH also translate into different real effects of the monetary shock in the two treatments. For example, the average income loss is roughly twice as large in the NH as in the RH over the first ten post-shock periods. Since the adjustment of nominal prices is much more inertial in the NH than in the RH, we conclude that the direct and indirect effects of money illusion are an important cause of nominal inertia (compare the two solid lines in figure 1). As a consequence, the anticipated monetary shock is far from neutral in this environment.

A closer look at expectations data reveals that the reason why nominal prices were much more sticky in the nominal representation (NH) than in the real representation (RH) is that expectations were much more sticky in NH than in RH. That is, subjects expected other subjects to choose high prices in the nominal representation. Because subjects act in an individually rational manner (more than 80 percent of subjects choose best replies to their expectations in NH and RH) and because of strategic complementarity, sticky expectations translate into sticky price choices.[7]

D) Asymmetric effects of positive and negative monetary shocks

So far, the results have shown that money illusion in fact causes nominal inertia and that the reason for this is that price expectations were much stickier in the nominal than the real representation. But why was this so? Since we implement a *negative* monetary shock, the equilibrium price level must fall. By definition, high nominal payoffs prevail at high price levels. If subjects believed that high nominal payoffs "look attractive" to other subjects and if they believe that this causes other subjects to choose high prices in the post-shock phase, they respond rationally by also choosing high prices in the post-shock phase. To test for this hypothesis, we implemented a *positive* monetary shock with human opponents (NH, RH). If our hypothesis about the cause of the stickiness of expectations is correct, prices should adjust much more quickly after the positive than after the negative shock, because equilibrium price levels have to rise with a positive shock and therefore subjects have to adjust their price choices in the direction of high "attractive" nominal payoffs. The experiments were run with an additional 96 subjects and strongly confirm this hypothesis (see Fehr and Tyran 2001 for details). We observe a pronounced *asymmetry* in nominal inertia, i.e., a much quicker convergence to the equilibrium after a positive shock than after a negative shock in the NH.

[7] Note that we asked each subject i to indicate first-order expectations EP_{-i} about the average behavior of the other $-i$ firms. To keep the experiment simple, we did not ask subjects to indicate second-order expectations [i.e., i's expectations about j's expectation about what everybody else is going to do $E_i(E_jP_{-j})$], or expectations of an even higher order. Data on higher-order expectations would be necessary to analyze in greater detail why first-order expectations are biased by money illusion. Suppose, for example, that i's first-order expectations are biased but i's second-order expectations are not. In this case, i expects the other $-i$ players to be prone to money illusion (or to be otherwise irrational), but does not believe that these players expect others (or expect others to expect again others, and so on) to be prone to money illusion. In contrast, suppose i's first-order and second-order expectations are biased. Then, i expects j's expectations to be partly shaped by $-j$'s money illusion (or $-j$'s expectation about others money illusion, and so on). While a more pronounced bias in first-order expectations in the NH compared to the RH does not allow us to determine exactly at which level money illusion distorts behavior, it clearly indicates that money illusion shapes expectations at some level.

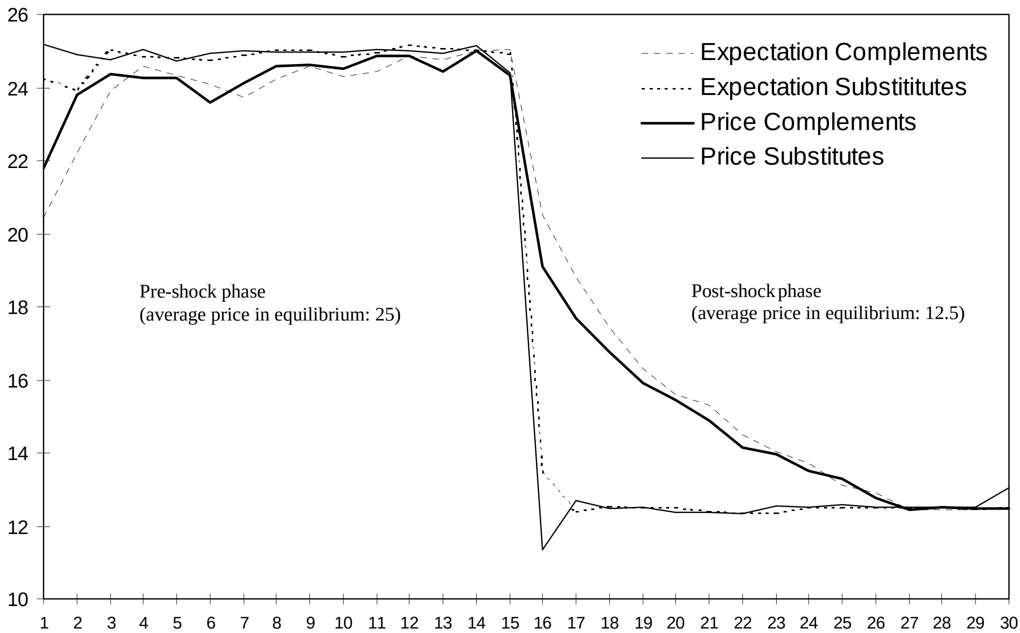
This finding also suggests that money illusion may provide a micro-foundation for the asymmetrical real economic effects of positive and negative monetary shocks which seem to have been observed (e.g., Cover 1992, Peltzman 2000).

E) Strategic complementarity as a cause of nominal inertia

The explanation provided above on why money illusion causes nominal inertia is based on the idea that money illusion systematically affects price expectations, and decision-makers react rationally to these expectations. Sticky expectations after the negative shock in NH translated into sticky price choices because of strategic complementarity. According to this reasoning, strategic complementarity plays a key role in determining whether sticky expectations translate into aggregate-level effects of money illusion. We implemented a negative shock with a nominal representation (NH) and either strategic complements (a positive slope of the reaction function) or strategic substitutes (a negative slope of the reaction function) to test for the role of strategic properties. Rational agents expecting under-adjustment by illusion-prone agents tend to imitate the behavior of illusion-prone agents if strategic complements prevail, but to *compensate* their behavior if strategic substitutes prevail. Therefore, subjects prone to money illusion should have a disproportionately large effect on the aggregate price level if strategic complements but a disproportionately small effect if strategic substitutes prevail. Our results (from an additional 76 subjects) support this hypothesis.

Figure 2 shows average prices and average price expectations in the two treatments. As can be seen, prices and expectations converge nicely to the equilibrium in the pre-shock phase (periods 1-15). In response to the anticipated negative monetary shock at the beginning of period 16, expectations differ dramatically across treatments. While expectations are very sticky with strategic complements (see upper dotted line), average expectations remain very close to the predicted equilibrium with strategic substitutes. While expectations only converge slowly to the equilibrium with strategic complements, they remain in equilibrium with strategic substitutes from the second post-shock period on. Fehr and Tyran (2002) provide a detailed account of the observation that strategic properties have such a marked effect on expectations. Simulation results suggest that the expectations formation process is much different in the two conditions. In particular, expectations with strategic substitutes are much more in line with the predictions of "rational expectations". Because expectations are almost instantaneously in equilibrium (and because agents choose best replies to their expectations), there is no nominal inertia and the anticipated monetary shock is almost neutral if subjects' actions are strategic substitutes (see Fehr and Tyran 2002 for the details).

Figure 2: Average expectations and prices with strategic complements and substitutes

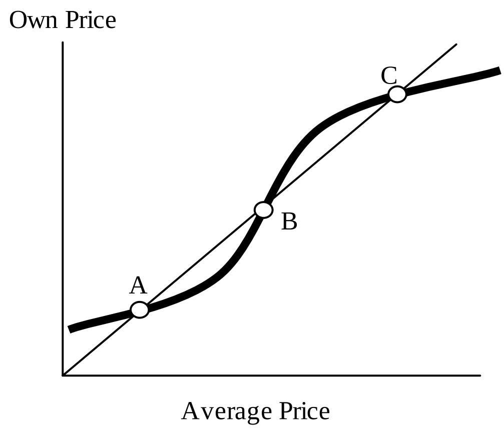


It is important to note that all experimental studies discussed above had unique equilibria. We found that money illusion systematically affects convergence to this unique equilibrium in such an environment because it shapes expectations. Eventually, however, prices converged to the unique equilibrium in all cases. As a consequence, the experiments discussed so far demonstrate a short-run real effect of money illusion which is more or less pronounced, but they do not provide evidence for permanent effects of money illusion.

5. Money illusion and coordination failure

We now analyze whether expectations can induce permanent effects of money illusion in an environment with strategic complements. To do so, we chose an experimental design that is very similar, but simpler, than that discussed in section 4. The main difference to the design described in section 4A is that there is no monetary shock but there are *multiple* equilibria. Multiple equilibria prevail if the degree of strategic complementarity is (locally) extreme (see Cooper 1999). Such a situation is illustrated in figure 3. The equilibria we implement are pareto-ranked. Equilibrium A (at a low price level) yields the highest real payoff for all players, equilibrium C the lowest real payoff. As in section 4, we capture the impact of money illusion by comparing behavior in a treatment condition in which payoff information is provided in real terms with the behavior in a treatment condition in which payoff information is provided in nominal terms. In the nominal representation, the *nominal* payoffs in the efficient equilibrium A are lower than those in the inefficient equilibrium C. Thus, if subjects take nominal payoffs as a proxy for real payoffs they may mistakenly prefer being in the inefficient equilibrium C and choose high prices accordingly. Our results clearly illustrate that money illusion can be a powerful source of coordination failure causing permanent real effects.

Figure 3: Best reply structure with multiple equilibria



A) Experimental design and hypotheses

As in the design described in section 4A, subjects had to simultaneously choose a price $p_i \in \{1, 2, \ldots, 30\}$. Each subject's real payoff depended only on his own price p_i and on the average price P_{-i} of the other n-1 players, and the payoffs were represented in a payoff matrix (see Fehr and Tyran 2003 for details). The three equilibria of the game are described in table 2. To play equilibrium A, each subject had to choose a price of $p_i = 4$. Because the game is symmetric, this led to a price level of $P_A = 4$, and resulted a real payoff of $\pi_A = 28$ for each player. In equilibrium B the price was $P_B = 10$ causing a real payoff of 5. In equilibrium C, the price level was $P_C = 27$ and each player earned a real payoff of 21. Each subject i had a unique and weakly increasing best reply for every given level of P_{-i}. Since the game is symmetric, this game's equilibria are located at the intersection of the best reply function with the 45-degree line in the (p_i, P_{-i})-space (see figure 3). If subjects have adaptive expectations and play a best reply to their expectation, equilibria A and C are stable, and equilibrium B is unstable.

Table 2: 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	$P_C = 27$	$\pi_C = 21$	$P_C\pi_C = 567$

The main purpose of our design 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. To examine the importance of nominal payoff dominance, we chose the parameters in such a way that the real payoff is highest for each player in equilibrium A but the nominal payoff is highest in equilibrium C (see table 1). Thus, the principle of real payoff dominance predicts that equilibrium A will be selected while the principle of nominal payoff dominance predicts that equilibrium C will be selected. If we indeed observe that players permanently coordinate on equilibrium C we have not only evidence that nominal payoff dominance is stronger but we also have evidence for the striking claim that money illusion may have permanent real effects.

Our price-setting game was implemented in four different treatment conditions analogous to the lines explained in section 4A (see table 1). The treatments differed with regard to the nominal vs. real presentation of the payoffs and whether subjects had to form expectations (because they played against other subjects) or whether they played against n-1 pre-programmed computers. In the latter case, subjects did not have to form expectations because they knew the computers' response to each of their feasible price choices. To maximize their payoffs, subjects had to solve an individual optimization problem taking the computers' aggregate response into account. Therefore, the treatments with computerized opponents measure the extent to which subjects are able to solve this optimization problem by choosing the efficient equilibrium A.

According to table 2, it is obvious 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 learn to play the best equilibrium when facing human opponents or their optimal strategy when facing computerized opponents. We repeated the same game for T = 30 periods in each treatment condition for this reason. When subjects faced human opponents, the group composition remained constant throughout the 30 periods. Subjects were informed in all conditions about the actual average price of the other players, P_{-i}, at the end of each period and about their real payoff.

The overall 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 informs us about the overall effect of money illusion on equilibrium selection.

Our particular interest concerns the role of *expectations* in the selection effects of money illusion. In principle, money illusion can affect equilibrium selection in two ways. First, there may be direct effects on equilibrium selection: subjects may play the inefficient equilibrium C because they are prone to individual-level money illusion. Second, indirect effects may arise from 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 expect that a sufficient number of other players suffer from money illusion and that these 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.

B) Results

In total, 174 subjects participated in our experiments. Subjects were randomly allocated to groups of $n = 5$ or $n = 6$ players. They received written instructions explaining the experimental procedures and nominal or real payoff matrices depending on the treatment condition. The calculation of real payoffs from nominal payoffs shown on the payoff matrix was carefully explained in the NC and the NH. Subjects had to choose a price $P_i \in \{1, 2, \ldots, 30\}$ in each period. In addition, they had to indicate their expectation of EP_{-i} in each period in the treatments with human opponents.

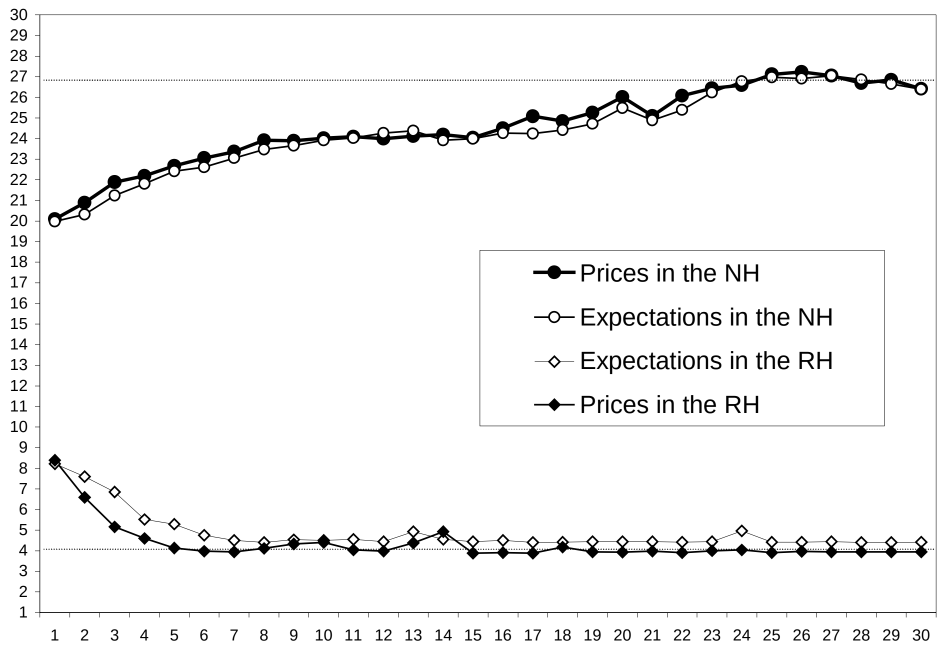
Our first main result concerns the comparison of the NH and the RH. The vast majority of the subjects converge to the *inefficient* equilibrium C in the Nominal treatment with Human opponents (NH), whereas almost all subjects quickly converge to the *efficient* equilibrium A in the Real treatment with Human opponents (RH). Figure 4 shows that there is already a large gap in average prices across treatments in period 1 – in the NH the average price is 20.1 in the first period whereas in the RH it is 8.4. The Mann-Whitney test yields a highly significant difference ($p < .0001$). Moreover, the average price quickly converges towards the efficient equilibrium $P_A = 4$ in the RH whereas a slow but steady convergence to the inefficient equilibrium $P_C = 27$ occurs in the NH.

Individual price choices in the NH and the RH differ radically. Not a single subject chose the efficient equilibrium in the NH throughout the 30 periods, while 64 percent of the subjects already chose $P_A = 4$ in period 1 in the RH. More than 90 percent of the subjects always chose the efficient equilibrium in the RH after period 7. In contrast, there is much disequilibrium play in the NH and a relatively slow convergence to the inefficient equilibrium

P_C = 27 occurs. 18 percent of subjects chose P_C = 27 in period 1 and they gradually increased to 84 percent in period 30.

This divergence between the NH and the RH is reflected in the real payoffs the subjects earned. They earned considerably less in the NH than in the RH in all periods. Recall from table 2 that the real equilibrium payoff in the efficient equilibrium A is 28 while in the inefficient equilibrium C it is only 21. There was rarely a period in which subjects did not earn an average of at least 10 units less in the NH. This indicates that the miscoordination in the NH goes beyond the fact that subjects coordinated on an inefficient equilibrium. The large payoff difference is partly caused by the larger incidence of disequilibrium play in the NH.[8]

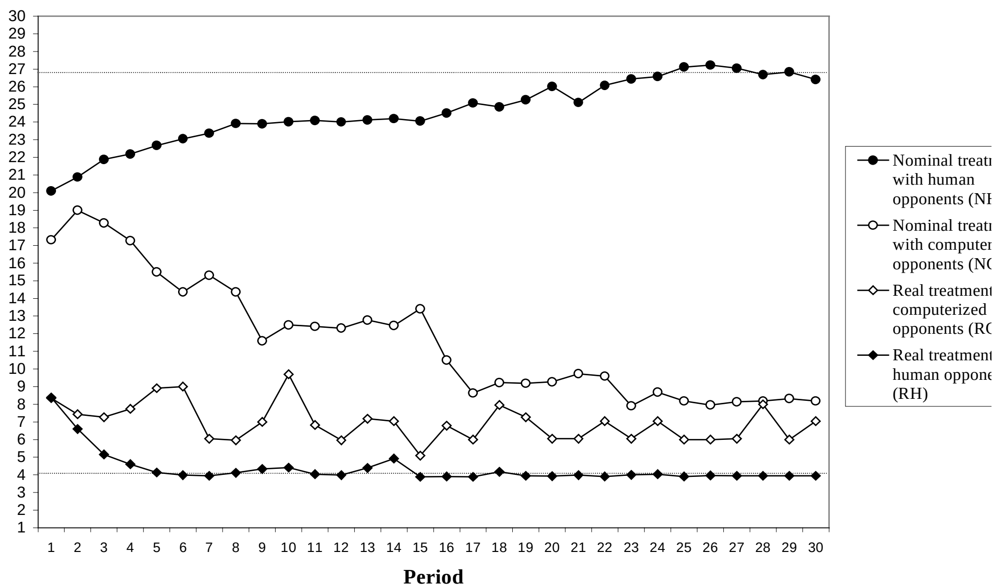
Figure 4: Average prices and expectations in the treatments with human opponents



[8] There were several cases where subjects initiated disequilibrium by deliberately trying to push the group towards the efficient equilibrium with the choice of low prices.

The striking price divergence across the NH and the RH suggests that money illusion has powerful effects on equilibrium selection. The mere fact of payoffs being represented in nominal terms induces subjects to predominantly choose the equilibrium with the higher nominal but the lower real payoff. This fact is to be explained by the movement of price expectations across treatments. The average price path closely parallels subjects' average expectations EP_{-i} (see figure 4) in both the RH and in the NH. Since subjects almost always played a best reply to their expectation EP_{-i}, this expectation is a decisive determinant of subjects' price choices. It is therefore interesting to know that subjects' price expectations already differed strongly in period 1: EP_{-i} was 20.0 in the NH whereas they expected a value of 8.2 in the RH. Not a single subject (out of 77) expected an equilibrium of $EP_{-i} = 4$ in period 1. In contrast, 48.1 percent (25 out of 52) held equilibrium expectations of $EP_{-i} = 4$ in the RH.

Figure 5: Average prices across all treatments



So far, our analysis suggests that the nominal representation of payoffs causes significantly higher price expectations, which in turn induces subjects to choose significantly higher prices in the NH. This raises the question whether there were indeed subjects who failed to see through the veil of money or whether the expectations of higher prices in the NH were solely rooted in subjects' beliefs about other players' money illusion. We obtain the following result with respect to the existence of individual-level illusion: only a minority of the 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 decrease and lose significance over time. Thus, 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 learn to pierce the veil of money better and to solve the optimization problem in the NC roughly in the same way as in the RC.

We examine next how strategic interaction in the RH affects individual irrationality other than money illusion. We find that strategic interaction increases the frequency with which the *efficient* equilibrium is played in the treatments with a real payoff representation and, eventually, removes almost all inefficiencies.

Figure 5 shows that the average price in the RC and the RH is almost identical in period 1. Following this period, 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. Thus, even though 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 largely absent in the RH. Interestingly, when payoffs are represented in real terms, strategic interactions do not magnify but remove the impact of individual-level bounded rationality on miscoordination.

In contrast, we find that strategic interaction causes a large increase in the frequency with which the *inefficient* equilibrium C is played in the treatments with a nominal payoff representation, and it completely removes the play of the efficient equilibrium from the beginning. Figure 5 indicates 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. 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 our view, the comparison between the NC and the NH is exciting because it suggests that most subjects do learn do play the efficient equilibrium when they are provided with individual learning opportunities and when they are not caught by the attraction power of an inefficient equilibrium. Thus, individual learning largely removes the power of the veil of money over subjects' behavior in a non-strategic environment. However, when subjects have to form expectations because they play the strategic game with other humans, the level of money illusion which initially exists throws subjects in the basin of attraction of the inefficient equilibrium from which no escape seems possible.

6. Summary and conclusion

In principle, money illusion is a candidate for the explanation of nominal inertia and, as a consequence, of the non-neutrality of money. However, mainstream economists have dismissed this "psychological" explanation for two reasons. First, money illusion is rejected a priori, simply because it contradicts basic rationality assumptions of economics. Second, there was no convincing evidence for the existence and relevance of money illusion. Recently, however, Shafir, Diamond and Tversky (1997) provided evidence from questionnaire studies suggesting that money illusion is an important phenomenon at the individual level. However, some economists tend to argue that the evidence such questionnaire studies yield on the existence of money illusion is weak and irrelevant. It is weak because people have no real incentive to think about their decisions, and it is irrelevant because individual-level effects may wash out with interaction. Experimental methods allow a response to these criticisms, as the actual behavior of real people is observed under controlled conditions in experimental studies, and these people are motivated by economic incentives.

The claim that money illusion must be irrelevant because individual-level effects are small and transitory is seriously misleading in our opinion, as money illusion can have important indirect effects by shaping expectations. Forming expectations is necessary for making optimal decisions in a strategic environment. Strategic complementarity prevails if agents have an incentive "to follow the crowd", and strategic complementarity may multiply the effects of expectations shaped by money illusion.

We developed an experimental design to investigate whether money illusion is a cause of nominal inertia. Our results show that money illusion can have massive aggregate-level effects under conditions of strategic complementarity, even if individual-level money illusion is small. Our results suggest that money illusion induces expectations of inertial price adjustment following a negative monetary shock and that these "sticky" expectations translate into inertial pricing decisions if strategic complementarity prevails. Furthermore, the results indicate that money illusion induces asymmetric effects of positive and negative nominal shocks. In particular, price adjustment is much faster and real effects are much less pronounced after a positive than after a negative nominal shock. Finally, it is shown that strategic complementarity is a key element in understanding the causes of nominal inertia. In particular, we show that nominal inertia is much more pronounced if strategic complementarity prevails than if strategic substitutability prevails.

We investigate potential long-run effects of money illusion in an environment with multiple pareto-ranked equilibria in a related set of experiments. Multiple equilibria arise if the degree of strategic complementarity is (locally) extreme. Our results show that money illusion can coordinate expectations on an inefficient equilibrium in which agents get locked-in.

We believe that these results constitute important insights into the aggregate-level effects of money illusion and the attainment of these insights seems almost impossible without controlled laboratory experiments. The experimental method makes the precise identification of the conditions possible under which rational expectations models are correct, and the conditions under which they fail to capture important economic forces and facts. Since we show that strategic complementarity is a key determinant of aggregate-level effects of money illusion, and since strategic complementarity seems to be an important feature of reality (Cooper and Haltiwanger 1996), our experiments suggest that it is time to take money illusion seriously in macroeconomics.

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