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Charles N. Noussair, Gregers Richter, and Jean-Robert Tyran

Studiestræde 6, DK-1455 Copenhagen K., Denmark
Tel.: +45 35 32 30 82 – Fax: +45 35 32 30 00
http://www.econ.ku.dk

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Charles N. Noussair, Gregers Richter, and Jean-Robert Tyran*

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Abstract

We test whether large but purely nominal shocks affect real asset market prices. We subject a laboratory asset market to an exogenous shock, which either inflates or deflates the nominal fundamental value of the asset, while holding the real fundamental value constant. After an inflationary shock, nominal prices adjust upward rapidly and we observe no real effects. However, after a deflationary shock, nominal prices display considerable inertia and real prices adjust only slowly and incompletely toward the levels that would prevail in the absence of a shock. Thus, an asymmetry is observed in the price response to inflationary and deflationary nominal shocks.

Keywords: Money illusion, Nominal inertia, Asset market bubble, Nominal loss aversion, Laboratory Experiment

JEL-codes: C9, E40

* Noussair: Department of Economics, Faculty of Economics and Business Administration, Tilburg, University, P.O.Box 90153, 5000 LE Tilburg, the Netherlands. E-mail: C.N.Noussair@uvt.nl. Richter: Department of Economics, University of Copenhagen, Studiestraede 6, DK Copenhagen 1455 K, Denmark. Tyran: Department of Economics, University of Copenhagen, Studiestraede 6, DK Copenhagen 1455 K, Denmark and CEPR, Goswell Road, London. E-mail: jean-robert.tyran@econ.ku.dk. We thank John Duffy, and seminar participants at the Universities of Innsbruck, Melbourne, Sydney, New South Wales, Pittsburgh, the 2008 Economic Science Association European Meetings, and the 2008 Australian Experimental Economics Workshop for comments.

1. Introduction

Money illusion is a general term describing the tendency of individuals to make economic decisions based on nominal rather than real variables. Fisher (1928) first proposed that individuals were subject to a bias in decision making of this type. The existence of money illusion is typically inconsistent with models of fully rational decision making. Nonetheless, the debate about the degree to which money illusion is empirically relevant has re-emerged in recent years, in light of empirical evidence suggesting that it has considerable effects in some settings. This evidence consists of results of surveys and empirical studies, as well as natural and laboratory experiments. Shafir, Diamond and Tversky (1997) conclude, after reporting that survey responses reflect nominal reasoning in a variety of decision tasks, and that this nominal reasoning is not eliminated with experience, that "it is easier and more natural for individual to think in nominal rather than in real terms." [1]

One might argue that, even if some individuals may be subject to money illusion in their decision making, market interaction might eliminate or overwhelm such clearly suboptimal behavior (Tyran, 2007). This argument is undoubtedly valid in some settings. However, one might presume that prices in asset markets, in which some participants speculate and seek to exploit arbitrage opportunities, might be particularly immune to individuals' money illusion. Nevertheless, there is empirical evidence that nominal variables can affect real activity in asset markets. Cohen et al. (2005) find that the three largest American stock markets trade at a higher premium when inflation is low than when it is high (Schmeling and Schrimpf 2008 report similar results for a broader set of markets using a measure of inflation expectations). This is consistent with a conjecture of Modigliani and Cohn (1979), that stock prices reflect discounting future cash flows at nominal, rather than at real, discount rates. Brunnermeier and Julliard (2008) find that the ratio of rental to purchase prices for housing depends on the values of nominal interest rates and inflation in a manner consistent with the existence of money illusion. Sonnemans (2006) finds that many transactions on the Amsterdam stock market occurred

[1] A particularly provocative suggestion is that the numerosity (or equivalently the value of each unit) of the medium of exchange can affect real decisions, and there is some evidence of such an effect (see for

at prices that are round numbers both before and after the introduction of the Euro in 2002. This implies real price changes resulting from the nominal change in currency unit, because the ratio of the values of the Dutch Guilder and the Euro was 2.20371, not a round number.

A specific mechanism whereby nominal reasoning appears to influence real asset prices is nominal loss aversion (Tversky and Thaler, 1996), a tendency to resist selling assets at nominal, as distinct from real, losses. Genesove and Mayer (2001) show, using data from real estate transactions in downtown Boston, that nominal loss aversion influences seller behavior in the housing market.[2] Engelhardt (2003) argues that nominal loss aversion in the housing market has a significant effect on household mobility. Shefrin and Statman (1985) and Odean (1998) show that the disposition effect, a tendency to hold on to stocks whose nominal prices have declined in value since their purchase longer than those that have experienced price increases, is widespread in stock markets. Odean argues that the disposition effect is a result of aversion to realized losses, and the losses are assumed (implicitly) to be nominal in his argument.[3] If a sufficient number of traders are subject to such nominal loss aversion, one consequence would be an asymmetric response to a nominal shock. Specifically, a deflationary nominal shock, which lowers nominal prices, could affect real economic activity in a manner that an inflationary shock would not. After a deflationary shock, agents subject to nominal loss aversion might withhold supply and cause nominal price inertia, and cause a slow or incomplete adjustment of real prices. No such effect would appear for a nominal inflationary shock.

The empirical studies mentioned above use data from markets in which many potentially relevant parameters are uncontrolled or unobservable to the researcher. These include the possible unavailability or opacity of data that would allow individual decision makers to distinguish between the nominal and real components of a shock, idiosyncratic properties of the particular markets studied such as changes in beliefs that a change in a

[2] When subject to nominal losses in a declining market, individuals set prices higher relative to the expected final price, the more they paid for the house. These sellers also wait longer for their house to sell, and receive higher selling prices than other sellers.
[3] Indeed, such downward wage and price rigidity is thought to influence the effect of macroeconomic policy and contribute to business cycles (see for example Yellen and Akerlof, 2006).

nominal variable may induce about real variables, and price inertia resulting from trading institutions, conventions, or budget and inventory constraints.[4]

In this paper we investigate, using an economic experiment, [5] whether two particular empirical phenomena described above appear in competitive asset markets in which money illusion is the only plausible explanation of their presence. The first phenomenon is the presence of an effect of a nominal shock on real prices, and the second is an asymmetric response of real prices to inflationary versus deflationary nominal shocks. We pose two specific research questions. The first question we consider is: (1) are real asset market prices affected by a purely nominal shock? The results above from the real estate and financial markets suggest that such effects might occur, while traditional economic theory implies that they do not. The second question concerns possible asymmetries in the effects of a positive versus a negative monetary shock. We ask: (2) does a deflationary shock lead to larger changes in real prices than an inflationary shock? That this would occur is suggested from the work cited above on housing markets and on nominal loss aversion. On the other hand, even if one supposes that markets adjust less than instantaneously or that money illusion influences decision making, there is no reason to suppose on theoretical grounds that markets would respond asymmetrically to inflationary and deflationary shocks.

[4] The nominal and real components of a financial shock may not be distinguishable to an individual who does not know the underlying rate of inflation. Asymmetries in the functioning of the trading institution exist for example, in real estate markets, where typically the seller initiates the process of exchange by placing his house on the market and posting a price. In a real estate market, constraints bind asymmetrically, as the buyer is more likely to be cash constrained, while the seller always has an item to sell. Often, a nominal shock, such as sudden inflation, may be an indication of unfavorable macroeconomic conditions or the result of poor government policy.

[5] There is also experimental evidence, from markets for single-period goods, rather than assets, that market interaction can fail to reduce and indeed even magnify the real effects of money illusion. Lian and Plott (1998) study an experimental macroeconomy with simultaneously operating input and output markets and a fiat money for trade. They subject the money supply to a nominal exogenous inflationary shock and observe a temporary increase in real output. Fehr and Tyran (2001) induce a nominal shock after a few periods of play of a pricing game. They find that nominal inertia, a tendency to price at pre-shock nominal levels, exists for individuals facing human but not computerized opponents. This indicates that there are market environments in which money illusion on the part of a single or a small number of individuals can affect responses of other individuals in such a way as to magnify the effect on real outcomes. In addition, the authors find that less nominal inertia, and thus smaller real distortion, is caused by a positive, or inflationary, nominal shock, than a negative, or deflationary, nominal shock. In a follow up paper, Fehr and Tyran (2007) find that money illusion can also have permanent effects through its influence on equilibrium selection if there are multiple equilibria. They show that money illusion can cause the economy to fall into suboptimal equilibria with real and permanent costs to agents.

As the arena in which to evaluate these two questions, we create an experimental asset market, and induce a nominal shock by suddenly rescaling the nominal variables by a factor of k, while the market is in operation. For $k > 1$, the shock is inflationary, and for $k < 1$, the shock is deflationary, and we investigate the effect of both types of shock on real prices. The rescaling has no effect on the real parameters of the market environment, but if individuals are subject to money illusion, the rescaling could potentially trigger a behavioral response on the part of agents that affects the values of real endogenous variables. Our market uses continuous double auction rules for trade. These rules are known to be rapid in responding to exogenous shocks to the market environment (Davis et al., 1993, Jamison and Plott, 1994), and the choice of these rules reflects our attempt to create favorable conditions for rapid adjustment of real prices to the nominal shock. The drawback of the use of the continuous double auction, with its highly complex message space and intractable strategy sets, is that it is not conducive to a focus on individual strategies. Thus, the research questions and results are formulated in terms of aggregate market activity and pricing biases rather than individual behavior or decision biases.

We take care to ensure that participants understand that the shock is purely nominal and not real. The nominal shock is completely exogenous, and no exogenous changes occur in the market other than the one time shock. Frictions arising from institutions and constraints are minimized. Therefore, any changes in real market behavior must be due to the endogenous behavioral response to the nominal shock itself, and such changes are taken as evidence of the presence of money illusion and its ability to exert real effects. Because our markets are exceptionally transparent and simple compared to those found in the field, we believe that the presence of real effects following nominal shocks suggests that behavior at least as anomalous would be observed in a class of markets outside the laboratory.

The next section describes the experiment. Section three presents our results and accompanying statistical support. Section four presents some concluding thoughts and observations.

2. The Experiment

2a. General Framework

The experimental design consists of three treatments. In each experimental session, regardless of treatment, there is an asset market in operation. In the market, a dividend-bearing asset with a life of 21 periods is traded. The asset has a constant fundamental value, derived from (a) dividends with an expected value of zero paid at the end of each period, and (b) a positive terminal value. In two of the treatments, the first third of the life of the asset (periods 1 – 7) comprises an initial phase, which will be referred to as the *pre-shock* phase. After this initial phase, between periods 7 and 8, there is an exogenous nominal shock to the economy. The shock takes the form of a revaluation of the currency used as the medium of exchange in the market. The time interval after the shock, comprising periods 8 – 21, is termed the *post-shock* phase.

In the *Inflation* treatment, the currency is revalued into smaller units, so that 14 units of the currency after the shock have the same value as one unit had before the shock. In the *Deflation* treatment, the currency is revalued is into larger units, so that one unit of the currency after the shock has the same value as 14 units did prior to the shock. In the third treatment, the *Control* treatment, there is no shock, and the currency has the same value during the entire course of the market.

To evaluate the first research question, whether nominal shocks have real effects, we compare the change in real price levels the shock induces in both the Deflation and Inflation treatments with the time path of prices in the Control treatment. The Control treatment, in which no shock occurs, provides the counterfactual data on the price dynamics that would be observed in the absence of a shock. The second research question, whether there is an asymmetry in the effect of inflationary and deflationary shocks, is considered with a comparison of the magnitude of the effect of the shock between the Inflation and Deflation treatments, using the Control treatment as a baseline.

2b. Procedures

The experiment consisted of a total of 18 sessions. Each of the three treatments was in effect in six of the sessions. There were 6 – 8 participants in each session, who all had the opportunity to trade in an asset market. Sessions averaged approximately 2 hours and 45 minutes in length. The experiments were conducted in English. They took place at the Laboratory for Experimental Economics (LEE) at the University of Copenhagen, Denmark. Subjects were recruited using the online system Orsee (Greiner, 2004), and all participants were undergraduate (1^{st} – 3^{rd} year) students at the University. No subject had previous experience with asset market experiments, each individual could only participate in one session, and no economics majors were allowed to take part.

At the beginning of each session, the experimenter distributed copies of the initial instructions for the experiment, which informed individuals on how to buy and sell in the market, and then read the instructions aloud. The market was constructed using the Z-tree software package (see Fischbacher 2007 for a description). It used continuous double auction rules (Smith, 1962) for transactions. During each period, any buyer could at any time submit an offer to buy a unit by entering a price at which he was willing to purchase the unit. Similarly, to sell, any individual could submit an offer by specifying a price at which he was offering to sell a unit. At any time, any individual could accept an offer to buy or sell that another participant had submitted, provided that he had sufficient units or funds to complete the transaction. Upon acceptance of an offer, a trade occurred and the cash and the unit were immediately transferred between the two parties. Offers and trade took place in terms of ECU, an experimental currency. Accumulated individual ECU currency holdings were converted to Danish Crowns (DKK) at the end of the session and paid to participants. After the initial instructions were read, participants practiced making offers, purchases and sales for roughly 10 minutes. The activity in the practice period did not count toward subjects' earnings. The purpose of the practice period was to ensure that individuals were familiar with the trading process.

After the ten minute practice period had ended, the specific instructions for this particular experiment were handed out and read aloud. The instructions described the market and the structure of the asset. They also indicated which sections of the instructions were not subject to change during the session and which sections were subject to possible change. No indication was given as to the timing of the possible change.

The instructions described the following features of the market, and explicitly indicated that these features were to remain the same for the entire session. The market would last 21 periods in each session, and each market period would be three minutes in duration. In the market, an asset could be traded. The asset yielded a dividend at the end of each period that was stochastic and independent from period to period. The dividend could take on positive or negative values, and the expected value of the dividend was zero. The realization of the dividend would be determined with the roll of a four sided die at the end of trading in each period. The dividend on a unit of asset was the same regardless of the identity of the individual who held the unit. The dividends an individual received were added (or subtracted in cases when they were negative) from his current cash balance, and the cash disbursed in the dividend payments was immediately available for the purchase of assets. The instructions also described the following elements and indicated that they were subject to possible changes later in the session: (a) the conversion rate from ECU to DKK, (b) the distribution of dividends, (c) the data in the *Average Holding Value Table,* and (d) individuals' current holdings of cash.

The Average Holding Value Table was a table displayed on a sheet of paper provided to individuals along with the instructions. The purpose of the table was to make the dividend structure and the final buyout value common knowledge. The table indicated the expected value, in terms of ECU, of holding a unit of the asset in one's inventory from any time in the session, until the end of the session, if no conditions in the environment changed. This expected value equaled the sum of the expected dividend in each period plus the final buyout value of the asset. Because the expected dividend in each period was 0, and the dividend draw in each period was independent of the draw in other periods, the value of holding an asset until the end of the session always equaled the final buyout value, expressed in ECU after conversion at the exchange rate currently in effect. There was no suggestion, in the Average Holding Value Table or in the instructions, that the expected future dividend stream was in any way related to a price at which traders should buy or sell.

After the market closed at the end of a period, the dividend for the period was realized, and the dividend payments were added or subtracted from individuals' cash holdings. Each individual then observed, displayed on his computer screen, the dividend for the period, the number of units of asset he currently held and his cash balance before and after the dividend payment. Subjects were then required to select a button labeled "*continue"* on their screen, before they could go on to the next period. This ensured that they had an opportunity to view the information on the screen.

The initial endowment at the beginning of period 1 for each agent was identical, and equaled 5 units of the asset and 250 Danish Kronor (DKK) worth of cash, but was denominated in ECU. At the end of period 21, each unit of the asset paid a terminal value of 10 DKK (= USD 1.80) to its bearer. The final dividend was described in DKK, while the dividends were described in terms of ECU, and the conversion rate was common knowledge. Final cash balances were converted to DKK and paid out to participants in cash. At the end of the session, participants received earnings from their final cash balance, converted from ECU to DKK at the prevailing exchange rate, as well as 10 DKK for each unit of asset they held at the end of period 21.

2c. Treatments

There were three treatments in the experiment, the *Inflation*, *Deflation*, and *Control* treatments. All sessions were interrupted after the dividend was realized at the end of period 7, one third of the way through the life of the asset, and additional instructions were read. In the Inflation and Deflation treatments, these additional instructions indicated that the conversion rate from ECU to DKK, the dividend distribution, current individual cash holdings, and the data in the Average Holding Value Table was changing immediately. These changes were purely nominal in nature, and all real variables remained unaffected by the change. In the Control treatment, the additional instructions simply indicated that there were no changes.

Table 1: Parameters in Pre-Shock and Post-Shock Phase of Each Treatment and End-of-Session Payouts

	Treatment		
	Inflation	Deflation	Control
Pre-shock Phase, Periods 1 – 7	100 ECU = 1 DKK Dividend ϵ {-166, -83,83,166} ECU	1400 ECU = 1 DKK Dividend ϵ {-2324, -1162,1162,2324} ECU	100 ECU = 1 DKK Dividend ϵ {-166, -83,83,166} ECU
Post-Shock Phase, Periods 8 – 21	1400 ECU = 1 DKK Dividend ϵ {-2324, -1162,1162,2324} ECU	100 ECU = 1 DKK Dividend ϵ {-166, -83,83,166} ECU	100 ECU = 1 DKK Dividend ϵ {-166, -83,83,166} ECU
After period 21 is completed (end of session)	All units of asset yield 10 DKK ECU cash balances converted to DKK at conversion rate in effect in periods 8 – 21		

Table 1 illustrates how the values of relevant nominal parameters changed between the pre-shock and post-shock phases and how they differed by treatment. In the Inflation treatment, just after period 7, the conversion rate between ECU and DKK changed from 100 ECU = 1 DKK, which was in effect until period 7, to 1,400 ECU = 1 DKK, from period 8 onward. Each individuals current cash balance at the end of period 7 was multiplied by a factor of k = 14 in the Inflation treatment. The distribution of dividend payments was also multiplied by a factor of 14. The distribution before the change was -166, -83, 83 and 166 ECU, each of which was equally likely. From period 8 onward the dividend was equally likely to be -2324, -1162, 1162, and 2324 ECU. Notice that both distributions have an expected value of zero, and therefore the fundamental value remains constant over time in terms of DKK, both before and after the nominal shock. The data in the Average Holding Value Table, indicating the sum of the expected future dividend stream and the final buyout value, was multiplied by a factor of 14, to reflect the fact that the 10 DKK final buyout value was worth 14 times more ECU. The real final buyout value, expressed in DKK, was unchanged. The instructions read after period 7 indicated clearly that there would be no further changes from that point until the end of the session.

The Deflation treatment was similar except that after period 7, the conversion rate of experimental currency to Danish Crowns decreased by a factor of $k = 14$, from 1,400 ECU = 1 DKK to 100 ECU = 1 DKK, increasing the value of each unit of the experimental currency by a factor of 14. Before the change the dividend was equally likely to be -2324, -1162, 1162, and 2324 ECU in each period, while after the change it was either -166, -83, 83 and 166 ECU. Individuals' cash balances were divided by 14, as was the indicated expected value of the future dividend stream indicated on participants' Average Holding Value Tables.

The choice of a factor $k = 14$, an integer that is not a round number, reflected a tradeoff. Using a factor that can be more easily multiplied or divided, such as 10 or 100, would provide unfavorable conditions for an asymmetry to emerge. This is because the application of a simple rule, adding or subtracting zeros from prices, would generate real prices that are the same before and after a shock.[6] On the other hand, using a non-integer factor for k would require a fairly difficult calculation on the part of participants to find the nominal price after the shock that preserved the previous real price. This raised the possibility that money illusion could arise primarily because of errors in division or multiplication, an effect we wished to minimize. It might be argued that it is easier to multiply a nominal price by 14 rather than divide by 14, and this alone could cause an asymmetry in the reaction of nominal prices to the shock. However, the same argument would hold for most real positive potential values of k, and thus presumably for typical values to be found outside the laboratory.

[6] Amado et al (2007) note "when one or more zeros are dropped from a currency, consumers rescale all prices relatively quickly rather than relearn them selectively through gradual exposure."

3. Results

Figure 1 shows the real price, defined as the nominal price in ECU divided by the exchange rate of ECU to DKK, in each period in of each of the three treatments. The vertical axis indicates price level, and the horizontal axis indicates the period number. Each of the three series represents the median real price in each session for the period indicated, averaged across all six sessions in the treatment, and the flat horizontal line indicates the fundamental value. The figure shows that, in the pre-shock phase of periods 1 – 7, prices in the three treatments are not much different from each other, although they are higher than fundamental values in each treatment on average.

In the early periods of the post-shock phase, real prices in the Control and the Inflation treatments are close to the pre-shock levels and to each other. Therefore, prices in the Inflation treatment do not appear to be greatly affected, in real terms, by the nominal shock that occurs between periods 7 and 8, as they are close to the trajectory they would have when no shock occurs. However, in the Deflation treatment, a different pattern emerges. While in the pre-shock phase, the price pattern is similar to the other treatments, in the post-shock phase beginning in period 8, real prices increase in most of the sessions to levels much higher than in the other two treatments. Prices then gradually decrease and converge to fundamentals near the end of the 21 period horizon. At the end of the session, prices are close to fundamentals in all three treatments.

The pattern in the Deflation treatment suggests pronounced nominal inertia of price adjustment, as the fall in nominal prices after the shock is insufficient to keep real prices unchanged. In contrast, the pattern in the Inflation treatment suggests little or no nominal inertia, as nominal prices adjust rapidly in proportion to the nominal shock to keep real prices constant.

[Figure 1: About Here]

Figures 2 – 4 show the data for each of the six sessions within the Inflation, Deflation, and Control treatments, respectively. Each data series in the figures is the time series of median period transaction price in one of the experimental sessions. It is readily evident from the figures that each of the treatments exhibits considerable heterogeneity between sessions. Figure 2 shows that some of the sessions in the Inflation treatment generated price trajectories that tracked fundamental values fairly closely, while others had prices considerably higher than fundamental values for sustained intervals of time. This pricing at higher than fundamental values is typical of experimental asset markets for long-lived assets (see Smith et al., 1988, Lei et al., 2001, Haruvy and Noussair, 2006, or Haruvy et al., 2008), including those with constant fundamental values over time (Noussair et al., 2001, Oechssler et al., 2007). Sessions 1, 2, and 5 of the Inflation treatment all have sustained episodes of 5 or more periods, during which prices exceed fundamental values by more than 30%.

However, in the Inflation treatment, no abrupt change occurs in any session as an immediate result of the introduction of the nominal shock in period 8. Thus, nominal prices instantaneously adjust to the nominal change in the environment, and the positive nominal shock had no perceptible effect on real activity as a consequence. The nominal price, averaged over all six markets in the seven periods before the shock, periods 1 – 7, was 1313.5. The nominal price was 16114, or 12.26 times the corresponding pre-shock level in nominal terms in the seven periods subsequent to the shock, periods 8 - 14. This represents a 12.37% price decrease in real terms in periods 8 – 14 from the level in periods 1 - 7. In the Control treatment, by comparison, real prices declined by 25.94%, from 1829.6 to 1335.0, between periods 1 – 7 and periods 8 – 14.

[Figures 2 – 4: About Here]

Figure 3 illustrates the price data from the Control treatment. Bubbles occur in three of the six sessions, *Control1*, *Control2*, and *Control4*, with two of the sessions having sustained intervals of time with prices of more than 25% of fundamental value. Both of these sessions experience market price crashes. Control1 exhibits a crash in periods 13-18, while Control2 does so in period 16, and Control4 in periods 7 – 10. The other three sessions tracked fundamentals values fairly closely throughout the life of the asset. In all six sessions, the market trades at close to fundamental value by the later periods of the session. The incidence of bubbles in the Control treatment, occurring in 50% of markets, is similar to that observed in previous studies of markets for finitelylived assets and constant fundamental values (see Noussair et al., 2001, and Oechssler et al., 2007).

Figure 4 shows the time series of transaction prices by session in the Deflation treatment. Bubbles appear in the first seven periods in three of the six sessions, in which prices exceed fundamentals by at least 27% in all seven periods. Most of the other sessions have prices that are somewhat higher than fundamentals. However, immediately after the nominal shock, the real price increases in period 8 in five of the six sessions, and more than doubles in two of the sessions. Afterwards, real prices decrease considerably, but deviate more from fundamentals than the other two treatments throughout the remaining life of the asset. In the Deflation treatment, real prices are on average 45.9% higher in periods 1-7 than in periods 8 – 14, with nominal prices averaging 19,343 before the shock and 1,922 after the shock.[7]

We now consider the research questions posed in the introduction. The first question is whether quick adjustment of real prices to previous levels occurs after a nominal shock. The second is whether the properties of this adjustment differ between inflationary and deflationary shocks. We first consider the Inflation treatment, and argue that it adjusts rapidly to its previous real price behavior, in that it exhibits similar post-shock dynamics as the Control treatment, in which there is no shock. Thus we conclude that the inflationary shock has no discernible impact on real activity. We then turn to the Deflation treatment and compare its post-shock behavior to the Control and the Inflation treatments, and conclude that the deflationary shock increases real prices significantly. Our first result, which concerns the effect of the inflationary shock, is the following.

Result 1, Rapid Adjustment to Inflationary Shock: Real asset prices are unaffected by a nominal inflationary shock.

Support for Result 1: We evaluate this proposition by comparing the behavior of markets in the Inflation treatment to those in the Control treatment, in which there was no shock. If the two treatments exhibit similar behavior, it is interpreted as evidence that the

[7] The ratios of average nominal prices of the pre- vs. post-shock phase in individual sessions were 4.81, 8.11, 11.74, 11.81, 13.61, and 19.74.

inflationary shock had no effect. We consider the change in real price between the average price for the seven periods before and the seven periods after the shock, using each session as an observation. We then test whether the distribution of these changes differs between the two treatments. That is, we compute

$$C = (\sum_{t=8}^{14} p_t * s - \sum_{t=1}^{7} p_t * r)/7 \qquad (1)$$

for each treatment. In the Control treatment $r = s = 1$. 1 In the Deflation treatment, $r = 1$ and $s = 1/k = 1/14$. In the Inflation treatment, $r = 1/k = 1/14$ and $s = 1$. Then we conduct a rank sum test for treatment differences in the value of *C*, using each session as an observation.

For the hypothesis that the distribution of values of *C* differs between the Control and the Inflation treatments, the test yields a sum of ranks of 37 ($n = m = 6$), which is not significant at conventional levels. Thus, the inflationary nominal shock appears to have no effect on the dynamic pattern of real prices, since the time path of prices does not follow a trajectory significantly different than it would have in the absence of the shock. □

The second result, described below, documents the asymmetry in the response of prices to the shock in the Inflation and the Deflation treatments.

Result 2, Asymmetry Between Inflationary and Deflationary Shocks: Real asset prices are increased by a nominal deflationary shock.

Support for Result 2: Consider the difference in average price in the seven periods before the nominal shock, periods 1 – 7, and the seven periods after the shock, periods 8 – 14. The real price is higher in the later time interval than in the earlier interval in all six sessions of the Deflation treatment in only one of the six sessions of the Control treatment. A rank-sum test of the null hypothesis that the distribution of *C* is the same in the two treatments, Deflation and Control, yields a sum of ranks of 26, so that the hypothesis of equality is rejected at the $p < .025$ level. □

We make four additional observations about our markets. The first is that we are unable to detect an effect on real prices of the numerosity of the currency. The second is that bubbles, prolonged and large differences between prices and fundamental values, are common in all treatments. The third is that a market that is mispriced relative to fundamental values before a shock is no more susceptible to having a nominal shock affect real prices than a market that operates close to fundamental values before the nominal shock. The fourth is that a deflationary shock induces an increase in real transaction price variance relative to the variance that would have existed in the absence of a shock.

Observation 1: There is no Numerosity Effect: Real prices in the pre-shock phase are not different in the Deflation treatment than in the other two treatments.

Support for Observation 1: To make this observation we consider the pre-shock phase in the three treatments. The fundamental value is 14 times greater in nominal terms in the pre-shock phase in the Deflation treatment than in the other two treatments. However, the real price is no different between the three treatments. Taking the average real price in periods 1 – 7 of each session as the unit of observation, we conduct a rank sum test on the differences across treatments. We find that real prices are not significantly different in the pre-shock phase between the Deflation treatment and either of the other two treatments at the $p = .1$ level of significance. Indeed, rank-sum tests of the average real price yield values that are insignificant at the $p = .05$ level for all three possible pairwise comparisons between treatments. □

Observation 2: Bubbles occur in about 50% of sessions.

Support for Observation 2: If we define a bubble as an episode of 5 or more periods in which prices exceed fundamental values of 25% or more for 5 consecutive periods, we see that the incidence of bubbles before the shock is similar in the three treatments, bubbles occurring in three of six sessions in each treatment. □

Observation 3: The likelihood that a nominal shock increases or decreases real price deviations from fundamental values is independent of whether the market is in a bubble prior to the shock.

Support for Observation 3: Consider the definition of a bubble proposed in the support for observation 2 above. In only one of the six markets in the Deflation treatment, was the real price closer to fundamentals in periods 8 – 14 than it was in periods 1 – 7. This was a market in which a bubble, according to the above definition, occurred during periods 1-7. In the Inflation treatment, in only one session did real prices deviate more from fundamental values in periods 8 – 14 than in periods 1 - 7, and it was a market that was not in a bubble prior to the shock. We find that the effect of the nominal shocks on mispricing is independent of whether the market tracks fundamental values or is in a bubble before the shock. □

Result two revealed an asymmetry between the behavior of the price level in response to an inflationary versus a deflationary nominal shock. We now consider if a similar asymmetry exists in the dispersion of transaction prices. A difference in the variability of transaction prices before and after a Deflationary versus an Inflationary shock would be further evidence that the two exert an asymmetric impact.

Observation 4, Variability the Shock Introduces: The standard deviation of real transaction prices increases after a deflationary shock. No effect on the standard deviation occurred as a result of the inflationary shock.

Support for Observation 4: Consider the standard deviation of real prices over periods 1 – 7 in comparison to those in periods 8 – 14. We calculate these standard deviations separately for each session, and then compare the average change in the three treatments between the earlier and the later time interval. In the Deflation treatment, the standard deviation of real prices increases from the earlier to the later time interval, from 912.4 to 1319.3, or by 44.6%. In contrast, it decreases after the shock from 763.6 to 468.8 in the

Inflation treatment, a decline of 38.6%. In the Control treatment, the standard deviation decreases from 821.8 to 382.4, a 53.5% decrease. □

4. Discussion

In our markets, we observe a distortion in real prices due to money illusion. The distortion is a property of the transition dynamics arising after a nominal shock and takes the form of nominal price inertia. An asymmetry exists in the way that prices respond to a nominal shock. They are very quick to revert back to the previous real price when the shock is inflationary, but slow to adjust when the shock is deflationary. These findings lead to two conjectures. The first is that the some of the episodes of mispricing in asset markets attributed to money illusion in the field may be a symptom of slow adjustment of activity to a change in a nominal variable or a property of decision making in unfamiliar situations which would dissipate over time. The second is that this inertia is much more severe when the shock is deflationary.

We advance a stylized conjecture that captures our intuition about the individual decision biases underlying this asymmetric response to inflationary and deflationary shocks. Suppose that after a nominal shock has occurred, some agents take some time to understand the new decision situation they find themselves in. Suppose further that these agents, whom we call *Biased Traders*, are subject to two particular decision biases during this transitional phase. These biases are (1) nominal loss aversion and (2) a particular type of bracketing of transactions. The biased trader brackets his transactions in such a way as to view a purchase followed by a resale as two linked transactions. However, a sale of a unit followed by the purchase of another unit is considered as two unrelated transactions. For example, this description would apply to an individual who, when he buys a car for 10,000 dollars and resells it the following week at a higher price, say 12,000 dollars, believes that he made money (2,000 dollars) on the sequence of trades. On the other hand, if he sells a car for 12,000 and buys a new one the following week for 10,000, he does not perceive it to be a capital gain, but rather as two unlinked transactions. We further suppose that biased traders are nominally loss averse in the sense of Tversky and Thaler (1996), so that they make decisions in terms of nominal variables.

The effect of biases (1) and (2) is that the traders subject to them are reluctant to realize nominal capital losses.

Consider an asset market populated by both "rational" and biased traders. The rational traders buy/sell when the market price is low/high relative to fundamental value. Suppose that an exogenous inflationary shock occurs with no effect on the real fundamental value of the currency, as in our experiment, so that the nominal fundamental value increases from x to $k*x$, where $k > 1$. The rational traders would have a willingness-to-pay and-to-accept that increases by the same multiple, k, as the decrease in the value of each unit of the currency. Biased agents are at least as willing as before to sell at the new higher, nominal market price, provided that it is k times higher than the previous price and they were willing to purchase at the pre-shock market price. Biased agents are also willing to purchase at the new nominal market price, since they do not associate the purchase price with the nominal prices at which they previously sold units. There is no withholding and prices increase smoothly to k times the previous level, as no individuals withhold demand or supply.

Suppose now that a deflation occurs, so that the nominal value of the asset is $1/k$ times what it was previously. The willingness to pay and willingness to accept of rational traders decreases by the same multiple as the increase in the value of the currency. Biased agents would be willing to purchase at the new lower nominal price. However, biased traders who currently hold units at the time of a shock would be unwilling to sell unit at nominal prices lower than those that they paid for them. Therefore, they would withhold supply and resist selling at a price equal to $1/k$ time the nominal price before the shock. This effect would exert upward pressure on real prices that would appear in the market in the form of nominal price inertia, and nominal prices would decline by less than a factor of k.

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((The instructions below were distributed at the beginning of the experiment))

Instructions for experiment

1. General Instructions

This is an experiment in the economics of market decision making. The instructions are simple and if you follow them carefully and make good decisions, you might earn a considerable amount of money, which will be paid to you in cash at the end of the experiment. The experiment will consist of a sequence of trading periods in which you will have the opportunity to buy and sell in a market. The currency used in the market is ECU. All trading will be in terms of ECU. The cash payment to you at the end of the experiment will be in Danish kroner (DKK). The conversion rate between ECU and DKK is described on the next page. In addition to any profits you earn in the market, you will also receive an additional DKK 50,- for your participation today.

2. How to use the computerized market

The goods that can be bought and sold in the market are called Shares. On the left-most column of your computer screen, in top left corner, you can see the Money you have available to buy Shares and in the middle of the column, you see the number of Shares you currently have.

If you would like to offer to sell a share, use the text area entitled "Enter ask price" in the second column. In that text area you can enter the price at which you are offering to sell a share, and then select "Submit Ask Price".

Please do so now to see how it works. Type in a number in the appropriate space, and then select "Submit Ask Price". You will notice that nine numbers, one submitted by each participant, now appear in the third column from the left, entitled "Ask Price". The lowest ask price will always be on the bottom of that list and will be highlighted. If you press "Buy", the button at the bottom of this column, you will buy one share for the lowest current ask price. You can also highlight one of the other prices if you wish to buy at a price other than the lowest.

Please purchase a share now by highlighting a price and selecting "Buy". Since each of you had put a share for sale and attempted to buy a share, if all were successful, you all have the same number of shares you started out with. This is because you bought one share and sold one share.

If at this point you do not have the same number of shares you started out with, raise your hand and I will come by and assist.

When you buy a share, your Money decreases by the price of the purchase. When you sell a share your Money increases by the price of the sale.

You may make an offer to purchase a unit by selecting "Submit bid price."

Please do so now to see how it works. Type a number in the text area "Enter bid price." Then press the red button labeled "Submit Bid Price".

You can sell to the person who submitted an offer if you highlight the offer, and select "Sell". Please do so now for one of the offers.

You will now have 10 minutes to buy and sell shares. This is a practice period. Your actions in the practice period do not count toward your earnings and do not influence your position later in the experiment. The goal of the practice period is only to master the use of the interface. Please be sure that you have successfully submitted bid prices and ask prices. Also be sure that you have accepted both bid and ask prices. You are free to ask questions, by raising your hand, during the practice period.

3. Specific Instructions for this experiment

The experiment will consist of 21 trading periods. You begin period 1 with 7 shares and 7.000 ecu in cash. In each period, there will be a market open, in which you may buy and sell shares. Shares are assets with a life of 21 periods, and your inventory of shares carries over from one trading period to the next. You may receive dividends for each share in your inventory at the end

of each of the 21 trading periods. The dividend may differ from period to period. It may be greater than 0 in some periods and less than 0 in other periods. On average, however the dividend in each period will equal 0,- kroner as explained below. At the end of the 21 trading periods each share pays a final amount of 10 DKK to the holder.
It is not possible to sell more shares than you own. That is, you may not "own" a negative number of shares. Also, you can only buy shares if you have enough money to pay for them.

Your earnings for the entire experiment will consist of 2 things:

1) The amount of cash that you have at the end of period 21, after the last dividend has been paid.
2) After the dividend is paid at the end of period 21, each share will pay an additional earning of 10 kroner. This earning is called the buyout value.

All of the above is constant throughout the experiment. The following 3 points (Points 4, 5 and 6) *may* change during the experiment but are valid until further notice. *If* a change takes place, you will be informed before it occurs. Also *if* a change takes place, the change will not affect the Danish kroner (DKK) equivalent of your earnings up to that point. In other words, earnings after each period are yours to keep regardless of any change in (4)-(6) that occurs after that period.

4. Conversion rates

The conversion rate between ECU and Danish kroner is 100 ECU = 1 DKK.

5. Dividends received for each share

At the end of each trading period, including period 21, the experimenter will roll a four-sided die to determine the dividend for the period. Each period, each share you hold at the end of the period:

earns you a dividend of -166 ECU if the die reads 1
earns you a dividend of -83 ECU if the die reads 2
earns you a dividend of 83 ECU if the die reads 3
earns you a dividend of 166 ECU if the die reads 4

Negative amounts will be subtracted from your ECU cash holdings. Positive amounts will be added to your ECU cash holdings.
Each of the four numbers on the die is equally likely. The average dividend in each period is 0. The dividend is added to your cash balance automatically.
After the dividend is paid at the end of period 21, each share will pay an additional earning of 1.000 ECU. This earning is called the buyout value.

6. Average Holding Value Table

You can use your **AVERAGE HOLDING VALUE TABLE** to help you make decisions. There are 5 columns in the table. The first column, labeled Ending Period, indicates the last trading period of the experiment. The second column, labeled Current Period, indicates the period during which the average holding value is being calculated. The third column gives the number of holding periods from the period in the second column until the end of the experiment. The fourth column, labeled Average Dividend per Period, gives the average amount that the dividend will be in each period for each unit held in your inventory. The fifth column, labeled Average Holding Value Per Unit of Inventory, gives the average value for each unit held in your inventory from

now until the end of the experiment. That is, for each unit you hold in your inventory for the remainder of the experiment, you will earn on average the amount listed in column 5.
Suppose for example that there are 7 periods remaining. Since the dividend on a Share has a 25% chance of being -166, a 25% chance of being -83, a 25% chance of being 83 and a 25% chance of being 166 in any period, the dividend is on average 0 per period for each Share. If you hold a Share for all 21 periods, the total dividend for the Share over the 7 remaining periods is on average 7*0 = 0. The buy-out value received after period 21 is 10 kroner. With a conversion rate of 100 ECU to 1 DKK the total value of holding a Share in the last 7 periods is on average 1.000 ECU.

AVERAGE HOLDING VALUE TABLE

Ending Period	Current Period	Number of Holding periods	Average Dividend in period	Ending period Buyout value (DKK)	Average holding Value Per Share in Inventory (ECU)
21	1	21	0	10	1.000
21	2	20	0	10	1.000
21	3	19	0	10	1.000
21	4	18	0	10	1.000
21	5	17	0	10	1.000
21	6	16	0	10	1.000
21	7	15	0	10	1.000
21	8	14	0	10	1.000
21	9	13	0	10	1.000
21	10	12	0	10	1.000
21	11	11	0	10	1.000
21	12	10	0	10	1.000
21	13	9	0	10	1.000
21	14	8	0	10	1.000
21	15	7	0	10	1.000
21	16	6	0	10	1.000
21	17	5	0	10	1.000
21	18	4	0	10	1.000
21	19	3	0	10	1.000
21	20	2	0	10	1.000
21	21	1	0	10	1.000

7. Your Earnings

Your earnings for the entire experiment will equal the amount of cash that you have at the end of period 21, after the last dividend has been paid. This cash is converted from ECU to DKK with the conversion rate. The 50 DKK you receive for participating is added to this.
The amount of cash you will have is equal to:
The cash (called “money” on your screen) you have at the beginning of the experiment
+ positive dividends you receive (when you have more than zero shares)
- negative dividends you pay (when you have more than zero shares)
+ money received from sales of shares
- money spent on purchases of shares
All this is converted to DKK.
+ buyout value of DKK 10,- for each share you own at the end of period 21.

((the following instructions were distributed at the end of period 7))

Change in conditions for the experiment

We are now at the end of period 7 out 21 in the experiment. The following will be in effect from period 8 on, and will not change until the end of the experiment:

- the conversion rate from ECU to Danish kroner (DKK).
- The dividends earned after each period of holding 1 share.
- All your ECU cash holdings will be multiplied by 14.

This has the following effect in points (4) - (6) you where previously given:

4. Conversion rates

The conversion rate between ECU and Danish kroner is now 1400 ECU = 1 DKK.

5. Dividends received for each share

At the end of each trading period, including period 21, the experimenter will roll a four-sided die to determine the dividend for the period. Each period, each share you hold at the end of the period:

earns you a dividend of -2324 ECU if the die reads 1
earns you a dividend of -1162 ECU if the die reads 2
earns you a dividend of 1162 ECU if the die reads 3
earns you a dividend of 2324 ECU if the die reads 4

Negative amounts will be subtracted from your ECU cash holdings. Positive amounts will be added to your ECU cash holdings.
Each of the four numbers on the die is equally likely. The average dividend in each period is 0. The dividend is added to your cash balance automatically.
After the dividend is paid at the end of period 21, each share will pay an additional earning of 14.000 ECU. This earning is called the buyout value.

6. Average Holding Value Table

You can use your **AVERAGE HOLDING VALUE TABLE** to help you make decisions. There are 5 columns in the table. The first column, labeled Ending Period, indicates the last trading period of the experiment. The second column, labeled Current Period, indicates the period during which the average holding value is being calculated. The third column gives the number of holding periods from the period in the second column until the end of the experiment. The fourth column, labeled Average Dividend per Period, gives the average amount that the dividend will be in each period for each unit held in your inventory. The fifth column, labeled Average Holding Value Per Unit of Inventory, gives the average value for each unit held in your inventory from now until the end of the experiment. That is, for each unit you hold in your inventory for the remainder of the experiment, you will earn on average the amount listed in column 5.
Suppose for example that there are 7 periods remaining. Since the dividend on a Share has a 25% chance of being 2324, a 25% chance of being -1162, a 25% chance of being 1162 and a 25% chance of being 2324 in any period, the dividend is on average 0 per period for each Share. If you hold a Share for all 21 periods, the total dividend for the Share over the 21 periods is on average 7*0 = 0. The buy-out value received after period 21 is 10 kroner. With a conversion rate of 1.400 ecu to 1 DKK the the total value of holding a Share in the last 7 periods is on average 14.000 ecu.

AVERAGE HOLDING VALUE TABLE

Ending Period	Current Period	Number of Holding periods	Average Dividend in period	Ending period Buyout value (DKK)	Average holding Value Per Share in Inventory (ECU)
21	8	14	0	10	14.000
21	9	13	0	10	14.000
21	10	12	0	10	14.000
21	11	11	0	10	14.000
21	12	10	0	10	14.000
21	13	9	0	10	14.000
21	14	8	0	10	14.000
21	15	7	0	10	14.000
21	16	6	0	10	14.000
21	17	5	0	10	14.000
21	18	4	0	10	14.000
21	19	3	0	10	14.000
21	20	2	0	10	14.000
21	21	1	0	10	14.000

7. Your Earnings

Your earnings for the entire experiment will equal the amount of cash that you have at the end of period 21, after the last dividend has been paid. This cash is converted from ECU to DKK with the conversion rate. The 50 DKK you receive for participating is added to this.

The amount of cash you will have is equal to:
The cash (called “money” on your screen) you have at the beginning of the experiment
+ positive dividends you receive (when you have more than zero shares)
- negative dividends you pay (when you have more than zero shares)
+ money received from sales of shares
- money spent on purchases of shares
All this is converted to DKK.
+ buyout value of DKK 10,- for each share you own at the end of period 21

Figure 1: Real median prices by treatment (median across sessions within treatment)

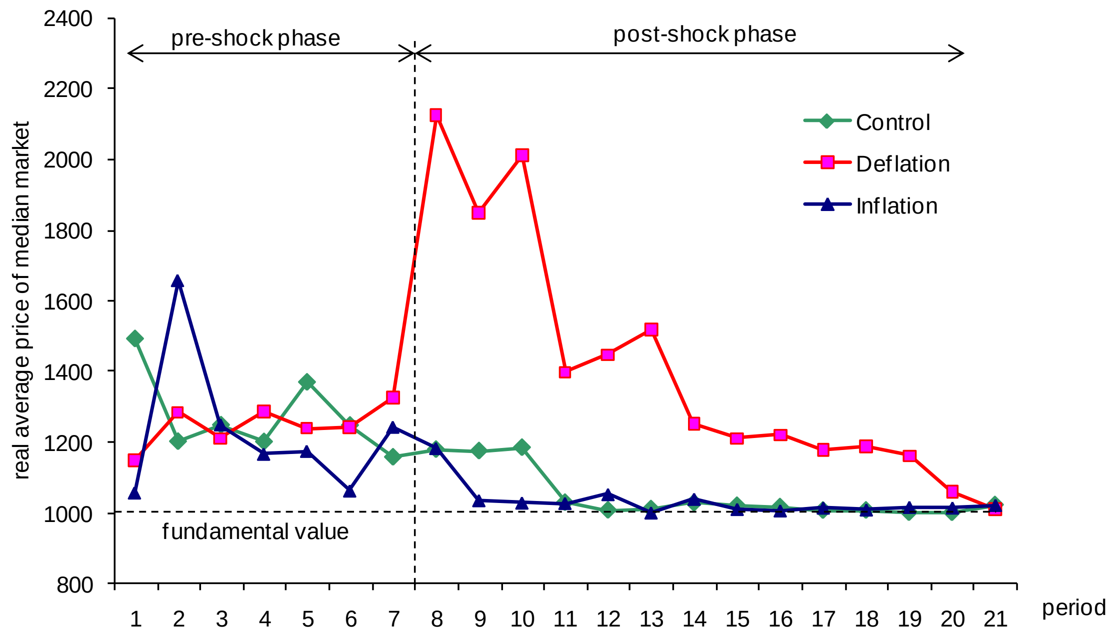

Figure 2: Real Average Prices in Each Session of the Inflation Treatment

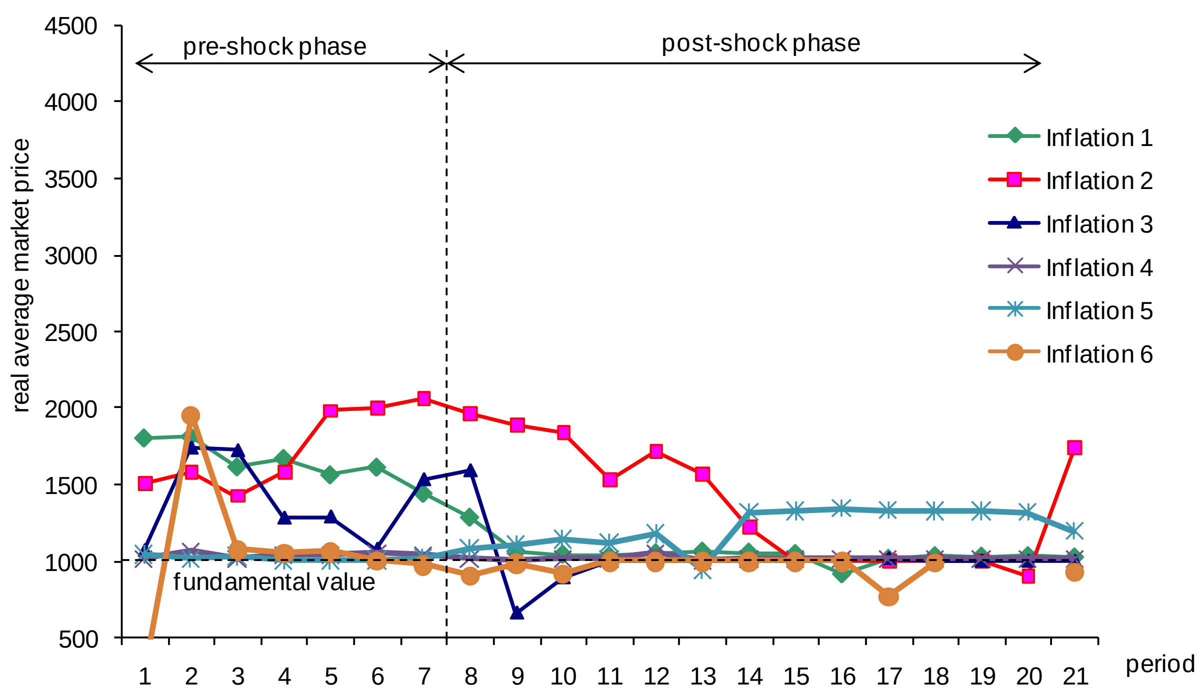

Figure 3: Real Average Prices in Each Session of the Control Treatment

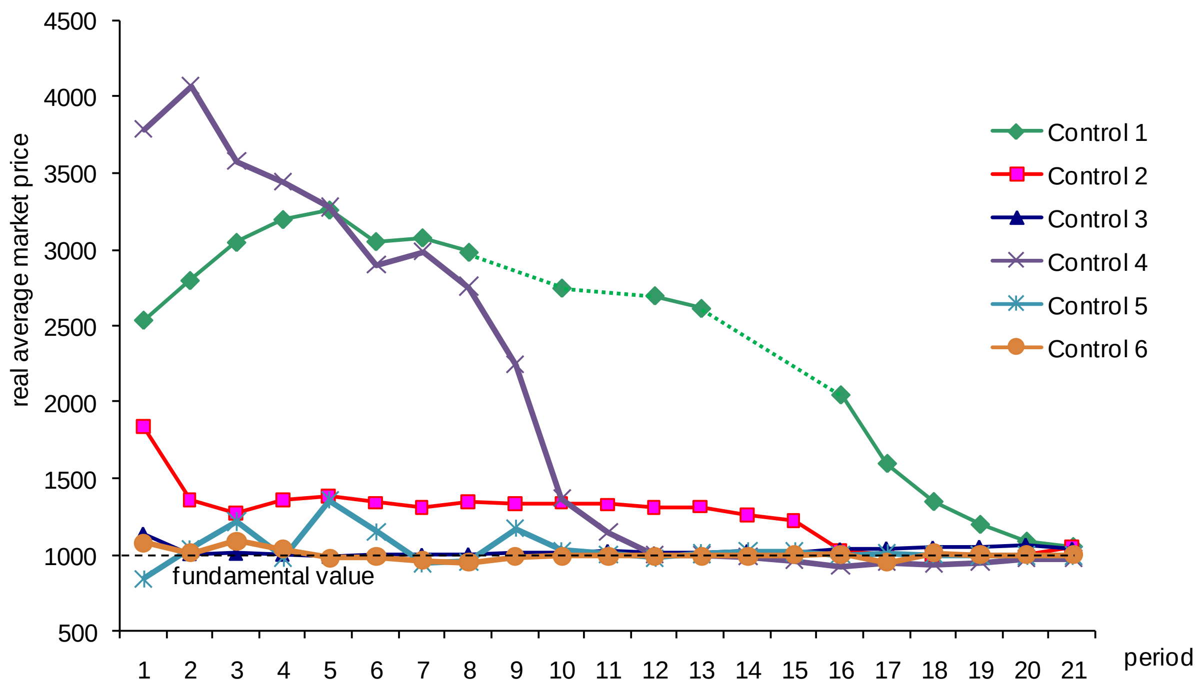

Figure 4: Real Average Prices in Each Session of the Deflation Treatment