

EXPERIMENTAL INVESTIGATION OF COORDINATION AT AGGREGATE VERSUS INDIVIDUAL LEVEL

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Abstract

We argue that the ability to coordinate under strategic complementarity is substantially affected by mutual interactive development at the individual and aggregate level. Optimal strategy which is followed by each player does not only depend upon strategy of the other player but also on conditions prevailed at the aggregate level. Results of our laboratory experiment suggest that certain type of player might be or might be not awarded depending on type of the economy, which has important implications at the aggregate level with respect to the speed of the convergence.

Keywords: Coordination, convergence, nominal inertia, expectations

Introduction

Keynesian coordination problems have received considerable attention in many studies, among others Ball, Romer, (1991), Cooper, John (1988), Ochs (1995), Cooper, and Haltiwanger, (1993), Oh, Waldmann (1994), Haltiwanger, and Waldman, (1989). These studies argue that an environment described by strategic complementarity with heterogeneous agents might have important implications at the aggregate level. In a nutshell, the presence of strategic complements causes that rational agents have a tendency to imitate the behavior of naive agents and through that multiply the effect of non-equilibrium behavior at the aggregate level. As a result the mix of sophisticated and naive agents in the economy in case of one time shock will result in an adjustment path similar to pure naive case adjustment with only slow movement to equilibrium in an environment of strategic complementarity. This mechanism is enabled by the presence of a small number of naive agents, whose effect on the adjustment process is disproportionately important for the first few periods after the shock. The first order effect of small fraction of naive agents at the aggregate level is

documented by many studies such as Akerlof and Yellen (1985) or Blanchard, Kiyotaki (1987).

Coordination issues were also investigated on experimental basis by Fehr and Tyran (2007), (2008), Van Huyck et. al (1990), (1991), Russell, Thaler (1985). Research of Fehr and Tyran (2007), (2008) suggests that the slow adjustment of nominal prices after a fully anticipated monetary shock is the case under conditions of strategic complementarity and coordination represents a problem. With help of experimental framework similar to Fehr and Tyran (2001) we aim to extend the latest research. We argue that the ability to coordinate under strategic complementarity is substantially affected by mutual interactive development at the individual and aggregate level. Optimal strategy which is followed by each player does not only depend upon strategy of the other player but also on conditions prevailed at the aggregate level. As a result coordination of individual player and coordination at the aggregate level has to be distinguished for our purpose. Our results suggest that certain type of player might be or might be not awarded depending on type of the economy, which has important implications at the aggregate level with respect to the speed of the convergence. Our conclusions will differ with respect to whether players face an environment of real or nominal values.

In the next section we introduce experimental design. The following section provides us with basic simulations related to the aggregate and individual level development. Presentation of the main results of the experiment and its comparison with simulations is the content of the next section. Summarization of our main findings follows.

Experimental design

The following section describes the nature of experimental design together with the character of experimental procedures and parameters

General description of Experimental Design

Experimental design inspired by Fehr and Tyran (2001) is based on n-player pricing game with strategic complementarity and unique equilibrium. All n subjects in the role of firms have to set simultaneously their nominal prices in each period of the game, but at no cost in any period. The experimental game is divided into a pre-shock and post-shock phase, with 2T length periods each. The pre-shock phase, which lasts T periods serves the purpose of equilibrating the system and is given by M_0 . Afterwards, a fully anticipated negative monetary shock is implemented, where money supply is reduced to M_1 . The post-shock phase then lasts an additional T periods. We need to emphasize that the shock was fully anticipated and was therefore common knowledge to participants, together

with the length of the post-shock phase. Post-shock phase enables to observe the character coordination to equilibrium at the aggregate level and also at the individual level. In other words we may observe how nominal prices adjust in response to the shock in various treatment conditions.

The subject's pricing behavior is governed by the size of pay-offs.

The *real payoff* of subject i , π_i , is given by

$$\pi_i = \pi_i(P_i, \bar{P}_{-i}, M) \quad i=1, \dots, n \quad (2)$$

Where P_i stands for i 's nominal price, \bar{P}_{-i} is the average price of the other $n-1$ group members and M denotes a nominal shock variable (money supply). The *nominal payoff* is expressed as $\bar{P}_{-i}\pi_i$.

We use the aforementioned payoff function Fehr and Tyran (2001) in our experimental setting with treatment condition, which relates to the form in which payoffs are expressed. The payoff can be either real or nominal. The real treatment (RH) marks the situation, where subjects receive the payoff information for their decision making in real terms. In the nominal treatment (NH), subjects receive the payoff information for their decision making in nominal terms. In order to compute their real payoffs, subjects in the nominal treatment have to divide their nominal payoffs by the average price of the other $n-1$ group members, i.e. $\bar{P}_{-i}\pi_i/\bar{P}_{-i}$.

Additionally, experimental subjects are in a group with other $n-1$ human subjects. The aggregate response rule is not known in advance, which implies that the subject has to form expectations about price choices of the other $n-1$ human opponents in his group. This induces uncertainty, which is substantially higher under nominal frame. As a result we may expect that character of coordination may differ depending on the type of frame with which subjects have to cope with.

Experimental parameters

In our experiment, group size of $n=4$ is set and remains constant for the whole period before and after the shock. Each group has two types of subjects, subject of type x and subject of type y , equally distributed within the group. The payoff function differs among the players, where x types have to select a relatively low price in equilibrium, whereas y types have to choose a relatively high price. The money supply before the shock in each treatment was given by $M_0=42$, while in the post-shock phase it was given by $M_1=M_0/3=14$. The average equilibrium price over all n group members in the pre-shock phase is given by $\bar{P}_0^*=18$, whereas in the post-shock equilibrium $\bar{P}_1^*=6$. The length of the pre-shock and the post-shock phase is $T=20$. Experimental subjects interact via computer terminals and have to select in each period an integer price P_i in interval from 1 to 30. They also have to form an expectation P_{-i}^e about \bar{P}_{-i} . In order to make the appropriate

aforementioned decisions the subjects receive information about their payoffs in a matrix form (See pay off tables of Fehr and Tyran (2001) for more details). The payoff matrices are designed for x and y-types of players for all treatment conditions. Either the real or the nominal payoff is present in the matrix for each feasible combination of (P_i, \bar{P}_{-i}) .

In total, 80 subjects participated in the experiment. 40 subjects participated in the nominal treatment NH, 40 subjects participated in the real treatment RH. Subjects were paid a show-up fee of 150 CZK. This was also the minimum amount, which they could win during the game. The total earnings of the subjects in the experiment were approximately 450 CZK on average. The experimental session lasted 90 minutes on average. The experiment was conducted in the Laboratory of Experimental Economics, Prague, in June 2011. In order to experimentally test the subjects' behavior through computers, the Java program was used to set-up the experiment.

Aforementioned experiment is not macroeconomic in Walrasian sense and rather concentrates on single market. However, this is not a problem since temporary macroeconomic models rest on microeconomic foundations. Thereby, laboratory experimentation is in line with current macroeconomic modelling and the size of experimental sample might be considered as a sufficient in order to form relevant conclusions at aggregate level. Exactly because macroeconomic models are based on individual behaviour, experiments might provide guidance for how subjects perceive examined phenomenon. For instance, in the economy with multiple equilibriums it might indicate what equilibrium subjects consider as more relevant, (Duffy, 1998, 2008).

Simulations of Coordination Issues at the Aggregate and Individual Level

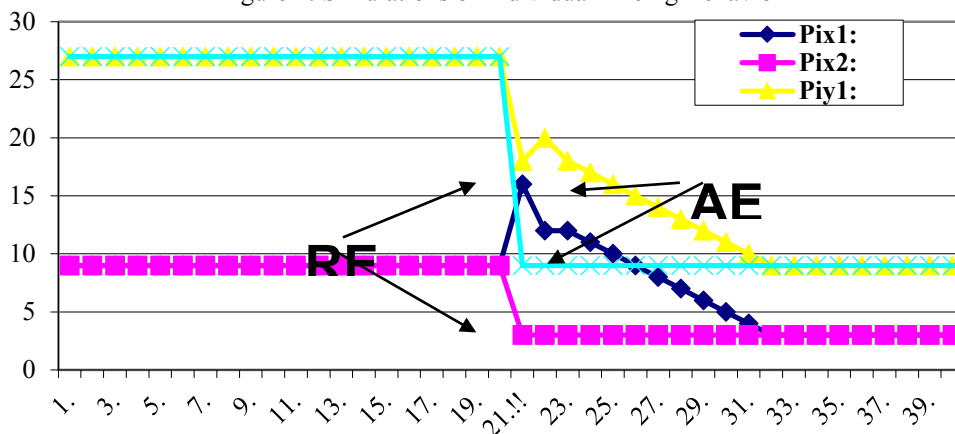
The so-called coordination problem appears to be a crucial factor which may affect the speed of adjustment in the economy after the shock. However, coordination as an effort to move quickly towards equilibrium with high expectation correction and immediate adjustment is not sufficient delineation as emerged during the course of research. In order to explain properly this phenomenon we need to distinguish coordination problem at the aggregate and individual level for our purpose. Our statements are underpinned by simulations based on aforementioned experimental design.

2.1 Coordination at Individual Level

Coordination at the individual level is understood as a strategy used by each player. Our simulations based on experimental design proved that mostly two basic types of players were responsible for the final development at aggregate level. Firstly, an adaptive player (AE) is present as a type of

player who does not coordinate at all, i.e. “no coordination is present”, and his behavior is dependent on past price development. His expected price is usually above the actual price, which means delayed expectations. As a result he expects the average price close to the pre-shock price development. Secondly, the rational player (RE) is present as a type of player, who offers coordination with respect to his strategy of immediate movement to the equilibrium. His expectations are in line with price development. Figure 1 shows individual pricing behavior of rational and adaptive players according to type of the player.

Figure 1: Simulations of Individual Pricing Behavior



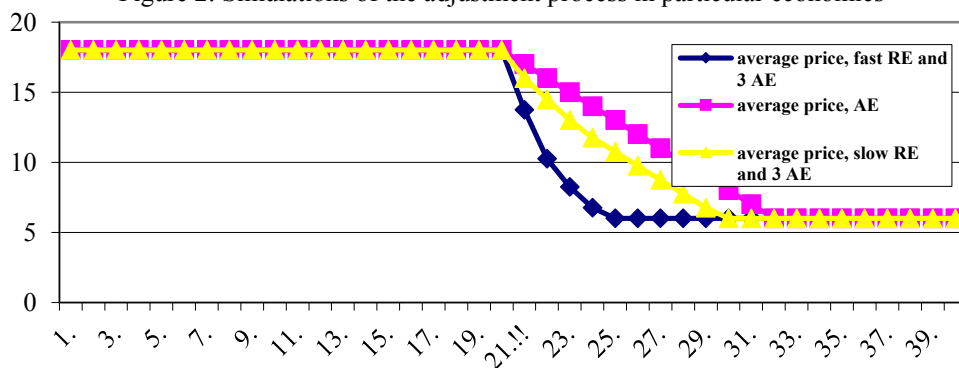
Also note the presence of two type of players x and y mentioned in experimental design. Later, results of the laboratory experiment will show that behavior of rational player may change if the rest of the individuals are not willing to coordinate. In that case rational player is persecuted by lower income. As a result, he stops to coordinate and switch to behavior closer to the adaptive one. He slows down his adjustment to the equilibrium because of his unconfirmed expectations, thereby causing nominal inertia. Although the player remains fully rational, the best way for him is to behave in an adaptive way in order to maximize pay-offs. His behavior therefore might be described as adaptively-rational and will be close to the behavior of adaptive player.

2.2 Coordination at the Aggregate Level

Various cases may arise from the combination of the aggregate versus individual level. In the economy, there may appear players who will be willing to coordinate, but might be outweighed by subjects who are not willing to coordinate or do not coordinate (i.e. adaptive players), which leads to no coordination or even discoordination at the aggregate level.

The character of coordination at the aggregate level has to be distinguished according to the type of economy present. Results show that a purely adaptive economy is considered an economy where no coordination is present after the negative shock because price adjustment together with formation of expectations is restricted purely to past development. This economy consists only of adaptive players. An economy where coordination takes place after the negative shock in a more or less successful way consists primarily of rational players willing to coordinate. Lastly, an economy with negligible coordination or even discoordination consists primarily of players, which are not able to cope with the character of an environment or adaptive players are present. Simulations in Figure 2 below show how the speed of convergence in the economy might be affected by the presence of particular players. If the economy is purely adaptive, the development after the shock follows backward-looking character. This is depicted by the line with slowest adjustment. On the other hand the presence of rational player in the economy, who is willing to coordinate, significantly fastens the adjustment to equilibrium after the shock. The adjustment to equilibrium is fastest. If rational player does not want to coordinate in the economy anymore because of his upset expectations, he will follow behavior close to adaptive player. This will substantially slow down the speed of adjustment and the performance of the economy is represented by the line which lies in the middle.

Figure 2: Simulations of the adjustment process in particular economies



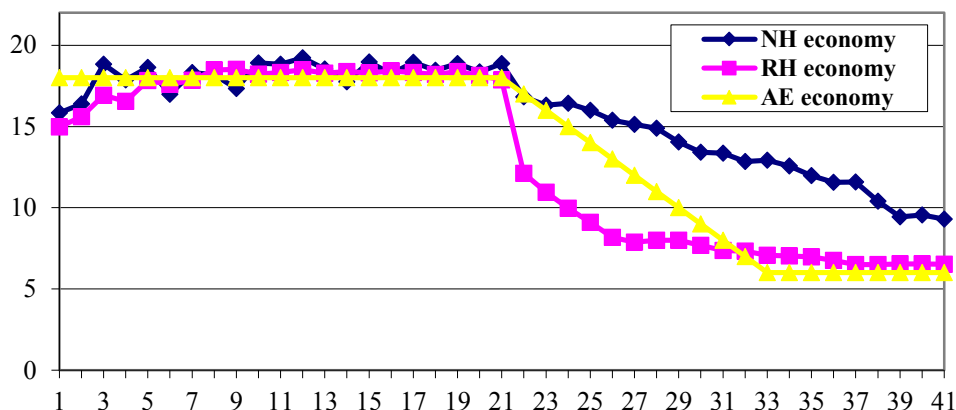
Results

The following section will reveal the main results of experiment and compare them to basic simulations mentioned above.

3.1 Results at Aggregate level

Figure 3 describes experimental results gained at the aggregate level. In order to compare the performance in the economy of the real (RH) and nominal treatment (NH), simulated case of purely adaptive economy (AE) with no coordination at aggregate level was added.

Figure 3: Development of the average price in the economy of NH, RH and AE.



Directly after the monetary shock is imposed, the tendency for inertial pricing is significantly lower for players in the real treatment. This indicates that sufficient coordination is the case due to frequent presence of rational players, who contribute to faster convergence to equilibrium as proved by simulations. The tendency of rational player to behave in complementary way is very low in this economy. The speed of adjustment of this economy is close to the simulated case of highly coordinated economy as suggested by Figure 2.

In contrast, the nominal treatment exhibits characteristics of no coordination or even discordination at the aggregate level, since its performance is even lower than that of adaptive economy. The speed of adjustment to the equilibrium is rather slow. We may presume frequent presence of players, who are defeated by the nominal frame or the presence of rational players who behave in complementary way since it is profitable for them. The performance of this treatment is in line with simulated case of the economy with rational player who behaves in complementary way to players, which are not willing to coordinate.

If expectations are to be evaluated, the nominal treatment expects price $\bar{P}^e=18$ directly after the shock, whereas the real treatment expects $\bar{P}^e=12$. This again confirms that the nominal treatment is more inertial in the period after the shock compared to the real treatment.

Development at the aggregate level raises the question, to what extent it is desirable to behave in the economy in a rational or adaptive way.

3.2 Results of Coordination at Individual Level

The following section provides closer look on the frequency of particular types of players with respect to the type of treatment.

The real treatment

Fast adjustment to equilibrium of the real treatment at the aggregate level is given by composition of players within the groups. Representative group RH 5 (where RH stands for the real human treatment and number of group), documents that it takes only 5 periods till the price will adjust to equilibrium after the shock, (See Figure 4). Results confirm the presence of rational players who speed-up the process of equilibrating. However, sometimes also the presence of adaptive players is the case, which is in line with the speed of the convergence of group which was not immediate. This composition of groups with mix of rational and adaptive players was mostly the case of all groups within the real treatment.

Figure 4: Average price development in Group RH 5

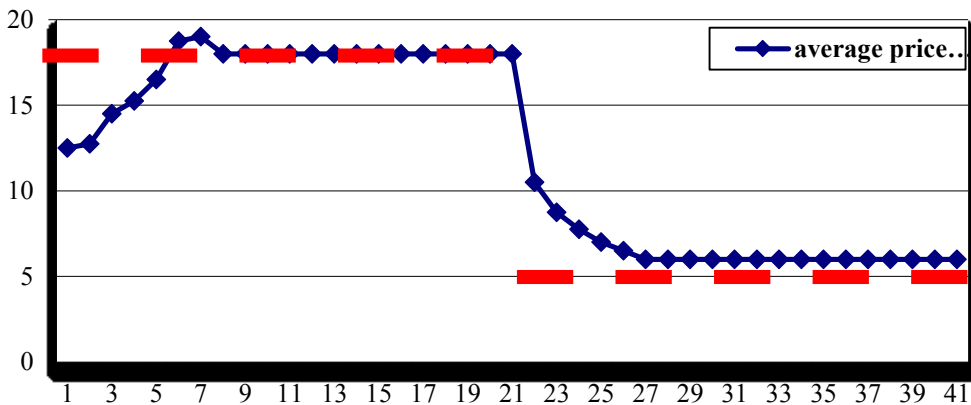
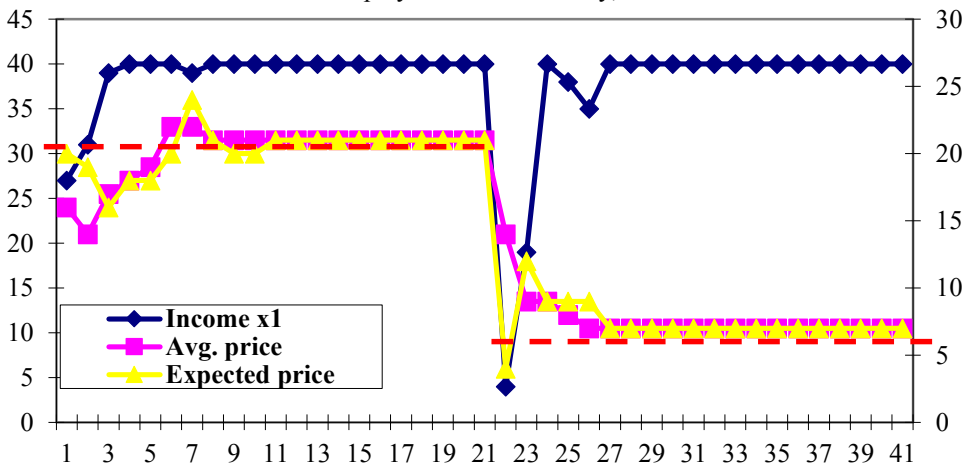


Figure 5 below documents the performance of player x_1 from representative group, whose pricing strategy definitely reflects rationality. Based on his coordination effort, he significantly reduces his price directly after the shock.

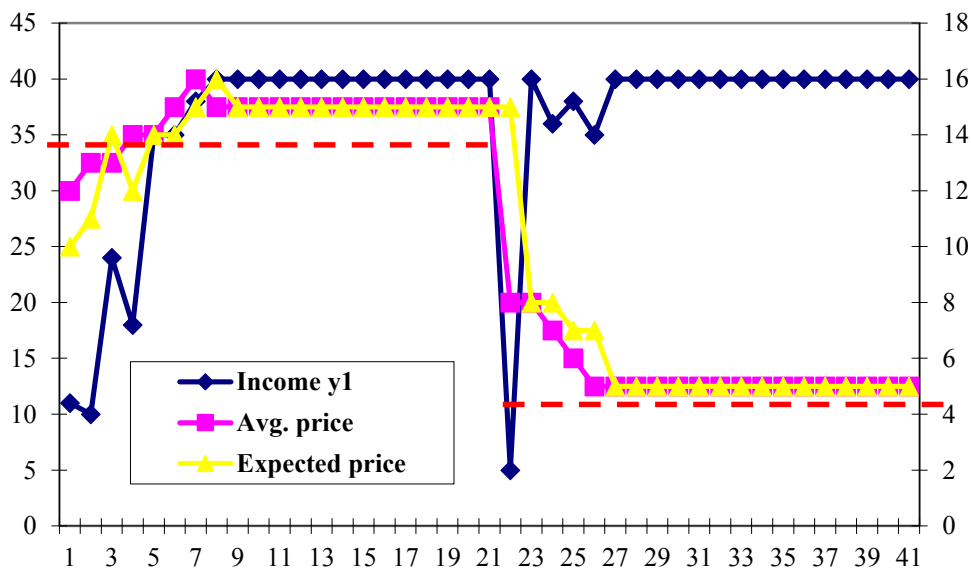
Figure 5: Development of income, expected price of player x_1 and average price of the other $n-1$ players in the economy, RH5



Since his expectations are not met with the development of the average price in the economy, which is much higher, his income is significantly reduced in the first post-shock period. From then, the best strategy is to behave in an adaptive way with a smooth adjustment to equilibrium. This provides proof that rational player who is upset in his expectations may switch to adaptive behavior. Behavior of player x_2 might be also described as a rational one directly after the shock. He also coordinates with his price downwards to new equilibrium, but the reduction is weaker as opposed to the previous player. After the correction is made, he follows adaptive behavior. Pricing behavior of both rational players is in line with performed simulations, (See Figure 1).

The behavior of player y_1 is typically adaptive, since his expectations are delayed in the first post-shock period and are in line with the pre-shock price development, significantly above the actual average price in the economy. Another piece of evidence that the player is adaptive is that his individual price exactly reflects the simulation price, which is set by the adaptive player of type y after the shock and which equals 18, (See Figure 1).

Figure 6: Development of income, expected price of player y_1 and average price of the other $n-1$ players in the economy, RH5

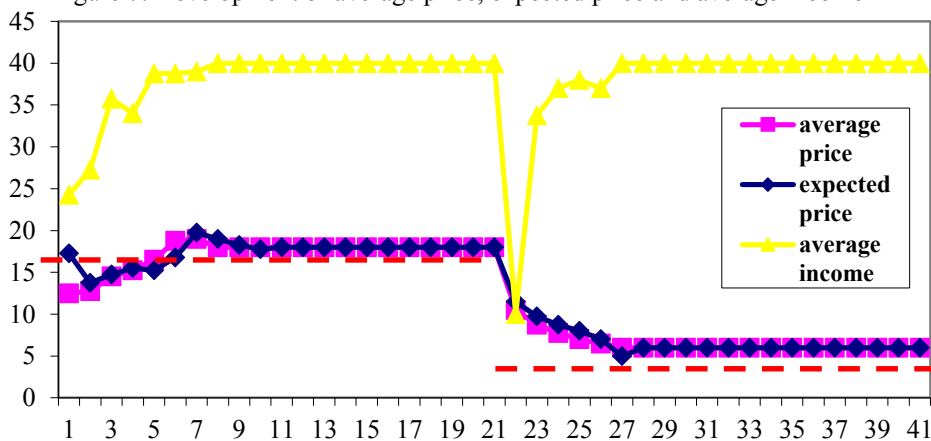


His adaptive behavior results in significant reduction in income for the first post-shock period. Player y_2 exhibits similar behavior and even overshoots his expectations, which are then above the pre-shock average price. He also sets an adaptive price of 18 after the shock, which results in significant reduction in income. As a result this player reacts in the next period by correcting his expectations downwards. This is met with success,

since his income immediately rises. From then, he follows the same adaptive behavior like player y_1 .

On average the group is coordinated in a good way, since the expected price is in line with the average price development and income is maximized most of the time, (See Figure 7). Coordination was mostly induced by rational players, who significantly correct their expectations towards the equilibrium in the first post-shock period, which is in line with flexible price adjustment. This also had a positive effect on the other adaptive players in the group, who reacted in the consequent period by correcting their expectations towards the average price. This contributed to the fact that the average price adjusted very quickly after the shock to the new equilibrium. This is also documented by the size of income, which is maximized for most of the time, the exemption being the first post-shock period. Rewards of rational players were slightly higher on average than that of adaptive players, which suggests that the real treatment benefits these players due to conditions prevailed at aggregate level.

Figure 7: Development of average price, expected price and average income in RH5

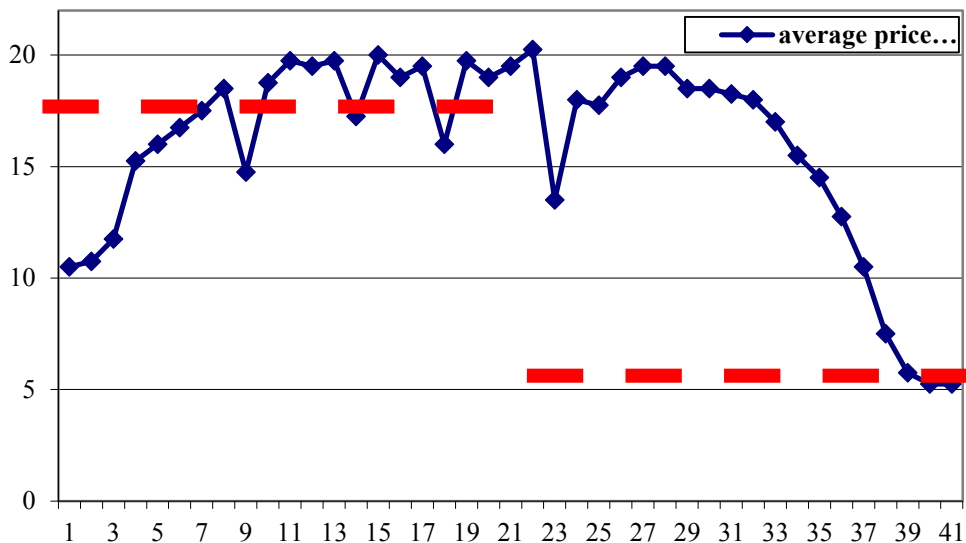


The nominal treatment

Groups present in the nominal treatment are mostly characterized by discoordination due to the fact that subjects have to cope with the nominal frame. The development of the average price in representative group NH5 is highly inertial, with a very slow speed of adjustment to the equilibrium, which is attained almost at the end of the post-shock phase, but eventually overshoot takes place. Slow adjustment suggests that confusion by nominal variables was so severe that some individuals were not willing to coordinate. The average price is even higher than the pre-shock level (See Figure 8 below). A closer look at individual pricing behavior shows that representative group consists mostly of players who are defeated by the nominal frame, less adaptive players are present. Most of the groups in the

nominal treatment exhibit similar features which in turn affects the speed of convergence at the aggregate level.

Figure 8: Average price development in NH5



The player x_1 is typical example of the player defeated by the nominal frame, who is not willing to coordinate to equilibrium. After the shock he raises his price to considerably high levels. His expectations are high and significantly above the average price in the economy.

Player x_2 is also not willing to coordinate, since he does not react anyhow after the shock and is still fixing his price at the same level. Since he achieves low income, he corrects his expectations about the average price upwards to 22 for 6 periods. This is in line with individual price, which is adjusted upwards to 17 and remains fixed for these periods. Although the player is penalized by quite a low income in these periods, he does not change his strategy anyhow. Then in the period 33 he corrects his expectations downwards, followed by price adjustment and is again fixing expectations and the price for the next three periods. From then he tries to adjust to the equilibrium in adaptive way.

Player y_1 retains his individual price at the same high pre-shock level, because he expects high average price. This is not met with the success as income reduction follows. As a result he reduces his price in the second period two units below the simulated price of the adaptive player and is rewarded by almost maximum income. His adjustment is full of downward and upwards swings, since he is probably confused by nominal values. He ends up overshooting the equilibrium price.

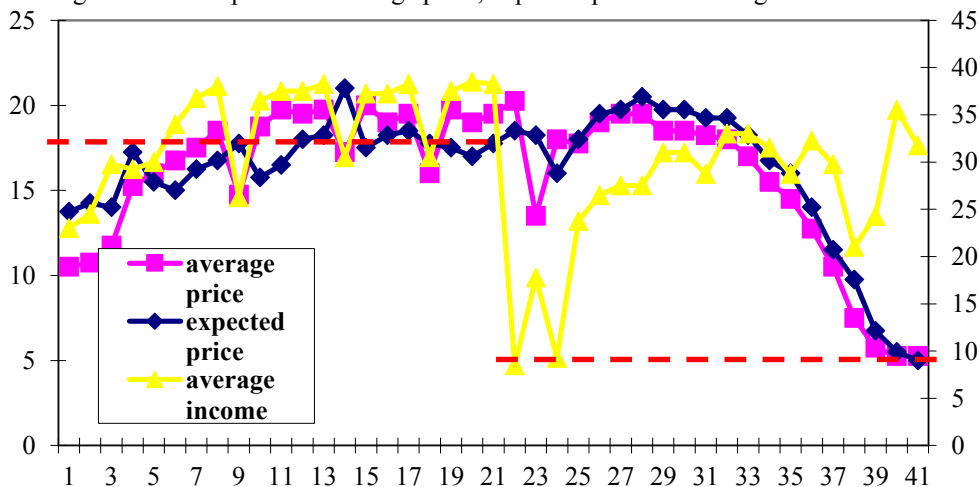
Player y_2 was the only one who reduced the price after the shock, which was in line with his expectations. In other words he tried to offer

coordination after the shock, but due to the behavior of player x_1 (who set a high price) and player x_2 (who was fixing the price), the average price was quite high and the coordinator achieved a low income. As a result he was no longer willing to coordinate and started to behave in complementary way to other players. As a result his pricing behavior became highly inertial.

The player x_1 later decided to correct his price closer to the equilibrium at the moment when player y_2 was already upset with his expectations. This shows that severe discoordination is present. Players who are willing to coordinate in a particular time are prevented from doing so, because other players are not willing to do so due to their confusion by nominal values. Coordination effort is persecuted by lower income and this provides incentives to behave in complementary way. As soon as the other players decide to adjust their price to equilibrium, because they start to see through the nominal veil, they are hindered in their behavior by upset coordinators, who already gave up any effort. Thus, the formation of expectations and consequent pricing behavior is much more difficult under the nominal frame, which leads instead to a discoordination at aggregate level.

If we have to evaluate the performance of the group NH5 on average in Figure 9, discoordination has a serious impact on the average price and expectations, which are fairly inertial.

Figure 9: Development of average price, expected price and average income in NH5



For the whole post-shock phase, expectations are delayed behind the average price. Rewards are not maximized, since the average price is fairly remote from the equilibrium. Only in the second half of the post-shock phase do subjects start to move downwards with their expectations and prices. Maximum rewards are achieved neither in the pre-shock phase, nor in the post-shock phase. After the shock, income reached the minimum levels

during three periods, but in consequent periods it grew only steadily, mostly being between 30 and 35.

Conclusion:

We tried to verify that the ability to coordinate under strategic complementarity is substantially affected by mutual interactive development at the individual and aggregate level. With help of the laboratory experiment inspired by Fehr and Tyran (2001) we conducted simulations, followed by evaluation of results gained at aggregate and individual level.

Simulations performed at the individual level reveal that basically two types of players are present. Either adaptive player not willing to coordinate or rational player willing to coordinate is present. Additionally, simulations at the aggregate level suggest that the presence of rational player increases coordination in the economy and speeds up consequent adjustment to the equilibrium. In contrast the presence of the player, who is not willing to coordinate (either adaptive player or upset rational player) slows down the adjustment to the equilibrium.

Experimental results at the aggregate and individual level are in line with our simulations. As a result we may confirm our presumptions that coordination, no coordination or discoordination exists at the aggregate level. The real treatment consists mainly of mix of rational and adaptive players with fast adjustment to equilibrium. Additionally, players have no tendency to exhibit complementary behavior in direction of naïve agents. This contributes to sufficient coordination at the aggregate level in this economy. The nominal treatment consists mainly of adaptive players or players confused by the nominal frame. Players tend to behave more in complementary way in direction of naïve adjustment. As a result, this treatment is rather representative of no coordination or even discoordination at the aggregate level.

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