Experimental Macroeconomics Evaluation of Coordination Favorableness at Aggregate Level

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Abstract

The experimental investigation of coordination issues is experiencing an upswing nowadays in macroeconomics. With the help of an experiment set in the New Keynesian framework of N-player pricing game with monopolistic competition and strategic complementarity inspired by Fehr and Tyran (2001), we address the question of coordination favorableness at the aggregate level. The results of our experimental research indicate that the extent to which coordination is favorable might, under nominal pay-off dominance, be accountable for existing nominal inertia at the aggregate level. As a result, the product might stay below its potential for a longer time, since convergence is decelerated through a strengthened channel of strategic complementarity.

Keywords: *experimental macroeconomics, coordination, rational player, convergence*

JEL Classification: C92, E52, E58

Introduction

Experimental macroeconomics as a subfield of experimental economics aiming to analyze aggregate phenomena through controlled laboratory experiments has gained considerable attention in contemporary economics. The testing of predictions or assumptions of macroeconomic models might be subject to considerable discussion within laboratory conditions that enable the testing of interactions of small groups of subjects for short periods of time. However, controlled laboratory experimentation might be justified in cases when it is almost impossible to generate findings through standard macroeconomic approaches and econometric analyses of essentially unavailable macroeconomic data, as

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observed by Robert Lucas (1986). His invitation to conduct laboratory tests of rational expectation macroeconomic models gave a boost to subsequent macroeconomic experimental research, including identification issues, endogeneity issues and equilibrium selection problems.

As emphasized by Duffy (2008), one of the pioneering topics subject to experimentation are coordination issues so crucial for understanding the persistence of business cycle fluctuations via the behavior of agents that coordinate on equilibrium. See for instance, Duffy and Ochs (1999; 2012), Van Hyuck, Battailo and Beil (1990), Ball and Romer (1991), Mankiw and Romer (1991), or Duffy and Fisher (2005), Fehr and Tyran (2007), Deverag and Ortmann (2007), Agranov and Schotter (2012), Arifovic, Jiang and Xu (2013), Anbarci and Feltovich (2013), Shurchkov (2013), Croix and Docquier (2012), Jacquemet and Zylbersztejn (2013), Arifovic and Jiang (2014), Fehr, Heinemann and Llorente-Saguer (2013). Coordination issues are prevalently affected by the composition of the economy, which is assumed to consist of heterogeneous agents. If a sufficient number of rational players are present in the economy and willing to coordinate towards equilibrium, then it is beneficial for the player to coordinate as well in terms of income. If a sufficient share of players are non-coordinators, then it is better to adjust their behavior according to the law of strategic complementarity, although the outcomes reached are suboptimal (Haltiwanger and Waldmann, 1989). Due to the imperfect adjustment induced by the strengthened channel of strategic complementarity where coordination is unfavorable, the economy may find itself out of the potential product. This is the case for many real economies as proved by Cooper and Haltiwanger (1996) Oh and Waldman (1990; 1994) and many others.

Since coordination issues appear to be decisive for development at the aggregate level in terms of the convergence to equilibrium, several questions are raised. This paper goes one step further, where coordination favorableness associated with the adjustment to equilibrium is evaluated in terms of its impact on income and with regards to whether agents face a market environment of nominal or real pay-offs. In other words, if people in a nominal environment take nominal values as a proxy instead of the real ones as documented by Fehr and Tyran (2005b), it raises the question of the extent to which coordination is beneficial, which might also explain the consequent nominal inertia occurrence with its resulting aggregate outcomes. Implementation of nominal values is supposed to reflect vulnerability of individuals to the veil of nominal values in the real world. As documented by Akerlof and Shiller (2009), Fehr and Tyran (2001) or Modigliani and Cohn (1979) people see through the veil of the nominal values rather with difficulties. Thereby they may tend to vote for rather suboptimal

outcomes, which together with strategic complementarity may affect coordination at the aggregate level.

A hypothesis inspired by a study of Fehr and Tyran (2001) will be examined with the help of the experiment set in the New Keynesian framework of the macroeconomic model of monopolistic competition (Akerlof and Yellen, 1985). Individuals are in the role of firms setting prices for their production in an artificial monopolistic competitive economy with unique Pareto-efficient equilibrium, with a fully announced negative monetary shock in the middle of the experiment. The returns of these firms are affected by their selling price and by the price level, which is determined by prices set by other firms in the artificial economy. Players in the role of firms, with strong incentives supported by financial reward, try to maximize their profit, defined as a function of their particular price and the average price level. During the process of learning, subjects are assumed to select the profit-maximizing price, which should be consistent with the total general equilibrium of the economy, if other subjects choose the correct price maximizing their profits as well.

On the basis of experimental data, we will try to evaluate whether or not potential coordination in the first period directly after the shock was beneficial for subjects in terms of income. This may provide an answer as to why rational individuals are willing to coordinate or not with regards to the type of treatment, with the consequent impact on price adjustment at the aggregate level. The first test will try to shed light on what impact the size of expectation correction of the subject for the first post-shock period has on income size and consequent coordination. The second test focuses on how the actual deviation of price from the equilibrium price in the first post-shock affects the size of income and consequent coordination.

Both expectation correction and adjustment to the equilibrium are significant factors in terms of coordination, which might shed more light on the coordination favorableness of subjects governed by the size of income with consequent effect at the aggregate level.

1. Experimental Design

The experiment inspired by Fehr and Tyran (2001) is based on *N*-player pricing game with monopolistic competition and strategic complementarity with unique equilibrium. Subjects in the role of identical firms are expected to set the price in each period of the game.[1] The experiment is divided into a pre-shock and a post-shock phase, each with length T. A fully anticipated negative monetary shock is implemented during the game, which is common knowledge to participants,

where a reduction is made from initial money supply M_0 to $M_1 = M_0/3$.[2] In order to test coordination favourableness with its resulting impact on economic outcomes, treatments differ with respect to pay-off functions, which provide them with information about their pricing strategy. The pay-offs of participants are expressed either in nominal terms or in real terms with regards to the treatment. The difference between pre-shock and post-shock phase is crucial since it enables to observe how subjects coordinate to equilibrium.

Pricing behavior of individuals can be described according to Akerlof and Yellen (1985), Blanchard and Kiyotaki (1987) and Fehr and Tyran (2001) as follows:

The real pay-off of subject i is given by:

$$\pi_i = \pi_i (P_i, P\text{-}_i, M) \qquad i = 1... n \qquad (1)$$

where the aim of individual is to maximize the real profit π_i. Profit depends on individual price P_i, the average price of the other n-1 group members $P\text{-}_i$ and the size of the nominal money supply M. In order for subjects in the nominal treatment to correctly decide on the price of their product they need to re-count nominal pay-off into the real pay-off. The nominal pay-off is given by $P\text{-}_i . \pi_i$. In order to compute real pay-off, individuals have to divide their nominal pay-offs $P\text{-}_i . \pi_i$ by $P\text{-}_i$.

Functional specification[3] of the pay-off function implies that:

- Function is homogenous of degree zero in $P_i, \overline{P}_{-i}$ and M.
- The equilibrium is unique for every M.

These conditions which reflect the neutrality condition, were implemented in order to examine the effects of veil of nominal values on the adjustment process in the economy with a unique money-neutral equilibrium P_i^*, $i = 1... n$. If M changes from M_0 to $\lambda . M_0$ and if prices change to λP_i and $\lambda \overline{P}_{-i}$, the real payment remains unaffected in order to ensure neutrality. In addition, if $\lambda P_i^{'}$,

[1] Subjects are endowed with pay-off matrices in order to make appropriate decisions. See section *Experimental Procedures and Parameters* for more information (pay-off tables are available upon request, more in Fehr and Tyran, 2000).

[2] We opted for negative and not positive monetary shock due to its asymmetric effects confirmed by experimental studies of Fehr and Tyran (2005a; 2005b; 2001). The adjustment of nominal prices to a unique equilibrium after a negative monetary shock is strongly retarded by subjects´ attraction to high nominal pay-offs if they believe other subjects opt for high pay-offs too. On the contrary, in case of positive shock subjects have to adjust their prices in the direction of high "attractive" nominal pay-offs, because equilibrium prices have to rise after this shock. Thereby, the convergence in this case is much quicker as proved by afore-mentioned experimental studies. Moreover, asymmetrical real economic effects of positive and negative monetary shocks have been observed by Cover (1992) or Peltzman (2000) or Ravn and Sola (2004).

[3] More thorough mathematical specification of the pay-off function is available in the original study of Fehr and Tyran (2000), i.e. <www.iew.unizh.ch/wp/iewwp045.pdf>.

$i = 1...\ n$, is a best reply to $\overline{P}_{-i}$ at M_0, then $\lambda P_i^{'}$ is a best reply to $\lambda \overline{P}_{-i}$ at λM_0. The post-shock equilibrium is then for all i equal to λP_i^{*}.

- The best reply is increasing in $\overline{P}_{-i}$.

Real pay-off of subject was made dependent on the average price of the other $n - 1$ subjects in the group $\overline{P}_{-i}$, which generates strategic complementarity. If the real pay-off of subject would be made dependent on $\overline{P}$, it would be much more difficult for the subject to play the best reply, because he would have to also include his own price choice.

- Equilibrium is the only Pareto-efficient point in pay-off space.

This property ensures that the equilibrium is the unique Pareto-efficient point in the whole economy. Unique equilibrium was selected due to complications induced by initial implementation of the price-setting game with monopolistic competition. The adjustment towards equilibrium in pre-shock and the post-shock phase was distorted by attempts to cooperate in the real and also nominal frame as proved by pilot experiment of Fehr and Tyran (2001).

- Equilibrium can be found by iterated elimination of weakly dominated strategies.

This property ensures that framing of pay-offs has no effect on whether a particular strategy is dominated. A method for finding the equilibrium remains the same regardless of the character of pay-offs. In the real frame a (weakly) dominated strategy P_i is set such as it has smaller real pay-offs values at any level of $\overline{P}_{-i}$. Also in the nominal frame a (weakly) dominated strategy P_i has smaller nominal pay-off values at any level of $\overline{P}_{-i}$. Subjects therefore only face a task of elimination of (weakly) dominated strategies with smaller pay-off values at any given level of $\overline{P}_{-i}$. Since the best reply function is the same regardless of the nominal or the real frame and this holds also for the number of dominated strategies, the nature of coordination between the real and nominal treatment should not differ if individuals are able to uncover the veil of nominal values.

We expect that the economy of the real control treatment will exhibit favorable conditions for coordination followed by sufficient expectation correction and fast adjustment to equilibrium due to a simple environment absent of the need to uncover the veil of nominal values. Whether coordination favorableness in the experimental economy of the nominal treatment prevails also or not depends on the channel of strategic complementarity, which might be strengthened or weakened depending on the type of players that prevail. If agents predominate who behave in a rigid way, coordination is then less beneficial in terms of income, thus leading to slower adjustment at the aggregate level, with the economy being below the potential product after the negative monetary shock. If a sufficient

number of rational coordinators prevail in spite of the nominal environment, coordination favorableness will lead to a reduction of nominal inertia at the aggregate level.

2. Experimental Procedures and Parameters

84 subjects participated in the experiment, which was conducted in the Laboratory of Experimental Economics, University of Economics, Prague (UEP), Faculty of Economics in June 2011.[4]

Subjects were master students from Faculty of Economics, UEP and 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. In order to experimentally test the subjects' behaviour through computers, the Java program was used to set-up the experiment. The game has 40 rounds plus one trial period, with a group size of $n = 4$, which remains constant for the whole game. The size of the group was selected as in the original design, since no significant net effects are associated with a different size of the group. With more members in the group, the probability of subjects who are unable to uncover veil of nominal values increases, but also the capability of an individual to affect average prices is smaller. Secondly, with regards to the heterogeneity of the players, the case of four different players with four different pay-off functions would be the most realistic one. However, the more different pay-off functions are present in the design, the more complicated the case. As a result, only two types of players *x* and y with two different pay-off functions are present in our experimental design.

[4] Experimental literature according to Riciutti (2008) distinguishes among two types of macroeconomic experiments: a) experiment centered on single market, which is in line with the current trend of macroeconomic modelling based on microfoundations; b) macroeconomic experiment of Walrasian nature, which centers on inter-relations between several markets and the spill-over between them. Our experiment falls within the latter category, which is in line with current macroeconomic modelling based on microfoundations. Thus, the size of the sample ($z = 84$ subjects, where $N = 40$ in the real treatment and $N = 44$ in the nominal treatment) is sufficient in order to derive appropriate implications at aggregate level. This is also documented by vast array of studies, which use similar size of sample for this type of experiment. See for instance Fehr and Tyran (2008), with number of subjects $z = 76$; Fehr, Kirchsteiger and Riedl (1998), $z = 52$; Adam (2007) $z = 30$; Duffy and Fisher (2005), $z = 10$; Arifovic and Sargent (2003), $z = 12$; Van Huyck, Battalio and Beil (1994), $z = 40$ and others. This argument is further supported by Smith (1962) who proves that the convergence to competitive equilibrium is sufficient only with few subjects (3 – 5) on side of supply and demand. Additionally he confirms that the big sample size is necessary neither in strategic environment, nor non-strategic environment. Considerations about the sample size may be summarized in vein of Duffy (2011, p. 6): "In practice, experimental macroeconomics is not distinct from microeconomic laboratory experiments, there is just a different focus or interpretation. A macroeconomic experiment is one that tests the predictions of a macroeconomic model or its assumptions or is framed in the language of macroeconomics."

The major experimental parameters inspired by Fehr and Tyran (2001) are summarized in Table 1 below. The experiment is divided into a pre-shock and a post-shock phase, each with length T = 20. A fully anticipated negative monetary shock is implemented during the game, which is common knowledge to participants, where a reduction is made from initial money supply $M_0 = 42$ to $M_1 = M_0/3 = 14$. Player *x* is supposed to set relatively low price in equilibrium, whereas the player y should vote for relatively high price. Average equilibrium price across n groups in pre-shock phase is $\overline{P}_0^* = 18$, whereas in the post-shock phase is $\overline{P}_1^* = 6$. 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 $\overline{P}_{-i}$. Moreover, they have to indicate their confidence about their expectation P_{-i}^e, which was measured by choosing an integer on scale from 1 to 6, where 1 indicates that the subject is not at all confident, whereas 6 indicates that the subject is absolutely confident.

T a b l e 1

Experimental Parameters

All Periods	
Representation of pay-offs in the nominal frame	$\overline{P}_{-i}\pi_i$
Representation of pay-offs in the real frame	π_i
Group size	$n = 4$
Information feedback in period *t*	$\overline{P}_{-i}, \pi_i, \pi_i$
Real equilibrium pay-off	40
Choice variable	$P_i \in \{1, 2 \ldots 30\}$
Length of pre-and post-shock phase in treatment with human opponents	T = 20
Pre-Shock Values	
Money Supply M_0	42
Average equilibrium price $\overline{P}^*$ and average equilibrium expectation for the whole group	18
Equilibrium price for type *x*	9
Equilibrium expectation $\overline{P}^e_{-i}$ for type *x*	21
Equilibrium price for type *y*	27
Equilibrium expectation $\overline{P}^e_{-i}$ for type *y*	15
Post-Shock Values	
Money supply M_1	14
Average equilibrium price $\overline{P}^*$ and average equilibrium expectation for the whole group	6
Equilibrium price for type *x*	3
Equilibrium expectation $\overline{P}^e_{-i}$ for type *x*	7
Equilibrium price for type *y*	9
Equilibrium expectation $\overline{P}^e_{-i}$ for type *y*	5

Source: Fehr and Tyran (2001).

In the treatments with human opponents subjects have to face a coordination problem which is closely associated with uncertainty. Confidence therefore serves as an indicator of subjects´ perceived uncertainty about the other subjects´ choices. At the end of each period (after the choice is made) subjects are informed about their performance on an outcome screen. The size of their actual real pay-off together with the actual realization of $\overline{P}_{-i}$ is depicted for the current round. Additional information regarding the subject´s past real pay-offs and past choices of $\overline{P}_{-i}$ is also available there.

In order to make the appropriate aforementioned decisions the subjects receive information about their pay-offs in a matrix form. The pay-off matrices are designed for *x* and *y*-types for all treatment conditions. Either the real or the nominal pay-off is present in the matrix for each feasible combination of (P_i, $\overline{P}_{-i}$). The best reply for any given $\overline{P}_{-i}$ is easily found owing to setting of pay-offs given by properties of the pay-off function. Subjects have to select the highest real or nominal pay-off associated with a given $\overline{P}_{-i}$ given their expectations $\overline{P}^{e}_{-i}$. The highest earned profit is 40 units ECU.[5] It is important to note that not only do subjects receive their own pay-off tables, but also pay-off tables of the other type.

Publicly announced negative monetary shock is implemented in the last period of the pre-shock phase. Based on that, subjects of x and y-types receive the new pay-off tables, adjusted for the new level of money supply $M_1 = M_0/3$. Except for the shock, nothing changes, which is common knowledge together with the length of the post-shock phase, which is another T period. Subjects also receive pay-off tables of the other type. In addition, they are still equipped by the pre-shock tables and are allowed to compare it with the post-shock ones. In order to fully understand the change and ensure that the nominal shock was anticipated, subjects have sufficient time to study the new and old pay-offs.

3. Assessment of Coordination Favorableness

The first period after the monetary shock is crucial for investigation of coordination favorableness, since it will enable us to detect the extent to which there was any expectation correction as well as whether the adjustment to equilibrium appreciated in terms of income, with the consequent impact for convergence at the aggregate level.

[5] Profits were expressed in experimental units. The following exchange rate was set for the consequent payment procedure, 1 ECU = 0.4 CZK.

3.1. The Impact of Expectation Correction on Income

In order to test coordination favorableness, the impact of the expectation correction on the size of income is subject to investigation on the basis of experimental data:

$$Income = \alpha + \beta*(\overline{P}_{-i} - \overline{P}^{e}_{-i}) + \varepsilon \quad (2)$$

where $\overline{P}_{-i}$ is the average price of a particular player in the period before the shock, computed as the average of individual pre-shock prices of other $n - 1$ players and $\overline{P}^{e}_{-i}$ is the expected price of the player for the first post-shock period. Deviation $\overline{P}_{-i} - \overline{P}^{e}_{-i}$ shows how close the player´s expectations are for the post--shock period compared to the pre-shock actual price, i.e. the size of his expectations correction. The closer the expectations to the pre-shock average price, the less willing the individual is to coordinate, which means the correction of expectations is lower. The further the expectations from the pre-shock average price of other $n - 1$ players, the more rational the individual is in terms of coordination and correction of expectations becomes higher. Coefficient β measures how the size of deviation $(\overline{P}_{-i} - \overline{P}^{e}_{-i})$ will be reflected in the size of income earned by the rational who is willing to coordinate. If the coefficient is equal to 0, then the size of deviation (the size of expectations correction) does not have any impact on the size of income earned and being the rational coordinator is not relatively more advantageous. If the coefficient is positive ($\beta > 0$), it implies that the higher the size of the deviation (i.e. the higher the correction in expectations), the higher the income earned and thus being the rational coordinator proved to be profitable. Thus, according to our hypothesis the coefficient β may be positive or equal to zero.[6]

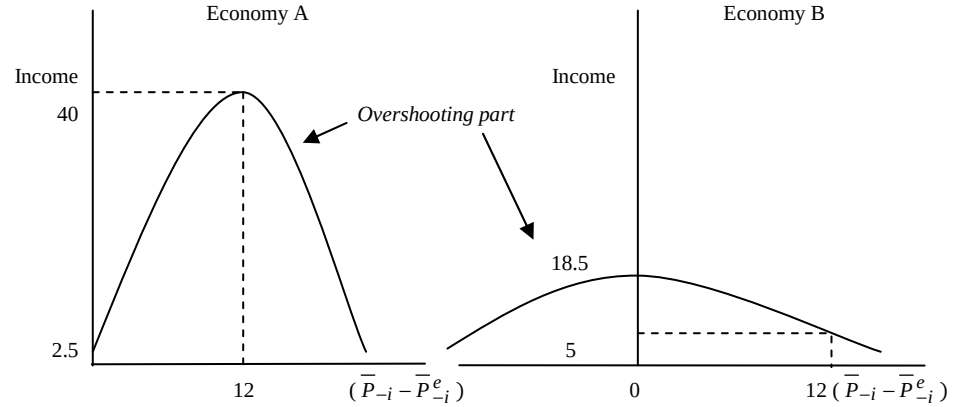
In order to capture all the effects in the economy, alternative non-linear representation may seem to be a better option for our purpose as illustrated by Figure 1. Since a majority of subjects in economy A are rational coordinators, correction of expectations is at size 12 (based on Table 1), which is the optimal size of expectations correction of the rational coordinator. As a result, most of the subjects achieve the maximum income of 40, demonstrated by the curve with a top peak (based on pay-off tables). Thus, high coordination (i.e. high expectation correction) is associated with high average income in the economy. Once an adaptive player emerges in a rational economy where coordination prevails at the aggregate level he achieves a significantly lower income compared to rational

[6] If the coefficient were negative, this would mean our hypothesis would have a different meaning, i.e. the lower the deviation (the lower the expectation correction), the higher the income earned. This would test whether adaptive behaviour is associated with a higher income. However, this is not subject of our investigation.

coordinators. Based on simulations, if his expectation correction is zero then an income of size 2.5 is earned (based on pay-off tables).[7]

F i g u r e 1

Income Development of the Rational Economy A versus Adaptive Economy B



Source: Own considerations.

The second graph of Figure 1 shows adaptive economy B with low coordination. In this case almost no rational coordinators are present. Zero correction of expectations ($\overline{P}_{-i} - \overline{P}^{e}_{-i} = 0$) corresponds to the case of the adaptive player who doesn´t coordinate and who achieves 18.5 based on pay-off tables.[8] Low coordination with the prevalence of adaptive players is associated with a lower average income in the economy at the aggregate level, which is demonstrated by a lower position of the parable, which is flatter than in case of a rational economy. If a rational subject emerges in this adaptive economy, where almost no coordination is present at the aggregate level, he will always achieve lower rewards (size of income 5), than purely adaptive player, whose reward equals 18.5 based on pay-off tables. Thus, if a rational coordinator emerges, a better strategy for him is not to coordinate and adjust to the rest of adaptive players to collect comparable rewards.[9] This reflects our initial hypothesis that coordination (expectation correction) in an adaptive economy is associated with lower income for the rational coordinator.[10]

[7] The right part of the parable reflects possible overshooting in the economy A.

[8] Income earned by pure adaptive players (with zero expectation correction) of type x and y is 25 and 12, which yields 18.5 on average.

[9] This might have serious implications for the economy, when a rational coordinator emerges in the economy where a low number of rational players are present; his coordination effort is penalized in consequent periods by a reduction in rewards. Thus, the best option for the next periods is to adjust his behaviour to the majority of individuals. This further worsens the adjustment of the economy to the equilibrium and the economy might have a tendency to stay below the potential product for longer time.

3.2. The Impact of the Size of Adjustment to Equilibrium on Income

In order to test how the actual deviation of price from the equilibrium in the first post-shock affects the size of income associated with coordination favorableness, the following regression has been conducted:[11]

$$Income = \alpha + \gamma^{*}(P_i - P^{*}) + \varepsilon \quad (3)$$

where P_i is the individual price of a particular player in the first period after the shock and P^{*} is the optimum price of an individual player for the first post-shock period. Deviation $(P_i - P^{*})$ shows how close the price of a player in the post-shock is to his price in the post-shock equilibrium. The closer the individual price is to the optimum, the more coordinating the individual is. In other words, the rational who coordinates in a perfect way immediately adjusts his price to the new optimum after the shock. The further the individual price is from the optimum price, the less coordinative the individual is, which means that he adjusts his price to the new optimum only reluctantly and rests his pricing strategy on the pre-shock price development. Coefficient γ measures how the size of deviation $(P_i - P^{*})$ (i.e. distance from equilibrium) will be reflected in the size of income earned by the rational who is willing to coordinate. If the coefficient is equal to 0, then the size of deviation (distance from equilibrium) does not have any impact on the size of income earned and being the rational coordinator is not relatively more advantageous. If the coefficient is negative ($\gamma < 0$), it implies that the higher the size of deviation (the farther from equilibrium the individual is), the lower the income earned and thus being the rational coordinator who adjusts his price towards equilibrium has proven to be beneficial. Based on our hypothesis the coefficient γ may be negative or equal to zero.

In order to capture all the effects in the economy, alternative non-linear representation seems to be a better option for our purpose. The first graph of Figure 2 shows that since the majority of subjects in economy A are rational coordinators and move towards equilibrium price (i.e. deviation between equilibrium and individual price is approaching zero on average), the highest earned reward in the economy is 40. Thus, a high incidence towards equilibrium is associated with high income on average in the economy. A more flexible adjustment towards equilibrium is associated with significant income increase as given by narrow

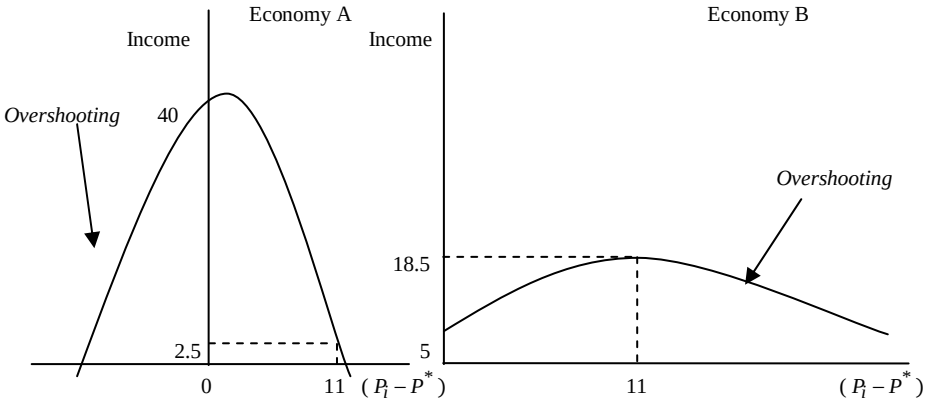
[10] Once the overshooting individuals emerge in this economy, then also the left upward rising part parable till the maximum becomes relevant.

[11] This test was conducted in order to provide additional verification regarding beneficial coordination, since expectations set by subject during the experiment might not provide such an accurate picture.

parable. Once an adaptive player emerges in a rational economy, he achieves a significantly lower income compared to the rational coordinators. Simulations of a pure adaptive player, whose distance from equilibrium is 11, shows that he earns an income of the size 2.5.

F i g u r e 2

Income Development of the Rational Economy A versus Adaptive Economy B



Source: Own considerations.

The second graph shows the adaptive economy B, with low coordination, where almost no rational coordinator is present. Zero adjustment to the equilibrium $(P_i - P^*) = 0$ corresponds to the case of adaptive player who doesn´t coordinate and who achieves 18.5 based on simulations. Low coordination with a prevalence of adaptive players is associated with a lower average income in the economy at the aggregate level, which is demonstrated by the lower position of the parable, which is flatter than in the case of the rational economy. The left part of the parable is relevant for our investigation in the case of zero overshooting subjects. The further from the equilibrium, the higher the income earned, but the increase in income is not so significant. If a rational subject emerges in this adaptive economy, which is characterized by almost no coordination being present at the aggregate level, he will achieve significantly lower rewards (size of income 5 based on simulations) than the reward of pure adaptive player.

4. Coordination Favorableness, Aggregate versus Individual Level

Before we approach the presentation of the results it is worth mentioning some basic theoretical possibilities related to the type of the economy and type of player which may account for the coordination effort based on income achieved in different conditions (see Table 2).

T a b l e 2

Illustration of Situations Related to the Type of the Economy and Type of Player

	Type of the economy	**Type of the player**
High expectation correction ($\overline{P}_{-i} - \overline{P}^{e}_{-i}$)	*Highly coordinated economy*	Rational coordinator
Full adjustment to equilibrium, i.e. ($P_i - P^*$) is approaching to zero	*Highly coordinated economy*	Non-coordinator
Expectation correction ($\overline{P}_{-i} - \overline{P}^{e}_{-i}$) is approaching to zero	*Economy with no coordination*	Rational coordinator
Inertial adjustment to equilibrium ($P_i - P^*$)	*Economy with no coordination*	Non-coordinator

Source: Own considerations.

In the case of a highly coordinated economy, which consists of prevalently rational coordinators, intensive expectation correction takes place at the aggregate level, where expectations are close to the post-shock equilibrium price. Thus, the deviation ($\overline{P}_{-i} - \overline{P}^{e}_{-i}$) is higher for this economy. For the perfect rational coordinator it yields exactly ($\overline{P}_{-i} - \overline{P}^{e}_{-i}$) = 12 according to simulations based on experimental parameters (see Table 1). This is accompanied by almost immediate price adjustment to the post-shock equilibrium, where the deviation ($P_i - P^*$) approaches zero. This economy, because of its equilibrating behavior and high expectation correction favors rational individual, where the maximum size of reward in the case of full adjustment is 40 based on the simulations. In contrast, if the player is not willing to coordinate in this economy, he is not in line with the development at the aggregate level. Because of weak expectation correction and inertial price adjustment as opposed to the majority, he will be penalized by a lower income of 2.5 for a pure non-coordinator.

In the case of a non-coordinative economy, formed prevalently of adaptive players, the expectations about the price in the first post-shock period rest on the pre-shock equilibrium price.[12] Almost no correction of expectations takes place at the aggregate level, which implies deviation ($\overline{P}_{-i} - \overline{P}^{e}_{-i}$) approaches zero. This is accompanied by an inertial adjustment to the equilibrium, where pricing strategy is backward-looking and deviation ($P_i - P^*$) is higher. For the pure adaptive player it yields exactly ($P_i - P^*$) = 11. The size of income earned in this economy is not at a maximizing level, but lower on average due to its slower convergence to the equilibrium, but it still favors non-coordinative players in terms of income, yielding 18.5 based on simulations. The explanation lies in the fact that

[12] Additionally, overshooting subjects might appear, whose behaviour might not be described as purely backward-looking, but expectations about the post-shock price in the economy might even overshoot the pre-shock equilibrium price followed with post-shock price overshooting.

weak expectation correction and inertial price adjustment is not only applied by this individual but takes place also at the aggregate level. If a rational coordinator emerges, his rewards will be significantly lower than that of adaptive players at size of 5, since he is not in line with overall development (see Table 1). This discussion suggests that players are either rewarded or persecuted depending on prevailing conditions in the economy. If the player is disadvantaged, it may motivate him to follow the crowd (depending on the nature of the economy) in order to increase his rewards in line with already mentioned strategic complementarity. The nature of coordination thus strongly depends on this phenomena. The next section will try to evaluate the nature of coordination depending on nominal versus real environment, which subjects face.

5. Results of Coordination Favorableness with Respect to Treatments

5.1. The Economy of the Real Treatment

Our results in Table 3 show that we cannot reject the hypothesis that expectation correction has no impact on the size of income earned in the first post-shock period at the 5% level of significance. However, as the t-value shows we can reject the hypothesis that expectation correction has no impact on income in favor of the hypothesis that expectation correction brings a higher income at the 10% level of significance. The results of regression are also documented with the help of Figure 1, where income is on the y axis and expectation correction ($\overline{P}_{-i} - \overline{P}^{e}_{-i}$) on the x axis. As the size of the coefficient points out the curve's steepness is lower than it should be in the case of a highly coordinated economy with a majority of rational coordinators. The coefficient β equals 0.5, which means that if expectations about the post-shock price level ($\overline{P}^{e}_{-i}$) are corrected by 1 unit downwards as opposed to the pre-shock price $\overline{P}_{-i}$, the income increase will be 0.5 units at the 10% level.

T a b l e 3

Income on Expectation Correction, the Real Treatment Economy

	Coefficient	**t-value**	**N**	**R^2**
Constant	13.9418***	6.52	40	7.6%
($\overline{P}_{-i} - \overline{P}^{e}_{-i}$)	**0.558150***	**1.78**		

Notes: $\widehat{Income} = 13.9418 + 0.558*(\overline{P}_{-i} - \overline{P}^{e}_{-i})$.

*** Significance at the 1% level.

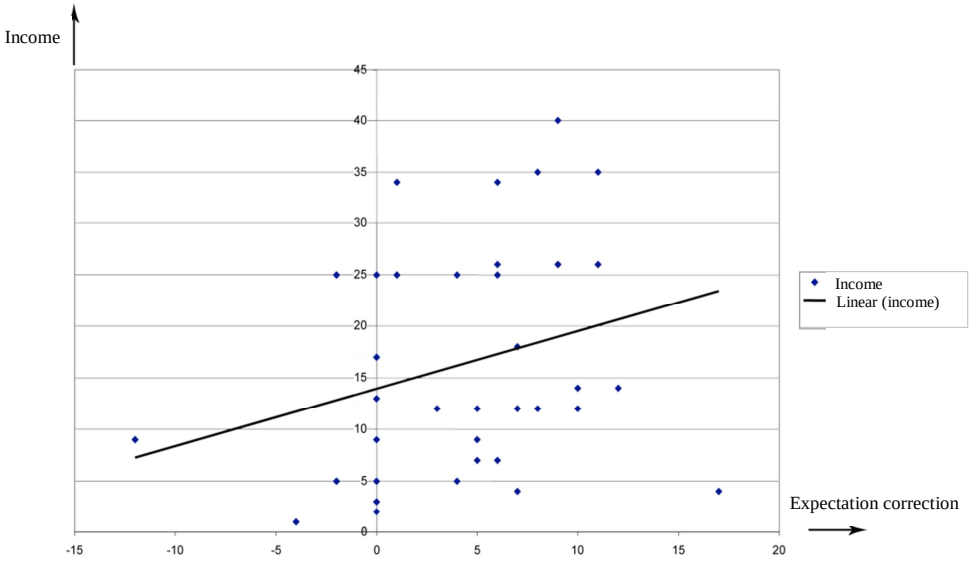
* Significance at the 10% level.

Source: Own computations.

This suggests that being a rational coordinator who corrects expectations is associated with a weaker income increase in the period after the shock at the 10% level of significance than it should be in the case of a highly coordinated economy.

F i g u r e 3

Income on Expectation Correction, the Real Treatment Economy



Source: Own computations.

However, although the weaker reaction is present at the 10% level, the real treatment economy still possesses a sufficient number of rational coordinators at the aggregate level for coordination to at least be profitable in a satisfactory way for the rational player. As was already documented, the non-coordinating player who enters a coordinated economy where rational coordinators prevail is penalized by lower rewards. This is illustrated again in Figure 3 above, where the lower expectation correction as we move closer towards origin, the lower the income earned as indicated by the curve.[13] If the subjects correct their expectations, i.e. do not coordinate at all and behave as adaptive subjects, they would earn 13.9418 on average. If the subjects do not correct their expectations at all, then the computation of functional values would yield an income of 14 as was already mentioned.[14] If the subject behave as a rational coordinator and thus have

[13] Points which are depicted in the negative quadrant of the Figure 1 are associated with individuals whose expectations overshot the price in the first post-shock period, but which proved not to be empirically relevant.

an optimal expectation correction of 12, then the income yields 21. As a result, the difference between the income of a rational coordinator and non-coordinative player who does not correct his expectation yields 6 units more in favor of the rational coordinator in the real treatment economy.

The second, previously outlined, hypothesis should provide an answer as to whether the distance of individual price from the equilibrium in the first post--shock period affects income. The results in Table 4 below show that the hypothesis that the higher deviation from the equilibrium has no effect on income has to be rejected in favor of the hypothesis that the further it gets from equilibrium the lower the income earned at the 5% level of significance.

T a b l e 4

Income on Difference from Price Optimum, Real Treatment Economy

	Coefficient	**t-value**	**N[15]**	**R^2**
Constant	20.4638*******	7.82	40	10.02%
$(P_i - P^*)$	**–0.679807****	**–2.06**		

Notes: $\widehat{Income}$ = **20.4638 - 0.679807* (** $P_i - P^*$ **).**

******* Significance at the 1% level.

***** Significance at the 5% level.

Source: Own computations.

The results are also documented with the help of Figure 4 below, where income is on the y-axis and the deviation from equilibrium ($P_i - P^*$) on the x-axis. The size of the coefficient β = –0.679807 implies that if an individual will deviate by 1 unit from the optimum he will be penalized by an income loss of –0.67 at the 5% level. Thus, being the type of subject who adjusts his price in an inertial way towards the equilibrium in the first post-shock period is associated with earning lower rewards, whereas being a rational coordinator who flexibly adjusts his price towards the equilibrium is appreciated, since movement along the curve closer to the origin implies higher rewards. However, we still have to bear in mind that this is contingent on the share of rational players willing to coordinate

[14] Y = 13.9418 + 0.558*X

where X stands for ($\overline{P}_{-i} - \overline{P}^{e}_{-i}$)

Y (12) = 0.5581.12 + 14 = 20.7

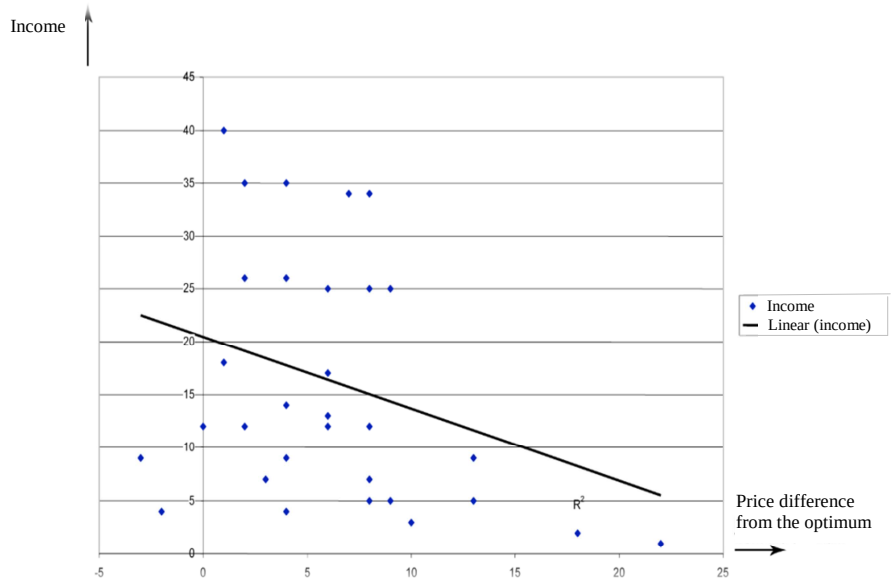
Y(0) = 14

[15] Number of subjects in the real treatment is N = 40, later in the nominal treatment N = 44. Experimental procedure sometimes doesn´t allow to include exactly the same number of subjects (some subjects don´t arrive and the number of substitute subjects is not enough to compensate, when experiment is organized in interactive groups). Nevertheless, samples with slightly different size are quite common in many laboratory experiments and is not an exemption in case of the original study of Fehr and Tyran (2001) and not an obstacle regarding econometric model.

at the aggregate level. If a sufficient number of players will not coordinate and stay out of the equilibrium, and only some of them adjust their prices properly, these rational coordinators will earn a lower income. As was documented by this test, we cannot say that an insufficient number of rational coordinators is present at the aggregate level and thus coordination is still associated with higher rewards for those coordinated in the economy of the real treatment.[16]

F i g u r e 4

Income on Difference from Price Optimum, the Real Treatment Economy



Source: Own computations.

The slope of our curve in the Figure 4 above is not as steep as in case of a highly coordinated economy, but still generates a lower income for players who are out of equilibrium, thereby benefiting rational coordinators, who adjust immediately.

As Figure 4 shows, if no deviation from equilibrium is present and instead a perfect adjustment to equilibrium is the case, then subjects would earn 20.46 on average. Our results regarding coordination favorableness in case of an adjustment to the equilibrium are therefore consistent with previous test on expectations correction. At the aggregate level it implies that coordination favorableness contributes to faster adjustment to equilibrium and the actual product does not remain below the potential product for a long time.

[16] Points which are depicted in negative quadrant of the Figure 4 are associated with individuals who made overshooting expectations about the price in the first post-shock period.

5.2. The Economy of the Nominal Treatment

Linear approximation appeared to be insufficient to cope with the occurrence of overshooting subjects in the nominal treatment, where we could not reject that expectation correction has no effect on income. Thus, non-linear regression was conducted in order to detect coordination favorableness in the economy. The presumption is that the lower the deviation for which the parable yields the maximum, the more the results speak in favor of the non-coordinative player who does not correct his expectations and expects the same price as in the pre--shock period. In contrast, the optimum size of expectation correction yields 12 for the perfect rational coordinator. If a non-coordinative economy prevails at the aggregate level, it should be reflected in the size of income earned by a rational coordinator, who should earn a significantly lower income compared to the non-coordinative players. The results of our experiment show that the coefficient $(\overline{P}_{-i} - \overline{P}^{e}_{-i})^2$ is significant at the 1% level (see Table 5).

T a b l e 5

Income on Expectation Correction, Nominal Treatment Economy

	Coefficient	**t-value**	**N**	**R^2**
Constant	15.0548*******	7.98419	44	14.77%
$(\overline{P}_{-i} - \overline{P}^{e}_{-i})$	0.619197 *****	1.72435		
$(\overline{P}_{-i} - \overline{P}^{e}_{-i})^2$	**–0.0853764*****	**–2.63391**		

Notes: $\widehat{\textbf{\textit{Income}}} = \mathbf{15.05 + 0.619*(\overline{P}_{-i} - \overline{P}^{e}_{-i}) - 0.0853*(\overline{P}_{-i} - \overline{P}^{e}_{-i})^2}$.

******* Significance at the 1% level.

***** Significance at the 10% level.

Source: Own computations.

Based on the results in Table 5, we search for the maximum of the following parable:

$$Y = 15.05 + 0.619*X - 0.0853*X^2$$

where X stands for $(\overline{P}_{-i} - \overline{P}^{e}_{-i})^2$, which is the size of expectation correction (for more details regarding computation see the remarks below).[17]

[17] Based on the results in Table 4, we get the following parable:

$$Y = 15.05 + 0.619*X - 0.0853*X^2$$

where X stands for deviation $(\overline{P}_{-i} - \overline{P}^{e}_{-i})^2$.

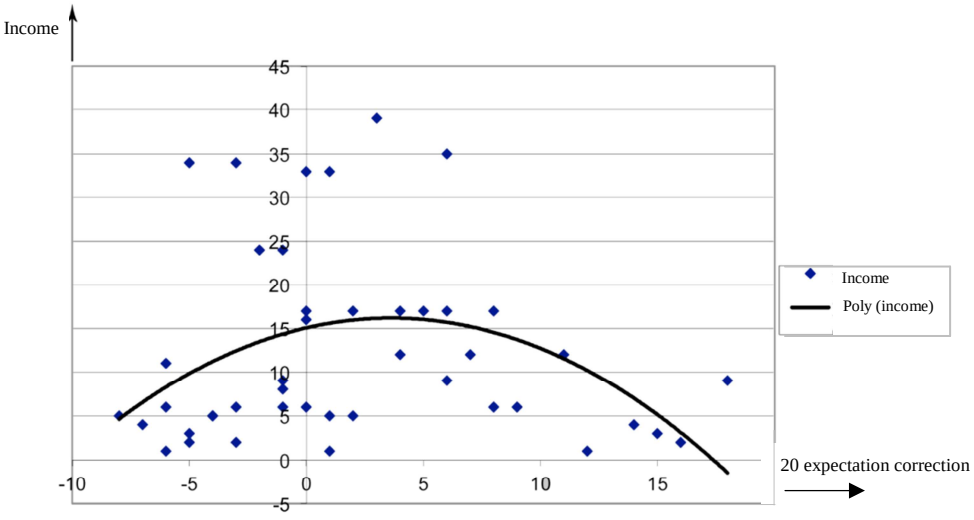
In order to search for the maximum, the following computation can be made:

$$Y'(X) = \frac{dincome}{dX} = 0.619 - 0.0853X = 0.$$

Figure 5 documents the situation more closely, where the left part of the parable was also delineated in the negative part of the graph, which confirms not only the presence of adaptive players, but also of overshooting ones.

F i g u r e 5

Income on Expectation Correction, Nominal Treatment Economy



Source: Own computations.

The results for the nominal treatment show that the parable yields maximum for deviation X = 3.6, where the size of income is 16, which is not far from the situation of the adaptive player with zero expectation correction (deviation X = 0), whose income is 15.[18] In contrast, the rational player in the economy who has

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This yields a maximum income for deviation X = 3.6, where the functional value, i.e. the size of income in our case, is computed:

$$\text{Income } (X = 3.6) = 16.$$

If the deviation X would be equal to 12 (which is exactly the size of the expectation correction for coordinated rational) then by substitution into parable equation we get:

$$\text{Income } (X = 12) = 11.$$

If the deviation X would be equal to zero, then by substituting into parable equation we get:

$$\text{Income } (X = 0) = 15.$$

[18] This discrepancy ensues from the fact that based on results from Table 5, the linear variable $(\overline{P}_{-i} - \overline{P}^{e}_{-i})$ is significant only at the 10% level, which implies that we may not reject at the 10% level that the peak of the parable lies at the y axis, which reflects zero expectation correction. This is also not a barrier for our evaluation of whether coordinated rationals or adaptive players are better off, i.e. if coordination is prevalent at the aggregate level or not (in addition the quadratic variable is significant).

a high expectation correction where X = 12 earns an income of the size 11. This suggests that players who still have expectations closer to the pre-shock price are rewarded more than rational coordinators. This is in line with the economy where almost no coordination is present at the aggregate level. Additionally, it is evident that it favors adaptive players in terms of maximum income achieved, whereas overshooting subjects are not at an advantage. If we compare the difference in income of a rational coordinator and adaptive player then (16 – 11) = 4 goes in favor of the adaptive player. Based on the results of non-linear approximation, the high expectation correction did not prove profitable in the nominal treatment, but rational coordinators still achieve rewards that are at least higher than in the simulated case of a non-coordinative economy, where the size of income is 5 (see Section 3).

The second hypothesis should provide an answer as to whether coordination associated with the distance of individual price from the equilibrium in the first post-shock period affects income in the economy of the nominal treatment. Due to the previous insignificant results in the linear model, where it cannot be rejected that the effect of movement further from the equilibrium has no effect on income, the non-linear regression is subject to investigation. The size of deviation $(P_i - P^*)$ for which the parable yields maximum rewards will be relevant since the non-linear model is significant at the 5% level and provides an appropriate approximation (see Table 6). The higher the deviation for which the parable yields the maximum, the more the results speak in favor of a non-coordinating player who does not correct his expectations and does not adjust to the equilibrium, but despite that is rewarded due to the weak coordination at the aggregate level. Thus, based on this result we also immediately recognize the character of coordination that prevailed in the economy since the income of the individual player is directly associated with the development of the economy at the aggregate level.

T a b l e 6

Difference from Optimum Price, Nominal Treatment Economy

	Coefficient	**t-value**	**N**	**R^2**
Constant	7.41892**	2.24	44	15.86%
$(P_i - P^*)$	1.78196**	2.64		
$(P_i - P^*)^2$	**–0.0874164****	**–2.78**		

Notes: $\widehat{Income} = 7.41 + 1.78*(P_i - P^*) - 0.087*(P_i - P^*)^2$.

*** Significance at the 1% level.

* Significance at the 5% level.

Source: Own computations.

Based on our results in Table 6, we search for the maximum of the following parable:

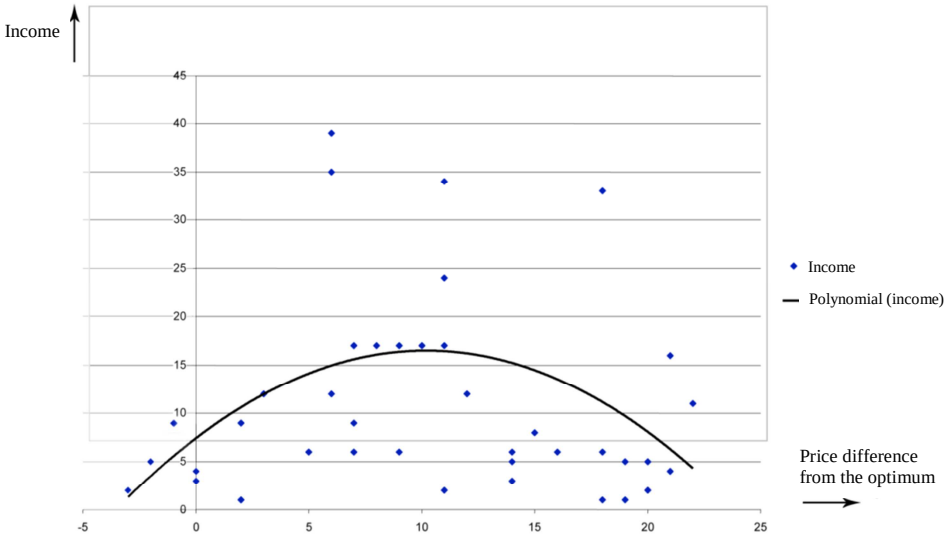
$$Y = 7.41 + 1.78*X - 0.087*X^2 \quad (4)$$

where X stands for $(P_i - P^*)$, which is a deviation of the individual price from the equilibrium.[19]

The results for the nominal treatment show that the parable yields a maximum for the size of deviation X = $(P_i - P^*)$ = 10.85, which indicates that the individual price is distant by almost 11 units from the equilibrium post-shock price. This suggests that the type of player rewarded in the economy is the one whose price is fairly remote from the equilibrium, as is documented in Figure 6.

F i g u r e 6

Income on Price Difference from the Optimum, Nominal Treatment Economy



Source: Own computations.

[19] $Y = 7.41 + 1.78*X - 0.087*X^2$; where X stands for deviation $(P_i - P^*)$.

In order to search for the maximum, following computation is made:

$$Y'(X) = \frac{dincome}{dX} = 1.78 - 0.16X = 0.$$

This yields a maximum income for deviation X=10.85 where the functional value, i.e. the size of income in our case, is computed:

$$\text{Income } (X = 10.85) = 16.49.$$

If the deviation X would be equal zero, then by substituting into the parable equation we get:

$$\text{Income } (X = 0) = 7.47.$$

Such a mechanism that rewards rigid behavior is in line with an economy with almost no coordination. If a functional value is computed the size of income earned by the player is: income (X = 10.85) = 16.49. Since the maximum income earned in a non-coordinative economy by the player in the case of zero adjustment is 18.5, the size of the income in our economy is seriously approaching this number. If a coordinated rational immediately adjusts his price to the equilibrium in the first period of the post-shock phase his deviation ($P_i - P^*$) is 0 and he earns an income of the size 7.47. The character of the economy itself is generating considerable inertia through an income incentive structure which penalizes flexible pricing behavior through unfavorable coordination. The privilege of an adaptive player in a nominal treatment economy can also be seen from the difference in incomes of a rational and adaptive player where the size (16.49 – 7.47) = 9 is in favor of the adaptive player.

In order to strengthen the above mentioned results, these will be compared with the simulated cases of rational and adaptive players. If we suppose a rational coordinator of type x, then in the pre-shock period (round 20), his optimum price is 9, whereas after the implementation of the monetary shock (round 21), his optimum price equals 3 if he is a rational coordinator according to the experimental parameters (see Table 1). The best option for an adaptive player of type x is to set his price to 16 directly after the shock according to the simulations (see Table 1). Therefore, deviation of the adaptive player of type x from the equilibrium price is 16 – 3 = 13. If we suppose instead a rational coordinator of type y, then his price in pre-shock period equals 27, where after the monetary shock he adjusts his price close to the equilibrium price of 9 (see Table 1). An adaptive player of type y in the period after the shock sets his price to 18 based on the simulations (see Table 1). Thereby the deviation of the adaptive player of type y from the equilibrium price is 18 – 9 = 9. Based on these results, the average deviation of the adaptive player is (13 + 9) / 2 = 11. This value precisely reflects the results obtained in our regression, where income in the economy is maximized for deviation of size X = ($P_i - P^*$) = 10.85.

Therefore, evidence is given that the nominal treatment economy distinctly privileges pure adaptive players over rational coordinators and generates even further nominal inertia through an incentive structure of rewards which suppresses the coordination effort at the aggregate level. The economy therefore stays below the potential product for a longer time since coordination favorableness is not ensured by a sufficient number of rational coordinators.

Afore-mentioned section analyzed, which players are privileged in terms of income, depending on the nature of the coordination in the economy. The Table 7 provides summarization of income achieved by the nominal versus real

treatment. Income achieved in the first post-shock period suggests bigger drop in income of the nominal treatment. Also values related to the total income achieved in the pre-shock and the post-shock phase suggest that higher income reduction after the shock occurred in case of the nominal treatment. Moreover, the total size of income is lower for this treatment. Results suggest that the coordination problem encountered in the real treatment is not as serious an issue as in the case of the nominal treatment. Coordination problem is intensified in the nominal treatment by the presence of nominal veil of values that subjects have to face. As a result, this treatment faces threat of staying below the potential product for a long time.

T a b l e 7

Income Development of Treatments

	Nominal treatment	**Real treatment**
Income in the first post-shock period	12	16
Pre-shock total income	700.4091	785.875
Post-shock total income	**559.25**	**700.8**
Total income	1 259.659	1 486.675

Source: Own computations.

Conclusion

This study tried to shed light on coordination favorableness and its effects at the aggregate level in the experimental framework of a New Keynesian economy with strategic complementarity, which seems to be well-founded in an era of modern macroeconomic models based on explicit micro-foundations. The results achieved underpin further the analysis of Fehr and Tyran (2001) from another standpoint since coordination proved to be less favorable when subjects are present in an environment with a high probability of taking nominal pay-offs as a proxy for real ones. Additionally, through the assessment of coordination favorableness with regards to income, implications might be derived for the economy at the aggregate level. It turned out that coordination favorableness is governed by the resulting interaction with respect to the individual versus aggregate level situation in terms of income.

In the economy of the nominal treatment it appeared that higher expectation correction is associated with lower income. This suggests that the economy favors adaptive players in terms of the maximum income achieved, as opposed to overshooting ones. This is further documented via a second test, where results show that income in the economy is maximized for deviation from the equilibrium, which is typical for the pure adaptive player. Since the system doesn't

reward rational coordinators, its consequent development is low expectation correction, inertial adjustment, thereby creating nominal inertia with direct impact at the aggregate level. The opposite is true of the real treatment. Although the real treatment economy did not possess complete expectation correction and full adjustment at the aggregate level, a sufficient number of coordinators still emerged for coordination to be favorable. Therefore the economy stays below the potential for shorter time with only negligible nominal inertia. It also appeared that the real treatment is privileged in terms of the total income achieved over the nominal treatment. This further suggests that coordination is a problem for individuals who have to face environment of nominal values with consequent impact on the size of income gained.

In New Keynesian economics, low coordination might be thereby, under nominal pay-off dominance, accountable for existing nominal inertia at the aggregate level. As a result, the product might stay below the potential for a longer time, since convergence is decelerated through a strengthened channel of strategic complementarity. Our results are relevant with regards to many studies, which prove that strategic complementarity matters in the real economy, among others Cooper and Haltiwanger (1996), Oh and Waldman (1990; 1994). Furthermore, the realistic case described by nominal values built in our design proved that individuals prone to nominal values behave much stronger in line with strategic complementarity to maximize their rewards. Since many recent studies as noted earlier proved that people are prone to nominal values, this further supports are conclusions about aggregate level consequences in terms of product and low income in real world.

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