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MARCUS GIAMATTEI

Can Cold Turkey Reduce Inflation Inertia? Evidence on Disinflation and Level- k Thinking from a Laboratory Experiment

It is widely believed that inflation inertia varies with the policy pursued. In a novel experiment, price setters determine inflation rates and react to a central bank's indicator, which is implemented exogenously either as cold turkey or gradual disinflation. In a third treatment, subjects in the role of a central banker set the indicator endogenously, potentially reducing inertia by signaling to be a tough central banker. I find inertia to be structurally stable and invariant to policies. The data can be organized by a model of level- k thinking, which shows that cold turkey improves only a few subjects' adjustment while leaving many behind.

JEL codes C72, C92, E31, E52, E71

Keywords: cold turkey, disinflation, gradualism, inflation inertia, level- k

The persistence of inflation is a well-documented phenomenon in the macroeconomic literature. While inflation inertia is widely evidenced, some authors argue that inflation inertia can be reduced because it may vary with the policy pursued (King 1996, Erceg and Levin 2003, Westelius 2005). This line of causation is also central to Lucas (1976). Lucas motivates his critique using

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rational expectations where there is no place for inertia in response to anticipated shocks. He points to the more general problem that subjects' behavior is not policy invariant and changes with the policy under consideration. Subjects may not pay attention to minor changes in policies. But major changes would induce large costs to those who fail to adjust and consequently increase attention (Akerlof et al. 2000), this way overcoming inertia. Such a major policy shift could reduce the number of inertial subjects and accelerate adjustment (Schaling and Hoerberichts 2010, Cogley, Matthes, and Sbordone 2015). It may also provide a clear signal that could dominate idiosyncratic noise or strategic uncertainty about others and thereby reduce inertia (Angeletos and Lian 2016).

Whether inertia varies with policies is hard to study with observational data, because policies are also chosen endogenously in response to given inertia. Therefore, I implemented a novel experimental design to allow for clear causal inferences. In my experiment, I focus on the role of cognitive limitations and nonstandard decision-making causing inflation inertia. To test my hypothesis, I take two classical policies to fight inflation. Central banks can do this by increasing the key interest rates. But disinflation can follow two very different approaches—cold turkey (CT) or gradualism. Starting with Sargent (1982), CT implies the enforcement of a clear and sudden policy change. Rational subjects immediately adjust to such a policy change and disinflation will occur at no cost. Gordon (1982, 11) challenges the view that CT disinflation is similar to a headache remedy that brings “an instant cure with no side effects.” He favors implementing disinflation gradually to account for the idea that people may not be fully rational such that “inflation has a stubborn, self-sustaining momentum, not susceptible to cure” (Hall 1982, 3).

In the experiment, four price setters set individual inflation rates and react to an indicator set by the central bank. In two treatments, I vary the indicator exogenously. My design assumes that price setters' decisions are strategic complements, and optimal individual levels of inflation depend on the average price setter inflation rates and the indicator of the central bank. Price setters maximize their payoff by choosing prices that are close to the equilibrium inflation rate and at the same time not too far away from the inflation rates that others set. Price setters have full information about the economy and the indicator and can flexibly adjust their inflation rates. Still, I observe high levels of inertia. This departure from rationality can be modeled in the form of level- k thinking. The concept of level- k thinking includes the cognitive failure to adjust rationally as well as the (rational) response to expectations that other price setters might fail to do so (Lambsdorff, Schubert, and Giamattei 2013). I hypothesize that CT reduces inertia and improves level- k thinking. Nevertheless, in the experiment only, some subjects show improved level- k thinking, while a large part is left behind and appear to be overburdened by the strong policy shift. I observe that the overall inertia is not reduced in the CT treatment.

If policy is not implemented as an automated rule as in the first two treatments but central bankers can flexibly decide on the indicator, inertia might, in addition, be responsive to the central banker's type. CT might be effective in a way that is not captured by the first two treatments. Price setters may be unsure about which type

of central banker they are confronted with. A “weak” central banker avoids costly adjustments. A “tough” central banker is willing to incur large adjustment costs and implements CT. Therefore, CT may serve as signal of being a “tough” central banker and to differentiate from a “weak” central banker. Once price-setters identify a tough central banker, they might anticipate strict future policies and adjust more quickly. I test this proposition by implementing a third endogenous treatment where the role of the central banker and actively embodied by subjects who decide on the disinflation strategy. Yet, even in this treatment, I do not observe that CT reduces inertia. Overall, my findings suggest that inertia is persistent and not easily affected by policies, contrary to the idea by Lucas (1976).

1. LITERATURE

It is well known that the standard New Keynesian model does a poor job in explaining inflation inertia (Buiter and Grafe 2001, Mankiw 2001, Fuhrer 2009). Several modifications to models with rational expectations have been proposed such as mechanical indexation (Yun 1996, Christiano, Eichenbaum, and Evans 2005, Ascari and Ropele 2012), real wage rigidities (Blanchard and Galí 2007, Ascari and Merkl 2009), staggered pricing policies (Calvo, Celasun, and Kumhof 2007), sticky information (Mankiw and Reis 2002, Agliari et al. 2017, Branch and Evans 2017), rational inattention (Zhang 2017), or habits (Collard, Fève, and Matheron 2007). But, as argued by Nimark (2008), these emerge as ad-hoc fixes, aimed at identifying features that might align theory with evidence rather than pushing toward a more general theory.

Another line of literature focuses on bounded rationality to explain inflation inertia (Roberts 1997, Ball 2000, Steinsson 2003, Adam 2007, Ormeño and Molnár 2015). Failures in expectation formation may be one type of bounded rationality. As evidenced by survey data, subjects only form slow-moving inflation expectations (Adam and Padula 2011, Fuhrer 2017). Subjects may be adaptive learners (Orphanides and Williams 2005, Milani 2007, Al-Eyd and Karasulu 2008, Evans and Honkapohja 2009, Kurz, Piccillo, and Wu 2013, Hachem and Wu 2017) and have to learn the parameters of the model.

Failures in decision making are another type of bounded rationality. Subjects may fail to optimize even if they have all information due to cognitive constraints, missing economic literacy (Burke and Manz 2014), limited capacities for monitoring current conditions (Woodford 2003a) or to save cognitive costs (Gabaix et al. 2006, Magnani, Gorry, and Oprea 2016). Such individual decision failures may translate into aggregate inertia. This may arise because inflation decisions are strategic complements (Ball and Romer 1991, Fehr and Tyran 2005). By introducing a few nonrational subjects together with strategic complementarity, inflation rates may become inertial due to the bounded rationality of some subjects and the high-order beliefs of others. With complementarity, rational subjects have an incentive to imitate nonrational behavior

(Haltiwanger and Waldman 1989, Fuhrer and Moore 1995, Galí and Gertler 1999, Angeletos and Pavan 2007). This is often referred to as beauty contest logic in the macroeconomic literature (Angeletos and Lian 2016, pp. 1135–1199), going back to the famous comparison between investment decisions and a newspaper beauty contest by Keynes (1936, 156).

While the studies mentioned above focus on explaining inflation inertia, the literature also extensively discusses which disinflation policies best reduce inflation inertia. The two obvious candidates are a quick and immediate CT disinflation versus a slow gradual policy.¹ Ball (1994) was the first to provide systematic empirical evidence on which policy to choose.² He concludes that CT reduces inertia, which makes it superior to a gradual strategy. This is confirmed by other empirical studies (Jordan 1997, Diana and Sidiropoulos 2004). But when controlling for initial inflation (Zhang 2005) or focusing on core inflation only (Mazumder 2014b), the empirical results remain inconclusive and subject to methodological criticism.³ In addition, identification of causal effects has remained a challenge. This idea was already raised very early in the empirical debate on disinflation. “What if central banks pursue their presumed goal of disinflation more rigorously when they have reason to believe that the short-run trade-offs associated with doing so are more favorable?” (Friedman 1994, 186). This implies that the policy becomes endogenous to the environment.

In light of this, macroeconomic laboratory experiments have gained prominence lately (Ricciuti 2008, Duffy 2014, ,2016), in particular those with a focus on monetary policy (Cornand and Heinemann 2014), and are also employed in central bank research (Amano, Kryvtsov, and Petersen 2014). Typical experiments in macroeconomics implement an economic model in the laboratory and substitute the assumption of a rational representative agent by real subjects who populate the model economy. Experiments allow to tackle endogeneity issues that may contaminate empirical data (Ricciuti 2008, 218). Laboratory data can help to better understand individual reasoning. Such reasoning is hard to address with aggregate empirical data (Heinemann and

1. A third approach is called opportunistic disinflation (Orphanides and Wilcox 2002, Aksoy et al. 2006), an asymmetric strategy to “guard vigorously against any rise in inflation, but wait patiently for the next favorable inflation shock to bring inflation down” (Blinder 1997, 6). CT as a policy advice does not only relate to disinflation. Other examples are the introduction of a new central bank like the ECB (Illing 1998), trade or stock market liberalization (Rodrik 1989, Kim, Kim, and Sung 2013) or a basic income reform (Spermann 2006).

2. Another branch of this literature argues that apart from the policy choice, central bank credibility is an important prerequisite for successfully reducing inertia (Ireland 1995, Loh 2002, Erceg and Levin 2003, Goodfriend and King 2005). Normally, central bank independence is used as a proxy for credibility because credibility is hard to measure (Blinder 2000, 1421). Sometimes, inflation targeting is used as a proxy for credibility (Gonçalves and Carvalho 2009, Roux and Hofstetter 2014). But results are mixed and, surprisingly, many studies show that credibility does not reduce the persistence of inflation (Fischer 1997, Jordan 1997, ,1999, Posen 1998, Boschen and Weise 2001, Diana and Sidiropoulos 2004).

3. The discussion of the right empirical strategy involves the optimal sample (Durham 2001, Mazumder 2014a), the nonlinearity of the Phillips curve (Filardo 1998), and the correct estimation of the sacrifice ratio (Cecchetti and Rich 2001, Hofstetter 2008). Andersen and Wascher (1999, 1) highlight that “one should be cautious about drawing strong implications for monetary policy from these kind of estimates” due to methodological concerns (Agénor and Taylor 1993, Baltensperger and Kugler 2000).

Noussair 2015). Additionally, experiments give an insight into disequilibrium behavior, which is difficult to approach theoretically. They also provide an optimal tool to study alternative policies without involving any economic cost by implementing the policy in reality (Cornand and Heinemann 2014, 170).

Macroeconomic experiments can be roughly classified into two categories—learning to forecast (*ltf*) and learning to optimize (*lto*) experiments. In *ltf* experiments,⁴ subjects make predictions and try to learn the parameters of the model economy (Hommes 2011).

This study falls in the category of *lto* experiments and studies decision-making and not inflation predictions. It provides subjects with full information and investigates whether they are capable of approaching the equilibrium. In *lto* experiments, “inefficiencies do not arise from conflicting objectives or from asymmetries of information; rather, they arise from individual’s strategic uncertainty with regard to the actions of other market participants” (Duffy 2008, 160). To assess my research question, I opted for a *lto* design, which employs price setters instead of inflation forecasters. They are supplied with full information and, once behaving rationally, can determine the equilibrium. Inflation inertia in such a design cannot be linked to a lack of information. In *lto* experiments, the widespread observation of inertia is attributed to boundedly rational decision-making, which is often modeled by level-*k* thinking (Heinemann, Nagel, and Ockenfels 2004). Level-*k* thinking is also used as a workable assumption for explaining behavior in many microeconomic experiments (Nagel 1995, Duffy and Nagel 1997, Ho, Camerer, and Weigelt 1998, Bosch-Domenech et al. 2002, Camerer 2003, Crawford, Costa-Gomes, and Iriberry 2013, Nagel, Bühren, and Frank 2016). Lamsdorff, Schubert, and Giamattei (2013) run an experiment on macroeconomic price setting and observe that convergence toward equilibrium remains incomplete in a nonstationary environment due to inertia and the use of heuristics. Fehr and Tyran (2001, 2008) find evidence for the use of anchor-and-adjustment heuristics where subjects are anchored to an old equilibrium and only react sluggishly to a monetary shock. Similar findings on inertial prices can also be found in the study by Davis and Korenok (2011). They test for nominal shocks in a monopolistically competitive environment and find sluggish responses to shocks even with flexible pricing. All these studies summarize evidence for inertial behavior in response to a shock, but do not analyze if inertia varies with the way the shock is implemented.

Arifovic and Sargent (2003) and Duffy and Heinemann (2021) test the time inconsistency hypothesis (Kydland and Prescott 1977, Barro and Gordon 1983) of monetary policy and use a similar setup to my experimental design. My experiment differs in three ways. First, my central bank is modeled by an exogenously given policy that is carried out as announced. Second, there is not incentive to increase production beyond its potential level and therefore no time-inconsistency problem. And third,

4. Such studies include Blinder and Morgan (2005), Blinder and Morgan (2008), Lombardelli, Proudman, and Talbot (2005), Engle-Warnick and Turdaliiev (2010), Adam (2007), Roos and Luhan (2008), Roos and Luhan (2013), Assenza et al. (2014), Assenza et al. (2021), Petersen (2015), and Pfajfar and Zakelj (2018).

in their design, the private sector decides first and the central bank moves second. This opens up issues with respect to the distribution of payoffs among players, and therefore, involves considerations of fairness or cooperation. In contrast, my experimental design focuses on the coordination problem between the price setters as the main cause for inflation inertia, and therefore, allows excluding social preferences.

2. EXPERIMENTAL DESIGN

In the experiment, subjects play in a group of four symmetric price setters and one subject representing the central bank across 12 rounds t . The group of price setters consists of four members to introduce heterogeneity and to account for the fact the private sector normally is larger than the governmental sector. First, the central banker decides on an indicator ι_t . Price setters are informed about this indicator and move second.

2.1 Price Setters

In each round t , each price setter n has to decide how to change prices by setting an inflation rate $\pi_{nt} \in [0; 150]$. Each price setter's payoff Π_{nt} is given by (1), where 0.1 times the quadratic difference between π_{nt} and π_t is subtracted from a fixed endowment of 40. This induces an incentive to come close to the overall inflation rate π_t .

$$\Pi_{nt} = 40 - 0.1(\pi_{nt} - \pi_t)^2. \quad (1)$$

The overall inflation rate π_t is shown in (2) and consists of two parts. With a weight of $2/3$, it depends on the average inflation decision of all price setters π_t^p , including price setter n . One-third of the overall inflation rate is directly set by the central bank with a policy indicator ι_t . This indicator ι_t is scaled with the factor 2 to prevent it from being a simple anchor.⁵

$$\pi_t = \frac{2}{3}\pi_t^p + \frac{1}{3}(2\iota_t) \text{ with } \pi_t^p = \frac{1}{4} \sum_{m=1}^4 \pi_{mt}. \quad (2)$$

The central bank directly setting part of the inflation rate “is clearly a heroic assumption” (Blackburn and Christensen 1989, 11), but can be macroeconomically interpreted as import prices with a central bank that determines the exchange rate or prices in sectors where firms are very dependent on central bank financing. Price setters' choices π_{nt} are strategic complements. The own optimal choice positively depends on the choice of other price setters. Such complementarity can often be found in

5. In addition, the factor 2 also equals the equilibrium relationship (4).

macroeconomics (Woodford 2003b, Cooper and Haltiwanger 1996). With this payoff function, price setters want to coordinate with the inflation rates other price setters set given the indicator of the central bank. The inflation rate π_t follows a functional form similar to a beauty contest game with an inner solution (Güth, Kocher, and Sutter 2002, Sutan and Willinger 2009). It can also be microfounded with a model of monopolistic competition as shown in Section A. The idea of strategic uncertainty about others is closely related to the models by Morris and Shin (2002) and Angeletos and Lian (2016) with limited information. My experimental design instead is characterized by full information and strategic uncertainty does not arise with respect to information others have but with respect to the rationality of other price setters.

2.2 Central Banker

In the first four rounds, ι_t is fixed to its maximum value of 50 to induce high inflation in the beginning. The central banker remains passive within these first four rounds. Depending on the treatment, then the policy indicator $\iota_t \in [10; 50]$ is exogenously set by a policy rule or the central bankers actively sets the indicator. The indicator is set before price setters decide on their inflation rate π_m . From round 5 on, the central banker gets a fixed endowment of 60 along with two deductions shown in (3). The payoff function of central bankers is also known to price setters.

$$\Pi_t = 60 - \iota_t - 0.5(\pi_t^p - \pi_t)^2 \quad \forall t \geq 5. \quad (3)$$

This function is closely related to the standard central bank loss function with two objectives: an inflation target and an output target (Barro and Gordon 1983, Blinder 1997). For the sake of simplicity,⁶ the inflation target is substituted by $-\iota_t$. With $-\iota_t$, the central bank is rewarded for lowering the indicator, which is part of the overall inflation rate π_t . The second objective, the difference between the average inflation rate of the price setters and the overall inflation rate $\pi_t^p - \pi_t$, is equivalent to the output gap, in line with the standard loss function. Appendix A shows this equivalence. The second part of the payoff function shows that the central bank is concerned only about the average deviation of price setters from equilibrium and not about miscoordination within the group of price setters. These losses from miscoordination within the group are only burdened by price setters themselves.

2.3 Stationary Repetition and Calibration

The experiment consists of three repetitions of the 12 rounds, which are named lives in the experiment. Each of the three lives is identical, with ι_t being fixed to 50 in the first four rounds. Lives are clearly separated and each life starts with an initial

6. In contrast to the standard formulation of central bank loss functions, ι_t is not squared. With this simplification, central bankers do not have to deal with two quadratic functions. Another difference is that deviations are not punished symmetrically, that is, that the central bank is not punished for too low indicator values. As the range of ι_t is restricted to a minimum of 10, this was not necessary.

payoff of zero. Over all three lives, subjects keep their randomly assigned role as central banker or price setter.⁷ These three lives make it possible for subjects to learn. After each life, a new central banker is matched to a group of price setters (absolute stranger rematch). Price setters remain in the same group over all lives. At the end of the experiment, one life is randomly drawn and paid out.

Three pilots were used to calibrate the experiment. The range for π_{nt} was set to $\pi_{nt} \in [0; 150]$, while ι_t was restricted to $\iota_t \in [10; 50]$. The lower bound was not set to zero in order to avoid the change of complexity with a boundary instead of an inner solution.⁸ The number of forecasters was set to $N = 4$ in order to have a large degree of heterogeneity within the laboratory capacities.⁹ The so-called p -value in equation (2) was chosen to be $2/3$ as to introduce enough complementarity between the forecasters' decisions and to allow for convergence within the number of rounds. The endowments were set to 60 and 40 to meet the salary targets of the laboratory and to account for the fact that the central bankers were subjects to higher deductions.

3. TREATMENTS

My first two treatments represent ideal types of policies. The first treatment is called CT and implements a sudden policy shift, similar to a sudden rehab. The path is displayed in Figure 1. Like in a CT rehab, where drugs are taken away from the addict at once, the indicator ι_t is lowered immediately to a value of 11 in round 5. Therefore, CT provides a clear signal of the new policy.

It also minimizes the central banker's payoff function if price setters play conditional Nash. The conditional Nash equilibrium π_t^* for price setters can be calculated according to (4). Nash price setters think that all others adjust rationally. This yields a symmetric choice with $\pi_{nt} = \pi_t^p = \pi_t^* \forall n$.

$$\pi_t^* = 2/3(\pi_t^* + \iota_t) \iff \pi_t^* = 2\iota_t. \quad (4)$$

The Nash equilibrium is characterized by a simple proportional rule (conditional on a given ι_t). If all price setters play conditional Nash, the second term of the central bank's payoff function (3) is always equal to 0. Maximization yields that the central bank sets ι_t to its minimum in round 5 and all price setters adjust immediately, setting $\pi_{nt} = 2\iota_t$. As can be seen in Figure 1, the CT treatment deviates a little from the theoretical solution by showing some mildness in the last rounds.

7. This is different to Duffy and Heinemann (2021) where central bankers are selected randomly at the beginning of each repetition.

8. You can further think about a central bank that has a positive inflation target like the ECB.

9. This is well in line with Arifovic and Sargent (2003) and "reflects that fact that the private sector is considerably larger than the government sector" (Duffy and Heinemann 2021, p. 13).

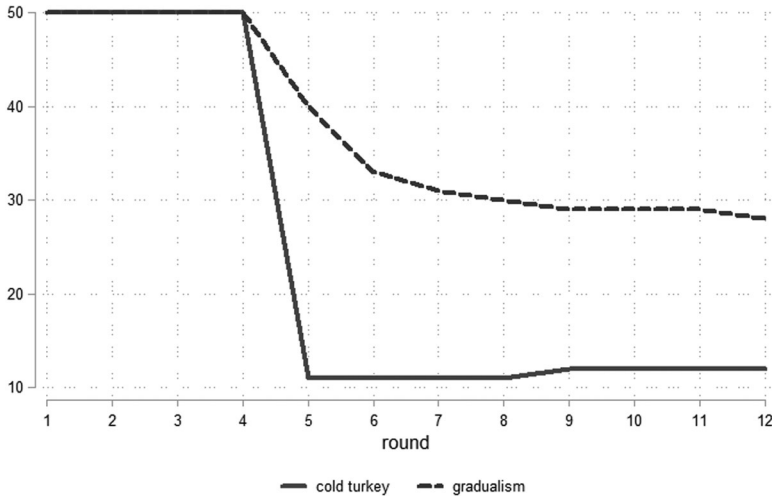


Fig 1. Indicator Path in Cold Turkey and Gradual Treatment.

NOTES: Indicator choices were taken as medians from the third life of the endogenous treatment. Cold turkey values are $t_5 = t_6 = t_7 = t_8 = 11$ and $t_9 = t_{10} = t_{11} = t_{12} = 12$. The corresponding values for gradualism are $i_5 = 40, i_6 = 33, i_7 = 31, i_8 = 30, i_9 = i_{10} = i_{11} = 29, i_{12} = 28$.

A gradual regime is implemented in the second treatment and displayed in Figure 1. The indicator t_t is lowered only hesitantly and remains at a high level until the last round. The path reduces the indicator to only 28 in round 12 and provides a very cautious version of a gradual strategy that shies away from drastic reductions. Such a strategy may be suitable if price setters do not play conditional Nash but react to the indicator with some inertia.

This inertial response of price setters may stem from level- k thinking—the cognitive failure to adjust rationally and the unwillingness to do so because others are expected to fail to adjust. This can be exemplified by looking at the best response function (5). It can be calculated by setting $\pi_t = \pi_{nt}$ in (2) and denoting the choice of all other price setters $-n$ with π_{-nt} .

$$\pi_{nt} = 0.6\pi_{-nt} + 0.8t_t. \tag{5}$$

For example, take an indicator $t_t = 10$. Rather than assuming that all other price setters set their inflation rate symmetrically, a price setter may think that all other price setters choose the previous inflation rate $\pi_{-nt} = \pi_{t-1} = 100$ (level-0). Performing one level of level- k thinking, he then should set $\pi_{nt} = 0.6 * 100 + 0.8 * 10 = 68$ (level-1). This departure from conditional Nash is only partly alleviated if a price setter assumes that other price setters are also level-1. Again, he may react and best respond with $\pi_{nt} = 0.6 * 68 + 0.8 * 10 = 48.8$ (level-2). Only with infinite steps, the conditional Nash equilibrium $\pi_{nt} = 2t_t = 20$ is reached by iterative elimination of (strictly) dominated strategies (level- ∞). In many studies, subjects are found to

TABLE 1
TREATMENT OVERVIEW

Treatment	Policy	Central banker	Indicator choices
Cold turkey	Sudden shift	Passive	Exogenous policy rule
Gradualism	Gradual shift	Passive	Exogenous policy rule
Endogenous	Mixed	Active	Central banker's choice

perform only level 1–2 (Nagel 1995, Duffy and Nagel 1997, Ho, Camerer, and Weigelt 1998, Bosch-Domenech et al. 2002, Camerer 2003, Nagel, Bühren, and Frank 2016). These limited levels may therefore result in inertial inflation rates. If price setters are inertial, setting the indicator $\iota_t = 10$ would not result in an immediate adjustment, so that $\pi_{nt} \neq 2\iota_t$. Given the second part of her payoff function (3), the central banker will try to reduce the average deviation of price setter inflation rates from the overall inflation rate. She might thus consider reducing the indicator step-by-step to balance the need for disinflation with price setters' insufficient adjustment.

In both exogenous treatments, CT and gradualism, the indicator choices were made by an automated policy rule and the central banker only received the payoffs from (3). She remained passive throughout the experiment and her only task was to estimate the average price setter inflation rate.¹⁰

In a third treatment, the indicator is actively set by the central banker, and not by an automated rule. This treatment is called the endogenous treatment. Central bankers can endogenously decide on the indicator in each round $t > 4$ and can evolve their own strategies and react to the price setters adjustment behavior. Central bankers are free to change the indicator ι_t in each round. Table 1 gives an overview over all treatments.

4. HYPOTHESES

The first hypothesis assumes that price setters play the conditional Nash equilibrium. The experimental design is sufficiently simple to allow price setters to understand that the optimal strategy is given by two times the indicator.

Hypothesis 1 (Nash price setters). Price setters play the Nash equilibrium conditional on a given value for the indicator $\pi_{nt} = \pi_t^* = 2\iota_t$.

10. Having a subject in the role of the passive central banker in the exogenous treatments and receiving payoffs ensures payoff comparability between the endogenous and exogenous treatments. It also allows me to model the social welfare according to the standard central bank loss function. While in the endogenous treatment, subjects could choose the order of implementing different strategies, in the exogenous treatments the order in which subjects face CT and gradualism over the three lives was fixed and differed between groups. One-fourth of the groups had three lives of only CT or gradualism (G) each, while 1/4 of the groups had the sequence G-CT-G and 1/4 the sequence CT-G-CT to check for order effects.

On the other hand, the evidence for inertia from other experiments may provide a warning that price setters may not be capable of finding the Nash solution in spite of its simplicity. This would mean that Hypothesis 1 has to be rejected.

Rejecting Hypothesis 1 calls for an alternative model of behavior.¹¹ This can be formalized in a level- k model that provides a parsimonious specification for the inertia of price setters. It fits well to an experiment with full information and a high coordination motive (Shapiro, Shi, and Zillante 2014, Bosworth 2017) and can explain disequilibrium behavior quite well (Giamattei and Lambsdorff 2015). In addition, it is tractable and often applied in macroeconomic models (Angeletos and Lian 2018, Iovino and Sergeyev 2018, Garcia-Schmidt and Woodford 2019). Furthermore, depending on assumptions regarding the average level of reasoning, it includes the pure Nash solution, purely adaptive behavior, or a mixture of such behavior within the level- k model.

Level- k uses the behavioral assumption that price setters' decisions are governed by being a certain cognitive type (level-0, level-1, ...). The standard assumption is that level-0 takes the previous inflation rate π_{t-1} as their choice.¹² This can also be interpreted as level-0 being purely backward-looking or being random-walk players like in Hachem and Wu (2017). With levels $k > 0$, price setters are assumed to think that they are able to perform one level more than all other subjects.¹³ Level-1 price setters assume that all other price setters are level-0 and therefore best respond with $\pi_{nt} = 0.6\pi_{t-1} + 0.8\iota_t$. This can be generalized to a level- k price setter choosing according to (6).

$$\pi_{nt} = 0.6^k \pi_{t-1} + (1 - 0.6^k) \pi_t^* \quad (6)$$

If we assume that in the population of price setters, each level k has the share ω_k and if we take a finite number of levels K , then the average choice of all price setters π_t^p can be expressed by (7) (see also Appendix B).

$$\pi_t^p = \phi \pi_{t-1} + (1 - \phi) \pi_t^* \text{ with } \phi \equiv \sum_{k=0}^K \omega_k 0.6^k \quad (7)$$

11. In addition to level- k , other alternative models of decision-making would be cognitive hierarchy models (Camerer, Ho, and Chong 2004), stochastic best response (Ho, Camerer, and Weigelt 1998), or endogenous depths of reasoning (Alaoui and Penta 2016). For an overview, see Crawford, Costa-Gomes, and Iriberrri (2013). Mauerberger, Nagel, and Buehren (2020) discuss how such models have recently become the framework for behavioral macroeconomics.

12. Ho, Camerer, and Weigelt (1998) use a weighted average of previous inflation rates instead. In round 1, level-0 price setters are assumed to choose randomly within the possible interval $\pi_{nt} \in [0; 150]$ yielding an average of 75 (Nagel 1995).

13. This is the basic assumption in many level- k models. Another specification would be that subjects assume that they respond to a distribution of lower level price setters (Camerer, Ho, and Chong 2004). As Ho, Camerer, and Weigelt (1998, 961) note, everybody's assumption of being one level smarter is "logically impossible, [but] consistent with a large body of psychological evidence showing widespread overconfidence about relative ability."

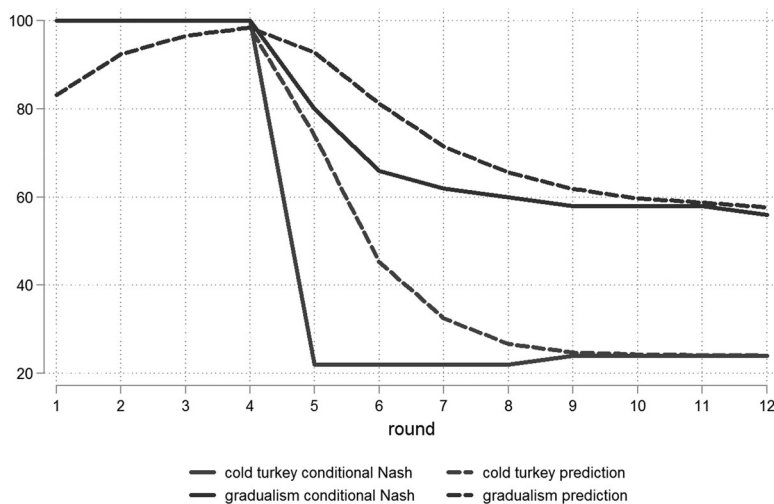


Fig 2. Level- k Prediction for Price Setter Inflation.

NOTES: Prediction is based on assuming price setters to be distributed over level- k with 40% level-0, 30% level-1, 20% level-2, and 10% level-3.

The parameter $\phi \in [0; 1]$ yields a simple measure for the inertia of price setters. With $\phi = 1$, all price setters are level-0 ($\omega_0 = 1$) and choose the previous inflation rate π_{t-1} . If all price setters play conditional Nash ($\omega_\infty = 1$), then $\phi = 0$ and price setters choose $\pi_t^p = \pi_t^*$. With finite and positive level- k , we get $0 < \phi < 1$. Previous inflation rates π_{t-1} and therefore previous indicators ι_{t-1} remain influential. Then, the average price setter inflation lies in between the previous inflation rate π_{t-1} and the conditional Nash π_t^* . As an example, we can assume 40% of the price setters being level-0, 30% level-1, 20% level-2, and 10% level-3. This gives a degree of inertia of $\phi = 0.67$. The value of ϕ together with equation (6) can be used to predict average price setter inflation rates for CT and gradualism. The paths for both treatments are displayed in Figure 2 together with conditional Nash. The prediction based on $\phi = 0.67$ can also be used to calculate hypothetical payoffs. Depending on the value of ϕ , CT is not the payoff dominant alternative. For values $\phi > 0.67$, gradualism becomes the payoff dominant strategy for the central banker. But CT may still be advantageous if the distribution of level- k is endogenous to the policy.

CT may enhance level- k thinking of price setters, thus speeding up the adjustment. This idea comes from studies with limited knowledge (King 1996, Schaling and Hoerberichts 2010, Kurz, Piccillo, and Wu 2013, Cogley, Matthes, and Sbordone 2015), which call for CT in order to speed up learning about the unknown model parameters. In a model with imperfect information, a large global shock due to CT would reduce uncertainty about the information other price setters have (Angeletos and Lian 2016). Such an argument is also brought forward by Gabaix et al. (2006) and similarly with reference to level- k by Alaoui and Penta (2016) who supply experimental evidence,

showing that the costs for acquiring and processing information are incurred most often when they fall short of the expected benefits. This idea may easily translate to my experimental design with full information (where all model parameters are known) but price setters are subject to level- k and uncertain about the rationality of others. CT would involve large errors in the beginning. Correcting for these errors might induce price setters to learn from them and to advance to equilibrium faster, thereby increasing their level- k . Errors may help the price setters in their reasoning process because lower levels are punished more heavily. It may also help higher level- k types as they can expect lower level- k types to better adjust, and therefore, also higher level- k types may increase their level- k . Another argument in the same line would be that with CT, the change of the indicator is very salient and cannot be neglected (Akerlof et al. 2000), which may further promote level- k thinking. Overall, this suggests higher level- k in the CT treatment.

Hypothesis 2 (CT and inertia). CT reduces the inertia ϕ of price setters measured by an improved level- k thinking.

In the endogenous treatment, CT may bring about an additional advantage, beyond the current exogenous treatments, because it yields some information about the type of central banker (Vickers 1986, King 1996, Persson and Tabellini 1999, King, Lu, and Pastén 2008). A “tough” type is willing to incur adjustment costs and reduce the inflation rate substantially. The implementation of CT may signal this type of central banker. CT prevents “speculation about future reversals, or U-turns, in policy” (Sargent 1986, 150). “A ‘tough’ central bank will disinflate just fast enough to differentiate itself from a ‘weak’ central bank that might otherwise be tempted to pass itself off as a true inflation-fighter” (King 1996, 33). The only way to demonstrate being a tough central banker is to implement CT. This toughness may help to reduce inertia. Price setters may recognize the type of central banker, anticipate that future indicators will be low for a “tough” central banker, and adjust prices more quickly downward in response. Price setters cannot make such inferences in the exogenous treatments. A gradual policy might be regarded as a signal of a “weak” central banker who cannot credibly reduce inertia.

Hypothesis 3 (Endogenous CT and inertia). In the endogenous treatment, the choice of a CT strategy reduces inertia.

5. EXPERIMENTAL PROCEDURES

The experiment was conducted computer-based at the class Ex Laboratory at the University of Passau using z-Tree (Fischbacher 2007) and Orsee (Greiner 2015). All written and oral instructions can be found in Appendix D. Upon arrival, subjects were randomly seated in the laboratory and publicly instructed about the purpose of the game, its expected length, the conversion of the experimental currency unit Taler (T) into Euros, dos and don'ts, the use of a pocket calculator, and (standard) payment and

blindness procedures. Informed consent by the participants was obtained for running the experiment.

To increase overall understanding of the rules, the first screens explained the game in a detailed manner for both roles. Subjects had to complete an incentivized comprehension test, where they could earn 2 \mathbb{T} per question if they answered the questions correctly in their first attempt. They had to find the correct answer in order to proceed. At the end of the instructions, they were assigned to the role of the central banker (B) or one of the four price setters (A). The instructions were framed completely neutral. ι_t was named an indicator and participants A had to simply set a number (instead of naming them inflation rates).

Payoffs in the first four rounds in each life were not paid out. Actual payoffs were earned in the following eight rounds of each life. After price setters had made their decision on π_{nt} , they were asked what they expected the three other price setters would choose on average. If their expectation was right ($\pm 5\%$), they earned 2 \mathbb{T} . Also, while price setters were deciding, the central banker's belief about the average decision π_t^p was elicited in this way. After the experiment, subjects participated in a cognitive reflection test (Frederick 2005) and had to answer some questions from an IQ test as well as filling in a questionnaire on demographic variables. The payoff in the experiment was converted at an exchange rate of 1 $\mathbb{T} = 10$ Eurocents and paid out to the participants at the end of the experiment by a third person.

The experiment included 160 participants in total and was conducted on May 28th, 2014, July 23rd, 2015, August 3rd, 2017, November 13th, and 14th, 2017 in eight sessions with 20 participants each. Each subject participated only once. Subjects needed 25 minutes for the instructions and the comprehension test and between 15 and 25 minutes for each life. At the end, the IQ test and the questionnaire lasted for another 15 minutes, which sums up to a total time of about 100–120 minutes. Payoffs to the participants amounted to a total of 3,761.60 Euros and an average of 23.51 Euros per person with a minimum of 3.5 Euros and a maximum of 40.40 Euros. Additionally, 336 Euros were paid out for the pretests. Pretests were used to calibrate the experimental design. Sixty one percent of the participants were female with an average age of 22.4 ranging from 17 to 36. All subjects were students from a broad range of courses (economics, law, cultural studies, and others).

6. RESULTS AND REGRESSIONS

6.1 Exogenous Treatments

Figure 3 shows the deviation of mean price setter inflation π_t^p from the conditional Nash equilibrium $2\iota_t$ for the two exogenous treatments—CT and gradualism. The conditional Nash equilibrium is depicted by the thick solid lines, the mean of actual inflation choices by dashed lines. While both treatments are characterized by larger

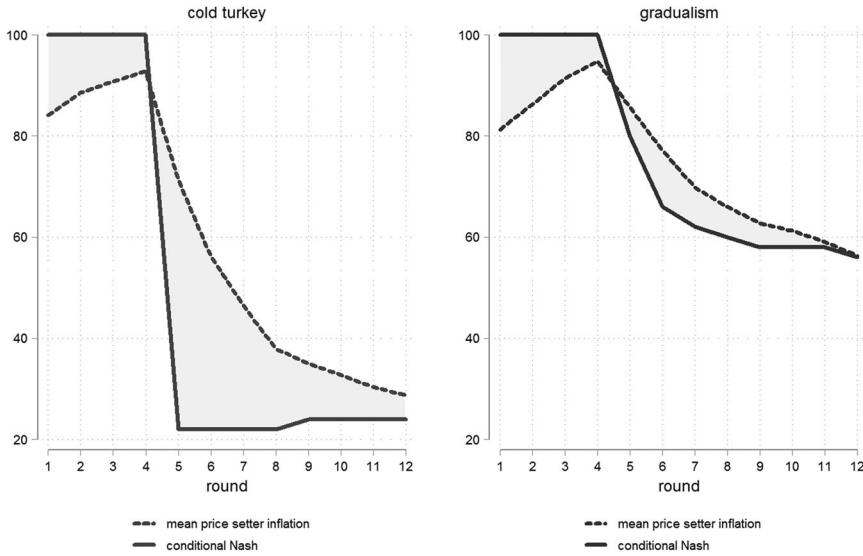


Fig 3. Price Setter Inflation by Treatment.

NOTES: All means are calculated by treatments over all price setters and lives.

deviations in the first four rounds, gradualism manages to reduce these deviations. The response to CT remains highly inertial across all rounds.¹⁴

Figure 4 provides some further insight into the heterogeneity among price setters and shows the standard deviation of inflation rates π_{it} within a group of four price setters.¹⁵ The central banker cares only about coordination with the group as a whole, because the central bank payoff function only punishes deviations of the average price setter inflation rate π_t^p from equilibrium. Price setters additionally suffer if they do not manage to coordinate within their group. Their payoff function (1) punishes individual deviations of their choices π_{it} from the overall inflation rate π_t . The standard deviation within a group therefore corresponds to additional losses that arise for price setters who exhibit heterogeneity and suffer from a failure to coordinate within their group. CT makes coordination within the group more difficult because standard deviations are higher especially in round 5 and remain high throughout the game. This provides another hint that CT does not provide the clear cut that every price setter can easily follow, but that it results in larger confusion among price setters.

Figure 5 shows cumulative payoffs separately for price setters and the central bank

14. The main results also hold when looking at lives separately. Appendix C shows results for lives separately.

15. Figures 4 and 5 show lines for the endogenous treatment, too. Results on the endogenous treatments are discussed at the end of the result section.

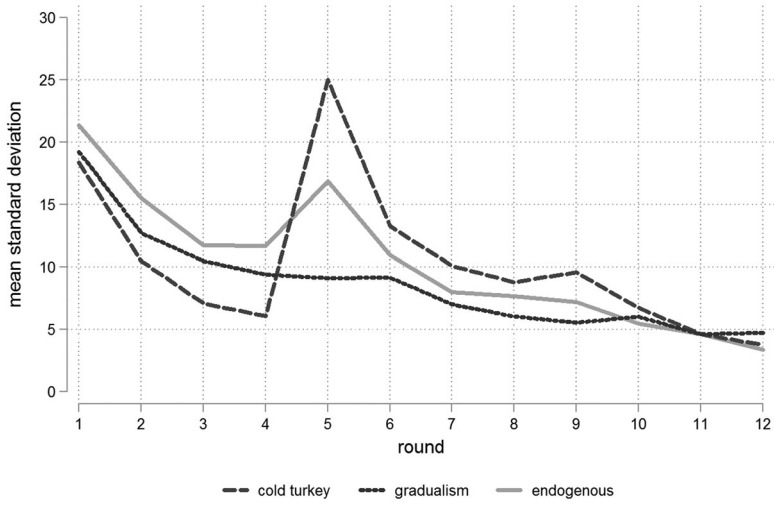


Fig 4. Standard Deviation of Price Setters' Choices.

NOTES: All standard deviations are calculated within a group and averaged over treatments.

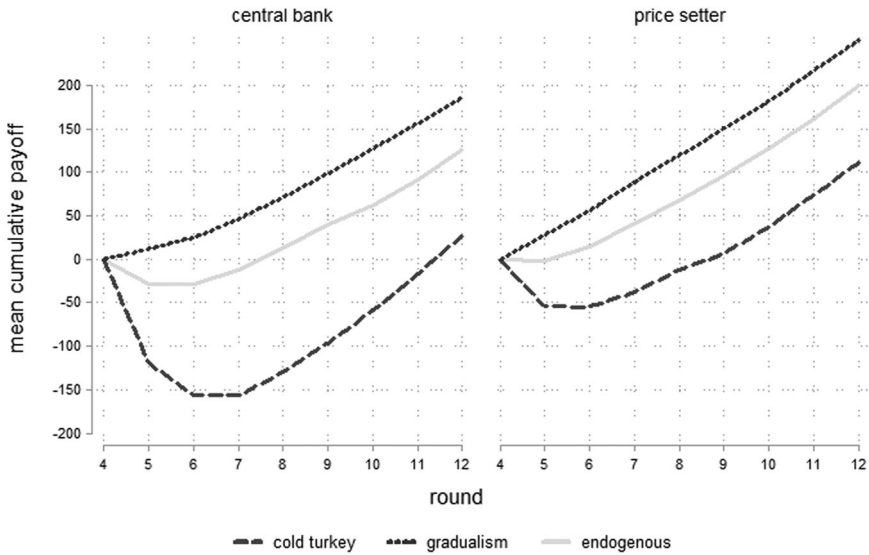


Fig 5. Mean Cumulative Payoffs by Treatments.

NOTES: All cumulative payoffs are calculated by round and treatment. Payoffs for belief elicitation are not included and payoffs are depicted in the experimental currency Taler. Maximum payoffs would be 320 for price setters and 480 for the central bank in round 12.

TABLE 2
PRICE SETTER INFLATION AND INERTIAS

	Price setter inflation π_{nt}		$\pi_t^p - \pi_t^*$	
	(1) Cold turkey	(2) Gradualism	(3) Cold turkey	(4) Gradualism
Indicator	1.203 (0.124)	1.254 (0.217)		
Constant	28.68 (3.522)	27.39 (6.857)		
$\pi_{t-1} - \pi_t^*$			0.810 (0.070)	0.691 (0.087)
Observations	1152	1152	192	192
R^2	0.456	0.316	0.839	0.656

NOTE: OLS, standard errors in parentheses, (1) – (2) clustered by price setter and group. (3) – (4) clustered by group. (3) – (4) data from round $t > 4$. Bold values indicate significant differences from theoretical values with $p < 0.05$.

by treatment. Gradualism provides higher payoffs both for price setters and the central bank. CT comes along with losses for price setters and the central bank in the first rounds, which is evidenced by falling cumulative payoffs. As from round 6 for the price setter and round 7 for the central bank, positive payoffs increase the cumulative ones. CT does not manage to counterbalance the initial losses with bigger gains in the later rounds of the experiment. Only if the experiment had lasted for many more than 12 rounds, the cumulative payoff lines of CT and gradualism could intersect as the slope of the cumulative payoff for CT is steeper (for central bankers only). The benefits would then counterbalance initial losses.

To analyze the first hypothesis, the first regression in Table 2 examines whether price setters play the conditional Nash equilibrium. This is done by estimating the equilibrium relationship (4) with $\pi_{nt} = \beta_1 \iota_t + \beta_2 + \epsilon_{nt}$ for each price setter individually. The conditional Nash equilibrium predicts a weight of $\beta_1 = 2$ and $\beta_2 = 0$.

Table 2 (top panel, regressions (1) + (2)) shows regression results for the price setters’ individual behavior in the exogenous treatments. β_1 is estimated to take a value of around 1.2 and is significantly different from 2 in all treatments. Subjects do not sufficiently react to changes in the indicator. Values $\beta_1 < 2$ show that responses to the indicator are inertial. The coefficients for β_1 are not significantly different between treatments. If subject plays the conditional Nash equilibrium, β_2 should be equal to zero. But the regressions results provide evidence for positive constants in both treatments. Overall, it can be concluded that subjects do not play the conditional Nash equilibrium and Hypothesis 1 has to be rejected.

RESULT 1 (Nash price setters). *Price setters do not play the Nash equilibrium conditional on a given value for the indicator $\pi_{nt} = \pi_t^* = 2\iota_t$.*

With hypothesis 1 being rejected, inertia and level- k provide an alternative explanation for actual behavior. Subjects underreact to changes in the indicator (as evidenced before with $\beta_1 < 2$). The inertia of price setters is captured by the parameter ϕ that

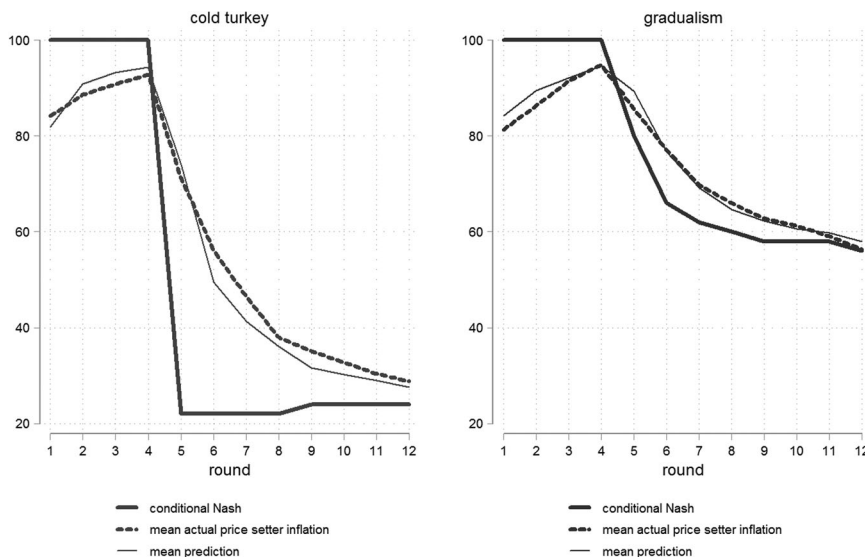


Fig 6. Illustration of Prediction with ϕ .

NOTES: Predictions were calculated based on the estimation of ϕ per group and life. Then the average prediction per treatment was calculated. Few values with $\phi > 1$ were censored to $\phi = 1$.

aggregates the distribution of level- k price setters with $\phi \equiv \sum_{k=0}^K \omega_k 0.6^k$. Figure 6 illustrates the prediction based on estimated values for ϕ together with the actual mean price setter inflation and the conditional Nash. Prediction and actual values are quite close, which shows that the model with ϕ can capture actual behavior quite well.

The bottom panel of Table 2 estimates the inertia of price setters ϕ by treatment. To estimate ϕ directly, equation (7) can be rearranged to $\pi_t^p - \pi_t^* = \phi(\pi_{t-1} - \pi_t^*)$ and is estimated in regressions (3)+(4). First, all coefficients are significantly positive and quite high, which shows that preround deviations from equilibrium are quite persistent. CT shows a high degree of inertia with $\phi = 0.810$. Subjects are largely anchored by the previous overall inflation rate π_{t-1} . Gradualism only yields $\phi = 0.691$. But ϕ is not significantly different between the two treatments. This means that CT is not able to reduce inertia successfully, given that ϕ is at least not lower for CT. This allows me to reject Hypothesis 2.

An analysis of individual level- k provides a better understanding of the reason for this result. Equation (6) states that level- k price setters set inflation rates according to $\pi_{nt} = 0.6^k \pi_{t-1} + (1 - 0.6^k) \pi_t^*$. This can be rearranged to $\pi_{nt} - \pi_t^* = 0.6^k (\pi_{t-1} - \pi_t^*)$ to estimate the individual level- k for each price setter.¹⁶ Level-5 or higher are

16. Each level k has a corresponding $\alpha_k \equiv 0.6^k$. These are $\alpha_0 = 1, \alpha_1 = 0.6, \alpha_2 = 0.36, \dots, \alpha_\infty = 0$. If the confidence interval from the estimation contains the value α_k , the price setter is classified as level- k . If the confidence interval contains different α_k , the average over these levels is used. α is estimated for

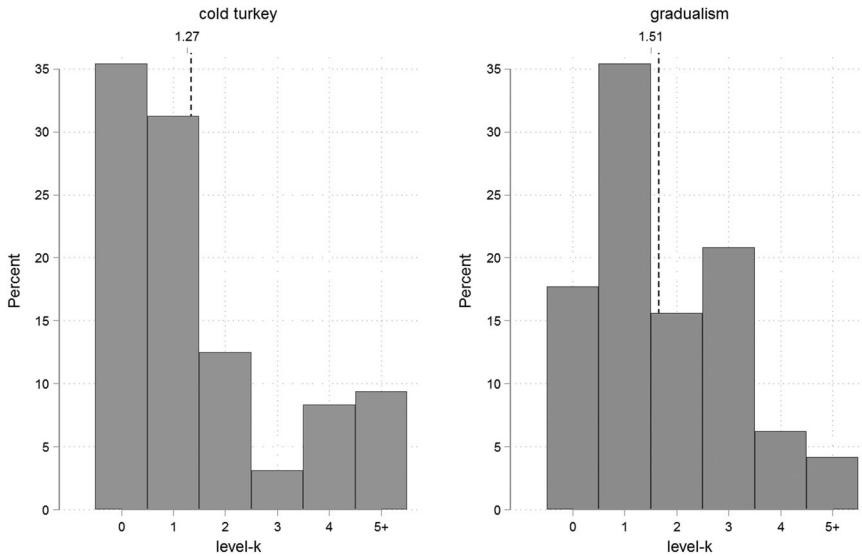


Fig 7. Level-*k* Distribution by Treatment.

NOTES: Levels are estimated by price setter and life. Levels are calculated by estimating level-*k* for each price setter in each life for $t > 4$. Further information on the estimation can be found in footnote . Level-5 or higher are classified into one category. Dashed blacked lines depict the mean level for each treatment.

classified into one category. Figure 7 shows the distribution of level types for each treatment. Overall, CT is not characterized by higher levels, as can be seen from the mean level depicted by the dotted line. Price setters who are confronted with CT have a mean level of 1.27, while those confronted with gradualism have a level of 1.51. The idea that CT increases level-*k* thinking does not find support.

Across all treatments, around 30–35% of the price setters are level-1. While 35% are classified as level-0 for CT, this level drops to 17% in the gradual treatment. In the latter treatment, less than 5% are level-5 or higher, in contrast to around 10% for CT. CT does increase the share of high-level price setters who play close to conditional Nash. On the other hand, it also increases the share of level-0 price setters. The latter means that a larger share of the price setters is left behind and just chooses previous round inflation rates. CT seems to bias the level more to its extremes and crowds out intermediate levels. This explains why we do not observe lower inertia for CT. The higher share of level-0 price setters may correspond to the increased standard deviation in Figure 4. CT is a shock that increases confusion among price setters, who are torn between their inertial preference for the *status quo*, the heterogeneous

each price setter and life separately together with the 95% confidence interval, which gives a total of three regressions per price setter.

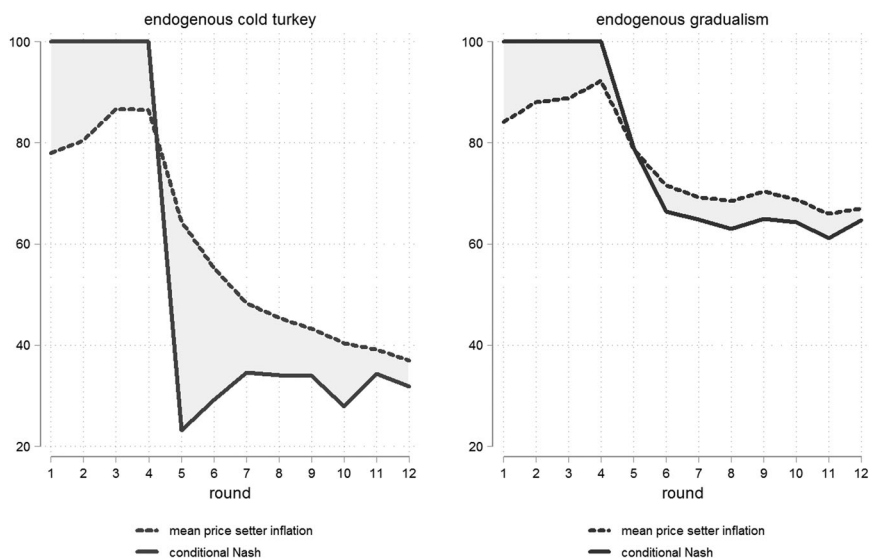


Fig 8. Conditional Nash and Price Setter Inflation in the Endogenous Treatment.

NOTES: All means are calculated over all price setters and lives separately for endogenous cold turkey and gradualism.

reaction by others and the large policy shock. Summarizing the overall result, level- k is not higher for CT.¹⁷

RESULT 2 (CT and inertia). *CT does not reduce inertia.*

6.2 Endogenous Treatment

Policies were chosen exogenously in the first two treatments. This guaranteed experimental control but disregarded one potential influential factor. In the endogenous treatment, the indicator can be adapted in each round so that central bankers may be of (at least) two different types, “tough” or “weak.” Therefore, central bankers in the endogenous treatment may prefer a CT strategy because it gives the additional advantage of providing some information on their type. One way for the central banker to signal to price setters that she is a “tough” type is to implement CT and to reduce the indicator very sharply in round 5.

The different policies in the endogenous treatment have to be classified as CT and gradualism for the analysis. They are classified as CT if $i_5 \leq 20$. All other strategies are classified as gradual. Around 48% are gradual strategies, while 52% of the central bankers choose an endogenous CT. Figure 8 depicts the mean indicator paths (by their corresponding conditional Nash equilibrium) and the mean price setter inflation. The

17. Controlling for order effects (CT-CT-CT, CT-G-CT,...) does not change the results.

TABLE 3
PRICE SETTER INFLATION AND INERTIA IN THE ENDOGENOUS TREATMENT

	Price setter inflation π_{it}		$\pi_t^p - \pi_t^*$		
	(1) Cold turkey	(2) Gradualism	(3) Cold turkey	(4) Gradualism	(5) All
Indicator	1.09 (0.077)	1.46 (0.120)			
Constant	29.25 (3.695)	19.59 (3.998)			
$(\pi_{t-1} - \pi_t^*)$			0.734 (0.075)	0.350 (0.078)	0.644 (0.083)
N	1200	1104	200	184	384
R^2	0.434	0.586	0.786	0.392	0.694

NOTE: OLS, standard errors in parentheses, (1) + (2) clustered by price setter and group. (3) – (5) clustered by group. (3) – (5) data from round $t > 4$. Bold values indicate significant differences from theoretical values with $p < 0.05$.

endogenous CT strategy is characterized by a large decrease of the indicator in round 5 but exhibits some reversal from round 6 on to values around an indicator of 15 (with a corresponding Nash equilibrium of around 30). The gradual policy is quite similar to the one that was implemented in the exogenous treatments and is characterized by a very cautious reduction in the indicator to a value of around 33 (with a corresponding Nash equilibrium of around 66).

As in the exogenous treatments, price setters adapt only sluggishly with $\beta_1 < 2$ (see Table 3, regression (1) + (2)). Coefficients β_1 are significantly different between endogenous CT and endogenous gradualism. This is also reflected in the measure of inertia ϕ that is estimated in Table 3 (3) + (4). Remarkably, CT strategies result in significantly higher levels of inertia, as evidenced by a higher value of $\phi = 0.734$. It can therefore be concluded that revealing to be “tough” by opting for CT does not reduce inertia. If, at all, one may infer that CT makes the future path of indicators uncertain, this way further increasing heterogeneity among price setters, which, in turn, tends to rather increase inertia.¹⁸

RESULT 3 (Endogenous CT and inertia). *The choice of CT in the endogenous treatment does not reduce inertia.*

7. CONCLUSION

I investigated in a laboratory experiment whether the strategy of CT is able to reduce inflation inertia. The experiment is characterized by flexible prices and full information. Four price setters have to set inflation rates given the central banker’s policy

18. Central bankers may endogenously react to inertia in rounds $t \geq 6$ which would bring about an endogeneity bias. However, I ran regressions for round 5 only with similar results.

choice of an indicator. Inflation rates are complementary so that price setters have to coordinate with each other as well. Two exogenous paths for the indicator—CT and gradualism—are implemented in the first two treatments, while central bankers can decide endogenously on the indicator in a third treatment. The payoff function of the central banker punishes high inflation and deviations of price setters from equilibrium. Price setters are not capable of playing the conditional Nash equilibrium (or expect others to fail) and show a persistent degree of inertia. CT does not help to reduce this inertia. In the endogenous treatment, CT strategies chosen by the central banker do not serve as a signal for a “tough” central banker and do not reduce inertia.

CT is widely believed to reduce inertia for at least two reasons. First, it increases costs for nonadjustment and alerts price setters to the necessity of being responsive to policies. Second, it signals that a central banker is “tough” and will continue with a rigorous policy in the future. I tested both arguments and did not find support. I trace the main reason for inertia to remain unaffected to the underlying heterogeneity. Level- k thinking provides a suitable model for this heterogeneity. While CT induces some price setters to increase their level of reasoning, also the frequency of level-0 players increases. This also contrasts with the ideas by Gabaix et al. (2006) and Alaoui and Penta (2016), which show that higher incentives increase levels of reasoning. In my experiment, this is not the case. In an environment where price setters must coordinate their prices, CT might increase the difficulty of this task. The higher amount of level-0 players might be interpreted as inertial players reacting with a shock-induced paralysis instead of a faster adjustment. The combination of individual cognitive limitations and a strategic environment with complementarities in sum induces the invariability of inflation inertia to the policy pursued.

The results from my experiment can be informative¹⁹ for the microfoundation of the New Keynesian Philips Curve (NKPC). It may help to better understand the high level of inflation inertia that is often found in empirical observation (Fuhrer 2009) and requires an inclusion of backward-looking inflation π_{t-1} to the NKPC. Equation (7) can be combined with equation (2) to provide the NKPC:

$$\begin{aligned}\pi_t &= \frac{2}{3}(\phi\pi_{t-1} + (1 - \phi)\pi^*) + \frac{1}{3}\pi^*, \\ \pi_t &= \pi_{t-1} + \frac{1 - \frac{2}{3}\phi}{\phi}(\pi^* - \pi_t^p).\end{aligned}\tag{8}$$

This shows how inflation inertia translates into a positively sloped Philips curve. As shown in equation (A8) in Appendix A, the deviation of prices from equilibrium yields the output gap. This correspondence also motivated the central bank’s target function (3), which commonly includes an output gap and an inflation gap. If prices are above the equilibrium price $\pi^* < \pi_t^p$ (which is the case most of the time in my

19. The experiment can only talk about the role of the backward-looking component as it does not include any menu costs or pricing rigidities.

experiment), this corresponds to a negative output gap. This negative output gap then helps to slowly reduce inflation. Cognitive limitations as captured by a level- k model therefore may provide a suitable candidate to better understand the backward-looking nature of the NKPC.

While the main goal of the experiment is on the invariance of inflation inertia, some cautious conclusion about the optimal policies can be made. In my experiment, CT achieves overall lower levels of inflation. A central bank has to balance the need for disinflation with the high levels of inertia in order to choose which policy is preferable. It may therefore also depend on the parameters of the policy objective function which policy is to be preferred. If a central bank has a large preference of inflation reduction but only a little preference for output gap stabilization, it may still go along with cold turkey. But if a central bank puts enough weight on inflation inertia and output gaps, it may value the problem of inertial adjustment high enough to choose a more gradual strategy.

One remark may be made regarding the group size. The limited sample size is one of the main critiques of experimental macroeconomics regarding the external validity—a few subjects in a lab setting represent interactions in a whole economy. While this is a characteristic similar to any theoretical model that builds on a representative agent assumption, many experiments show that even with a small number of subjects outcomes are close to market equilibrium (Duffy 2008, p. 161). Related to that, with groups of more than three players, subjects tend to think about the others as a composite and not as individual players (Camerer 2003, 210, fn. 8). Given the space restrictions in the lab, groups in my experiment were large enough to ensure sufficient heterogeneity in the subjects' behavior.

My findings on inflation inertia certainly do not quantitatively translate to the real world, but may still yield some qualitative indications. Inertia due to level- k may be externally valid as a wide range of studies show that students' behavior in such experiments is quite similar to that of business professionals (Davis and Holt 1993, Camerer 2003, Charness and Fehr 2015, Fréchette 2015). In addition, a first study started applying the concept of level- k to surveys conducted to access managers' higher order expectations (Coibion et al. 2018). The increased real-world complexity for price setters may translate into an even larger inertia and a lower degree of level- k thinking. Central bankers in the real world may have even more reason to regard inflation to be inertial due to habits, indexation or sticky information, which were all excluded in the experimental design. In theory, price setters might reduce inertia over time if they are repeatedly confronted with cold turkey central bankers. But such a learning process is unrealistic. I presume that also in the real world, it is likely that central bankers rather learn about the inertia than shaping it via their policy. They will thus have good reason to take inertia as given, in a sense as structural, rather than believing erroneously that due to their type or their policy, they can take a shortcut through the inertial adjustments.

ACKNOWLEDGMENTS

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APPENDIX A: MICROFOUNDATION OF THE EXPERIMENTAL DESIGN

The payoff function (1) in conjunction with (2) can be derived as a reduced form of a monopolistically competitive market where other price setters compete for final customers but also supply intermediate products to each other and where the central bank directly controls prices of some further goods. The calibration of the model is made in a way to get p -value of $2/3$ in equation (2), which is a standard value in the literature on beauty contest games, see, for example, Mauersberger, Nagel, and Buehren (2020, p. 6). The p -value determines the strength of the complementarity of decisions. The linear demand function is similar to Davis and Korenok (2011, p. 579).

Let us assume demand for player n 's product to be given by (A1). For convenience, the optimal quantity \tilde{q}_{nt} is centered around 0.

$$q_{nt} = \frac{5(1.6j_t + 0.2p_{-nt} - p_{nt})}{\tilde{p}_{nt}}. \quad (\text{A1})$$

The demanded quantity q_{nt} positively depends on the prices set by the central bank j_t and the average price p_{-nt} set by all players other than player n . It negatively depends on player n 's own price p_{nt} . The denominator calibrates the demand function around the optimal price $\tilde{p}_{nt} = 0.8j_t + 0.6p_{-nt}$. Let us further assume that the other players' product enters production as an intermediary good, the unit costs amounting to p_{-nt} . Total profit is thus given by (A2).

$$\Pi_{nt} = (p_{nt} - p_{-nt})q_{nt} = (p_{nt} - p_{-nt}) \frac{5(1.6j_t + 0.2p_{-nt} - p_{nt})}{\tilde{p}_{nt}}. \quad (\text{A2})$$

Taking the first derivative with respect to p_{nt} yields the first-order condition (A3).

$$\begin{aligned} \frac{5(1.6j_t + 0.2p_{-nt} - p_{nt})}{\tilde{p}_{nt}} - \frac{5(p_{nt} - p_{-nt})}{\tilde{p}_{nt}^2} &\stackrel{!}{=} 0, \\ \Leftrightarrow (1.6j_t + 0.2p_{-nt} - p_{nt}) - (p_{nt} - p_{-nt}) &= 0, \\ \Leftrightarrow p_{nt} &= 0.8j_t + 0.6p_{-nt} = \tilde{p}_{nt} \quad \square. \end{aligned} \quad (\text{A3})$$

Once prices are set according to (A3), the optimal quantity \tilde{q}_{nt} is given by (A4).

$$\tilde{q}_{nt} = \frac{5(0.8j_t - 0.4p_{-nt})}{\tilde{p}_{nt}}. \quad (\text{A4})$$

The output gap is defined by $q_{nt} - \tilde{q}_{nt}$ and calculated in (A5):

$$q_{nt} - \tilde{q}_{nt} = \frac{5(0.8j_t + 0.6p_{-nt} - p_{nt})}{\tilde{p}_{nt}} = \frac{5(\tilde{p}_{nt} - p_{nt})}{\tilde{p}_{nt}}. \quad (\text{A5})$$

If prices are set according to their equilibrium values $p_{nt} = \tilde{p}_{nt}$, the output gap is equal to 0. Any deviation between p_{nt} and \tilde{p}_{nt} goes along with an output gap. The output gap can be also formulated with respect to the unconditional optimal price $p^* = 2j_t$ with $q^* = 0$, which gives:

$$q_{nt} - q^* = \frac{5(0.4(p^* - p_{nt}) + 0.6(p_{-nt} - p_{nt}))}{\tilde{p}_{nt}}. \quad (\text{A6})$$

At the aggregate level, the average price p_{-nt} is equal to the average price p_{nt} . This allows us to simplify the output gap to:

$$q_t - q^* = \zeta(p^* - p_t) \text{ with } \zeta = \frac{0.2}{\tilde{p}_{nt}}. \quad (\text{A7})$$

This implies that the output gap is positive if $p^* > p_t$ and negative if $p^* < p_t$ (which is mostly the case in my experimental data).

With a marginal deviation ϵ from the optimal price proportional to p_{nt} , the chosen price is given by $p_{nt} = 0.8j_t + 0.6p_{-nt} + \epsilon p_{nt}$. Profits can then be calculated according to (A8).

$$\begin{aligned} \Pi_{nt} &= (0.8j_t - 0.4p_{-nt} + \epsilon p_{nt})q_{nt} \\ &= (0.8j_t - 0.4p_{-nt} + \epsilon p_{nt}) \frac{5(1.6j_t + 0.2p_{-nt} - 0.8j_t - 0.6p_{-nt} - \epsilon p_{nt})}{\tilde{p}_{nt}} \\ &= (0.8j_t - 0.4p_{-nt} + \epsilon p_{nt}) \frac{5(0.8j_t - 0.4p_{-nt} - \epsilon p_{nt})}{\tilde{p}_{nt}} \\ &= \frac{5((0.8j_t - 0.4p_{-nt})^2 - \epsilon^2 p_{nt}^2)}{\tilde{p}_{nt}} = \frac{5(0.8j_t - 0.4p_{-nt})^2}{\tilde{p}_{nt}} - \frac{5\epsilon^2 p_{nt}^2}{\tilde{p}_{nt}} \\ &= (p_{nt} - p_{-nt})\tilde{q}_{nt} - \frac{5\epsilon^2 p_{nt}^2}{\tilde{p}_{nt}} = e - \frac{5}{\tilde{p}_{nt}}(p_{nt} - \tilde{p}_{nt})^2. \end{aligned} \quad (\text{A8})$$

With optimal prices and quantities, profits amount to $e \equiv (\tilde{p}_{nt} - p_{-nt})\tilde{q}_{nt}$. For prices being symmetric in equilibrium, $p_{nt} = p_{-nt}$, profit is zero. For a price \tilde{p}_{nt} around 50, this comes close to my payoff function (1) for price setters $e - 0.1(\pi_{nt} - \pi_t)^2$. However, the experimental design deviates from (A8) by setting $e > 0$ as an endowment in order to incentivize laboratory subjects. The experiment seeks to shed light on inflation inertia. To arrive at (5), the equation $p_{nt} = 0.8j_t + 0.6p_{-nt}$ has to be transformed into inflation rates.²⁰ The transformation can be achieved by setting p_{nt} into relation

20. Remember that in the experimental instructions, subjects were only informed to set a number (without any references to inflation or prices).

to a basis price $p_0 = 0.8i_0 + 0.6p_{-n0}$. This gives the inflation rate π_{nt} as denoted in (A9).

$$\begin{aligned}\pi_{nt} &= \frac{p_{nt} - p_0}{p_0} = \frac{0.8j_t + 0.6p_{-nt} - p_0}{p_0} \\ &= 0.8 \frac{(j_t - j_0)}{p_0} + 0.6 \frac{(p_{-nt} - p_{-n0})}{p_0} \\ &= 0.8\iota_t + 0.6\pi_{-nt} \quad \square.\end{aligned}\tag{A9}$$

This is the best response function (5) from the main text with ι_t being defined as $\iota_t \equiv \frac{(j_t - j_0)}{p_0}$. The condition for the basic price $p_0 = 0.8i_0 + 0.6p_{-n0}$ includes two simplifying assumptions. First, the central bank sets its inflation rate starting from the previous price level p_0 . This means that the central bank sets an inflation target and does not follow a strict price target, which implies that inertia does not translate into a more rigorous policy in the next round where price setters would have to catch up. Second, π_{nt} and π_{-nt} are simplified as they assume that price setter n and the other price setters $-n$ start from the same level p_0 . But deviations would have to be balanced out in future rounds. Individual price setters' deviation from the average are neglected for future rounds. This might be justified by assuming that price setters adjust to the average price as soon as they get to know it and was done to further simplify the task for experimental subjects. Given the second simplifying assumption, we can also rewrite the output gap from equation (A7) as $q_t - q^* = \zeta'(\pi^* - \pi_t^p)$. This implies that the output gap corresponds to the deviation between the target rate of inflation and its current level.

APPENDIX B: LEVEL-K MODEL

In a level- k model, the standard assumption is that level-0 takes the previous inflation rate π_{t-1} as their guess. Level-1 price setters assume that all other price setters are level-0 and therefore best respond with $\pi_{nt} = 0.6\pi_{t-1} + 0.8\iota_t$. Level-2 price setters best respond to all others being level-1 and choose $\pi_{nt} = 0.6(0.6\pi_{t-1} + 0.8\iota_t) + 0.8\iota_t = 0.6^2\pi_{t-1} + 0.8\iota_t(1 + 0.6) = 0.6^2\pi_{t-1} + 0.8\iota_t(0.6^0 + 0.6^1)$. Level-3 price setters assume that all others are level-2 and choose $\pi_{nt} = 0.6^3\pi_{t-1} + 0.8\iota_t(0.6^0 + 0.6^1 + 0.6^2)$. This can be further iterated to level- k price setters choosing according to (B1)

$$\begin{aligned}\pi_{nt} &= 0.6^k\pi_{t-1} + 0.8\iota_t \sum_{j=0}^{k-1} 0.6^j = 0.6^k\pi_{t-1} + 0.8\iota_t \frac{1 - 0.6^k}{1 - 0.6} \\ &= \pi_{nt} = 0.6^k\pi_{t-1} + (1 - 0.6^k)\pi_t^*.\end{aligned}\tag{B1}$$

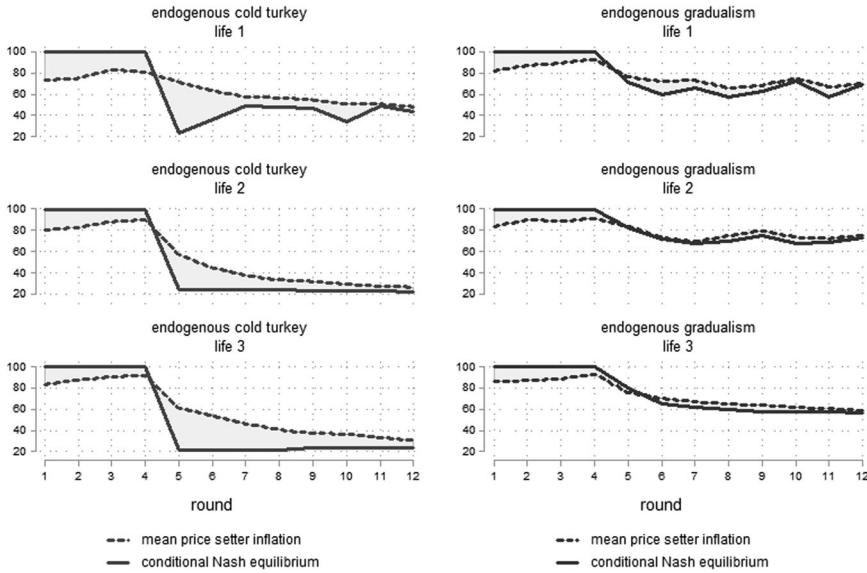


Fig C4. Price Setter Inflation in the Endogenous Treatment.

NOTES: All means are calculated by life over all price setters and for endogenous cold Turkey and gradualism separately. Policies were classified as endogenous cold Turkey if $t_5 \leq 20$.

Taking a finite number of levels K and assuming that in the population of price setters each level k has the share ω_k , then the average choice of the price setters π_t^p can be derived by aggregating (B1)–(B2).

$$\pi_t^p = \sum_{k=0}^K \omega_k 0.6^k \pi_{t-1} + \sum_{k=0}^K \omega_k (1 - 0.6^k) \pi_t^* = \phi \pi_{t-1} + (1 - \phi) \pi_t^* \tag{B2}$$

$$\text{with } \sum_{k=0}^K \omega_k = 1 \text{ and } \phi \equiv \sum_{k=0}^K \omega_k 0.6^k.$$

APPENDIX C: RESULTS PER LIFE

This appendix shows the main finding separately for each life in Figure C1, Figure C2, Figure C3, and Figure C4.

APPENDIX D: INSTRUCTIONS AND QUESTIONNAIRE (ENGLISH TRANSLATION FROM GERMAN)

D.1 Oral Instructions

A very warm welcome to this experiment and thank you very much for your participation. I will read some general instructions for the experiment. Please listen carefully

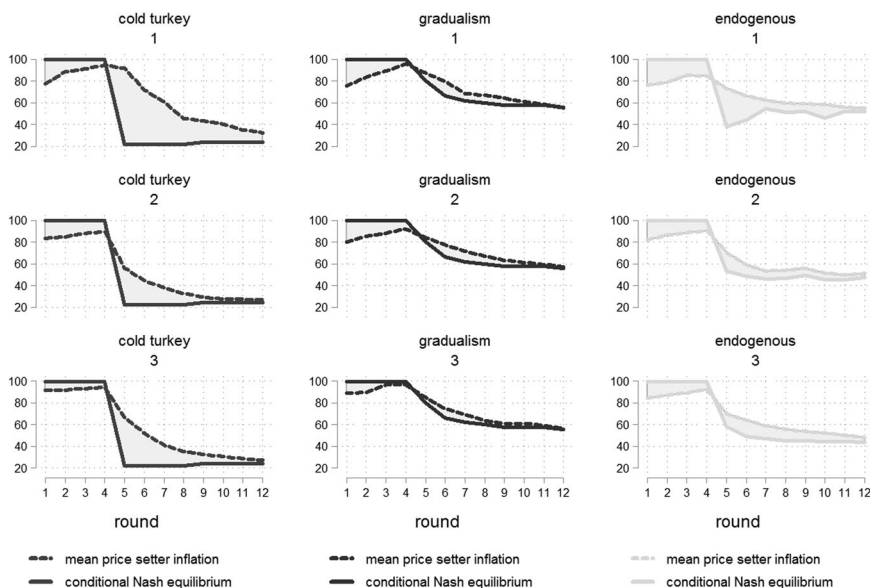


Fig C1. Price Setter Inflation by Treatment.

NOTES: All means are calculated by treatment and life over all price setters.

and only click the button “Start Experiment” after you have listened to these instructions. All participants of this experiment are in this room and are participating at the same experiment. With the experiment, we want to gain insights into human behavior. The game will last about 90–120 minutes. Your earnings in this experiment depend on your decisions and the decisions of the other participants. In the experiment, the payoff will be calculated in the currency “Taler.” 1 Taler will be converted into 10 cents. At the end of the experiment, you will get 10–15 euros per hour on average, but at least 3 euros per hour.

You interact anonymously and cannot communicate with others. The payoff will be paid out anonymously, too. No other participant will see how much you earn. Also, the persons who conduct the experiment will not be informed about that. Not the experimenter but another person will hand out the payoff. This person cannot infer your behavior from your payoff. During the experiment, you may have to wait for other participants. This may also take some minutes. Please remain seated patiently. Use the waiting time in order to recalculate the examples and to think about your decisions during the experiment.

After the experiment, you will be asked to leave the laboratory on your own. Outside of the laboratory, you get your payoff. You will find all instructions and explanations on the following screens. Please read all information carefully before leaving a screen. You cannot go back to screens you have left. If you want, you can take notes. Pen and paper are lying at your desk. You also have a pocket calculator on your desk.

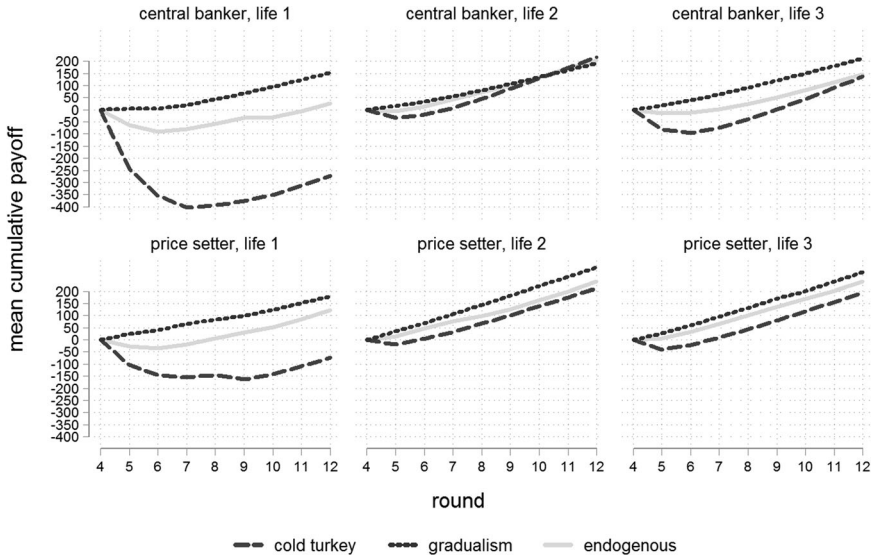


Fig C2. Mean Cumulative Payoffs by Treatment and Life.

NOTES: All cumulative payoffs are calculated by round, life, and treatment. Payoffs for belief elicitation are not included and payoffs are depicted in the experimental currency Taler. Maximum payoffs would be 320 for price setters and 480 for the central bank in round 12.

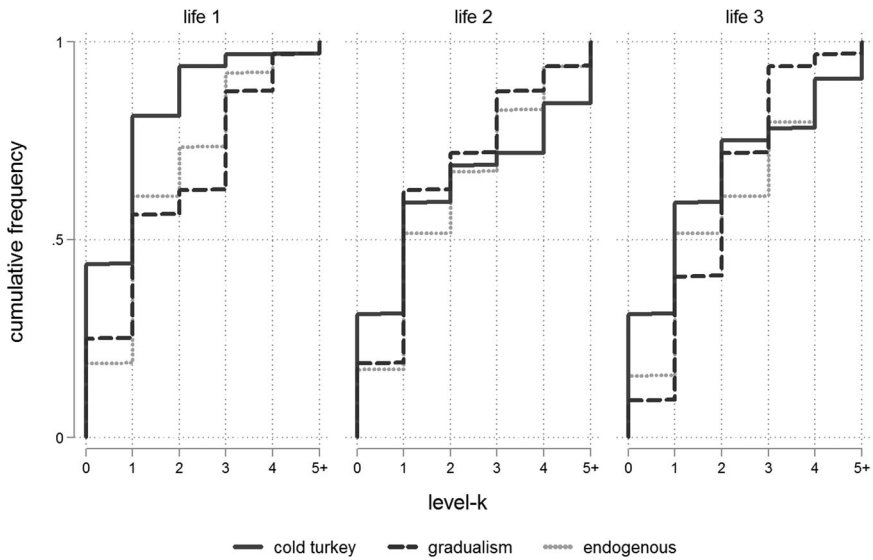


Fig C3. Cumulative level- k distribution by treatment and life.

NOTES: Levels are calculated by estimating level- k for each price setter in each life for $t > 4$. Further information on the estimation can be found in footnote 16. Level-5 or higher are classified into one category.

Please remain seated quietly at your desk. Please do not talk at all. If you do not comply with these rules, you may be excluded from the further participation at the experiment. If you have any questions, please raise your hand. We will then come to your desk. Please now click on the button “Start Experiment.”

D.2 Written Instructions

[Instructions are shown for all treatments. They differed between the exogenous treatments (cold turkey and gradualism) and the endogenous one. Differences are marked in the instructions.]

A very warm welcome to the experiment! At the beginning of the experiment, you are instructed about the general procedures in the lab. These will be read aloud by the experimenter. Please only click on “Start experiment” if you are told to do so. *[Oral instructions are read aloud.]*

Screen 1. Please read the instructions of the experiment carefully. At the end of the instructions, you will be asked some comprehension questions. For each answer you get right, you earn 2 Taler. On your desk, you find an overview over the flow of the experiment, which will be explained in the following.

In this experiment you have three lives. In each life, you interact in a group of 5 persons for 12 rounds. The group consists of four participants A and one participant B and remains constant within a life. After each life, participant B will be matched with another group of participants A, that is, all participants A will interact with a different participant B in each life. At the beginning of the experiment, you will be told whether you are participant A or B.

Screen 2. All participants A have the same task in each round and life, participant B has a different task. Also, participant B has the same task in all rounds and lives. In the following, the tasks of participants A and participant B will be explained. Each life thereby follows the same structure.

At the end of the experiment, one of the three lives will be chosen randomly. For all participants, the same life will be chosen. The chosen life determines your payoff and the other participants’ payoff. Not chosen lives have no impact on your payoff. You do not know which life will be chosen until the end of the experiment. Each life can be the one, which determines your payoff.

Screen 3—Task of participants A. Every life consists of 12 rounds. All four participants A have the same task. Every participant A has to set an integer number between 0 and 150 in every round. With the number, participant A tries to get close to a target value. The target value is determined by: **target value = $\frac{2}{3}$ * (average number + indicator)**. The average number is the average of all numbers of all participants A in a group (i.e., including the own number). The indicator (a value between 10 and 50) is announced to all participants at the beginning of each round. All relevant formula are stated later in the experiment, too.

Screen 4—Task of participants A continued. In each round, participant A receives an initial payoff of 40 Taler, from which $0.1 \times$ the **squared** deviation between his number and the target value will be deducted. The payoff in one round can also be negative. Please notice that the deviation will be squared first and will then be deducted, that is, the round payoff of participant A is: **Payoff A** = $40 - 0.1 \times \text{deviation}^2 = 40 - 0.1 \times (\text{number} - \text{target value})^2$. The round payoff from round 5 onward will be summed up over all rounds. The first four rounds of every life are trial rounds. If the life is chosen, the life payoff will be paid out in euros at the end of the experiment.

Screen 5—Comprehension questions for task of participants A. [Comprehension questions had to be filled in correctly to continue. After each wrong question participants got additional help to complete the question.] For every correct answer, you earn 2 Taler if you provide the correct answer in the first place. Taler you earn for the comprehension questions are paid out in euros at the end of the experiment.

Question 1. Four participants A and one participant B ...

- always interact with the same participants A, but in each life with a different participant B;
- interact in each life and each round with the same participants A and B;
- are matched to a new group in each round.

Question 2. At the end of the experiment ...

- the first life will always be chosen to be paid out;
- the payoff of all lives will be summed up and paid out;
- one life will be randomly chosen to be paid out.

Question 3. If the average number is 130 and the indicator is 50, the target value is ...

Question 4. If the average number is 10 and the indicator is 50, the target value is ...

Question 5. The indicator ...

- will be announced to participants A before they decide on a number;
- will be announced to participants A after they decided on a number;
- can have no values between 10 and 50.

Screen 6—Task of player B. [endogenous treatment]. Participant B has a different task than participants A. In the first four rounds, participant B does not have to make a decision and gets no round payoff. In the first four rounds, the indicator is automatically set to 50 and participant B can only observe the average number chosen by participants A. From round 5 on, participant B sets the indicator in the range between 10 and 50. Participant B sets the indicator **before** participants A set their number. The indicator will be told to participants A.

Screen 6—Task of player B. [exogenous treatment]. Participant B has a different task than participants A. In the first four rounds, participant B does not have to make

a decision and gets no round payoff. In the first four rounds, the indicator is automatically set to 50 and participant B can only observe the average number chosen by participants A. From round 5 on, the computer sets the indicator in the range between 10 and 50. The computer sets the indicator **before** participants A set their number. The indicator will be told to participants A. The indicator from round 5 on is based on decisions made by other participants B in previous sessions of the experiment in May 2014 and July 2015. Participant B does not have to make any further decision and can only observe the average numbers of participants A.

Screen 7—Task of player B continued. Participant B gets an initial payoff of 60 from round 5 on. From this payoff, two terms will be deducted: **Payoff B** = $60 - 0.5 * (\text{average number} - \text{target value})^2 - \text{indicator}$. First, $0.5 * \text{the squared average deviation of participants A}$ will be deducted, that is, the deviation of the average number from the target value will be calculated and then squared. This implies that the round payoff of participant B will be reduced if participants A deviate from the target value. Second, the value of the indicator will be deducted from the initial payoff. The payoff in one round can also be negative. For participant B, the round payoff will be summed up over the rounds 5–12. If the life is chosen, the life payoff will be paid out in euros at the end of the experiment.

Screen 8—Comprehension questions for task of participant B. For every correct answer, you earn 2 Taler if you provide the correct answer in the first place. Taler you earn for the comprehension questions are paid out in euros at the end of the experiment.

Question 1. Participant B ...

- has the same task as participants A;
- has a different task than participants A;
- decides on the indicator in the first round rounds.

Question 2 [Endogenous Treatment]. Participant B ...

- sets the indicator in the range from 10 to 50 from round 5 on;
- sets the indicator in the range from 10 to 150 from round 5 on;
- does not set the indicator.

Question 2 [Exogenous Treatment]. Participant B ...

- does not set the indicator, the computer sets the indicator from round 5 on based on sessions of the experiment in May 2014 and July 2015;
- sets the indicator in the range from 10 to 50 from round 5 on;
- sets the indicator in the range from 10 to 150 from round 5 on.

Question 3. If the average number deviates from the target value by 4 and the indicator is 50, the round payoff of participant B is ...

Question 4. If the average number deviates from the target value by 0 and the indicator is 50, the round payoff of participant B is ...

Question 5 [Endogenous Treatment]. Participant B ...

- does not have to make a decision in the first four rounds and can only observe the behavior of participants A;
- gets the same round payoff as participants A;
- gets more payoff if the indicator is higher.

Question 5 [Exogenous Treatment]. Participant B ...

- does not have to make a decision in the first four rounds and can only observe the behavior of participants A. From round 5 on the computer decides;
- gets the same round payoff as participants A;
- gets more payoff if the indicator is higher.

Screen 9A—Final instruction [Player A]. You are one of the four participants A, that is, you decide on a number in each round, after you are told the value of the indicator. Additionally, you are asked, what you believe which number the other participants A will pick on average. If your belief is equal to the correct average number $\pm 5\%$, then you get 2 Taler extra. Additionally, during the whole experiment a table with all values will be shown. Start Experiment.

Screen 9B—Final instruction [Player B, endogenous treatment]. You are participant B. The four others in your group are participants A, that is, from round 5 on you decide on the indicator, before participants A set their numbers. While participants A decide on their numbers, you are asked what you believe which number participants A will pick on average. If your belief is equal to the correct average number $\pm 5\%$, then you get 2 Taler extra. Additionally, during the whole experiment, a table with all values and a diagram with the indicator and the average number will be shown. Start Experiment.

Screen 9B—Final instruction [Player B, exogenous treatment]. You are participant B. The four others in your group are participants A, that is, from round 5 on the computer decides on the indicator, before participants A set their numbers. The indicator is based on decisions that were made in previous sessions of the experiment in May 2014 and July 2015 by other participants B. You do not make any decision. While participants A decide on their numbers, you are asked what you believe which number participants A will pick on average. If your belief is equal to the correct average number $\pm 5\%$, then you get 2 Taler extra. Additionally, during the whole experiment, a table with all values and a diagram with the indicator and the average number will be shown. Start Experiment.

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