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ESCAPING SECULAR STAGNATION WITH UNCONVENTIONAL MONETARY POLICY

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ABSTRACT

We design a new experimental framework to study policy interventions to combat secular stagnations and liquidity traps in an overlapping-generations environment where participants form expectations and make real economic decisions. We observe that participants can learn to coordinate on high inflation full-employment equilibria. Permanent deleveraging shocks induce pessimistic, backward-looking expectations and considerable consumption heterogeneity as the economies experience persistent deflation. We explore the ability of unconventional monetary policy to lead economies out of deflationary traps. Permanently increasing the central bank's inflation target is insufficient to generate inflationary expectations due to low central bank credibility. Negative interest rates stimulate spending and generate the necessary inflation for the economies to escape the zero lower bound. Negative interest rates are more potent than raising the inflation target at shifting consumption to the present.

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A data appendix is available at http://www.nber.org/data-appendix/w30117

1 Introduction

Many developed economies exhibit tell-tale symptoms of secular stagnation: decades-long downward trends in natural interest rates, tepid output growth well below estimates of potential, growing debt-to-GDP ratios, negative real interest rates, and below-target inflation. These conditions persisted despite expansionary policies employed by the Federal Reserve and by other central banks. For instance, the United States spent seven years at its zero lower bound (ZLB) before lifting off in 2015 and slowly climbed up to a meager 2.25% by 2019 thanks to, among other things, extraordinary quantitative easing and forward guidance. Summers and Stansbury (2019) argued that this was insufficient space to operate in a future recession. At the 2019 Jackson Hole Economic Policy Symposium, Federal Reserve Chairman Jerome Powell described this proximity to the effective lower bound as "the pre-eminent monetary policy challenge of our time" as central bankers sought fresh policy tools.

The recently un-anchored inflation and tight labor market conditions associated with the COVID-19 pandemic recovery have not made secular stagnation less relevant. As central banks respond to burgeoning inflationary pressures by raising their policy rates, households and governments will be forced to reckon with an incredible amount of debt that they accumulated since 2020. Deleveraging and constrained demand can push economies now contending with inflation back towards their zero lower bound. Further, Jordà et al. (2022) show empirically using European data that pandemics typically depress natural rates of interest and the effect can persist for many decades. As inflation abates and real rates increase, central banks may once again struggle to close the gap between the prevailing real and natural rates.

Monetary interventions once considered too extreme are now finding their way into mainstream policy discussions. In addition to raising inflation targets, many central banks are now either implementing or seriously considering negative policy rates. Both policies could potentially stimulate inflation expectations and propel economic activity.

After implementing inflation-targeting frameworks, most countries keep their targets constant or lower them as inflation becomes better managed. The Bank of Japan (BoJ) and the Reserve Bank of New Zealand (RBNZ) are two exceptions. The BoJ doubled its inflation target from 1% to 2% in 2013 while RBNZ has gradually raised the mid-point of its inflation target from 1% to 2% since the mid-1990s. Inflation subsequently increased to slightly above 1% before tumbling again due to an April 2014 consumption tax spike. The adjustment of the mid-point of the targeted range was credible given recent inflation experiences. Overall, New Zealand inflation has been well-anchored on the higher targets. In both cases, the magnitude of change in the policy target was rather small. There is a theoretical basis for permanently increasing the inflation target. Eggertsson et al. (2019c) show that a sufficiently aggressive and permanent increase in the central bank's inflation target can generate inflation via inflationary expectations and alleviate secular stagnation.

The European Central Bank (ECB), BoJ, Swiss National Bank, Danmarks Nationalbank, and Sveriges Riksbank have implemented negative rates. Despite this limited experience with negative rates, we still lack critical data on their potency for at least two reasons. First, the experimentation with negative rates was understandably cautious, with the lowest policy rate implemented by any of these banks being $-.75\%$ by Danmarks Nationalbank and Swiss National Bank. Second, there was limited, if any, pass through of these negative rates to commercial savings accounts due to concerns that it would induce bank runs and public outcry. Whether a more aggressive negative policy rate would have the ability to propel spending and inflationary expectations is unclear.

Extreme economic episodes often demand extreme policy actions. There is little evidence of how an economy would fare with significant negative interest rates or large increases in inflation targets. To this end, we design a flexible experimental frame based on EMR to test-bed these unconventional policy approaches, thereby providing policy makers with evidence on their effectiveness. Importantly, this environment captures many realistic and pressing concerns by allowing for secular stagnation (Hansen, 1939) and liquidity traps at the zero lower bound. We use this framework to provide the first experimental evidence on permanently increasing an inflation target and negative nominal interest rates to combating secular stagnation. To evaluate the performance of unconventional monetary policy requires data on both price expectations and real decisions.

Forward-looking rational expectations play a central role in determining inflation and output in the workhorse New Keynesian models. This paradigm has generated an intense focus on expectations management and led to many policy prescriptions that operate explicitly through the expectations channel. However, evidence is mixed on whether embedding rational expectations into these models has a basis in reality with some authors finding support for the practice (Cogley and Sbordone, 2008) and others not (Rudd and Whelan, 2006). Our framework allows for a careful investigation into how people form expectations in stable economic conditions, following significant structural shocks, and novel policy responses. Coupled with data on real decisions, this yields considerable insight into the reasons underlying the success and failure of the policies we test.

Each of our experimental economies consist of groups of participants who form inflation expectations and make financial decisions. They interact together with automated firms, households, and a monetary authority. To study behavior at the ZLB, we expose each economy to an exogenous and permanent deleveraging shock with the intention of forcing our experimental economies into a liquidity trap or secular stagnation through pessimistic expectations and depressed demand.

We explore behaviour in four environments. Our *Baseline* treatment studies the transition of an economy from a high inflation steady state to the secular stagnation steady state following the deleveraging shock. In three policy treatments, we extend our *Baseline* environment to allow for monetary policy interventions. After a lengthy episode at the ZLB, we introduce either a permanently higher inflation target (*HigherTarget*) or allow for negative interest rates (*NegativeIR* or *NegativeIR+Portfolio*) in an effort to stimulate inflation expectations and household demand.

In our *Baseline* treatment, we find that most economies converge to a unique full-employment equilibrium upon initialization of our experimental economies. Exogenous deleveraging shocks consistently generate pessimistic expectations and manufacture various degrees of instability manifesting permanent deflation. Most experimental economies converge in the direction of the secular stagnation equilibrium. We then explore alternative policy options to return economies to the full-employment equilibrium after an extended episode at the zero lower bound.

In our *HigherTarget* treatment, we allow a mechanistic central bank to permanently increase its inflation target, which creates an equilibrium selection problem by introducing a multiplicity of locally-determinate equilibria: a full-employment equilibrium, a liquidity trap equilibrium, and a secular stagnation equilibrium. We find that permanently increasing the inflation target does not effectively return any of our experimental economies to the targeted, full-employment equilibrium. This intervention fails primarily because it cannot re-coordinate the expectations of dynamically-optimizing agents.

In our *NegativeIR* treatment, we instead allow the central bank to use negative interest rates (i.e. we remove the ZLB constraint on policy). Removing the ZLB reshapes the aggregate demand curve, eliminating the secular stagnation equilibrium and re-creating the unique full-employment equilibrium. Participants exhibit significant loss aversion at the prospect of their wealth being taxed away by negative interest rates (Kahneman and Tversky, 1979). Negative policy rates consistently stimulate consumption on impact, which in turn encourages and coordinates inflationary expectations. These economies converge quickly to the unique full-employment equilibrium that coincides with the central bank's inflation target.

Our *NegativeIR+Portfolio* treatment embeds *NegativeIR* and introduces a portfolio choice wherein subjects can transfer wealth between periods by holding interest-bearing liquid bonds or cash. This allows us to study directly the impact of negative savings rates on preferences for cash and whether these preferences moderate the effectiveness of negative interest rates. We find that results from *NegativeIR* are robust to portfolio choice. Though some subjects choose to hold cash, many subjects leave their savings in bonds and respond strongly to negative interest rates. Both the mechanism and dynamics of recovery in *NegativeIR+Portfolio* closely match those observed in *NegativeIR*.

We see in all treatments that deleveraging shocks generate considerable heterogeneity in consumption and welfare. This is true despite all subjects having identical preferences, information, and access to optimization tools. We also observe that deleveraging shocks affect expectations formation. Economic instability following deleveraging shocks leads to significant heuristic switching, inducing a high level of constant-gain learning and backward-looking expectations.

The deleveraging shock consistently generates deflation and an increase in real net income. We find no evidence in support of a Pigouvian effect, which predicts that higher real balances lead to higher aggregate demand. Recessions are not self correcting via associated price deflation.

The main takeaway from our paper is that negative interest rates more effectively stimulate consumption and inflation expectations than does increasing the central bank's inflation target. Consequently, negative interest rates consistently pull our experimental economies out of secular decline. Increasing the central bank's inflation target consistently fails to stimulate either inflation expectations of consumption. Though the policy intervention creates a pathway out of secular stagnation, it consistently fails to follow that path.

We also make a number of valuable methodological and empirical contributions in this paper. First, we demonstrate how a complex general equilibrium theoretical framework can be distilled to a simple implementation that nonetheless allows for a meaningful interaction of expectations, decisions, and monetary policy. This flexible framework can be easily extended to allow for fiscal policy, credit markets, policy communication, and coordination. Additionally, we contribute to the experimental literature by bridging learning-to-forecast and production economy experiments. Fusing these frameworks allows us to link expectations and real decision in response to policy, filling a crucial but neglected empirical gap.

The rest of the paper is organized as follows. Section 2 places our paper in the context of the existing macroeconomics and experimental research. Section 3 lays out the theoretical framework and hypotheses for our experiment, and Section 4 provides details of the experimental implementation. Section 5 presents our experimental results, and is followed by a discussion of the impact of unconventional policy on forecasting heuristics in Section 6. Section 7 discusses factors driving our findings, and Section 8 concludes.

2 Literature

Many theories of liquidity traps have employed representative agent frameworks where the long-run interest rate is uniquely determined by a representative discount factor (Krugman et al., 1998; Eggertsson and Woodford, 2003; Eggertsson and Krugman, 2012). Deflationary episodes in these studies are driven by temporary negative shocks to the natural rate of interest that lead to ZLB episodes, which abate as the economy recovers from the temporary shocks. The optimal policy in these settings is to keep interest rates low for an extended period of time. This 'wait-and-see' policy approach would not work well for an economy suffering from secular stagnation, which is potentially permanent.

Eggertsson et al. (2019c) (EMR hereafter) fill an important gap in this literature by providing a thorough treatment of secular stagnation. Their adoption of an overlapping-generations structure allows for the possibility of a permanently negative natural rate of interest, and deflation and output gaps that last for an arbitrary duration. EMR demonstrate that permanently raising the central bank's inflation target can alleviate secular stagnation. However, this policy prescription generates a multiplicity of rational expectations equilibria. Our paper provides an experimental framework to test this policy recommendation and resolve the associated equilibrium selection problem.

Deflationary steady-states can emerge in both homogeneous and heterogeneous agent New Keynesian frameworks. Schmitt-Grohé and Uribe (2001); Evans et al. (2008); Benigno and Fornaro

(2018) feature a ZLB that binds due to hysteresis. ZLB steady-states in these models are locally indeterminate and are open to the criticism that ZLB episodes driven by hysteresis are not 'learnable' and it is therefore unclear how such a steady-state can coordinate expectations (Christiano et al., 2018). However, Arifovic et al. (2018) show that the liquidity trap equilibrium is learnable under social learning. Additionally, Gibbs (2018) shows mathematically that both the deflationary and targeted-inflation equilibrium in EMR's model are both E-stable when they exist and that the full-employment, liquidity trap equilibrium is only stable whenever agents in this overlapping generations (OLG) model face sufficiently large borrowing limits. More recently, Honkapohja and Mitra (2022) show how pessimism and productivity shocks due to the COVID-19 Pandemic can generate convergence to a secular stagnation equilibria.

We provide experimental evidence of the learnability of these three equilibria. We observe that agents can coordinate on the targeted inflation equilibrium *before* entering into the ZLB. Moreover, our experimental economies converge in the direction of the secular stagnation equilibrium. We do not find support for coordination on either the full-employment liquidity trap equilibrium or the targeted equilibrium *after* the central bank permanently increases its inflation target to address secular stagnation.

We contribute to an empirical literature that documents conditions consistent with secular stagnation. Eo and Morley (2022) use a Markov-switching time series model and show that the Great Recession generated a large and persistent output gap with the economy eventually recovering to a lower trend path due to a reduction in productivity growth that began prior to the onset of the Great Recession. This decline in productivity growth follows more than a decade of only moderate-to-good growth achieved in United States despite unsustainable financial practices and the internet bubble of the 1990s (Summers, 2018). These low growth conditions coincide with a decades-long downward trend in real interest rates both in the United States and abroad (Rachel and Smith, 2018), and an apparent decline in neutral rates of interest (Rachel and Smith, 2015; Kiley, 2015; Laubach and Williams, 2016; Holston et al., 2017). We show that these empirical patterns indicative of secular stagnation can be replicated in a laboratory setting.

This paper also contributes to an emerging empirical literature that studies the use of negative interest rates. Eggertsson et al. (2019a) use empirical data to show that negative policy rates produce a lower bound on household deposits and that negative rates are expansionary only under some conditions. Altavilla et al. (2022) show empirically using Euro-area data that the transmission mechanism of monetary policy does not break down when rates become negative. Wu and Xia (2016) build a shadow rate term structure model calibrated to the Euro Area and show that all four of the European Central Bank's negative rate cuts lowered maturities along the short-end of the yield curve. Further, they show that forward guidance may facilitate the transmission of negative rates.

A missing component of empirical evidence on negative policy rates is how these rates affect household consumption. This is because commercial banks have largely refused to pass negative rates to through to customers, perhaps out of fear that negative deposit rates will cause households to hoard cash.[*] This experimental framework fills two critical gaps in the literature by providing evidence on how negative rates affect intertemporal and portfolio choices.

This paper also makes several contributions to the experimental macroeconomics literature through its blending of production economy, overlapping-generations, dynamic optimization, and learning-to-forecast frameworks. This fusion of experimental domains allows for the simultaneous collection of expectations and real decisions in a dynamic, endogenously evolving macroeconomic setting, and is essential for robust testing of macroeconomic policies.

Production economy experiments involve studying the simultaneous coordination of decisions of multiple agents in settings with input and output markets. Such experiments have been used to study patterns of international trade, exchange rates and economic growth (Lei and Noussair, 2002; Noussair et al., 1995, 1997, 2007), effects of monetary injections on real and nominal variables (Bosch-Domènech and Silvestre, 1997; Lian and Plott, 1998), as well as business cycle dynamics (Noussair et al., 2014, 2015, 2021; Petersen, 2016). Our experiment introduces an overlapping generations (OLG) structure to this production framework. Overlapping generations models have been taken to the lab to study inflation and coordination (see for example Arifovic (1995); Offerman et al. (2001)). We make two methodological contributions to this literature. First, we introduce a novel approach to implementing OLG economies in the laboratory by having participants interact in only one period of their life-cycle. Second, we introduce a pricing algorithm based on numerical methods that facilitates laboratory experimentation with models that lack closed-form solutions for price equations. This allows us to focus our analysis on household behaviour and avoid prices set by subjects playing the role of firms.

Dynamic optimization is at the core of our production economy experiment. We build on an extensive literature that studies intertemporal optimization where the underlying state of the economy is either stochastic or pre-determined (see Hey and Dardanoni (1988); Carbone and Hey (2004); Carbone and Duffy (2014); Duffy (2016); Meissner (2016)). Importantly, these frameworks study choices in the absence of subjects' corresponding expectations about the evolution of endogenous variables. Our experiment introduces two novel features to the conventional 'learning-to-optimize' environment. We simultaneously elicit decisions and expectations in an endogenously evolving environment to evaluate whether participants are making optimal intertemporal decisions given their expectations. Our experiment is also the first to study the effects of negative interest rates on optimization.

We blend together the learning-to-optimize approach with expectation formation. 'Learning-to-forecast' experiments (LtFE) initiated by Marimon and Sunder (1993, 1994) and developed by Heemeijer et al. (2009); Hommes (2011), involve subjects forming incentivized price forecasts that simultaneously determine automated demand decisions of traders and aggregate price outcomes. The combination of price expectations and decisions has been studied in Bao et al. (2013), Petersen (2016), and Petersen and Winn (2014).

Our paper is the first to study both expectation formation and real decisions at the zero lower

[*]This may soon change given that many Swiss banks have recently begun implementing negative savings rates.

bound, in response to negative policy rates, and the first to produce persistent deflationary episodes. Related LtFEs studying expectation formation at the ZLB have shown that deflation can be very challenging to escape. Arifovic and Petersen (2017) show in a learning-to-forecast experiment that expectations can become significantly unanchored at the ZLB. Neither qualitative nor quantitative communication of a central bank's higher inflation target can effectively rescue an economy mired in a deflationary trap. Keeping the episodes at the ZLB brief through quick and guaranteed fiscal stimulus can stabilize expectations and facilitate economic recovery. Hommes et al. (2015) also find that fiscal stimulus is effective at mitigating deflationary spirals. Ahrens et al. (2018) extend this by allowing for human vs. robotic central bankers. They find that human central bankers can more effectively build up credibility by slowly adjusting their inflation projections upward while at the ZLB. Kostyshyna et al. (2021) emphasize the importance of simple-to-understand monetary policy at the ZLB. More complex policy mandates such as those that incorporate history-dependence only serve to confuse forecasters.

Even though our participants are incentivized primarily based on real outcomes (i.e. their utility from consumption), which is greatest whenever our experimental economies are at full productive capacity, they are still willing to form deflationary expectations and contract their demand. These two forces exacerbate and prolong output gaps. Compared to the dynamics observed in LtFEs, deflation evolves much slower in our OLG economy, suggesting participants exhibit significant downward rigidity in their output demand. On the other hand, inflation can occur very quickly when negative interest rates are implemented. Participants are very eager to increase their spending to avoid the effects of negative interest on their saving. The aversion to negative interest rates that we observe aligns with Fenig et al. (2018)) who demonstrate how negative interest rates can fuel investment in a production economy.

3 Theoretical Framework and Hypotheses

We build our experimental economies using the three-period OLG model of secular stagnation introduced in EMR. This section outlines the model, explains how decisions from our participants influence the evolution of our economies, and lays out our testable hypotheses.

3.1 Households

Our experimental economies feature young, middle-aged, and old households where the population size of each is stable over time. Households derive utility from a single consumption good, C_t for each period t. Young households earn no income and may borrow up to a fraction, D_t, of their middle-aged income to consume. Middle-aged households earn income from their inelastic provision of labor, $\overline{L}$, and from firm profits Z_t. These households repay debt accrued while young, and then split remaining income between consumption and savings. Old households consume all their savings. A one-period, risk-free bond facilitates lending and borrowing between middle-aged and young households in the loanable funds market. The central bank controls the per-period nominal rate of return, i_t, on this asset. Thus, households maximize:

$$\mathbb{E}_t\{ln(C_t^y) + \beta ln(C_{t+1}^m) + \beta^2(C_{t+2}^o)\} \tag{1}$$

subject to the following budget constraints:

$$(1+g_t)B_t^y = -B_t^m \tag{2}$$

$$C_t^y = B_t^y = \frac{D_t}{1+r_t} \tag{3}$$

$$C_{t+1}^m = \frac{W_{t+1}}{P_{t+1}}L_{t+1} + \frac{Z_{t+1}}{P_{t+1}} - (1+r_t)B_t^y + B_{t+1}^m \tag{4}$$

$$C_{t+2}^o = -(1+r_{t+1})B_{t+1}^m \tag{5}$$

where W_t represents the nominal wage, P_t represents the aggregate price level, and B_t^y and B_t^m represent the borrowing of the young and savings for the middle-aged. Equation (3) implies that D_t is always binding, while Equation (5) implies that old households consume all wealth. This maximization problem yields the Euler equation

$$\frac{1}{C_t^m} = \beta\mathbb{E}_t\frac{1}{C_{t+1}^o}(1+i_t)\frac{P_t}{P_{t+1}} \tag{6}$$

3.2 Firms

Firms are perfectly competitive price takers with technology $Y_t = L_t^\alpha$ that maximize profits via an optimal hiring decision:

$$\frac{W_t}{P_t} = \alpha L_t^{\alpha-1} \tag{7}$$

where α governs the marginal productivity of labor. The model includes wage rigidity as the key source of market friction. Wages in each period t are a convex combination of the flexible wage $W^{flex} = \alpha P_t L_t^{\alpha-1}$, and wages from the previous period, W_{t-1}, and are given by

$$W_t = max\{W_t, W_{t-1} + (1-\gamma)W^{flex}\} \tag{8}$$

where $\gamma \in [0,1]$ represents the degree of nominal wage rigidity. W_t equals W^{flex} unless the economy is experiencing deflation.

3.3 Central Bank

The central bank sets nominal interest rates according to a Taylor-type monetary policy rule

$$1 + i_t = max\left(1, (1+i^*)\left(\frac{\Pi_t}{\Pi^*}\right)^{\phi_\pi}\right) \tag{9}$$

where i^* is the steady-state nominal interest rate, Π^* is the central bank's gross inflation target, and $\phi_\pi > 1$ is the central bank's reaction coefficient to deviations of inflation from the inflation target. Gross inflation is given by $\Pi_t = \frac{P_{t+1}}{P_t}$.

3.4 Equilibrium

The existence of downward wage rigidity creates a kink in the aggregate supply curve. If an economy faces deflation, wage rigidities lead to labor rationing and an output gap (Equation (11)). When the economy experiences inflation, there is full employment and $Y_t = \overline{L}^\alpha = Y^f$ (Equation (10)). Aggregate supply (AS) is then split into two segments:

$$Y_t = \overline{L}^\alpha, \qquad \Pi \geq 1 \tag{10}$$

$$Y_t = Y_f \left(\frac{\gamma - \Pi}{\Pi(\gamma - 1)} \right)^{\frac{\alpha}{1-\alpha}}, \qquad \Pi < 1 \tag{11}$$

where Equation (10) describes the vertical portion of the AS curve and Equation (11) the upward sloping portion of the AS curve.

The presence of zero lower bound on nominal interest rates also creates a kink in the aggregate demand curve. At the ZLB, increases in the magnitude of deflation lead to a higher real interest rate, which increases the opportunity cost of consumption. Aggregate demand (AD) is then split into:

$$Y = D + \frac{(1+\beta)(1)D}{\beta} \frac{1}{\Pi^{\phi_\pi - 1}} \frac{(\Pi^*)^{\phi_\pi}}{(1+i*)}, \qquad i > 0 \tag{12}$$

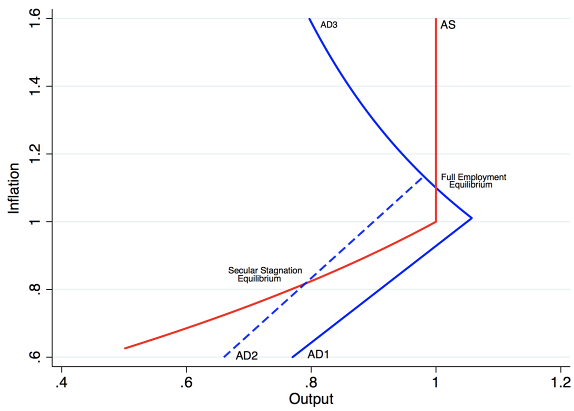
$$Y = D + \frac{(1+\beta)(1)D}{\beta} \Pi, \qquad i = 0 \tag{13}$$

where Equation (12) is the downward sloping portion of AD and Equation (13) the upward sloping portion of AD.

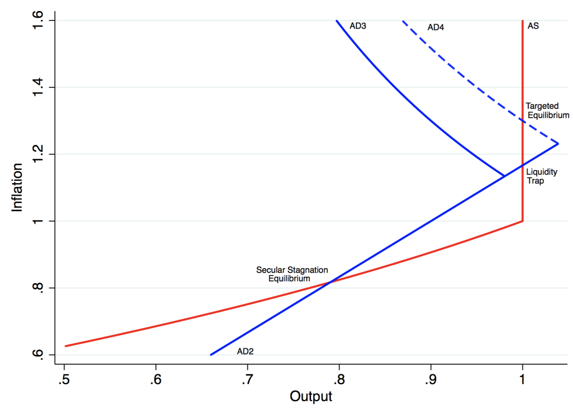
3.5 Hypotheses

We now present testable hypotheses of the model given the parameterizations we consider in our laboratory experiments. We assume that $\Pi^* = 1.1, \phi_\pi = 2, \gamma = .3, Y_f = 1, \alpha = .7, \beta = 1, L = 1$.

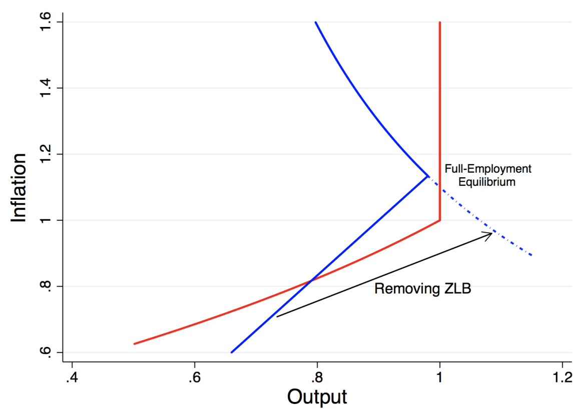
Suppose an inflationary economy faces a permanent deleveraging shock that reduces the amount of money that young households may borrow for consumption. This results in a sharp decrease in the demand for loans but not the supply of loanable funds which, in turn, causes the market clearing interest rate to fall. Thus, the young who face a deleveraging shock in period t will have excess resources in period $t + 1$. This causes an increase in the supply of loanable funds in $t + 1$, further decreasing the interest rate. We illustrate the impact of such a shock on steady-state levels of output and inflation in Figure 1a.



(a) Deleveraging shock



(b) Increased inflation target



(c) Removing the ZLB

Figure 1

A deleveraging shock impacts both segments of AD. However, a simultaneous adjustment of $i*$ in Equation (12) offsets the shock so that only the upward sloping portion of the AD shifts significantly. Importantly, shocks to D can eliminate a unique inflationary equilibrium and create instead a unique deflationary equilibrium. We set the pre-shock value of $D = 35\%$, which yields a unique inflationary equilibrium with 10% inflation. This equilibrium occurs where AD3 intersects AS in Figure 1a. A deleveraging shock reduces the borrowing constraint to $D = 30\%$, which shifts the upward sloping demand curve inward and yields a unique secular stagnation equilibrium where AD2 intersects AS. The model produces our first two testable hypotheses:

H1. The economy stabilizes at the unique inflationary equilibrium in the pre-shock phase.

H2. A sufficiently large deleveraging shock will cause an economy to stabilize at the unique secular stagnation equilibrium.

The central bank, facing a binding ZLB on its policy rate, addresses secular stagnation by permanently increasing its inflation target from $\Pi^* = 10\%$ to $\Pi^* = 30\%$. This shifts AD3 rightward to AD4 in Figure 1b, introducing two new rational expectations inflationary equilibria: a full-employment, targeted equilibrium (where AD4 intersects the vertical portion AS) and the liquidity trap equilibrium (where AD2 intersects the vertical portion of AS). This gives us our third testable hypothesis

H3. Raising the inflation target to a sufficiently high level will move an economy out of secular stagnation to the targeted inflationary equilibrium.

Increasing the inflation target from 10 to 30% is arguably extreme but serves a few purposes. First, it allows sufficient separation between the liquidity trap and targeted equilibria so that we can cleanly observe equilibrium selection with potentially boundedly rational participants. Second, we want to avoid the homegrown biases participants may exhibit with more familiar inflation targets. A baseline inflation target of 10% would be sufficiently out of the recent inflation experiences of most of our North American student populations. Increasing the inflation target three-fold during the secular stagnation brings needed attention to the Bank's objectives since garnering the public's attention is a necessary component for the success of a policy intervention meant to operate primarily through the expectations channel (Sims, 2003; Gabaix, 2020).

The limited empirical evidence that we do have on stimulating inflation expectations via increasing an inflation target highlights the need for extreme policy action. Even when Japan doubled its inflation target from 1 to 2 percent in January 2013, this was insufficient to generate sufficiently inflationary expectations. It is reasonable to think that a central bank employing this unconventional policy in the real-world would want to more-than-double its inflation target to circumvent a timidity trap Krugman (2014). This intuition is nicely captured by former Federal Reserve governor Randall Kroszner who said at the 2019 Jackson Hole Symposium that central bankers were searching for a "shock and awe strategy...to make sure that markets realise they're serious, and that they are going to have an impact".

We also study the use of negative nominal interest rates to combat secular stagnation. The idea of using negative policy rates has gained in popularity over the last two decades as many advanced- and emerging-economy central banks have found themselves constrained by the ZLB. There is some evidence that banks may be able to successfully employ negative rates (Eggertsson et al., 2019b; Altavilla et al., 2019).

Eliminating the ZLB removes the kink in the AD curve, so that AD is fully described by Equation (12). We show in Figure 1c that this change eliminates the unique secular stagnation equilibrium and restores the full-employment equilibrium that coincides with the central bank's 10% inflation target. This leads us to our fourth testable hypothesis:

H4. Allowing the central bank to use negative nominal interest rates moves an economy out of secular stagnation and back to the targeted inflationary equilibrium.

Finally, we study how households' portfolio decisions respond to negative interest rates. To do this, we consider a simplified setting where households can choose to hold either cash or bonds. This provides evidence on how households' real decisions and demand for cash respond to negative policy rates, which is missing in observational data. This is because in countries where central banks set negative interest rates, few if any commercial banks passed those rates onto depositors out of concern it would spur 'bank runs'.[†]

Our last hypothesis follows that real-world logic by supposing that introducing a portfolio choice into our negative rates treatment will lead subjects to hold cash rather than bonds whenever rates become negative. This decreases aggregate demand in equilibrium, thereby muting the effectiveness of negative interest rates. Intuitively, this is akin to allowing our experimental subjects to opt back into a world where the zero lower bound is binding. This effectively reintroduces the kinked aggregate demand curve and the secular stagnation equilibrium as in Figure 1a.

H5. Introducing a portfolio choice between bonds and cash mutes the efficacy of eliminating the ZLB.

4 Experimental Implementation

Each laboratory session is an independent economy consisting of seven young, seven middle-aged, and seven old households interacting in our three-period overlapping generations framework. For simplicity, we automate the young and old agents to behave in a theory-consistent manner. We focus our attention on the behavior of the middle-aged households, played by participants, who set a household's current period spending and saving. These design decisions reduce the complexity of our experimental environment while still capturing how policy operates through expectations and intertemporal choice. We provide more details of the automation in our online appendix.

Timing

The experiment consists of 30 to 50 decision periods (depending upon treatment) and each decision period consists of three stages. Instructions with screenshots can be found in our online appendix.

Stage 1: All participants simultaneously submit a nowcast about the current price, $E_{i,t}P_t$ and a forecast about the subsequent period's price, $E_{i,t}P_{t+1}$. Subjects also submit a qualitative nowcast about the change in the nominal interest rate relative to the previous period (increase, stay the same, decrease).

Stage 2: Participants, playing the role of middle-aged households, receive information about the current period's expected net income after repaying debts accrued while they were young, the cur-

[†] Eisenschmidt and Smets (2019) show that the distribution of household deposit rates is truncated at zero following the 2014-2017 implementation of negative interest rates by the ECB.

rent period's expected nominal interest rate, and the current and next period's expected prices. Participants can use this information to make a consumption decision, $C_{i,t}$. Any savings are automatically spent in the subsequent period on consumption. Figure 2 shows the evolution of the OLG economy and how period t middle-aged household decisions impact their $t+1$ outcomes.

Period	Middle-Aged Household	Old Household (Automated)
1	Decision 1 (e.g. spend 40% / saving 60%)	
2	Decision 2	Decision 1 (e.g. spend remaining 60% + interest earned)
3	Decision 3	Decision 2
4	Decision 4	Decision 3
5	...	Decision 4

Figure 2: Co-determination of middle-aged and old spending

After all participants have submitted their spending decisions, we use the spending decisions of the automated young agents and the middle-aged participants' spending decisions in period t, as well as the remaining spending dollars of the period t old agents determined in period $t-1$, to compute total period t dollars for consumption spending.

We compute aggregate spending in period t by summing the spending decisions of all middle-aged (determined in period t), old households (determined in period $t-1$), and the automated young participants (determined in period t). We use this information to clear markets, allocate output, and assign utility. Subjects earn points based on consumption utility and on forecast accuracy.

We face the challenge of simultaneously clearing markets and allowing young agents to borrow from future uncertain income. We circumvent this issue by employing aggregate price expectations to determine income, price, and interest rate signals, which can inform participants' decisions before markets clear. Coupling subjects' expectations with a novel pricing algorithm allows us to determine the aggregate spending, price, wage, output, labor demand, and the interest rate in period t. The algorithm is described in detail in our online appendix.

Stage 3: The third stage provides participants with summary information about the realized current-period outcomes. Participants observe the total amount of output produced, the unit price of output, the nominal interest rate, and the amount of points earned from consumption.

4.0.1 Information

Participants are provided with detailed information about the structure of the OLG economy. In particular, they know the number of households of each type, the borrowing constraints and consumption decisions of the young households, an explicit function describing the central bank's monetary policy, and the central bank's inflation target. They receive qualitative information about the link between expectations, consumption spending, output and inflation, and are encouraged to use the software tools (described below) to make precise calculations. Participants are also informed that that all information, other than personal decisions and points, is common information.

We provide a history of all aggregate-level variables to subjects in all periods (following the first period) during both stages of each period. Additionally, the central bank announces the current inflation target during both stages of each period. In the NegativeIR and NegativeIR+Portfolio treatments, we pause the experiment in Period 30 before the start of Phase 3 and announce that the central bank has the ability to set negative nominal interest rates. In a new set of paper instructions, we explain how negative interest rates affect savings and debt and emphasize that this change in the policy rule is permanent.

We provide subjects with two tools to facilitate forecasting and decision-making. The first tool, available in Stage 1 of each period, allows subjects to convert between price and inflation expectations. We do this so that subjects can easily incorporate both inflation and price information when forming price forecasts. The second tool, available in Stage 2, takes as inputs a subject's price expectations and returns to them a suggested level of spending conditional on their individual price expectations. We note to subjects in our instructions that this suggested level of spending is conditional on their expectations and also inform them that they may enter any strictly positive number for their consumption. They are beholden to neither the price prediction provided in Stage 1 nor the median price predictions displayed to them on the Stage 2 screen. Finally, we also provide subjects with a full history of aggregate outcomes and individual decisions on all screens of the game.

4.0.2 Incentives

Participants earn utility points based on their consumption decisions while middle-aged and old. We induce participants to behave as if they had a per-period utility function given by $U_it = 5 + ln(0.00673 + C_{i,t})$, so that if $C_{i,t} = 0$, $U_{i,t} = 0$. Each period t participants receive points based on their period $t-1$ and t decisions (with the exception of the first period where there was no previous decision).

We incentivize price forecasts using the following payoff function, $ForecastPoints_t = 2^{-|E_tP_t - P_t|} + 2^{-|E_{t-1}P_t - P_t|}$

Note that subjects can earn a maximum of 4 points per period for perfect price forecasts. Forecasting points for either forecast drop by one half for each lab dollar that a subject under or over forecasts. Each period subjects also earn two points for correct qualitative interest rate forecasts and zero points otherwise. We convert experimental points into real dollars at a rate of 20-to-1. This amounted to an average payoff of $34.50.

4.0.3 Procedures

The experiments were conducted at Texas A&M University with inexperienced participants drawn from a diverse subject pool, recruited with ORSEE (Greiner, 2015) from September 2018 to December 2021. The sessions were conducted in-person and lasted up to two hours of which instructions took 45 minutes, three practice periods took 15 minutes, and the paid experiment the rest. The experimental lab was closed during the onset of the pandemic. Participants were paid in cash prior to the pandemic and via e-transfer when the lab re-opened during the pandemic.

4.1 Treatments

We conduct a series of treatments to explore the learnability and stability of different equilibria with and without policy action. We initialize all sessions at the unique full-employment equilibrium where we assume that the economy is operating along the steady-state inflation path. A surprise exogenous and permanent deleveraging shock creates a unique secular stagnation equilibrium. Our interest is in the ability of different unconventional monetary policy actions to move the experimental economies out of secular stagnation and back to the full-employment equilibrium. Let π^{tgt}, π^{ss}, π^{lt} denote the following rational expectations equilibria: an inflationary steady-state equilibrium, a secular stagnation steady-state equilibrium, and a liquidity trap equilibrium, respectively.

4.1.1 *Baseline*

Baseline explores the transition of an economy from π^{tgt} to π^{ss}. This treatment features 30 periods of play divided into a 15-period pre-shock phase (Phase 1) and a 15-period post-shock phase (Phase 2). The pre-shock phase features a unique equilibrium of π=10% with full-employment and output. This is followed by a deleveraging shock in period 16 that moves $D_t = .35$ to $D_t^{shock} = .28$, which creates a unique secular stagnation equilibrium of $\pi^{ss} = -24.4\%$ with labor rationing and output well below potential. We announce the deleveraging shock to subjects at the beginning of period 16 before the start of Phase 2. This announcement informs subjects about the magnitude of this shock, how it impacts the economy, and that the shock is permanent. This is common information to all participants.

4.1.2 Policy treatments

Each subsequent treatment embeds *Baseline*, with the caveat that shocks in *HigherTarget*, *NegativeIR*, and *NegativeIR+Portfolio*, are from $D_t = .35$ to $D_t^{shock} = .3$. All policy interventions are announced verbally by the experimenter and are common information.

HigherTarget: This treatment features 50 periods of play divided into three phases. The first two phases are fully described by *Baseline*. The third phase begins when the central bank announces on-screen a permanent increase of its inflation target at the end of period 30.

NegativeIR: This treatment is identical to *Baseline* in Phases 1 and 2. Phase 3 begins following the removal of the ZLB after period 30.

NegativeIR-Portfolio: This treatment is identical to *NegativeIR* in terms of timing and policy intervention, but includes a portfolio choice.

We summarize the treatment predictions in Table 1 below.

	Sessions	Periods	Phase 1	Phase 2	Phase 3
Baseline	8	30	$\pi^{tgt} = 10\%$	$\pi^{ss} = -24.7\%$	N/A
HigherTarget	7	50	$\pi^{tgt} = 10\%$	$\pi^{ss} = -18.3\%$	$\pi^{tgt} = 30\%, \pi^{ss} = -18.3\%, \pi^{lt} = 16.7\%$
NegativeIR	7	50	$\pi^{tgt} = 10\%$	$\pi^{ss} = -18.3\%$	$\pi^{tgt} = 10\%$
NegativeIR+Portfolio	7	50	$\pi^{tgt} = 10\%$	$\pi^{ss} = -18.3\%$	$\pi^{tgt} = 10\%$

Table 1: Parameterized equilibria across treatments and phases

5 Results

We begin by providing a descriptive overview of aggregate results from the *Baseline* and three intervention treatments in Section 5.1 to Section 5.4. We then present the outcomes of formal hypothesis tests in Section 5.5.

5.1 *Baseline*

We first consider results from *Baseline* where we initialize our experimental economies with a unique targeted equilibrium and then introduce a deleveraging shock that depresses the spending of young households, thereby eliminating the targeted equilibrium and creating in its place a unique secular stagnation equilibrium. Results for this treatment are shown in Figure 3, which presents session-level (light blue lines, 8 sessions total) and treatment-level (dark blue lines) median outcomes for aggregate inflation, consumption, inflation expectations, output, and the nominal interest rate. All variables are displayed in percentage terms except for consumption, which we present as units demanded.

Note in Figure 3 that six of the eight experimental economies converge to the targeted steady-state equilibrium in Phase 1. Inflation is on average 10% and the output gap is closed by the end of Phase 1. This convergence is particularly impressive given that the overwhelming majority of subjects adopt a forecasting heuristic that involves updating as a function of recent economic outcomes (discussed in detail in Section 6).

Introducing the deleveraging shock consistently generates deflationary episodes, albeit of varying

Baseline Results

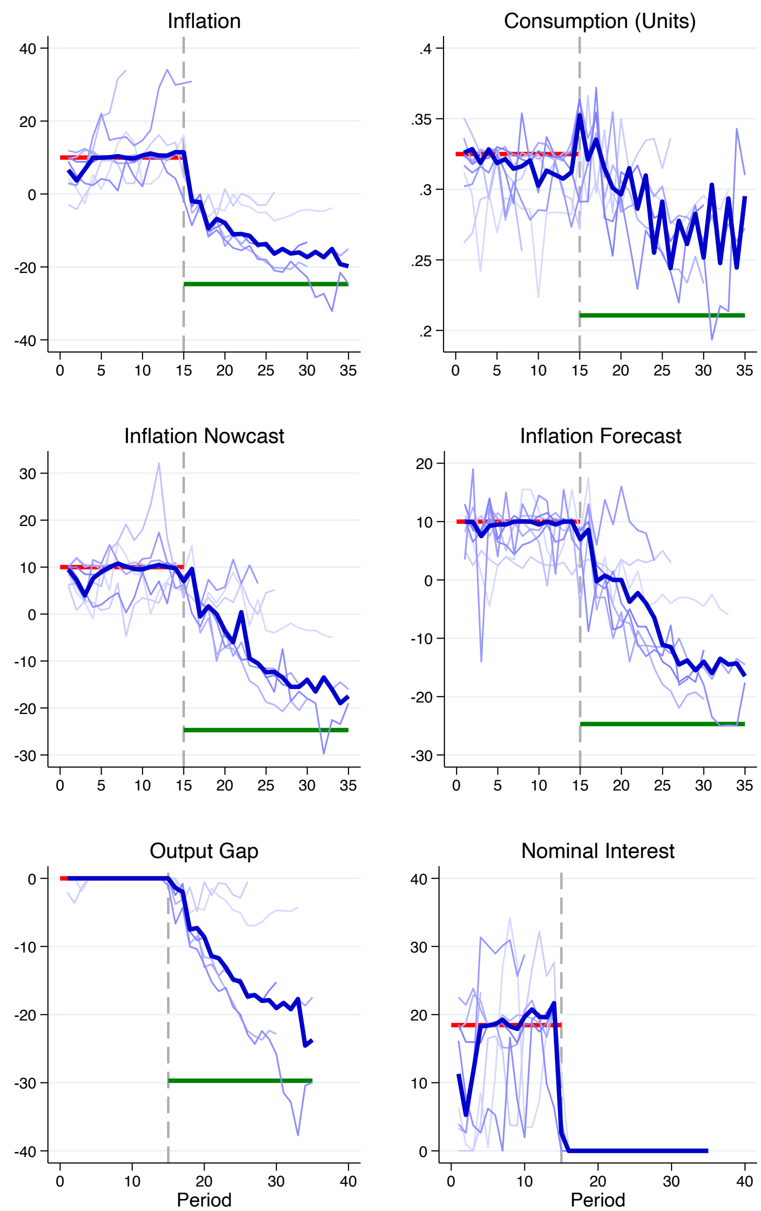


Figure 3: This figure summarizes results for *Baseline*. Light-blue lines represent session-level medians and the thicker, dark-blue lines represent treatment-level medians. All data is given in percentage terms except for consumption, which is displayed in units demanded. Colored horizontal lines denote steady-state equilibrium values and vertical dashed lines denote the point of transition from Phase 1 to Phase 2 in the experiment. Red equilibrium lines correspond to the targeted, full-employment equilibrium and green lines to the secular stagnation equilibrium.

magnitude. Though two of our economies arguably converge to the secular stagnation equilibrium, we also observe a mix of both mild and moderate deflation in our remaining economies. Corresponding output gaps emerge, leading to real welfare losses for our experimental economies.

This lack of convergence to the secular stagnation equilibrium is due to a combination of sluggish adjustments in expectations and consumption. Expectations adjust sluggishly following the deleveraging shock, leading to downward wage rigidity and a slower adjustment toward the secular stagnation equilibrium. This sluggish adjustment is exacerbated by over-consumption that occurs once subjects begin to experience deflation (Consumption sub-figure of Figure 3).

Interestingly, two of our experimental economies experience hyperinflation. Their time series are truncated due to scaling issues. This hyperinflation is driven by a confluence of highly optimistic expectations and a few subjects vastly over consuming. This is perhaps surprising given that the central bank pursues an aggressive policy response to inflation. Because expectations remain relatively anchored through early periods of Phase 1 in these sessions – despite increasing inflation rates – we eventually see that pursuing a Taylor-type rule reinforces this inflationary pressure i.e. increasing the interest rate exacerbates runaway inflation). The lack of responsiveness of the economy to the high interest rate suggests that the wealth effect strongly dominates the substitution effect for participants.

Overall, results from *Baseline* indicate that we are able to successfully implement the EMR theoretical framework in an experimental laboratory setting. Though not all economies converge fully to the secular stagnation steady-state equilibrium following the deleveraging shock, we do consistently create economic conditions that warrant intervention by generating deflation, consumption shortfalls, and output gaps.

5.2 *HigherTarget*

We now consider results from *HigherTarget*, which nests *Baseline* but also includes an intervention phase Phase 3) where the central bank addresses secular decline by permanently increasing its inflation target. The intuition for this intervention is that permanently increasing the central bank's inflation target should stimulate forward-looking inflation expectations, thereby increasing aggregate demand and closing the output gap. Additionally, coordinating expectations on a higher target can increase expected wages, which should also stimulate aggregate demand.

Increasing the central bank's inflation target does not eliminate the secular stagnation equilibrium. Instead, this intervention adds a full-employment and a liquidity trap equilibrium. The ability to discern among this multiplicity of equilibria highlights one of many strengths of using an experimental approach in macroeconomics. Tightly-controlled, repeated experimentation can give insight about equilibrium selection problems even when theory cannot.

We show the results from *HigherTarget* in Figure 4. Similar to *Baseline*, subjects in *HigherTarget* converge to the targeted equilibrium in Phase 1 and the deleveraging shock consistently generates pessimistic expectations, generates deflation ranging from mild to severe, and opens output gaps that mimic the magnitude of deflation. This creates an interesting setting where we can test the efficacy of our policy intervention at addressing secular declines of various magnitude.

We find that, regardless of the severity of the deflationary trap, permanently increasing the central bank's inflation target fails to restore aggregate dynamics in our experimental economies to the targeted steady state equilibrium values. Instead, we observe in most economies that inflation exhibits an underwhelming response to the new inflation target. Further, we see that session-level inflation expectations never re-coordinate on the central bank's new targeted equilibrium. In fact, it is only for a single experimental economy that the session-level inflation forecast reaches the targeted equilibrium. However, this happens only briefly and, in each instance, is followed by a quick collapse. This inability to generate sufficiently inflationary expectations leads to a treatment-level average consumption that falls well short of the targeted equilibrium level of consumption. This shortfall of inflation, inflation expectations, and consumption leads to a persistent output gap in most economies. In those few economies where the output gap does close in Phase 3, reprieve is only fleeting.

The confluence of these things - the inability to coordinate expectations and consumption on the targeted equilibrium values, to generate sufficient aggregate inflation, and to consistently close the output gap - leads us to conclude that permanently increasing the inflation target is not a promising intervention into secular stagnation. The obvious question then is why does this intervention fail? The answer - subjects in *HighterTarget* economies do not perceive the increased inflation target as credible.

Subjects in the *HighterTarget* economies know very well the central bank's original inflation target. We highlight this inflation target in our instructions, display this inflation target on screen in each period, and remind subjects of this target in a summary screen at the end of each decision period. Thus, any wedge between this target and prevailing aggregate inflation during Phases 1 and 2 is salient for our subjects. This means that subjects are quite aware that our mechanistic central bank is unable to achieve its initial inflation target given the binding zero lower bound.

It is worth noting that several *HigherTarget* economies in the post-intervention environment do manage to mitigate deflation by coordinating loosely on zero inflation. This is true despite there being no stable price equilibrium among the set of predicted rational expectations equilibria. In fact, EMR point out that such a steady-state is impossible in their model. Coordination on zero-percent inflation has the effect of trivializing price forecasts for subjects and greatly reducing the complexity of the two-period optimization problem subjects face in stage 2 of each period.

5.3 *NegativeIR*

This subsection considers results from *NegativeIR*. This treatment differs from *HigherTarget* in that the mechanistic central bank now intervenes during deflationary episodes by implementing negative nominal interest rates rather than by increasing its inflation target. Crucially, the

HigherTarget Results

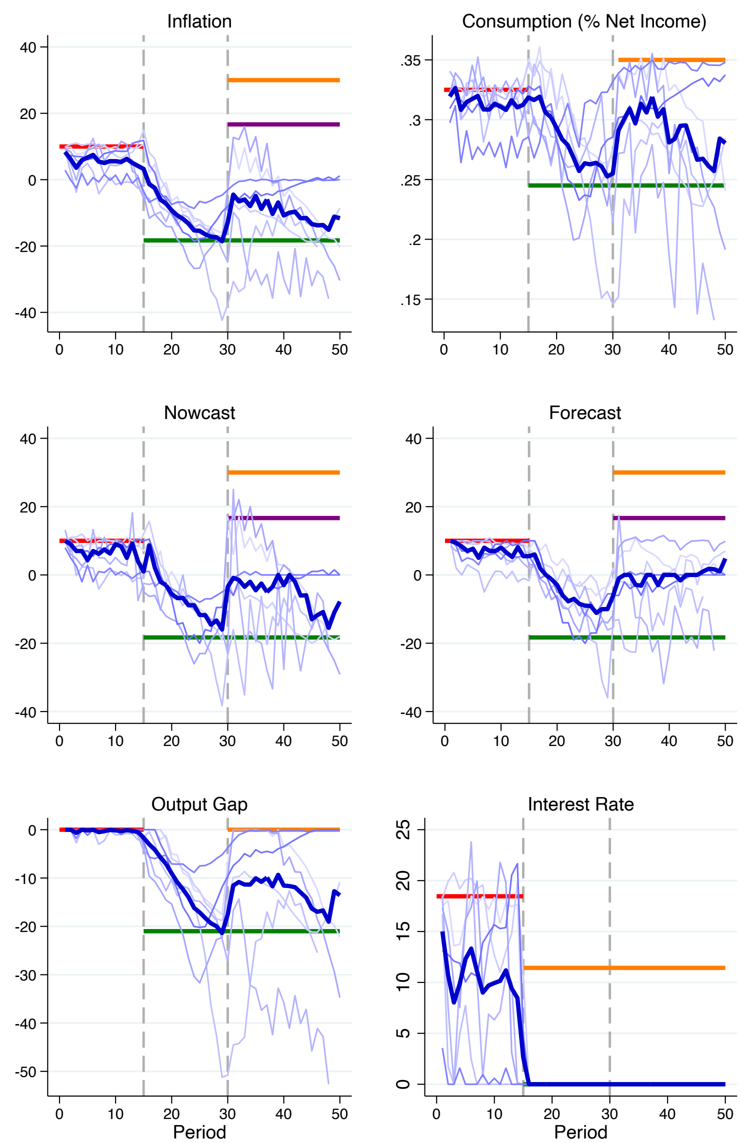


Figure 4: This figure summarizes results for *HigherTarget*. Light-blue lines represent session-level medians and the thicker, dark-blue lines represent treatment-level medians. All data is given in percentage terms except for consumption, which is displayed in units demanded. Colored horizontal lines denote steady-state equilibrium values and vertical dashed lines denote the point of transition between phases in the experiment. Red and green horizontal lines again denote targeted and secular stagnation equilibria, purple horizontal lines denote the liquidity trap equilibrium, and orange horizontal lines denote the targeted equilibrium that corresponds to the central bank's higher inflation target in Phase 3.

efficacy of this intervention does not hinge on primacy of the expectations channel. Rather, negative nominal interest rates threaten to erode real wealth and therefore encourage more present-period consumption. This increase in present-period consumption should immediately increase inflation via its impact on aggregate demand.[‡] Increased inflation should lead to higher inflation expectations. These two effects - increased inflation coupled with increased inflation expectations - should become reinforcing.

We can also highlight the difference between these interventions by considering the relationship between inflation expectations, inflation, and consumption in each treatment. Inflation expectations should react immediately to the central bank's inflation target in *HigherTarget*, which leads in increased consumption and increased inflation. However, increased consumption leads to increased inflation and this leads to increased inflation expectations in *NegativeIR*.

Results from *NegativeIR* are shown in Figure 5. First, note that implementing negative interest rates does not lead to the same equilibrium selection problem as does increasing the central bank's inflation target. Instead, removing the zero lower bound removes the kink in the aggregate demand curve, thereby eliminating the secular stagnation equilibrium and restoring the unique targeted equilibrium present in Phase 1 of each treatment (as depicted in Figure 1c). As was true with experimental economies in *Baseline* and *HigherTarget*, we again observe convergence in Phases 1 and 2 toward the targeted and secular stagnation equilibria, respectively. Deleveraging shocks generate deflationary episodes with now-familiar session-level heterogeneity in the magnitude of deflation.

Now when the central bank intervenes, we see in Figure 5 that our economies converge to the targeted equilibrium. As one might expect, we see a sharp increase in consumption, which generates considerable inflation in the period immediately following the policy intervention. We also observe that both the nowcast and forecast of inflation also respond to the announcement of the central bank's decision to use negative nominal interest rates. Finally, implementing negative nominal rates also consistently closes the output gaps that emerged during Phase 2 of the *NegativeIR* sessions. This closure is both immediate and stable for all but a single experimental economy.

Also interesting here are Phase 3 consumption dynamics in *NegativeIR* relative to *HigherTarget*. Excluding the single economy in *NegativeIR* that does not eventually achieve the central bank's inflation target, we see that cross-sectional, session-level consumption heterogeneity in Phase 3 of *NegativeIR* is significantly lower than in the *HigherTarget*, which suggests that the ability of *NegativeIR* to re-coordinate expectations on the bank's inflation target also has the effect of stabilizing consumption. Because consumption is mostly expectations-consistent, reducing cross-sectional disagreement in expectations also reduces the cross-sectional dispersion of consumption and savings.

[‡]Supply in this economy is constrained by the size of the middle-aged cohort. Whenever supply is at capacity, increased spending necessarily leads to increased inflation. If production is below capacity, then spending in excess of whatever restores full production leads to inflation.

NegativeIR Results

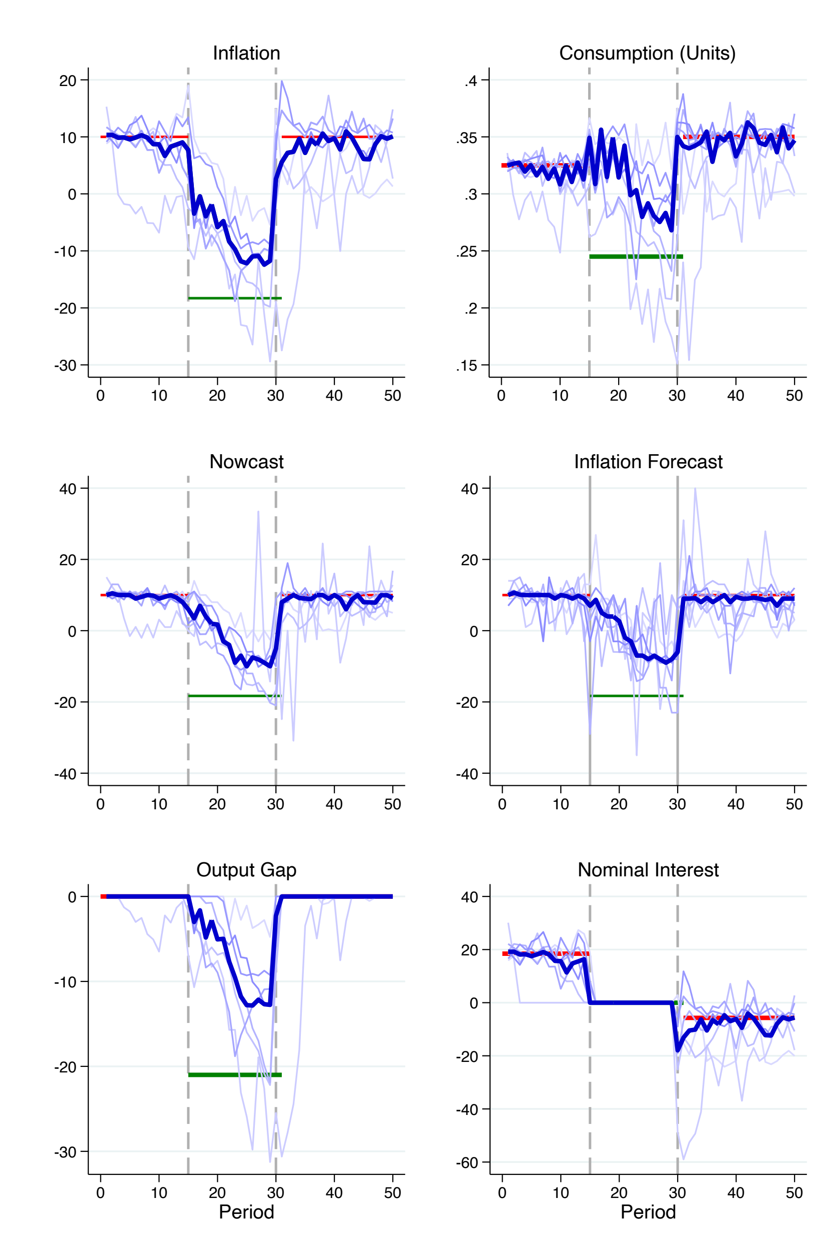


Figure 5: This figure summarizes results for *NegativeIR*. Light-blue lines represent session-level medians and the thicker, dark-blue lines represent treatment-level medians . All data is given in percentage terms except for consumption, which is displayed in units demanded. Colored horizontal lines denote steady-state equilibrium values and vertical dashed lines denote the point of transition between phases in the experiment. Red and green horizontal lines again denote targeted and secular stagnation equilibria.

5.4 *NegativeIR+Portfolio*

An important real-world concern is that if commercial banks pass negative rates through to consumers then those consumers will opt to hold cash rather than endure negative savings rates. If true, the absence of portfolio choice in *NegativeIR* poses a challenge to the external validity of our results. To address this concern, we implement *NegativeIR+Portfolio*, which is identical to *NegativeIR* but allows subjects to transfer wealth between periods by holding either interest-bearing bonds or cash. Introducing a portfolio choice allows for real-world concerns like cash hording that might mute the effectiveness of negative nominal rates.

However, we are agnostic about how introducing this portfolio choice would change our results relative to *NegativeIR*. On one hand, negative savings rates are quite salient for subjects and make the opportunity to hold cash rather than bonds whenever rates are negative appealing. If subjects do hold cash, this is akin to selecting back into the zero lower bound where only the secular stagnation equilibrium exists. This sort of concern is at least part of why commercial banks in the Euro area did not pass negative rates through to household deposit rates whenever the ECB implemented negative nominal interest rates in the Euro area.[§]

On the other hand, subjects may also understand that negative rates are a 'necessary evil' that prevent deflation and an output shortfall. Further, the economic instability inherent in such circumstances increases the complexity of inflation forecasting and in solving the two-period optimization problem. Thus, subjects may choose to endure negative interest rates if they think it is favorable to sacrifice some per-period net wealth in exchange for increasing available output in each period and for potentially reducing the complexity of both incentivised tasks. It is easy to think of real-world analogs for this sort of logic. People in the real-world may be willing to endure negative rates whenever they perceive the alternative as a deep, protracted recession or economic collapse. That is, people may view negative rates as a short- or medium-term trade off that restores long-term economic stability and growth. Additionally, there are obvious mechanical reasons - like the inconvenience that comes with using only cash to spend - that may also contribute to a real-world tolerance of negative rates.

Results from *NegativeIR+Portfolio* are shown in Figure 6. Before discussing results, we first note key differences between *NegativeIR* and *NegativeIR+Portfolio*. First, the added complexity of the portfolio choice leads to less stability in early periods of play in Phase 1. Because of this, we do not see the customary convergence to the high inflation steady state in Phase 1 and we observe particularly severe deflation in several economies in Phase 2.

That said, results from *NegativeIR+Portfolio* overwhelmingly indicate that negative nominal rates are robust to portfolio choice. Introducing negative nominal rates leads to an almost immediate convergence to the targeted equilibrium. this is true despite the very severe deflation experienced in many of our economies in Phase 2. Despite the increased session-level disagreement relative to *NegativeIR*, we also see that introducing negative rates still coordinates treatment-level

[§]We discuss this in more detail in Section 8.

NegativeIR+Portfolio Results

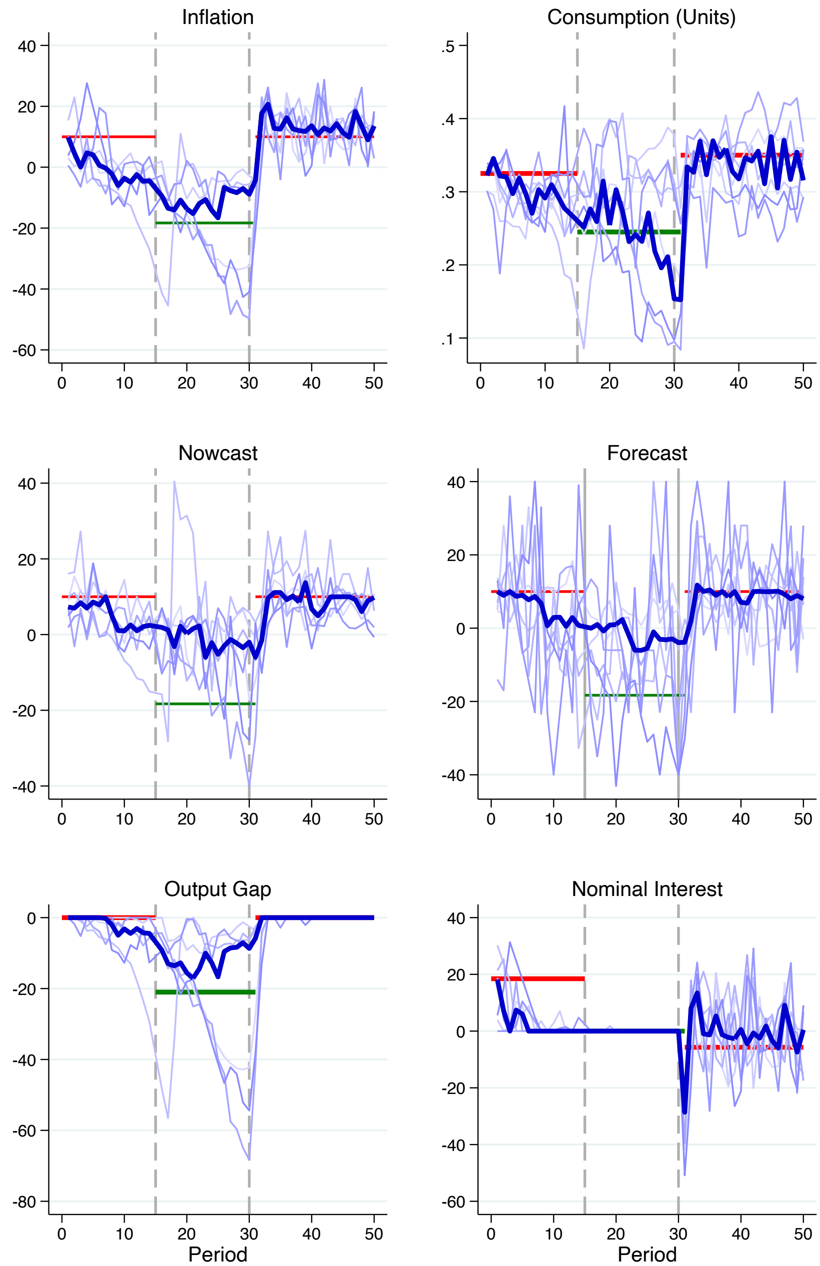


Figure 6: This figure summarizes results for *NegativeIR+Portfolio*. Each thin line represents data averaged across individuals for a single session. Thick lines treatment medians. For the second sub-figure depicting expectations, solid lines are session-level median nowcasts and dashed lines are session-level median forecasts.

median nowcasts and forecasts at the central bank's targeted equilibrium. Interestingly, we also see that the treatment-level median interest rate is quite often positive or non-zero in Phase 3. This is likely due to the oscillatory pattern we observe in consumption leading to the corresponding spikes we see in inflation, which prompts our mechanistic central bank to increase rates to reduce inflation to its target.

5.5 Convergence

We next evaluate the convergence of the economies, for each phase, to the predicted equilibria outlined in Section 3.5. In Table 2 we report the mean inflation rate in the final three periods of each phase. We evaluate, for each treatment and phase, whether the mean inflation rate is statistically different from the predicted steady state. Asterisks denote significance at the 1% (***), 5% (**), and 10% (*) levels, respectively, based on Wilcoxon signed-rank and rank-sum tests ($N = 7$ in all tests).

Treatment	**N**	**Phase 1**	**Phase 2**	**Phase 3**
Baseline	7	13.13	-15.33**	
		(9.505)	(5.86)	
HigherTarget	7	4.14	-17.69	-9.73**
		(6.34)	(9.78)	(10.54)
NegativeIR	7	7.03	-13.05	8.59
		(6.79)	6.23)	(3.27)
NegativeIR+Portfolio	7	-6.87**	-19.60	12.00*
		(9.82)	(18.42)	(2.31)

Table 2: Mean inflation in final three periods of each phase, by treatment

In Phase 1, we fail to reject H1 that inflation converged to the steady state target in *Baseline*, *HigherTarget* and *NegativeIR*. Inflation was significantly lower than the 10% target in *NegativeIR+Portfolio*.

We hypothesized in H2 that large deleveraging shocks would cause inflation to stabilize at the secular stagnation equilibrium. We cannot reject that inflation converged to the deflationary steady state of -18.3% in *HigherTarget*, *NegativeIR* and *NegativeIR+Portfolio*. Inflation also fell substantially in *Baseline*, but had not yet converged to the steady state predicted inflation rate of -24.3%.

We reject H3 that raising the inflation target to 30% would move the economy to the targeted equilibrium. Inflation in *HigherTarget* converged to -9.73% on average, with some sessions nearing zero inflation and others experiencing very negative inflation, which was significantly below 30%.

We predicted in H4 that removing the ZLB would restore inflation rate to the targeted equilibrium of 10%. We fail to reject H4 in *NegativeIR*, where the inflation rate average 8.59%. In *NegativeIR+Portfolio*, we find inflation modestly exceeds the target at 12%.

Finally, in H5, we hypothesized that introducing a portfolio choice would mute the stimulative effects of negative interest rates. We find the opposite. Inflation is significantly higher in Phase 3 when participants have a portfolio choice ($p = 0.0476$).

6 Unconventional Monetary Policy and Expectations

Critical to the success of inflation targeting policies is the management of inflation expectations. In this section we characterize how participants form their expectations in stable periods, and whether the deleveraging and policy interventions influence their nowcasting and forecasting heuristics.

We consider seven different general forecasting models employed in the macroeconomic and finance literatures. Table 3 describes how both nowcasts and forecasts would be formed under each heuristic.

Model Class	**Heuristic Name**	**Model**
M1	Target Equilibrium	$E_{i,t}\pi_t = E_{i,t+1}\pi_{t+1} = \pi^{tgt}$
M2	Liquidity Trap Equilibrium (LT)	$E_{i,t}\pi_t = E_{i,t+1}\pi_{t+1} = \pi^{lt}$
M3	Secular Stagnation Equilibrium (SS)	$E_{i,t}\pi_t = E_{i,t+1}\pi_{t+1} = \pi^{ss}$
M4	Constant Gain (CGL)	$E_{i,t}\pi_t = E_{i,t-1}\pi_{t-1} - \gamma_i(E_{i,t-1}\pi_{t-1} - \pi_{t-1})$ $E_{i,t+1}\pi_{t+1} = E_{i,t-2}\pi_{t-1} - \gamma_i(E_{i,t-2}\pi_{t-1} - \pi_{t-1})$
M5	Trend-chasing (Trend)	$E_{i,t}\pi_t = \pi_{t-1} + \tau_i(\pi_{t-1} - \pi_{t-2})$ $E_{i,t+1}\pi_{t+1} = E_{i,t}\pi_t + \tau_i(E_{i,t}\pi_t - \pi_{t-1})$
M6	Naive Inflation (Naive Pi)	$E_{i,t}\pi_t = \pi_{t-1}$ $E_{i,t+1}\pi_{t+1} = E_t\pi_t$
M7	Naive Price	$E_{i,t}\pi_t = E_{i,t+1}\pi_{t+1} = 0$

Table 3: Nowcasting and forecasting heuristics

The first three heuristics are associated with rational expectations equilibria, depending on the phase of the experiment. M1 Target assumes that a subject bases her price forecast on the assumption that inflation today will equal the central bank's inflation target. The share of participants exhibiting M1 expectations can also be interpreted as the degree of central bank credibility.

M2 Liquidity Trap (LT) assumes that subjects forecast according to the liquidity trap equilibrium while M3 Secular Stagnation (SS) assumes that subjects forecast according to the secular stagnation equilibrium. M1 is ex-ante rational in Phases 1 and 3 of all treatments. M2 is ex-ante rational in Phase 3 of *HigherTarget*, and M3 is ex-ante rational in Phase 2 of all treatments and Phase 3 in *HigherTarget and NegativeIR-Portfolio*.

M4 Constant Gain Learning (CGL) assumes that a subject forms an inflation forecast today by updating their most recently forecasted and observed inflation expectation based on their most recent forecast error. In the case of their period t nowcast, we assume they update their previous period's nowcast about period $t-1$ based on their most recent error, which would be observed at the beginning of period t. For their period $t+1$ forecast, we assume they use their most recent one-period ahead forecast performance to update their past forecast. Specifically, they would update their period $t-2$ forecast about period $t-1$ according to error, which would be observed at the beginning of period t. Given these formulations, we consider a range of parameterizations of $\gamma \in [0.1, 1.5]$.

M5 Trend-chasing assumes that a subject's inflation nowcast and forecast are an extrapolation of yesterday's inflation based on the recent trends in inflation. In particular, the period t nowcast will be extrapolated based on the change in inflation between $t-2$ and $t-1$. The period $t+1$ forecast will use the period t nowcast as the anchor, and the extrapolation is based on the difference between $t-1$ inflation and their nowcast about period t inflation. Given these formulations, we consider a range of parameterizations $\tau \in [0.1, 1.5]$.

M6 Naive Inflation assumes that a subject bases both her period t nowcast and $t+1$ forecast on the assumption that inflation will equal period $t-1$ inflation. Finally, M7 Naive Price assumes that a subject forms their inflation nowcast and forecast assuming no change in prices, i.e. inflation of zero.

We classify a subject by comparing, in each period, her inflation nowcast and forecast for today to the predictions arising from each of M1-M7. We then calculate the mean absolute error for each hypothetical heuristic (and for each parameter value for M4 and M5) and classify participants as belonging to the heuristic that has the minimum MSE. Note that the nowcasting heuristic M4 is equivalent to M6 for $\gamma_i = 1$. In the case that participants were classified in both, we assign their type to be M6 Naive Inflation.

EMR's policy prescription to raise the inflation target in response to secular stagnation demands a strong expectations channel of monetary policy to work optimally. Gibbs (2017) has since shown that the targeted equilibrium predictions of EMR are e-stable and thus survive under a form of least squares learning.

Phase 1

We observe relatively consistent heuristics in Phase 1 across the four treatments. Participants use a mix of nowcasting approaches, with Trend-chasing followed by Target being the most prevalent heuristics. The exception is in *NegativeIR-Portfolio* where more than one-third of participants are best classified as constant gain learning and approximately 18% of participants nowcast zero inflation. The increased heterogeneity and usage of naive price nowcasting heuristics in *NegativeIR-Portfolio* reflects the relatively greater cognitive complexity and endogenous volatility associated with the environment.

Figure 7: Distributions of nowcasting heuristics, Period t inflation, by phase and treatment

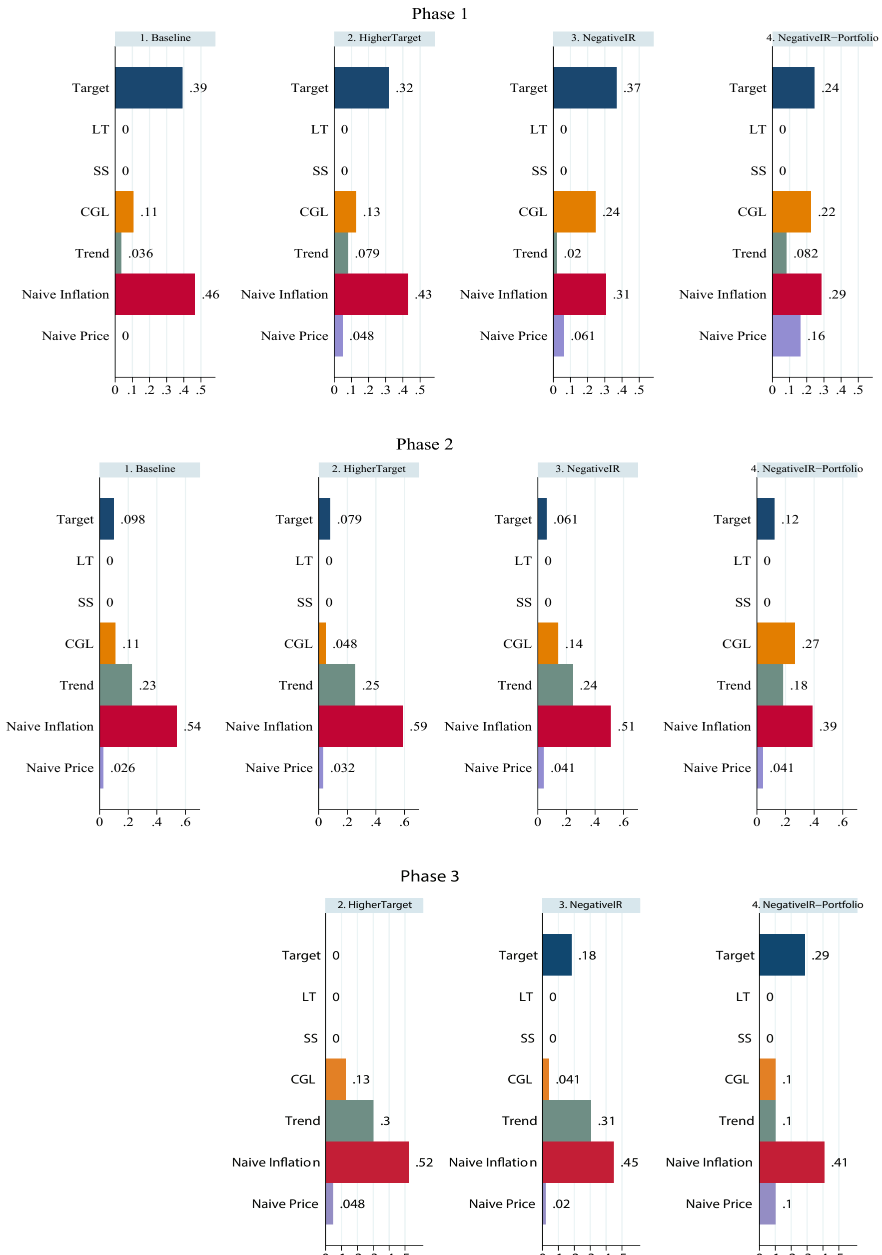


Figure 8: Distribution of forecasting heuristics, Period $t + 1$ inflation, by phase and treatment

Participants use notably different heuristics for their one-period ahead inflation forecasts. In all treatments, we observe a larger proportion of participants anchor their inflation forecasts on the central bank's inflation target or on the previous period's inflation. This reliance on focal inflation information is indicative of increased cognitive challenge in forming longer-term forecasts and is characteristic of surveyed longer-term expectations that tend to be more effectively anchored than shorter-term expectations.

Phase 2

The deleveraging shock at the beginning of Phase 2 generates significant heterogeneity in heuristics, with all five classes of heuristics represented. Usage of the central bank's target declines in all treatments (from 34% to 14% in *Baseline*, 16% to 6% in *HigherTarget*, 24% to 4% in *NegativeIR*, and 16% to 14% in *NegativeIR-Portfolio*. This decrease in M1 Target heuristic is rational as the target is no longer an equilibrium outcome. Note that neither the liquidity trap or secular stagnation equilibria are focal points for participants. This is because we did not inform them of these equilibrium values. Nonetheless, participants' expectations do not adjust in line with these equilibria. The relatively minimal adjustment in *NegativeIR-Portfolio* away from the M1 heuristic is further evidence that participants were more cognitively taxed in this treatment and relied heavily on focal information even when it was no longer relevant.

M4 Constant-Gain Learning heuristic becomes the dominant nowcasting heuristic as participants grapple with making predictions in an unfamiliar environment. This comes at a significant reduction in the Trend-chasing heuristic.

Participants' one-period ahead inflation forecasts also shift away from anchoring on the inflation target toward more backward-looking expectations such as M5 Trend-Chasing and especially M6 Naive Inflation.

Phase 3

Increasing the inflation target to 30% in Phase 3 does not increase the share of participants using the central bank's target to form their nowcast (the share falls from 6% in Phase 2 to less than 2% in Phase 3). Likewise, no participant perceived the central bank's new inflation target of 30% as credible when forming their one-period ahead inflation forecast. The distributions of nowcasts and forecasts do not change in a meaningful way between Phase 2 and Phase 3, suggesting that increasing the central bank's inflation target did not significantly effect how participants perceived their environment.

When the central bank eliminates the ZLB in *NegativeIR* more participants are willing to utilize the central bank's 10% inflation target as their nowcast (increase from four to 10%) and forecast (six to 18%). In other words, negative interest rates are effective at generating more credibility in the central bank. Participants also rely less on constant gain learning and naive inflation to formulate their forecasts in favour of trend-extrapolation. We observe a qualitatively similar pattern in *NegativeIR-Portfolio*, albeit a more muted response in heuristics to the policy intervention. Credibility in the target is even higher in Phase 3 than in Phase 1, suggesting that negative interest rates generated sufficient inflationary pressures to improve anchoring on the central bank's inflation target.

7 Why do negative rates work but higher targets fail?

This section explores why negative interest rate policies are more effective than inflation targeting policies in our experimental economies. To aid in this discussion, we include Figure 9, which focuses on treatment-level effects of policy interventions for the five periods before and ten periods after the policy intervention.

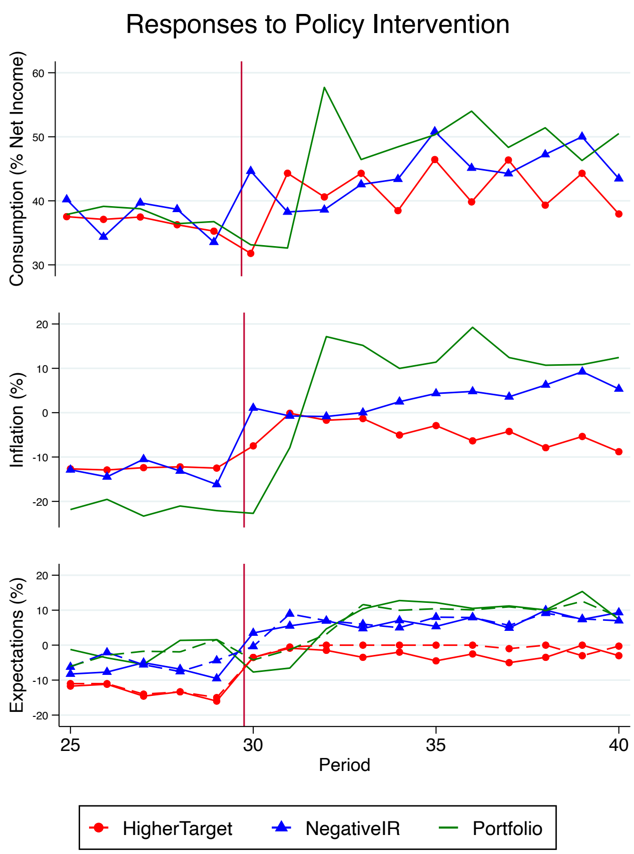


Figure 9: Aggregate dynamics around the policy intervention

We begin with *HigherTarget*. In theory, successful intervention in this treatment requires the new inflation target to coordinate the expectations of forward-looking, dynamically optimizing agents. However, this policy action does not eliminate the secular stagnation equilibrium because agents do not necessarily expect the ZLB to become non-binding in the future.[§] A breakdown of any of these three necessary conditions (forward-looking expectations, coordinating expectations on the higher target, or expectations-consistent real decisions) will prevent economies from converging to the full-employment equilibrium.

This means that we need to know which of the necessary conditions break down in *HigherTarget* in order to understand why increasing the inflation target fails in our experimental economies. Do subjects make real decisions consistent with their expectations? Yes. We show this in Figure 10a, which depicts deviations from expectations-consistent consumption decisions expressed in percentage terms. Though there is considerable consumption heterogeneity, the mean treatment-level deviation from expectations-consistent consumption is never statistically indistinguishable from zero.

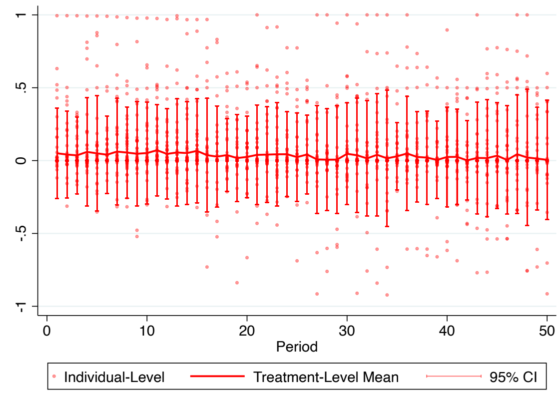
Does the intervention in *HigherTarget* coordinate expectations on the target? No! As discussed in Section 5.2 (and depicted in Figure 4), neither inflation nowcasts or forecasts re-coordinate on the central bank's inflation target. This is because subjects in our experiment overwhelmingly employ backward-looking forecasting heuristics (see Figure 7). The majority of subjects in *HigherTarget* form expectations using trend extrapolation in Phase 1, and constant gains learning in Phases 2 and 3. Subjects base their expectations largely on the recessionary conditions at the end of Phase 2 – rather than on the new inflation target – when transitioning into Phase 3.

To summarize, increasing the inflation target in *HigherTarget* fails because the new target cannot coordinate subjects' backward-looking expectations. Instead, inflation expectations fall far short of the new target. Because consumption is expectations-consistent, this yields a significantly muted consumption response. The confluence of these two factors results in below-target inflation, a negative output gap, and depressed wages.

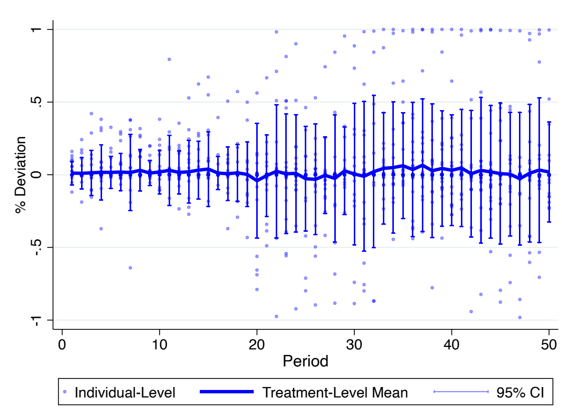
Why do we not see transition dynamics that lead us toward the full-employment equilibrium? The initial under-reaction to the increased inflation target does very little to assuage the concerns of any subject who initially perceived the intervention as non-credible. The underwhelming effect on impact of the intervention further reduces the perceived credibility of the new inflation target with all subjects. This is evident in the gradual decline of expectations over the subsequent periods of Phase 3 (red lines in the expectations panel of Figure 9).

Next we consider *NegativeIR* and *NegativeIR+Portfolio*. For negative nominal rates to be effective, we would expect agents to dynamically optimize in response to negative interest rates. Anticipating the possibility of negative interest rates, agents should respond by increasing their spending. Increased spending and expected spending should lead to increased nowcasts and forecasts, and in turn even greater spending. Together, these forces should lead economies to converge to the full-employment equilibrium.

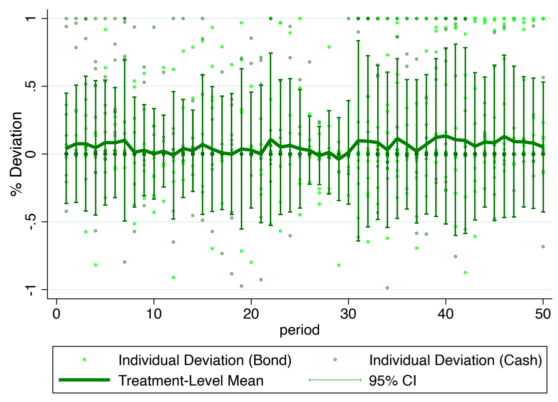
[§] As discussed by EMR, this is different from models of temporary liquidity traps (Krugman et al., 1998; Eggertsson and Woodford, 2003) where increasing the inflation target *would* have an effect since the liquidity trap must abate and the economy can always achieve the higher inflation target in the future.



(a) HigherTarget



(b) NegativeIR



(c) NegativeIR+Portfolio

Figure 10: These sub-figures show individual-level deviations (dots) of consumption from the level of consumption that is optimal conditional on that individual's price expectations. Lines denote average deviations. Vertical bars denote a 95% confidence interval. This graphs show that, on average, consumption is consistent with expectations.

As was true with subjects in *HigherTarget*, subjects in *NegativeIR* and *NegativeIR+Portfolio* do make real decisions that are consistent with their inflation expectations (see Figure 10b). Also clear from this figure is that subjects' consumption decisions respond in a way that is qualitatively consistent with prevailing rates in our negative rates treatments. In both *NegativeIR* and *NegativeIR+Portfolio*, consumer spending increases by an average of more than 80% on impact of the interventions.

Do inflation expectations respond to the introduction of negative interest rates? Yes. This is visible in the expectations panel of Figure 9, where both treatment-level nowcasts and forecasts increase in the period immediately following the announcement of the new policy change. Because subjects have gained no new economic information, this response in expectations must be driven by the announcement of the new policy, their own spending decisions, or both.

We conduct a series of Granger causality tests using session-level aggregate results 5-periods before and 5-periods after the intervention and evaluate the direction of causality in consumption and expectations. We observe that increased consumption following the policy intervention Granger causes inflation expectations in subsequent periods in the negative rates treatments. This effect is statistically significant at the 1% level. The opposite is true for *HigherTarget*, where inflation expectations Granger cause consumption. This further bolsters the idea that intervention in *HigherTarget* fails precisely because expectations under-react to the new target because participants do not perceive it as credible.

Why are negative rates still effective in *NegativeIR+Portfolio* where at least some subjects choose to hold cash? This is because enough subjects continue holding bonds that aggregate dynamics shift in a theory-consistent way in response to the introduction of negative rates. This means we see inflation, higher inflation expectations, higher wages and higher output following intervention. Because of this, subjects holding cash in later periods face similar erosive effects on their real wealth due to experiencing inflation without the counter-balancing effect of positive interest rates. Though this effect is not as strong as that experienced by subjects holding bonds, it does reinforce the expansionary effects of negative rates.

8 Conclusion

This paper introduces a new experimental framework to investigate secular stagnation and study policy prescriptions designed to alleviate potentially permanent output gaps. Our experimental economies evolve endogenously according to the inflation forecasts and budgetary decisions of subjects. We engineer secular stagnation by imposing exogenous and permanent deleveraging shocks, and then allow the central bank to address the persistent recessions by either permanently increasing its inflation target or implementing negative policy rates.

In our economies, raising inflation targets has limited ability to stimulate inflation expectations and alleviate secular stagnation after a sufficiently lengthy episode of deflation. The central bank's credibility in achieving a higher target is limited when it struggles to achieve its original target. This intervention hinges critically on its ability to coordinate the expectations of forward-looking agents on the higher target. However, subjects in our experiment overwhelmingly employ backward-looking forecast heuristics, which mutes the effect of this intervention on impact. An underwhelming response to the policy intervention further erodes the new target's already-tenuous credibility, which leads to a slow decline in inflation expectations, inflation, output, and wages.

Negative rates, by contrast, facilitate rapid economic recovery in our experimental economies. Subjects' spending increases immediately at the prospect of negative interest rates. The immediate inflation leads backward-looking subjects to form more inflationary expectations and spend more in subsequent periods. Introducing a portfolio choice does not mute the effectiveness of negative interest rates. Rather than hoard cash, a majority of subjects in our experimental economies continue to hold bonds and incorporate negative rates into their real decisions. Their rapid increase in consumption and inflationary expectations work in tandem to pull experimental economies out of deep deflationary traps.

Results from our *NegativeIR* and *Portfolio* suggest that real-world implementations of negative interest rate frameworks were perhaps unnecessarily handicapped by the reluctance of commercial banks to impose negative deposit rates on households. This imposition of a ZLB on household deposit rates dampened the intertemporal transmission channel. Perhaps surprisingly, our results suggest that households are willing to endure some degree of negative interest rates and that aggregate demand would respond to these negative rates.

Another important advantage of this experimental framework is that it produces individually-linked expectations and consumption data. This rich data source allows important insight about the relationship between expectations and real decisions that complement an existing empirical literature (D'Acunto et al., 2022; Coibion et al., 2019, 2020). To discern why inflation targeting can fail at the ZLB, we need to understand whether the problem is that people do not form expectations consistent with the policy objectives of the central bank or that they do not form expectations-consistent decisions.

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