

Online Appendix: Escaping secular stagnation with unconventional monetary policy^{*}

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I Automation of Young and Old Agents

We automate the behavior of young households to align with EMRs theory. We also automate the decisions of old households in that our software automatically spends everything assigned to that household in the previous period by one of our student subjects.

Below we summarize how the Young, Middle-Aged, and Old households' spending decisions are computed.

The Young: We automate young households such that young household i in period t will automatically borrow a proportion $D_t^i \in [0, 1]$ of its middle-aged income. This is clearly problematic since the middle-aged income of these agents is not actually determined until markets clear in the following period. However, EMR's assumption of rational expectations circumvents this issue in theory. If subjects' expectations are rational, then there should be no difference in expected and realized prices. Thus, we compute the consumption expenditure of a Young household i in period t as $c_t^{i,y} = D_t^i E_t\{P_{t+1}\} = D_t^i E_t[Y_{t+1}^{i,m}]$.

The Middle-Aged: Subjects make budgeting decisions as Middle-aged households in stage 2 of each period. Subjects here have two considerations: a debt-repayment obligation incurred automatically by the household when young and a consumption/savings decision. However, our subjects face these considerations before income is actually determined. To deal with this, we suppose that the income of Middle-aged households is equivalent to the market expectation for current period prices. If we again suppose that we are in period $t = 0$ then middle-aged income is given as $E_0\{P_0\}$. Thus, a Middle-aged subject has net income $ni = E_0\{P_0\} - c_{-1}^j(1 + i_{-1})$. Suppose α_j is the proportion of net income allocated to savings so that $c_0^{j,m} = \alpha_j(E_0\{P_0\} - c_{-1}^j(1 + i_{-1}))$. We can then use $c_0^{j,m}$ for market clearing, which informs us how much money Middle-aged agents actually earn. One issue here is that if subjects systematically deviate from RE then we can have that $E_0\{P_0\} > P_0$ or $E_0\{P_0\} < P_0$. Because we have already cleared markets using a consumption level based on the market-expected price, we occasionally must adjust for deviations from RE by changing the amount of money that these middle-aged agents hold in savings for consumption while old. This is because deviations from RE (and from the correspond consumption/savings decision) can drive a wedge between expected and realized savings for middle-aged agents. If we call t expected savings of middle-aged agent j as $E_0\{s_0^{m,j}\}$ then $E_0\{P_0\} > P_0$ would cause $E_{j,0}\{s_0^{j,m}\} > s_0^{m,j}$ and opposite for the opposite case.

The Old: The decision for a given old household in period t is determined by the budgeting deci-

sion of a subject acting as a middle-aged household in period $t - 1$. Old households automatically spend all remaining wealth on output. For example, if a subject i assigned a Middle-aged household in period $t - 1$ instructs its household to save $s_{t-1}^{m,i}$ dollars then in period t that household will allocate $p_t c_t^{t,i} = s_{t-1}^{m,i}(1 + i_{t-1})$ to consumption dollars.¹ Note then that subjects, anytime following period 1, earn consumption points from a currently-assigned Middle-aged household and an Old household. This Old household is the Middle-aged household assigned to that subject in the previous period.²

2 Solving for Prices

This section of the appendix describes the algorithm we use to solve for prices in our experimental economies. First, we define the per-period, market-clearing price as:

$$P_t = \frac{C_Y + C_M + C_O}{Y_t}. \quad (1)$$

This gives us the following piece-wise, per-period price function:

$$P_t = \frac{C_Y + C_M + C_O}{Y^f}, \quad \Pi \geq 1 \quad (2)$$

$$P_t = \frac{C_Y + C_M + C_O}{Y_t}, \quad \Pi < 1. \quad (3)$$

We proceed by first supposing that prices are determined by Equation (3), which can be rewritten as

$$P_t = \frac{C_Y + C_M + C_O}{\frac{w_t}{P_t \alpha} \frac{\alpha}{\alpha-1}}. \quad (4)$$

¹Here, c_t represents units of output and $s_{t-1}^{m,i}$ is the dollar amount saved by agent i in period $t - 1$ while middle-aged.

²We automate Old households in period 1 based on the assumption that the economy moved along the steady-state inflation path in all periods before the start of our experiment.

Isolating P_t yields

$$P_t^{\frac{-1}{\alpha-1}} = \frac{C_Y + C_M + C_O}{\frac{w_t}{\alpha} \frac{\alpha}{\alpha-1}}. \quad (5)$$

However, we know that per-period wages w_t are also a function of P_t since we have that

$$w_t = \max(P_t \alpha \bar{L}^{\alpha-1}, \gamma w_{t-1} + (1 - \gamma) P_t \alpha \bar{L}^{\alpha-1}). \quad (6)$$

Substituting yields

$$P_t^{\frac{1}{\alpha}} = (C_Y + C_M + C_O)^{\frac{1-\alpha}{\alpha}} w_t \alpha^{-1} = C(\gamma(w_{t-1}) + ([1 - \gamma] P_t \alpha \bar{L}^{\alpha-1})) \quad (7)$$

where

$$C = (C_Y + C_M + C_O)^{\frac{1-\alpha}{\alpha}} \alpha^{-1}.$$

Collecting prices, factoring, and making the following variable substitutions,

- i. $b = \frac{1 - \alpha}{\alpha}$
- ii. $A = C(1 - \gamma) \alpha \bar{L}^{\alpha-1}$
- iii. $B = C \gamma w_{t-1}$

yields

$$P_t [P_t^b - A] = B. \quad (8)$$

We solve this via the Newton-Raphson method of numerical approximation.

For example, suppose $f(P_t) = P_t^{b+1} - AP_t - B = 0$ and define an initial guess for our price as $X_0 = P_{t-1}$ and some stopping rule predicated upon meeting some minimum error rate ϕ . Then, if $f(X_0) \leq \phi$ the algorithm stops and $P_t \approx P_{t-1}$. Otherwise, if $f(X_0) > \phi$ the algorithm proceeds as follows:

$$X_1 = X_0 - \frac{f(X_0)}{f'(X_0)} = P_{t-1} - \frac{P_{t-1}^{b+1} - AP_{t-1} - B}{(b+1)P_{t-1}^b - A}$$

Once the algorithm arrives at some X_i such that $f(X_i) \leq \phi$, define a temporary price as $P_t \approx X_i$.

Finally, we calculate output given this price and aggregate spending. If output exceeds potential then we know that our assumption that Equation (3) determines prices in a given period is incorrect, and the algorithm instead sets prices according to Equation (2).

3 Instructions

We provide a copy of our experimental instructions in this section. To save space, we include the common component of the instructions and then denote throughout whenever things differed between treatments.

EXPERIMENTAL STUDY OF ECONOMIC DECISION MAKING

Welcome! You are here today to participate in an economic experiment involving the experimental simulation of an economy. If you read these instructions carefully and make appropriate decisions, you may earn a considerable amount of money that will be paid to you in cash immediately following the experiment.

We will pay each participant \$10 for attending this experimental session. Throughout the experiment you will also earn points based on the decisions and predictions you make. Every 20 points you earn is worth \$1.

During the experiment you are not allowed to communicate with other participants. If you have any questions, the experimenter will be glad to answer them privately. If you have not done so already, please turn off your cell phone now. If you do not comply with these instructions, you

will be excluded from the experiment and deprived of all payments aside from the minimum payment of \$10 for attending.

Your task is to make predictions and budgeting decisions for computerized households that interact in an experimental economy. These instructions will explain how you will make forecasts and budgeting decisions, and your actions will translate into points and payments for you.

Overview:

In this experiment, you will make budgeting decisions for assigned households. These households live for three periods. We describe them as **Young** in the first period of life, **Middle-Aged** in the second period of life, and **Old** in the third period of life. You will be responsible for making budgeting decisions for an assigned household in the Middle-Aged and Old periods of its life. A computer automates decisions for Young households.

At any point in time, there will be 7 Young, 7 Middle-Aged, and 7 Old households, for a total of 21 households.

Households in this economy purchase a single good called **output**. You will do two things in each period of this experiment.

1. You will **predict** the unit price of output for the current period and the next period.
2. You will decide how your assigned household should **split its spending** between Middle-Aged and Old periods of its life.
3. *You will decide how much of your savings you want to hold as cash (earns no interest) and bonds (earns interest). We call this your portfolio decision.*

Note that the third item was included only in the NegativeIR+Portfolio sessions

You will earn points based on the accuracy of your output price forecasts. The more accurate your forecast, the more points you earn. You also earn points when your assigned household purchases output. The more your assigned household buys, the more points you earn.

Throughout the game, you will receive historical information about your personal decisions and the points you have earned. You will also receive information about the overall economy. Since

we will refer to these different pieces of information in the instructions, we will give you simple definitions below.

Output Produced - The total amount of production in the economy.

Price - The price for one unit of output.

Inflation - The percentage change in the price between the last period and the current period. Inflation can be **negative, zero, or positive**. Negative inflation means prices are falling; positive inflation means prices are rising; zero inflation means prices remain constant.

Inflation Target - The level of inflation the central bank is aiming to achieve over a number of periods. **Interest Rate** - The rate at which your savings will grow between two periods. This interest rate is determined by the central bank.

Income - The amount of lab money you can split between spending and saving when Middle Aged.

Portfolio: *The mix of cash and bonds that you use to make up your savings.*

Note the definition for Portfolio was only included in the NegativeIR+Portfolio sessions

Period

Each period will consist of two stages: a forecasting stage and a budgeting decision stage.

Stage I - Price/Inflation Forecasts

Each period will involve you making two price forecasts. You will make predictions about the current and next period's output prices. You will earn points based on the accuracy of your forecasts.

We provide you with two tools that assist you in making the connection between prices and inflation. These are provided in Boxes A, B, C, and D.

Tool I: Boxes A and B

Boxes A and B allow you to experiment with different levels of expected inflation for the current and next period to see what this would imply for the actual price level.

Begin by sliding the marker in Box A to indicate by what percentage you expect prices to fall or rise in the current period. The **Implied Price** for the current period will update as you move this slider. After making your prediction in Box A, adjust the slider in Box B to see an Implied Price for tomorrow. Box B's implied price will depend on your prediction in Box A. Importantly, if you change your prediction in Box A, you must reset and update your prediction in Box B to receive the correct implied price in Box B.

Tool 2: Boxes C and D

Boxes C and D allow you to translate predicted prices into inflation expectations. Type in your forecasts of current and next period's prices in Box C. By clicking on the grey button "Calculate Expected Inflation", you will see in Box D what your implied inflation forecasts are. You can do this as many times as you'd like. The program records no information until you submit your final price forecasts.

Submitting Your Price/Inflation Forecasts:

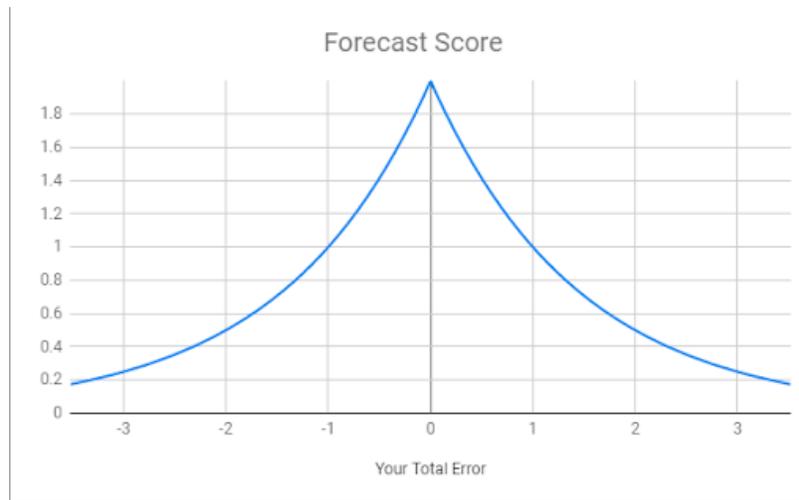
To submit your forecasts, you must type your **final price forecasts into Box C** and click on the **red "Finished" button**. You will have 60 seconds to submit your price forecasts. You will earn zero points if you do not submit your forecasts on time. Notice that the sliders allow you to select an inflation forecast from -25% to +25%. However, your final price forecasts can always imply a price change outside of this range.

How You Earn Points For Your Price/Inflation Forecasts:

Once a price is calculated at the end of a period, the software will evaluate your forecast formed in

the previous period about the current price and your forecast formed in the current period about the current price. Your forecasting score, at the end of a round, will be given by:

$$ForecastPoints_t = 2^{(2-|FuturePriceForecastError_{t-1}|+2-|CurrentPriceForecastError_t|)}$$



- A perfect forecast for each of these forecasts for a given time earns you 2 points
- Thus, A perfect forecast yesterday and today earns a total of 4 points
- Your score drops in one-half for each lab dollar your price forecast is incorrect
- You will never earn negative points for your forecasts

Submitting your Interest Rate Forecast

Before clicking the “Finished” button, please indicate whether you think the interest rate in the current period will decrease, increase, or remain unchanged. For each correct guess, you will earn 2 points.

How do forecasts influence the economy?

The median (i.e. middle) price forecast for the current period collected from all subjects will be used to calculate expected income in the current and future periods and expected current interest rates. The expected current income and interest rate will be presented to all subjects when

they make their budgeting decisions. The expected future income will determine how much the automated Young households can spend on output.

Suppose we have 5 participants providing price forecasts. Then, the following is an example of how we select the median price forecast:

~~\$2~~, ~~\$6~~, \$6.75, ~~\$10~~, ~~\$1000~~
 ↑
 Median Price Forecast

Finally, the automated Young households will spend 35% of their expected future income.

Forecasts about the current interest rate change will have no impact on the economy.

Stage 2 - Individual Decisions:

In Stage 2 of each period, you will make a budgeting decision for an assigned Middle-Aged household.

Your assigned Middle-Aged household is predicted to earn a certain level of income in the current period. You will decide what percentage of that predicted income your household should spend today. The unspent income will earn interest and be available to that household in the next period when the household becomes Old. Importantly, the Old household will automatically spend all of its remaining wealth on output and you will earn points for its purchase of output. The table below shows how decisions impact current and next period's 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 1: Co-determination of middle-aged and old spending

Portfolio:

You may hold savings as cash or as bonds. Cash does not earn interest whereas bonds do earn interest. Note that both cash and bonds are equally easy to spend in this experiment.

Suppose you end the period with 100 lab dollars and that the interest rate is 10%. If you hold your savings as bonds, then your household will have $100 \times (1 + .1) = 110$ lab dollars for spending in the following period while old. If instead you hold cash, your household will have 100 lab dollars to spend in the following period.

Suppose instead the interest rate is -10%. If you hold your savings as bonds, then your household will have $100 \times (1 + (-.1)) = 100 \times .9 = 90$ lab dollars to spend in the following period. If instead you hold cash, your household will have 100 lab dollars to spend in the following period.

The central bank uses interest rates to keep output and employment as high as possible without creating too much, or allowing for too little, inflation. Sometimes the central bank does this using positive interest rates. Sometimes the central bank does this using negative interest rates. In this experiment, the central bank uses interest rates to influence how each of you spends and saves money.

Note that we only included these 3 paragraphs for the NegativeIR+Portfolio sessions

Information:

You will receive forecasts about your current income, the current interest rate, the median subject's expected price for the current and next period, as well as information about how much young households will be borrowing from their future income.

Budgeting Tool:

You must decide how much of its **forecasted income** your middle-aged should spend today. We provide you with a calculator (pictured below in the middle box titled 'Optimal Spending Calculator') to help you make this budgeting decision. Begin by typing in predictions of the price level in the current and next periods. These price predictions may be the same as your previous price predictions, may be the median price prediction displayed here, or may be any other strictly positive number. Clicking the "Calculate Optimal Spending" button will cause the current period's predicted interest rate and the optimal level of spending to update. Note these values are conditional on your price expectations and will be different for different price expectations. By 'optimal level of spending' we mean the level of spending today that, conditional on your price expectations, will maximize your household's lifetime consumption. This implies that 'optimal level of spending' is the level of spending today that, conditional on your price expectations, will

maximize the money you earn from your household.

You can also experiment with different spending decisions. In the box “Lab Dollars for Spending Today”, indicate how many dollars you would like to spend. By clicking “Calculate Predicted Points” you can see how many points you would hypothetically earn given your price forecasts and spending decisions.

Note that all these values are hypothetical. The actual price levels, interest rate and optimal decisions will depend on the spending decisions of all households in the economy.

The screenshot displays a simulation interface with the following sections:

- Period:** 1 out of 13. Remaining time (sec): 8.
- Units:** A table showing utility values for 10 periods:

Units	1	2	3	4	5	6	7	8	9	10
Utility	2.70	3.39	3.80	4.08	4.31	4.49	4.64	4.78	4.89	5.00
- Information:**
 - Forecasted income: 73.25
 - Forecasted interest rate (%): 18.45
 - Market expected price today: 110.90
 - Market expected price tomorrow: 121.00
 - Borrowing percentage of current Young Households: 35.00
 - Central Bank's inflation target (%): 10.00
- Optimal Spending Calculator:**
 - Expected price today?: 111
 - Expected price tomorrow?: 122
 - Based on your expectations, the current nominal interest rate will be (%): 20.63
 - Based on your expectations, the optimal amount of lab dollars to spend is: 35.08
 - Buttons: Calculate Optimal Spending
- Your Spending and Savings Decisions:**
 - Lab dollars for spending today: 35.08
 - Predicted lab dollars for spending tomorrow: 45.04
 - Predicted total points from middle-aged and old-aged spending: 7.91
 - Buttons: Calculate Predicted Points, Submit Decision

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

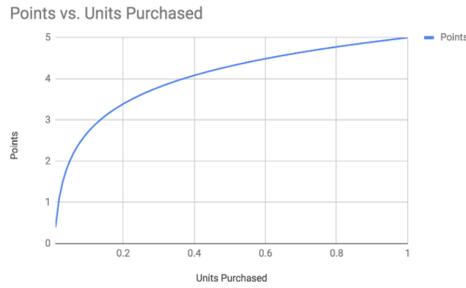
Submitting Your Spending Decisions:

To submit your spending decision, you must input your budgeting decision as any number between 0 and your predicted income and click on the red “Submit Decision” button. You may use up to two decimal places for your entry. Please review your decision before clicking the Submit button. Once you have clicked it, you may not reverse your decision.

How You Earn Points for Your Spending Decisions

Each additional unit purchased by your household within a single period earns you a positive, but diminishing number of points. Specifically, the number of points you will earn for your purchases in a single period is given by: $Points = 5 + \ln(.0067 + \text{units purchased})$

- Spending more money in a single period will allow you to earn more points
- Each additional lab dollar you spend in a single period earn you less than the previous dollar



Units Purchased	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Points	0	2.7	3.39	3.8	4.08	4.31	4.49	4.64	4.78	4.89	5

Figure 3

- The above table is a coarse grid of payoffs. In fact, you may purchase and consume fractions of a unit to two decimal places. E.g. Purchasing 0.35 units would earn you 3.97 points. It is possible to purchase and consume more than 1.0 unit.

To understand how this diminishing returns to consumption spending within a period works, we provide three examples.

Suppose you are assigned a Middle-Aged household in Period 1 whose income is 10 lab dollars. Further, assume that the price of output is 10 lab dollars and that the interest rate and inflation rates are 0% (so your savings earn no interest and the price of output does not change in the following period).

1. If you instruct your household to spend all of its \$10, then today it will purchase 1 unit of output ($\$10 \text{ income spent} / \$10 \text{ price per unit} = 1 \text{ unit purchased}$) and tomorrow it will purchase nothing. This will earn you a total of 5 points in Period 1 and 0 points in Period 2.
2. Now assume that you instruct your household to spend \$4 (40% of its income) today. It will purchase 0.4 units today ($\$4 \text{ income spent} / \$10 \text{ price per unit} = 0.4 \text{ units purchased}$), and have \$6 in saving. If prices remain the same tomorrow, you will purchase 0.6 units tomorrow ($\$6 \text{ spent} / \$10 \text{ price per unit} = 0.6 \text{ units purchased}$). This will earn you a total of $4.08 + 4.49 = 8.57$ points.

3. Finally, suppose that you instruct your household to spend \$2 (20% of its income) today. Then today your household will purchase 0.2 units and tomorrow it will purchase 0.8 units. This earns you a total of $3.39 + 4.78 = 8.17$ points.

The above are examples that are meant to clarify the diminishing benefits to consumption spending.

- You will frequently observe interest rates above zero. Higher interest rates mean more return on saving and, all else equal, more money for your Old household to spend.
- You will frequently see prices change. Your household will be able to purchase more units of output, and earn more points, when prices are lower.

Income, Prices, and Units

After all players specify how much their Middle-Aged households should spend, the software will compute the total amount of output that will be produced, the number of dollars to be spent on output in the current period and the market clearing price. Once the market clearing price is determined, the income of the Middle-Aged will be calculated. Middle-Aged income will be simply equal to the price of output.

The more (less) total dollars being spent on output, the more (less) output will be produced. The economy can produce a maximum of 7 units. These units will be divided among Young, Middle-Aged, and Old households. Households will be able to purchase fractions of a unit. Your household will receive more units of output if they have a larger amount of money to spend.

Monetary Policy

A computerized **central bank** operates in the background. The central bank's objective is to keep prices growing at a constant rate. This constant rate is called their **inflation target**. The central bank will announce its inflation target at the beginning of each period. This will be shown in the upper-middle of your screen.

Suppose the central bank's inflation target is 10%. This means that if the price of a unit of output is 10 in the previous period, the central bank's targeted price for the current period is $10 \times 1.10 = 11$ and for the next period is $10 \times 1.10 \times 1.10 = 12.10$ (equivalently, $11 \times 1.10 = 12.10$)

Note that this is only a target for inflation. You may observe inflation levels that are negative, positive, or zero.

Central Bank's Inflation Target

10.00

Figure 4

To achieve its targeted inflation, the central bank will adjust their interest rate at the end of each period in response to changes in the current price of output. It will increase the nominal interest rate when inflation is above its target, and it will lower the nominal interest rate when inflation is below its target. More precisely, it will use the following rule to set its interest rate:

$$interestrate_t = \max\left\{1, \psi \left(\frac{inflation_t}{inflation\ target}\right)^2\right\} - 1$$

Note that $\psi = 1.13$ in our baseline sessions and $\psi = 1.846$ in all other sessions

baseline session example

For example, suppose that inflation = 10 and the inflation target = 10. Then the central bank will set the interest rate at $1.13(10/10)^2 - 1 = 1.13^*1 - 1 = 1.13 - 1$. In words, this is saying that if actual inflation is 10-percent when the central bank is targeting 10-percent then the central bank's interest rate will be 13%.

Example for all other sessions:

For example, suppose that inflation = 10 and the inflation target = 10. Then the central bank will set the interest rate at $1.846(10/10)^2 - 1 = 1.846^*1 - 1 = 1.846 - 1$. In words, this is saying that if actual inflation is 10-percent when the central bank is targeting 10-percent then the central bank's interest rate will be 18.46

Note that the central bank will increase (decrease) the interest rate more than one-for-one with increases (decreases) in inflation relative to its target. For example, if inflation rises from 10% to 15%, then the central bank will increase the nominal interest rate by more than 5% in an effort to return inflation to its 10% target.

Importantly, if inflation falls too low, the nominal interest rate will decrease to zero and not decline any further.

Stage 3 - Review Screen

After you have made your budgeting decision, you will receive information about what happened in the current period to your currently assigned Middle-Aged household and your currently assigned Old household. Note that the the outcomes of the assigned Old household depended, in part, on your budgeting decision for your assigned Middle-Aged household **in the previous period**.

You will also receive information about the price of output, inflation in prices, the central bank's interest rate, and the total production in the economy.

Summary of Period	
Your Points	
Middle-Aged consumption units:	0.32
Middle-Aged consumption points:	3.88
Old consumption units:	0.35
Old consumption points:	0.00
Forecasting points:	3.26
Economic Information	
Unit price this period:	109.33
Inflation this period:	9.33
Interest rate this period:	17.02
Output this period:	1.00

In the next period, the following will occur:

1. You will make a new set of forecasts for the current and subsequent period.
2. You will be assigned a new Middle-Aged household whose budget you will set.
3. Your previous period's Middle-Aged household will now become an Old household and will automatically buy goods with the budget you previously allocated it. Importantly, the Old household will spend all of its remaining wealth on output.

You will repeat this game for many periods. After a household is Old, it dies and is replaced by a new Young household.

To help you keep track of your decisions over time, we provide you with a history box located at the top of all screens.

Period	Current Price Forecast	Future Price Forecast	Points Earned from Forecasts	Middle-Aged Units	Middle-Aged Points	Old Units	Old Points		Price	Inflation (%)	Inflation Target	Income	Interest Rate (%)	Output Produced
1	11.00	12.10	1.31	0.33	3.89	0.33	0.00		10.39	3.94	10.00	10.39	5.77	3.00

Payments

After the experiment and questionnaire, we will convert your total points into dollars and pay you immediately in cash.

In addition to these primary instructions, *NegativeIR* and *NegativeIR+Portfolio* including a second handout that we provided to subjects between periods 30 and 31 whenever we announced the central bank's intention to begin using negative nominal rates.

Removing the Zero Lower Bound

The central bank will now allow interest rates to become negative if inflation falls sufficiently below its target.

Negative interest rates cause savings to shrink. For example, saving 10 lab dollars with a -10% interest rate would yield savings equal to $10(1 + (-.1)) = 9$ lab dollars.

On the other hand, negative interest rates imply that you will have less debt to repay when middle-aged household. For example, a young household that borrows 10 lab dollars will only owe 9 lab dollars once middle-aged. Thus, you have more disposable income to split between consumption and saving while middle-aged.

This change is permanent.

4 Session-Level Data with Individual Consumption and Expectations

HigherTarget

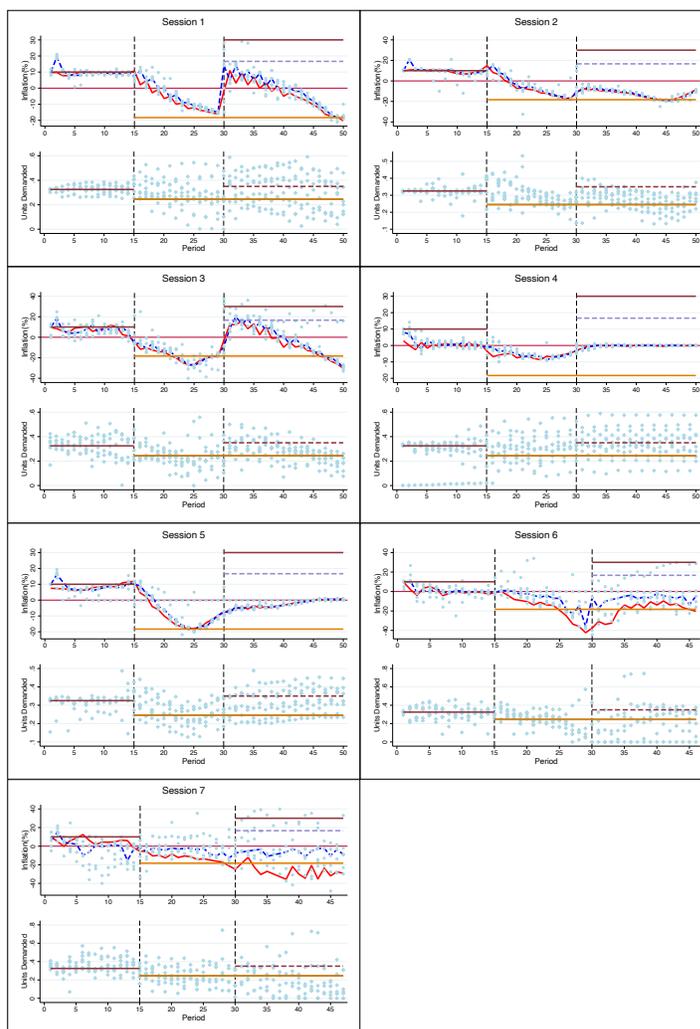


Figure 5: Individual-level inflation expectations (top, dots) and consumption (bottom, diamonds) data for *HigherTarget* sessions. Horizontal lines denote steady state levels of consumption and inflation. Maroon lines correspond to the central bank's inflation target, dark orange lines correspond to the secular stagnation equilibrium, and dashed lines correspond to the liquidity trap equilibrium. Dashed time series line denotes median inflation expectation. Solid time series line denotes actual inflation.

NegativeIR

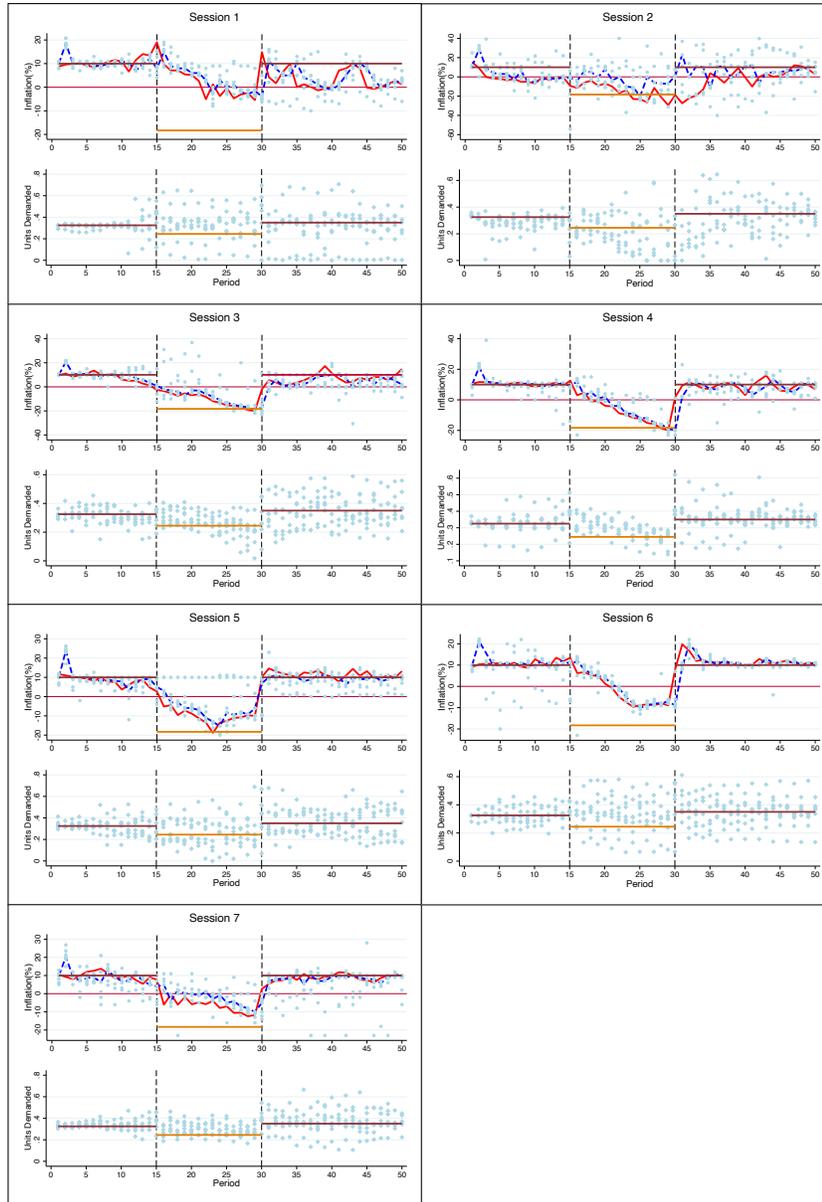


Figure 6: Individual-level inflation expectations (top, dots) and consumption (bottom, diamonds) data for *NegativeIR* sessions. Horizontal lines denote steady state levels of consumption and inflation. Maroon lines correspond to the central bank’s inflation target, dark orange lines correspond the secular stagnation equilibrium. Dashed time series line denotes median inflation expectation. Solid time series line denotes actual inflation.

NegativeIR+Portfolio

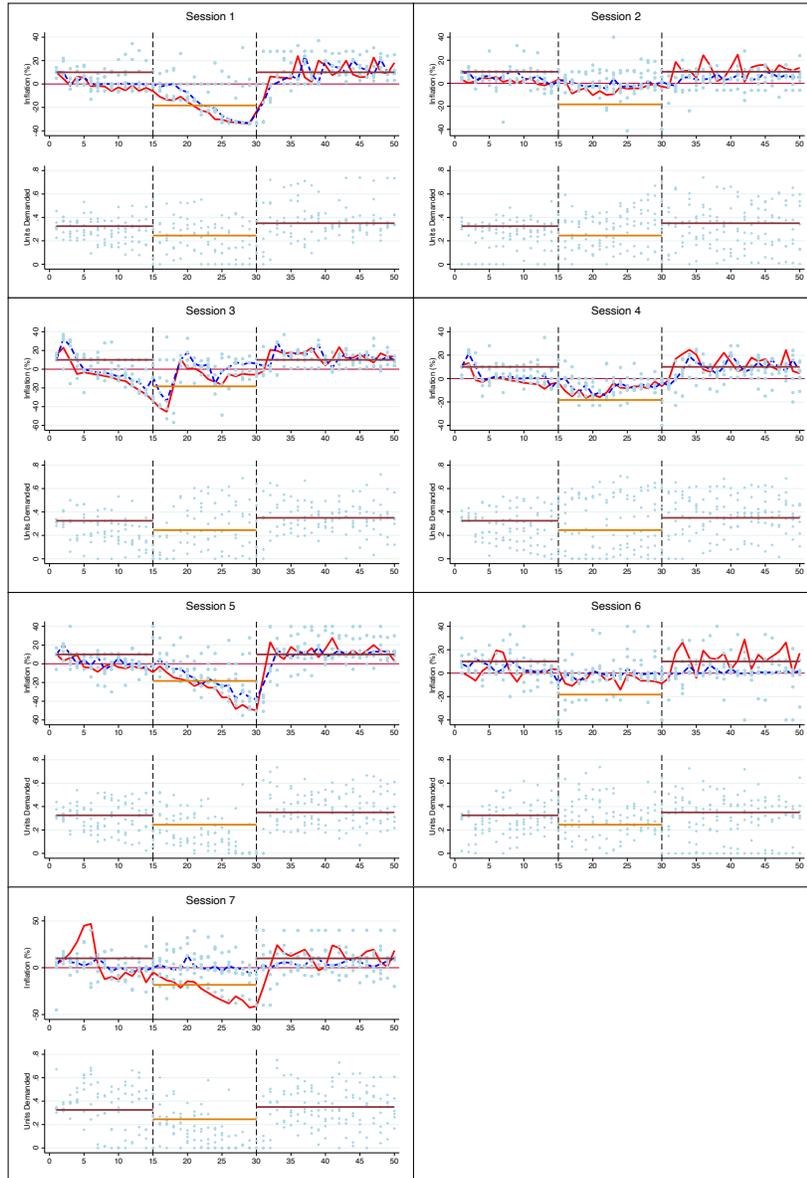


Figure 7: Individual-level inflation expectations (top, dots) and consumption (bottom, diamonds) data for *NegativeIR+Portfolio* sessions. Horizontal lines denote steady state levels of consumption and inflation. Maroon lines correspond to the central bank's inflation target, dark orange lines correspond to the secular stagnation equilibrium. Dashed time series line denotes median inflation expectation. Solid time series line denotes actual inflation.

5 Central bank credibility

We measure the evolution of central bank credibility in each treatment. We classify a subject's nowcast or forecasting as exhibiting credibility if it is within 1 percentage point of the central bank's target. Figure 8 plots the share of participants exhibiting credibility in each period of each treatment.

At the beginning of all treatments, credibility in the central bank is considerably high. Credibility in Period 1 of Phase 1 exceeds 50% in *Baseline*, *HigherTarget*, and *NegativeIR*. It is lower in *NegativeIR+Portfolio*, at roughly 45% for nowcasts and 38% for forecasts. This lower credibility is not surprising given that participants are tasked with additional portfolio decision making in *NegativeIR+Portfolio*, and potentially direct less attention on the central bank's target.

Very rapidly, participants' credibility in the central bank's target declines as the economy evolves. In Phase 1, participant credibility averages between 21 and 36% in the first three treatments and 14 to 18% in our *NegativeIR+Portfolio*. This decline in credibility occurs despite inflation trending toward the inflation target in all treatments.

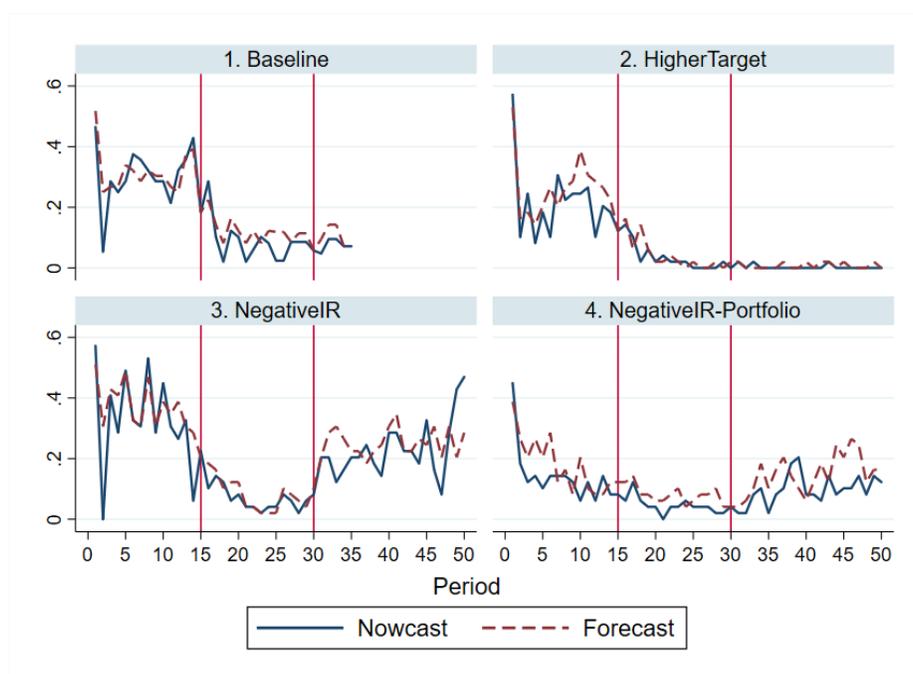


Figure 8: Share of participants exhibiting credibility in the central bank's inflation target

Rather than anchoring their expectations on the central bank's inflation target, most participants rely on recent historical inflation to form their forecast. See ?? for a detailed discussion of the

distribution of forecasting heuristics.

On impact of the deleveraging shock, before participants have had an opportunity to change their real decisions, credibility in the central bank's inflation target falls significantly. Nowcast and forecast credibility in the target decline more than 20 percentage points in *Baseline* and 6-8 percentage points in *HigherTarget*. In *NegativeIR*, forecast credibility declines by 8 percentage points while nowcasts exhibit an increase in credibility of 16 percentage points. Overall, these results suggest that the credibility was fragile before entering Phase 2, and there was heightened uncertainty in the central bank's ability to achieve its target after the announcement of the deleveraging shock. We observe no notable change on impact of the deleveraging shock in *NegativeIR+Portfolio*, again indicative of limited attention on the target.

Following the deleveraging shock at the beginning of Phase 2, less than 15 percent of participants in any of the treatments deem the central bank's target as credible. What little credibility remains is notably persistent, and declines relatively slowly over Phase 2.

At the beginning of Phase 3 in *HigherTarget*, the central bank announces it is raising its inflation target from 10% to 30%. The announcement is met with complete skepticism. Only 2% of participants (one participant) is optimistic about the central bank's ability to achieve the new target. After two periods into Phase 3, even this participant has lost credibility in the central bank.

The announcement of negative interest rates is also met with some initial skepticism. In *NegativeIR* credibility on impact of the announcement only results in a 2-percentage point increase in nowcasts and 6 percentage point increase in forecasts anchored on the 10% inflation target. With time the credibility in the target of 10% began to rise. Economies that had a higher proportion of participants perceive the target as credible experienced faster inflation, which in turn encouraged greater credibility. Likewise, credibility does not immediately jump in *NegativeIR+Portfolio*. Credibility remains quite muted, even as economies shoot past the central bank's inflation target. Instead, participants rely heavily on historical prices and inflation to formulate their expectations.

6 Consumption Demand

We evaluate the determinants of middle-aged consumption demand in a series of random effects specifications. We estimate an Euler-like equation using data from our *HigherTarget*, *NegativeIR*, and *NegativeIR+Portfolio* treatments.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. Var.	HigherTarget and NegativeIR		HigherTarget	NegativeIR	NegativeIR+Portfolio		
	Phase 1	Phase 2	Phase 3	Phase 3	Phase 1	Phase 2	Phase 3
$C_{i,t}^m/NI_{i,t}$							
$C_{i,t-1}^m/NI_{i,t-1}$	-0.109 (0.10)	-0.211*** (0.05)	-0.079 (0.06)	0.012 (0.07)	-0.247*** (0.06)	-0.019 (0.05)	-0.043 (0.07)
$C_{i,t-2}^m/NI_{i,t-2}$	0.692*** (0.11)	0.653*** (0.05)	0.797*** (0.06)	0.725*** (0.06)	0.524*** (0.06)	0.648*** (0.04)	0.623*** (0.06)
$E_t \dot{i}_t$	-0.132** (0.06)	-0.414*** (0.12)	-0.694*** (0.21)	-0.537*** (0.08)	-0.557*** (0.09)	-0.091 (0.88)	-0.149* (0.08)
$E_t \pi_{t+1}$	0.301*** (0.12)	0.300*** (0.05)	0.272*** (0.06)	0.100 (0.11)	0.670*** (0.19)	0.354*** (0.11)	0.361** (0.16)
$ExpNegIR_t$				-2.147 (3.40)			3.764** (1.90)
α	19.592* (10.00)	24.478*** (4.39)	14.055*** (4.76)	9.105* (5.41)	32.357*** (4.88)	14.571*** (2.77)	13.800** (5.68)
N	1456	1568	1323	1029	637	735	980
χ^2	216.3	756.4	892.5	453.6	257.8	297.7	434.4

This table presents results from a series of random effects panel regressions. The dependent variable, $C_{i,t}^m$ is the number of output units demanded by subject i in period t . $E_t \dot{i}_t$ refers to expected nominal interest rate, $E_t \pi_{t+1}$ is the expected inflation rate, and $ExpNegIR_t$ is a dummy variable that takes the value of 1 if the expected nominal interest rate is negative, and 0 otherwise. α denotes the estimated constant. Robust standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.