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Leave the bubble alone!:
Deflating asset price bubbles in an experimental macroeconomy *

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Abstract

This paper examines the effects of monetary policy on asset price bubbles and production in a laboratory experimental economy. Participants play the role of household investors who are faced with consumption, labor, and investment decisions. In a between-subject design, we compare how participants' decisions and aggregate dynamics respond to the presence of an asset market and to policies that are intended to stabilize asset prices. We find that introducing asset markets to the economy does not generate significant real effects despite large deviations of asset prices from fundamental value. Both leverage constraints and monetary policy responses to asset price inflation inadvertently generate larger deviations of asset prices from fundamental value. The prospect of a binding leverage constraint results in increased labor supply and, consequently, larger cash balances that fuel larger and more persistent asset price deviations. A "leaning against the wind" interest rate policy generates low nominal interest rates in the early periods of participants' lifecycles due to its relatively weaker response to output price inflation. Low interest rates incentivize subjects to speculate and thereby generate a quick acceleration in asset prices. As interest rates rise quickly and significantly in response to asset price inflation, monetary policy becomes more salient and effective at stabilizing asset demand.

JEL classifications: C92, E52, D91, E21
Keywords: Experimental macroeconomics, laboratory experiment, monetary policy, asset price bubbles, general equilibrium, production economy.

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1 Introduction

The bubble and subsequent collapse of dot-com technology stocks in 2000, and of housing markets in North America and Europe in 2008, have called into question the role that central banks can play in reducing speculative investment. While central banks have focused predominantly on stabilizing inflation and output, increased volatility in asset markets has made asset market stabilization an increasingly important priority. How and when to respond to asset price bubbles has been a matter of considerable, and largely unresolved, debate.

Proponents of an interventionist policy reaction to asset price bubbles advocate for more stringent borrowing regulations such as raising mortgage insurance premiums and lowering the maximum loan-to-value ratio, making speculative investment more expensive and less attractive.[1] The proposition is that this would, ideally, reduce liquidity in asset markets and, consequently, asset price growth. An alternative and more controversial interventionist proposition is to adjust nominal interest rates with asset price inflation. As asset prices grow, nominal interest rates would rise, disincentivizing investors from borrowing for speculative purposes; as asset prices decrease, the central bank would lower savings and borrowing rates to encourage speculative investment in an effort to stabilize asset prices.[2] The interventionist perspective can be critiqued on two fronts. First, it can be challenging to identify and measure deviations of asset prices from fundamental value. Only after an asset price crashes can one infer whether it was previously overpriced. Second, it remains unclear whether contractionary monetary policy could effectively reduce asset bubbles. Exuberant and

[1] Proposals such as placing caps on speculative investment (De Grauwe (2008)) or raising interest rates as asset prices inflate (Smets (1997), Cecchetti et al. (2000), Filardo (2001, 2003), Borio and White (2004), and Roubini (2006)) discourage excessive leveraged speculation, while minimizing asset price bubbles and the fallout associated with crashes in the asset market.

[2] Theoretical work by Greenspan (1996), Bernanke and Gertler (1999, 2001), and Gilchrist and Leahy (2002) shows that an economy can be kept stable by following conventional inflation targeting policies in the presence of asset market bubbles.

optimistic investors may well be willing to speculate regardless of increased borrowing costs or higher yields on secure interest-bearing bonds.

The consequences of these interventionist policies to the aggregate economy are potentially significant. Given the general reluctance of central banks to resort to such policies, it is difficult to identify instances where perceived bubbles have been met with an aggressive response—which perpetuates the uncertainty about the effectiveness of such policies. Consequently, the prevailing argument is that policy makers should leave asset markets alone and respond solely to inflation and fluctuations in unemployment. The reasoning is that by keeping inflation low by way of policies currently in place, central banks can maintain an environment in which bubbles are less likely to occur. If asset bubbles are driven, at least in part, by real and relevant factors in the economy (e.g., by increased demand for houses in cities with growing populations), then targeting asset price inflation can have significant negative repercussions on the economy.

Our primary goal is to understand whether monetary policy can attenuate investors' incentives to speculate and lead to more stable asset markets and an overall more stable economy. As a first step, we propose circumventing the empirical limitations discussed above by studying monetary policies in the controlled setting of a laboratory experiment. In the laboratory, both the fundamental value of an asset and the monetary policies set by the central bank are specified by the experimenter, making both the identification of asset price bubbles and the effects of monetary policy straightforward. Evidence from such an experiment allows us to draw qualitative inferences about how an economy populated by human agents would behave under different market and policy scenarios. Compared with computational or theoretical analyses which require agents' expectations and decision-making process to be specified, participants in our experiment bring their heterogeneous preferences and expectations into the laboratory, thereby allowing for a more natural response to our proposed policies. Moreover, an experimental testbed can be particularly useful for exploring policies that have not been previously implemented, and for illuminating any unintended or irreversible consequences that policy makers would be advised to consider in their final implementation.[3]

We design and implement a laboratory economy to study the effects of the presence of asset markets and policy intervention on real and nominal variables. Incentivized participants play the role of household investors who interact in labor, output, and asset markets. Our experiments build on the structure of earlier production economy environments used to study predictions of international trade and finance theory (Noussair, Plott and Riezman (1995, 2007)), economic growth (Lei and Noussair (2002)), money supply and credit on production and demand (Bosch-Domènech and Silvestre (1997), Lian and Plott (1998), Baeriswyl and Cornand (2015)), and the effects of stochastic shocks (Noussair, Pfajfar and Zsiros (2014, 2015); and Petersen (2015))—where decisions made by the participants are the sole determinants of aggregate outcomes. Given that our focus is on household-investor decisions, we simplify the previous frameworks by automating firms and the monetary authority decisions to follow theoretically motivated rules.

Our experiment is also the first to combine an asset market and a production economy to study the aggregate implication of speculative trading. While the highly in-

[3]See Duffy (Forthcoming) and Cornand and Heinemann (2014) for surveys of macroeconomic laboratory experiments and Croson (2002) for further discussion on the benefits of studying policies and market design in the lab before final implementation. The Dutch Ministry of Social Affairs and Unemployment commissioned Riedl and van Winden (2001, 2007) to conduct a series of laboratory experiments to study government tax policies to finance unemployment benefits. The Bank of Canada recently conducted experiments to test whether targeting price levels, rather than inflation rates, would result in improved stability in a small economy (Amano, Engle-Warnick and Shukayev (2011)). Kryvtsov and Petersen (2013) conduct online experiments for the Bank of Canada to study the importance of monetary policy in influencing public expectations about the future state of the economy and whether this expectations channel of monetary policy can be enhanced by improved communication.

fluential asset market framework developed by Smith, Suchanek and Williams (1988) has been extensively used to study policies or market features to reduce asset price bubbles, no prior experimental work has investigated how these policies influence labor and consumption decisions.[4] As these decisions have a potentially critical impact on later investment strategies, it is essential to map the general equilibrium effects to understand the aggregate implications of policy. Indeed, one of the key concerns with "leaning against the wind" policies centers on the potential consequences to the real side of the economy.

Our experimental treatments are designed to identify the combined effects of the presence of an asset market and policy interventions on economic decisions and asset prices. In our baseline economy, participants interact only in labor and output markets. In a second treatment, we introduce an opportunity for speculative investment by endowing all participants with tradable assets. The third and fourth treatments examine the effects of asset market interventions: We consider leverage constraints on speculative investment and an interest rate policy that responds to asset price inflation.

Our results from the benchmark treatment demonstrate that participants learn over time to make optimal consumption and labor decisions despite the complexity of the environment. When endowed with assets, participants are willing to trade assets despite having no induced incentive to do so. As a result, asset prices consistently

[4] Asset price bubbles and crashes are frequently observed in partial equilibrium experimental markets, and much work has explored methods to minimize their occurrence. Mostly closely related to our policy interventions are the inclusion of an interest-bearing bond (Fischbacher, Hens and Zeisberger (2013), Giusti, Jiang and Xu (2014)), consumption smoothing motives (Crockett and Duffy (2015)), alternative tasks to speculation (Lei, Noussair and Plott (2001)), and adjusting the available liquidity in the markets (Caginalp, Porter and Smith (2000)). Fischbacher, Hens and Zeisberger (2013) explore whether interest rate policies affect portfolio decisions and market liquidity. They find that raising interest rates leads investors to redirect their investments toward the risk-free bond and generates a significant decrease in asset market liquidity. Raising interest rates in response to asset price growth does not have a considerable effect on trading prices. The authors also consider the effects of reserve requirements in an additional treatment. They find that simply announcing the possibility of reserve requirements is highly effective at dampening asset price bubbles.

and significantly deviate from their fundamental values. We find that neither policy intervention—more stringent borrowing regulations, or interest rate adjustments in keeping with inflation—is effective when it comes to reducing asset price bubbles. Imposing constraints that prevent subjects from borrowing for speculative purposes does not appear to reduce the incentive to trade the asset. The potentially binding leverage constraint motivates subjects to supply more labor which generates a larger accumulation of wealth that can be used for speculation. Consequently, asset price deviations are significantly amplified and more persistent.

Implementing an interest rate rule that targets asset prices has mixed success in reducing asset price growth. Asset price deviations are significantly amplified relative to the No-Intervention treatment but are less persistent than in the leverage constraint treatment. This is a result of monetary policy responding relatively less to output price inflation and more to asset price inflation compared with the No-Intervention treatment. Relatively lower interest rates in the initial periods of play creates more incentive to borrow for speculation and less incentive to save wealth in the form of bonds, which fuels an upswing in asset prices. Accelerating asset prices in turn raise interest rates dramatically which motivates subjects to reallocate their wealth to bonds. Despite the fact that both intervention policies are ineffective when it comes to stabilizing asset prices, both nonetheless have important positive effects on the economy. Leverage constraints lead to higher and more stable labor supply and production, although this comes at the cost of larger spillovers from asset markets to the real economy. Asset targeting rules improve the effectiveness of monetary policy in stabilizing individual decisions. Decisions that subjects make with respect to labor supply and asset trading are significantly more responsive to changes in the nominal interest rate as those changes become more salient.

2 Experimental Design

We begin by introducing the experimental design that we implemented in all of our treatments, and we proceed to describe the treatment variations in the following subsection. The experiment was designed to capture key features of the theoretical framework found in our Appendix. Each participant was given the role of a household which exercised control over labor supply, output demand, and in some treatments, investment decisions over multiple sequences of linked periods. In each experimental economy nine participants interacted with monopolistically competitive automated firms, a commercial bank, and a central bank which responded to their aggregate decisions. In each period, participants earned points through purchasing and automatically consuming units of an output good,, C_t, and lost points by supplying hours of labor, N_t. The number of points that a participant earned each period was calculated according to the following function:

$$Points_t = \left(\frac{1}{1-\sigma}\right) C_t^{1-\sigma} - \left(\frac{1}{1+\eta}\right) N_t^{1+\eta},$$

where $\sigma = 0.33$ and $\eta = 1.5$. To appropriately incentivize participants to take their decisions seriously, the points earned from all periods were exchanged for cash at a pre-specified rate at the end of the experiment.

In the baseline environment involving only labor and output markets, the per-period budget constraint for each participant was given by

$$P_t C_t + B_t = (1 + i_{t-1}) B_{t-1} + W_t N_t + \pi_t, \tag{1}$$

where P_t is the price of a unit of C_t, B_t is the nominal bank account balance (i.e., nominal wealth in the form of one-period bonds) held at the end of period t, W_t is the nominal wage, and π_t is a transfer of the profits from the automated firms. Each household received an equal share of the automated firms' per-period profits.

Participants received a one-time endowment of 10 units of lab money to make purchases within the sequence. Additional lab money was earned by way of supplying labor and earning interest on savings. Unspent balances were automatically saved and carried over to the next period. Participants who lacked sufficient money to complete a transaction would borrow automatically from an automated bank who faced no limits on its supply of loans. Both savings and debt accrued interest which was added to the balance in the next period.

In order to induce subjects to discount their future consumption and labor points exponentially, we generated indefinite-length sequences in which each period had a constant probability of continuation. This method was first applied by Camerer and Weigelt (1993) to induce exponential discounting and stationarity.[5] In order to make the random termination rule credible and salient, at the end of each period we drew with replacement from a bag of 193 blue and 7 green marbles. The sequence continued if the selected marble was blue; otherwise, the sequence ended. This implied a constant probability of 3.5 percent or an average of 28.5 periods. After a repetition ended, upon the selection of a green marble, a new repetition would begin if there were more than 25 minutes remaining in the session.

Participants held either positive or negative cash balances at the end of each sequence. To disincentivize excessive cash or debt accumulation, we imposed the following end-of-sequence rule. Participants who held positive cash balances were required to spend the remaining cash to purchase output at the price set in the last period of the sequence, earning additional $\frac{1}{1-\sigma}(\frac{BankAccount}{P_t})^{1-\sigma}$ points. Due to the diminishing marginal utility associated with consumption, participants with a constant income stream would earn more points by consuming more each period

[5]Crockett and Duffy (2015) also use this method. See Duffy (Forthcoming) for a discussion of the approach.

than they would earn by saving a large amount of cash until the end of the sequence. Indebted participants were required to work the necessary number of hours to produce the amount of goods that the owed money would purchase. In that case, their final point balances were deducted based on the amount owing and the previous period's market price, $\frac{1}{1+\eta}(\frac{BankAccount}{zP_t})^{1+\eta}$, where z is the marginal product of labor. As debts grew large, the disutility associated with repayment grew exponentially.[6] We provided participants with a supplementary calculation of their adjusted points based on bank account balances, assuming that the sequence had ended in the previous period.[7]

The monopolistically competitive firms, the commercial bank, and the central bank were automated to simplify the experiment.[8] A continuum of firms set their prices as a markup over the nominal wage. In each period, a fraction $1 - \omega = 0.1$ were able to update their prices while the remaining ω firms were required to use the previous period's price, which resulted in nominal rigidities in the aggregate price level. Firms produced based on realized demand (i.e., all output was made to order). Firms required labor as the sole input in their production process and were able to produce $z = 10$ units of output with every hour of work hired. The price and wage

[6] No upper bound was placed on the adjustment of points associated with end-of-sequence bank account balances.

[7] In the final periods of experienced rounds, the share of indebted subjects was 32% in the Benchmark treatment, 30% in the NI treatment, 15% in the C treatment, and 20% in the AT treatment. The final payoff for each subject was associated with the sum of their adjusted points from all sequences. A small number of participants ended the experiment with negative points overall. We paid these participants only their show up fee of $5, which was very modest given the time spent participating in the experiment.

[8] This simplification allows us to focus on the behavior of participants who took on the role of household investors, and it affords us more participants per session. Other experiments such Noussair, Pfajfar and Zsiros (2014) and Petersen (2015) use 3 and 4 participants respectively, playing the role of firms in order to generate monopolistic competition opposite the same numbers of worker-consumer participants. Davis and Korenok (2011) employ 6 participants in a firm pricing game with automated consumer demand.

were calculated using median consumption and labor decisions:[9]

$$P_t = P_{t-1}\Pi_t,$$
$$W_t = P_{t-1}\Pi_t \left(N_t^{med}\right)^{\eta} \left(C_t^{med}\right)^{\sigma},$$

where gross inflation was given by

$$\Pi_t = 1 + \gamma^c(C_t^{med} - C^{SS}) + \gamma^n(N_t^{med} - N^{SS})$$

and $\gamma^c = 0.0016$ and $\gamma^n = 0.0744$. The median, rather than the average, of participants' labor and consumption decisions was implemented, given that the latter may be biased due to decisions that were not submitted on time or by extreme outliers. Participants submitted their maximum willingness to work and to buy output each period. They were able to work and purchase up to a maximum of 10 hours and 100 units respectively. After all decisions were submitted, the aggregate supply of labor (N_t^S=$\sum_{i=1}^{N} N_i^S$) and the aggregate demand for output (C_t^D=$\sum_{i=1}^{N} C_i^D$) were computed. Firms were able to produce only output that could be sold, implying no opportunity for inventories to be built or depleted. This resulted in one of three possible outcomes each period. If $C_t^D = ZN_t^S$, there was a sufficient supply of labor to produce all the output demanded and all participants worked and consumed the amount that they submitted. If $C_t^D < ZN_t^S$, implying an excess supply of labor relative to the amount of output demanded, firms hired only the hours necessary to produce the output demanded, namely $N_t^D = C_t^D/Z$. All participants received the units of output they requested but faced rationing of labor hours. Finally, if $C_t^D > ZN_t^S$, implying an excess demand for output relative to the amount of labor supplied, firms were unable to hire enough workers to satisfy demand and produced only a fraction of the output

[9] See the Appendix for a detailed derivation of the equations.

requested ($C_t^S = ZN_t^S$). Participants received the labor hours they requested but faced rationing of output.

A *priority* rationing rule was employed to allocate scarce hours and output. Priority for scarce hours was given to those participants willing to purchase the output associated with their supplied labor. Similarly, priority for scarce units of output was given to those willing to supply the necessary labor to produce the output. Participants who did not contribute to the excess supply of labor or demand for output received all the hours and output they requested. If there was an aggregate excess demand for output, participants who contributed to the excess demand by demanding more units of output than was consistent with their labor supply, initially received only the output produced by the labor hours they supplied. If excess units of output were available due to other participants over-supplying labor, they could receive a random allocation of the remaining units. Similarly, if there was an excess supply of labor, participants contributing to the excess obtained only the number of hours of labor consistent with their consumption decisions. If remaining units or hours were available because some participants choose to over-consume, those participants with unsatisfied demand would receive a random allocation of the remaining units. None of the participants ended up with more hours or output than they requested. The rationing scheme placed some control on the aggregate amount of money or debt that occur in the economy. In order for a participant to borrow (i.e., underwork relative to his consumption demands), another participant would be required to save (i.e., overwork).[10]

The computerized central bank followed a nonlinear nominal interest rate rule

[10] Fenig and Petersen (2016) compare aggregate outcomes under the priority rationing rule to those where participants were able to select from the pool of hours and output according to a random spot in a queue and to an equitable rationing rule that distributes the scarce units equally among participants. They find that the priority rationing rule is the most effective at generating stable and steady convergence to the competitive equilibrium.

that responded more than one-for-one with inflation. The monetary policy rule was given by

$$\frac{(1+i_t)}{(1+\rho)} = \left(\frac{1+i_{t-1}}{1+\rho}\right)^{\gamma} \left[(\Pi_t)^{\delta}\right]^{1-\gamma}. \tag{2}$$

where $\rho = 0.0363$, $\gamma = 0.5$ and $\delta = 1.5$. The interest rate was computed at the end of the period after inflation was determined from aggregate outcomes and could be positive or negative; that is, no zero lower bound was imposed. Thus, we design the supply of money to be perfectly elastic so that nominal interest rates are pinned down by the central bank's response function. Higher interest rates should incentivize subjects to save a greater proportion of their wealth in interest-bearing bonds and reduce their demand for output, which in turn, reduces inflation.

2.1 Treatments

We systematically varied features of the experimental environment described here in order to identify whether policies aimed at minimizing speculation had any effects on activity in the asset market or the production side of the economy. We discuss in detail below the treatments and provide a brief discussion of predictions; we lay out more formally our testable hypotheses in the following subsection. A summary of the experimental treatments can be found in Table 1.

Our Benchmark (B) treatment followed the experimental design described above. The purpose of this treatment was to understand how individual and aggregate decisions in a production economy would evolve over time. We expected that, with sufficient stationary repetition of the environment, participants would learn over time to form optimal consumption and labor decisions.

We extended the Benchmark treatment by introducing asset markets in three additional treatments. In these asset market treatments, participants received 10 nondivisible shares of an asset at the beginning of each sequence. Each share paid an exogenous and constant dividend of 0.035 units of lab money to its owner at the end of each round.[11] Bids and asks were submitted simultaneously, and the assets were traded through a uniform price call market, where a single market clearing price was determined by the intersection of traders' demand and supply curves. Traders with bids (asks) that were higher (lower) than the clearing price were able to trade at the market clearing price. Units of the asset held at the end of a sequence had zero redemption value. Employing a call market for the exchange of assets had two key benefits. It allowed us to conduct exchanges relatively faster than would have occurred under a continuous double auction and at a single market clearing price.[12]

The No-Intervention (NI) treatment introduced an asset market to the Benchmark environment in order to identify the impact of the asset market on individual and aggregate real outcomes. Under the assumption of identical preferences and information, and because the asset's dividend was not linked to economic fundamentals, we did not expect to observe assets trading above their fundamental value, nor did we expect the real side of the economy to be affected by the presence of the asset market. However, other motives may drive participants to trade the asset above its fundamental value (e.g., a preference for holding the asset as a store of value or the belief that others will want to buy the asset at a higher price in the future).

We also conducted two interventionist policies that modify the NI treatment in order to observe their effects on asset market activity and asset price volatility, as well as on labor and consumption decisions. In the Leverage Constraint (C) treatment,

[11] Our intention was to focus on the simplest asset market where the stream of dividends was constant and would create minimal wealth effects. We leave the endogenous dividend case for future research.

[12] Van Boening, Williams and LaMaster (1993) observe bubble-and-crash pattern found in markets with inexperienced investors, and the convergence toward fundamentals with experience in both double auctions and call markets. The key differences arise with experienced participants: Asset prices in call markets tend to have smaller absolute deviations from fundamental value but larger amplitudes. Similar findings are also obtained by Cason and Friedman (1997) and Haruvy, Lahav and Noussair (2007).

participants faced a leverage constraint which prevented them from borrowing for investment purposes. In order to purchase assets, participants were constrained to cover the purchase of assets in the current period out of balances carried over from the previous period, i.e., purchases could not be financed by income earned in the same period. Importantly, participants were nonetheless able to borrow freely for consumption purposes. Given that participants needed to acquire money by supplying costly labor or by earning interest on their savings, and that the dividend was quite small, we expected that the borrowing constraint would reduce trading activity in the asset market and produce smaller deviations in prices from fundamentals.

In the Asset Targeting (AT) treatment, the automated central bank adjusted nominal interest rates in response to both current inflation and asset price inflation according to the following policy rule:

$$\frac{(1+i_t)}{(1+\rho)} = \left(\frac{1+i_{t-1}}{1+\rho}\right)^{\gamma} \left[(\Pi_t)^{\delta} \left(\Pi_t^A\right)^{\alpha}\right]^{1-\gamma}, \tag{3}$$

where Π_t^A is the gross asset price inflation and $\alpha > 0$ represents the aggressiveness of the central bank when asset prices vary. In the experiment, we implemented $\alpha = 0.15$. As asset prices increased, the interest rate increased in lock-step, discouraging investors from borrowing for speculative purposes, and vice versa. The asset inflation target policy was expected to generate smaller deviations in asset prices from fundamentals and reduced asset price volatility. Participants were not explicitly informed about the central bank's additional response to asset price inflation but were instead told that the central bank responded to output price inflation when setting interest rates. This was done in order to avoid having participants invest speculatively simply to manipulate interest rates and the return on their savings.

The budget constraint of a participant in the asset market treatments included income from asset dividends as well as expenditures and income associated with buying and selling shares of the asset. In the NI and AT treatments, a participant's budget constraint was given by:

$$P_tC_t + B_t + Q_tX_t = (D + Q_t)\, X_{t-1} + (1 + i_{t-1})B_{t-1} + W_tN_t + \pi_t,$$

where Q_t is the market price of the asset, X_t is a subject's end-of-period holdings of assets, and D is the constant dividend paid out at the end of the period on each asset. In the C treatment, participants were restricted from borrowing in order to purchase units of the asset, and in this way they faced an additional cash-in-advance constraint: $Q_tX_t^D \leq B_{t-1}$.

2.2 Testable hypotheses

Our testable hypotheses originate from the predictions generated by a relatively standard New Keynesian framework, based on the assumption that participants behave as optimizing agents with rational expectations with respect to their non-stochastic environment. We divide hypotheses into two categories: Hypotheses related to asset markets and hypotheses related to individual behavior and the production economy.

2.2.1 Asset market hypotheses

In the No-Intervention treatment, the fundamental value of the asset is computed using the following intertemporal tradeoff condition for the asset from the representative household's optimization problem:

$$Q_t = \beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{(D + Q_{t+1})}{(1 + \pi_{t+1})} \right]. \tag{4}$$

Equation (4) states that expectations of future asset prices, inflation, and consumption growth influence current asset prices. Given that subjects knowingly interact in a non-stochastic environment, expectations of these variables should converge to their steady-state levels. Assuming that the economy remains at its steady state, we can derive a constant fundamental value that is simply the sum of all expected future dividends, i.e., $Q^* = 1$. However, given common knowledge of the dividend process and identically induced preferences and endowments, subjects have minimal incentives to trade the asset. We can then form the following hypotheses about asset trading and prices in all our asset market treatments:

Hypothesis 1 *Assets are not traded between subjects.*

Hypothesis 2 *If assets are traded, they will be traded at a price equal to the fundamental value.*

The steady state fundamental value of 1 is appropriate given the deterministic nature of the environment. However, it is possible that aggregate consumption may differ from the steady state predictions due to, for example, homegrown preferences and forecasting heuristics, or optimization errors. In that case, we compute the dynamic fundamental value as it is stated in Equation (4). Given that we do not elicit subjects' expectations of future variables in the course of the experiment we assume, for simplicity, that aggregate expectations are accurate and that they rationally set expected variables equal to their realized values.

Introducing a leverage constraint alters the household's optimization problem such that asset prices can be described by the following Euler equation:

$$Q_t = \beta E_t \left[\frac{C_{\mathrm{t+1}}^{-\sigma}(D + Q_{t+1})}{(C_t^{-\sigma} + \mu_t P_t)(1 + \pi_{t+1})} \right], \tag{5}$$

where $\mu_t > 0$ is the Lagrange multiplier associated with the leverage constraint. Note that Equation (5) implies that, all else equal, asset prices in the C treatment are predicted be lower than in the NI treatment when the leverage constraint binds.

Hypothesis 3 *A binding leverage constraint reduces the market price of assets, i.e.,* $Q_t^C < Q_t^{NI}$.

An asset price targeting monetary policy that involves raising nominal interest rates in response to asset price inflation will alter the central bank's ad-hoc policy function according to Equation (3). The equilibrium asset price equation (4) can be combined with the household's consumption Euler equation to obtain an alternative asset pricing equation that is a function of the nominal interest rate:

$$Q_t \approx E_t \left[\frac{D + Q_{t+1}}{1 + i_t} \right]. \tag{6}$$

As the automated central bank raises nominal interest rates in response to asset price inflation, participants have less incentive to borrow for speculation and the demand for bonds is predicted to increase, generating a downward pressure on asset prices. Expectations of future asset prices may also be dampened by the expectation of higher accompanying interest rates.[13] Thus, an asset targeting policy is predicted to keep asset prices relatively more stable than would occur were there no policy intervention.

Hypothesis 4 *Asset prices will be less volatile in the AT treatment than in the NI treatment,* $\sigma_Q^{AT} < \sigma_Q^{NI}$.[14]

2.2.2 Individual decisions, production and general equilibrium hypotheses

We now turn our attention to the real side of the economy and consider how asset markets and policy interventions influence production and output volatility.

[13] As subjects are not explicitly informed about the concurrent response of nominal interest to asset price inflation, the stabilization of subjects' asset price expectations depends on how quickly and effectively they come to understand this relationship on the basis of observing past data.

[14] σ_Q^{AT} and σ_Q^{NI} are the standard deviations of the asset price in the AT and NI treatments respectively.

The prediction is that the representative household will form output demand and labor supply decisions according to two optimality conditions. First, the Euler equation defines the intertemporal tradeoff which the household faces between two periods of consumption given the current nominal interest rate and the expected future inflation:

$$C_t^{-\sigma} = \beta E_t \left[C_{t+1}^{-\sigma} \frac{1+i_t}{1+\pi_{t+1}} \right]. \tag{7}$$

Second, the household equates the marginal rate of substitution between leisure and consumption to the real wage:

$$N_t^{\eta} / C_t^{-\sigma} = w_t. \tag{8}$$

Together with the assumption that the net household saving is zero, $B_t = 0$, the optimality conditions imply that the representative household supplies $N_{i,t} = N_i^{SS} = 2.24$ hours of labor and demands $C_{i,t} = C_i^{SS} = 22.4$ units of output each period in the non-stochastic environment.

Hypothesis 5 *All subjects supply* $N_{i,t} = N^{SS} = 2.24$ *hours of work and demand* $C_{i,t} = C^{SS} = 22.4$ *units of output, resulting in a total production of* $Y_t = Y^{SS} = 201.6$ *units. Consequently, no rationing will occur and output volatility will be zero.*

While the environment participants are interacting in what may appear complicated at first, we were confident they could learn to make optimal decisions over time. Subjects are given interactive tools to find their optimal decisions. The instructions explicitly indicate the steady state values of aggregate consumption and labor to ensure a better understanding of the simulated economy. The parameterization of the environment established a steep expected payoff hill in order to facilitate quick learning. The initial endowment of lab dollars is intended to provide subjects with initial resources to purchase output and assets in the first period of a repetition. Finally, and most importantly, stationary repetition which involves resetting cash and asset balances at the start of new sequences ensures that subjects will have an opportunity to learn the environment while mitigating the effects of past suboptimal play.

Our intuition is as follows: While asset trading can influence the balance of an individual's bank account and their optimal decisions, the aggregate economy in the NI treatment should remain unaffected by asset exchange. Following an exchange of assets, the buyer's bank account balance will fall while the seller's will increase. In response, their output demand and labor supply decisions should decrease and increase respectively. In the aggregate, the traders' decisions will offset each other, resulting in zero net change in aggregate production. This intuition yields our next hypothesis:

Hypothesis 6 *Introducing an asset market has no real effects on the aggregate economy in the NI treatment, i.e.,* $Y^B = Y^{NI}$.

We earlier hypothesized that a binding leverage constraint would lower asset prices relative to an environment with no policy interventions. However, participants who have a preference for speculating may respond to the prospect of a binding leverage constraint by increasing their labor supply above the steady state prediction. The household's intertemporal tradeoff of labor supply under a binding leverage constraint is given by:

$$N_t^{\eta}/w_t = \beta E_t[\frac{(N_{t+1}^{\eta}/w_{t+1}(1+i_t) + \mu_{t+1}P_{t+1})}{(1+\pi_{t+1})}], \tag{9}$$

Equilibrium labor supply increases with expectations of future binding leverage constraints.[15] Increasing one's own labor supply enables a participant to earn additional

[15]All else equal, the comparable NI Euler equation, $N_t^{\eta}/w_t = \beta E_t[\frac{(N_{t+1}^{\eta}/w_{t+1}(1+i_t))}{(1+\pi_{t+1})}]$, implies a relatively lower supply.

income to finance asset or output purchases. Given extensive experimental evidence that subjects will speculate in asset markets, we expect similar investment behavior in our environment. This leads us to three related hypotheses about the effect of leverage constraints on production:

Hypothesis 7a *The introduction of a leverage constraint increases aggregate labor supply, i.e.,* $N^C > N^{NI}$.

Hypothesis 7b *With sufficiently increased labor supply, the leverage constraint is relaxed and trading behavior is not significantly different from the NI treatment.*

Hypothesis 7c *With sufficiently increased labor supply, the leverage constraint is relaxed and asset price volatility is not significantly different from the NI treatment,* $\sigma_Q^C = \sigma_Q^{NI}$.

Changes in asset prices are expected to have sizeable effects on aggregate production in the AT treatment. If a trade occurs which raises the price of the asset, the nominal interest rate will increase in response to asset price inflation. Due to nominal rigidities, the real interest rate will rise, thereby lowering the optimal labor supply and output demands for the household which will result in lower aggregate production.

Hypothesis 8 *Fluctuations in asset prices will have a significant effect on aggregate production in the AT treatment.*

2.3 Procedures

The experiment was conducted at the University of British Columbia and at Simon Fraser University, where the participant pool consisted of undergraduate students recruited from a wide variety of disciplines. After 30 minutes of instructions and 10 minutes of practice, all participants interacted in the Benchmark treatment for at least 30 minutes in order to gain a thorough understanding of how to make labor and consumption decisions before we introduced an asset market. Once a sequence ended after the 30 minute mark, the inexperienced phase of the experiment was concluded and we commenced the experienced sequences. In the Benchmark sessions, participants continued to play in the same environment for the remaining available time (usually about 45 minutes). Participants in the asset market sessions were provided with additional instruction with respect to the asset market, and they then played for roughly an additional 60 minutes. Six sessions of each treatment were conducted: four sessions per treatment were conducted at University of British Columbia, and two sessions per treatment were conducted at Simon Fraser University (for a total of 24 sessions). Nine inexperienced participants interacted in each invited session.[16] Earnings, including a $5.00 show up fee, ranged from $5.00 to $45.38, and averaged $27.42. The experiment interface was programmed in zTree (Fischbacher (2007)).

Participants were provided with detailed instructions at the beginning of the experiment. Using clear, non-technical language, we explained how they would earn points by purchasing output and how they would lose points by working. We explained the way in which their wages and prices would change based on median labor and consumption decisions, and we emphasized that this would reduce the ability of individual participants to manipulate either market. The participants were also given qualitative instructions about the way in which the central bank would adjust nominal interest rates in response to output price inflation. Participants who did not wish to trade the asset were not required to submit an asset decision.

Understanding how to make optimal labor and consumption decisions can be challenging. In order to facilitate learning, we provided participants with an innovative

[16] In sessions NC1, NC6, and AT1 there were 8 participants.

interactive grid by way of the experimental software. Two markers on the screen denoted, respectively, the participant's own decision (represented as a red square), and the median decision of the group (represented as a green triangle), respectively. By clicking and moving the markers around the grid, participants quickly learned how aggregate decisions affected wages and prices in the economy, as well as their own payoffs. By presenting the payoff space to participants in a visual manner, we avoided having participants either search through numerous payoffs sheets or use a calculator to conduct a potentially limited search for optimal payoffs. Beginning in the second period of each sequence, participants also had access to tables allowing them to view both the history of their individual decisions and market outcomes. Participants in the asset market treatments were able to experiment with different trades which allowed them to observe hypothetical changes to their bank account balances. Importantly, as the subjects interacted with the interface, they quickly learned that their points would not change in response to their asset holdings.

3 Aggregate Findings

In this section, we summarize our findings across treatments. Our analysis focuses on experienced participants who had interacted in the Benchmark economy for at least two sequences. The data from the experienced sequences are treated as one time series, unless otherwise noted.

3.1 Asset markets

Figure 1 presents the path of asset prices of the experienced sessions.[17] Visual inspection of the asset price data indicates that assets are frequently traded – usually above the constant fundamental value. On average, and consistently across treatments, 62%−65% of the time subjects are willing to engage in trade by submitting bids or asks. Wilcoxon signed-rank tests reject the null hypothesis (Hypothesis 1) that the session-mean willingness to trade among all subjects is zero. ($N = 5$ per treatment, $p < 0.043$ for all treatments).

For each of the five non-outlier sessions of the NI, C, and AT treatments, we compute the mean trading price. In the No-Intervention treatment, the mean price is 2.31 (s.d. 0.12). The introduction of a leverage constraint in the C treatment increases the mean price to 5.46 (s.d. 0.29), while an asset price targeting monetary policy increases the mean price to 3.27 (s.d. 0.15). Signed rank tests reject the null hypothesis (Hypothesis 1) that the mean asset price equals the constant fundamental value of 1 ($N = 5$, $p = 0.043$ for all treatments). We also consider the possibility that asset prices track the dynamic fundamental value. For each session, we compute the mean period deviation of prices from the dynamic fundamental value and conduct signed rank tests to determine whether the values are different from zero. The mean deviation is 0.003 (s.d. 0.005, $p = 0.686$) in the NI treatment, 0.28 (s.d. 0.01, $p = 0.043$) in the C treatment, and 0.08 (s.d. 0.004, $p = 0.043$) in the AT treatment.

Finding 1 *Observed mean asset prices are significantly different from the constant fundamental value in all three asset market treatments, and significantly different from the dynamic fundamental value in the C and AT treatments.*

[17] Each asset market treatment possessed a significant outlier with extremely high prices (NC5, C1, and AT1). To better see the differences in asset prices across treatments, we remove these outliers for all analysis presented here. An identical figure—and results from all empirical tests—which includes the outliers session can be found in the Appendix. For reference, in the Appendix we plot the asset prices and trading volume for each session.

Table 2 reports measures of trading activity and mispricing at the session-level with mean and standard deviation statistics. Panel A considers asset price statistics in levels. Two-sided Wilcoxon rank-sum tests are conducted with session-mean measures to identify any differences in distribution across treatments, with the associated p-values presented at the bottom of each table. Figure 3 presents box-plots of session-level statistics. We also provide an identical table and figure that includes outlier sessions in the Appendix.

Given that participants were paid primarily on the basis of their consumption and labor decisions, it seemed reasonable to expect minimal trading activity in the asset market (Hypothesis 1). Our results indicate that this was not the case. In all sessions we observed considerable asset trading. Turnover of the asset between traders is computed as $T = \sum_t V_t/S$, where V is the total volume of trade and S is the total stock of outstanding assets in the market. We observe little difference in turnover across treatments. Mean turnover ranges from 0.72 in the C treatment to 0.80 in the AT treatment, with the differences across treatments not statistically significant ($p > 0.75$ for all treatment comparisons using two-sided Wilcoxon rank sum tests).

We hypothesized that the introduction of a leverage constraint in the C treatment would reduce the market value of bids relative to the NI treatment because the asset price would be lower if the constraint were binding (Hypothesis 3). For each session, we calculate the average market value of all bids (measured as bid price times quantity demanded). A two-sided Wilcoxon rank sum test fails to reject the null hypothesis that the distribution of mean market value of bids are identical ($N = 5$, $p = 0.347$) in the two treatments. Neither the bid prices nor the quantities being demanded differ significantly across the treatments. We obtain a comparable result for the mean market value of asks.

We use a variety of measures to assess whether the leverage constraint and asset-price inflation targeting policies influenced asset price deviations. We first consider the amplitude of the asset price deviation which is measured as the trough-to-peak change in the market asset price relative to its fundamental value. The amplitude is computed as $A = \frac{max_t(P_t - f_t) - min_t(P_t - f_t)}{E}$, where P_t is the market-clearing price of the asset in period t and E is the expected dividend value over the lifetime of the asset. The average amplitude in the NI treatment is 5.15 (s.d. 1.96) under the steady state calculation of the FV and 4.59 (s.d. 1.75) under the dynamic FV calculation. The measures of amplitude increase in the C treatment to 11.81 (s.d. 6.49) and 17.31 (s.d. 10.80) under both amplitude measures ($p = 0.08$ in both cases). The amplitudes in the AT treatment reach 9.56 (s.d. 1.30) and 12.25 (s.d. 3.51) under the constant and dynamic FV measures. Amplitudes in the AT treatment are significantly higher than in the NI treatment under both specifications of the fundamental value ($p = 0.01$ in both cases). Weighting the amplitude by the volume of trade, we compute the market value amplitude as $M = \frac{max_t((P_t - f_t)V_t)}{E}$. The mean market value amplitude is higher in both intervention treatments than in the baseline asset market environment, and significantly higher in the AT treatment.

The relative asset deviation measures the degree of mispricing in asset market experiments weighted by the number of periods of potential trade (see Stöckl, Huber and Kirchler (2010) for details). We compute this as $RAD = \frac{1}{T}\sum_{t=1}^{T} \frac{|P_t - f_t|}{f_t}$, where T is the total number of periods in the asset market. The average RAD under a constant fundamental value in the NI treatment was 1.79 (s.d. 1.33). Mean RAD in the C and AT treatments are 4.70 (s.d. 2.48) and 2.30 (s.d. 0.92), respectively. The differences in RAD across the NI and C treatments are statistically significant at the 5%. Our results are qualitatively similar when we consider the dynamic fundamental value measure of RAD.

Finally, we consider how volatility in asset markets may change in response to the policy interventions. We calculate the realized volatility of the asset prices as the standard deviation of the asset's log returns. The price of the asset in a period with no trade is set equal to the last trading price. We find that neither policy leads to significant changes in asset price volatility. While volatility falls from 0.33 in the NI treatment to 0.29 in the C and rises to 0.35 in the AT treatments, the treatment differences are not statistically significant ($p \geq 0.75$ in both pairwise comparisons).[18] Our results reject our null hypothesis (Hypothesis 4) that asset prices are less volatile under the AT policy. We do, however, find support for Hypothesis 7c where, due to increased labor supply, leverage constraints do not frequently bind in the C treatment and we should not observe a significant difference in asset price volatility.

Panel B of Table 2 reports asset price statistics controlling for total wealth in bonds.[19] We find that our results remain intact qualitatively when we control for the supply of wealth in bonds. Amplitudes are still significantly higher in the C and AT treatments relative to the NI. We also observe that market value amplitudes and relative absolute deviations from fundamental value are mostly higher in the C and AT treatments. The relative absolute deviation of the C treatment is now no longer significantly larger than in the NI treatment. This finding suggests that some of the persistence in deviations from fundamental value in the C treatment can be attributed to the growing stock of wealth.

Finding 2 *Compared to a no-intervention environment, imposing leverage constraints*

[18] Computing asset price volatility as the standard deviation of log returns for periods with only positive trade does not change our general results.

[19] Define $B_t = \sum_i B_{i,t-1}$ as the sum of all wealth held in bonds in each experimental session at period t. We compute the Asset Price-to-Cash Ratio $APCR_t = \frac{P_t}{B_t}$ as the asset price that emerged at the end of the period dividend by the total sum of wealth held in bonds at the beginning of the period. The turnover to cash ratio is computed as $\sum_t \frac{V_t}{B_t}/S$. The modified amplitude calculation is computed as $A = \frac{max_t(\frac{P_t - f_t}{B_t}) - min_t(\frac{P_t - f_t}{B_t})}{E}$. The RAD to cash ratio is calculated as $\frac{1}{T}\sum_{t=1}^{T}\frac{|P_t - f_t|}{B_t f_t}$. Finally, the modified volatility measure is computed as the standard deviation of the log return of the $APCR$.

or asset price targeting generates larger asset price amplitudes and deviations of asset prices from fundamental value. The policy interventions do not significantly affect asset price volatility.

The representative agent model predicts that asset prices decrease in the presence of a binding leverage constraint or where monetary policy is more aggressive in response to asset prices (see the discussion related to Hypotheses 3 and 4). We test both these predictions using panel data from our asset market treatments. We employ a generalized least squares (GLS) estimation strategy that corrects for heteroskedasticity and autocorrelation in errors. Our most basic specification is based on the intertemporal asset price equation given in Equation (4):

$$logQ_{j,t} = \alpha + \beta_1 E_{j,t} log\left(\frac{Y_{j,t+1}}{Y_{j,t}}\right) + \beta_2 E_{j,t} logQ_{j,t+1} + \beta_3 E_{j,t} log(1+\pi_{j,t+1}) + \epsilon_{j,t}, \quad (10)$$

where j denotes the session, $Y_{j,t}$ is the level of production in period t,[20] and $\epsilon_{j,t}$ is a session-specific error term. We replace consumption with production in our regression specification to account for the fact that we have implemented a non-representative framework where individual output demand is not always equal to realized consumption. This specification seeks to identify whether asset prices are consistently influenced by expectations of future asset prices, current and future production, and expected future inflation. Given that we did not elicit expectations from our subjects in the course of our experiment, we proxy for expected future variables using two approaches. We first assume aggregate expectations are rational and equal to the next period's realized outcome (e.g., $E_{j,t}logQ_{j,t+1} = logQ_{j,t+1}$), and, second, we assume subjects form naïve expectations equal to the outcome realized in the prior period (e.g., $E_{j,t}logQ_{j,t+1} = logQ_{j,t-1}$).

Our second treatment specification considers the effects of binding borrowing con-

[20]Production is adjusted for the number of subjects that submitted their decisions on time.

straints on asset prices and is motivated by Equation (5). To capture the degree of binding budget constraints, we introduce an additional variable—$PercEnteringWithDebt_t$—which is the share of subjects entering the period with debt. Equation (5) predicts that binding leverage constraints reduce asset prices. Thus, according to our model, the percentage of subjects entering a period with debt should only have a significant negative effect on asset prices in the C treatment where indebted subjects would be barred from purchasing assets. By contrast, leverage constraints in the NI and AT treatments do not bind and should not have a quantitative effect on asset prices.

Our final specification considers the effect of nominal interest rates on asset prices. Motivated by Equation (6), we estimate the following equation:

$$logQ_{j,t} = \alpha + \beta_1 E_{j,t} logQ_{j,t+1} + \beta_2 log(1 + i_{j,t+1}) + \epsilon_{j,t}$$

where $i_{j,t}$ is the net nominal interest rate in period t. As discussed in Section 2.2, increases in the concurrent nominal interest rates are predicted to have a contractionary effect on asset prices. In our experiment, subjects do not observe the current period's interest rate when making their real and investment decisions. As in our earlier specifications, we assume subjects either form rational or naïve expectations about the nominal interest rate for the current period. We have no a priori reason to expect any difference in the response of the asset price to a one-unit change in the nominal interest rate across the NI and C treatments. In the AT treatment, nominal interest rates do react positively to asset price inflation; rather, they are predicted to generate a stronger contractionary effect on asset prices.

We focus our discussion in the text on the estimated specifications involving naïve expectations as it performs better in the vast majority of cases.[21] Our estimation re-

[21] The goodness of fit measure χ^2 is higher when we assume naïve expectations in 33 out of 36 estimations.

sults are presented in Panel A of Table 3, where we study each asset market treatment in isolation under the assumption of naïve expectations.[22] We also consider a second set of specifications where we control for the quantity of money in the economy. We focus on the asset price to cash ratio, Q_t/M_t, where M_t is the total money balances held at the beginning of period t. These additional results are presented in Panel B of the same table.

We begin our analysis with the NI treatment. Across all of our specifications, we observe that asset prices are have a strong positive correlation with lagged asset prices. Asset prices increase between 0.85 and 0.86 percent for every one percent increase in lagged asset prices, suggesting that asset prices exhibit strong serial correlation. This correlation becomes even stronger when we control for the quantity of money in the system. Expected future growth in production has a negative albeit inconsistent effect on asset prices in most NI specifications. Expected inflation (measured as period $t-1$ inflation) has a sizeable positive effect on the price of assets—which is inconsistent with our theoretical predictions which suggest that as inflation, and subsequently interest rates rise, agents should be seeking to invest relatively more in bonds. In Specification (2), we consider the effect of the proportion of indebted subjects on asset prices. In line with our predictions, an increased proportion of indebted subjects has no effect on asset prices in the NI treatment. In Specification (3), we consider the effect of nominal interest rates on asset prices. Higher nominal interest rates generate large and significant positive effects on asset prices contrary to our assumption that our subjects would subject expectations with respect to nominal interest rates. That is, contractionary monetary policy stimulates asset prices. However, when we control for the total amount of money (and debt) held by participants, this expansionary effect is eliminated, which suggests that contractionary monetary policy fuels asset

[22] A comparable set of tables involving rational expectations can be found in the Appendix. Our results are unchanged when we include all asset market sessions.

price inflation by increasing the supply of money in the economy.

Next we consider asset price dynamics in the C treatment. Consistent with the NI treatment, we observe significantly high serial correlation of asset prices in all of our specifications. In Specification (1), under the assumption of naïve expectations, we see that larger prior economic growth generates large and significant increases in asset prices. A 10% increase in production growth in the prior period increases asset prices by 3%. This effect rises to nearly 5% when we instead consider the asset price-to-cash ratio. In Specification (2) we find that the proportion of indebted subjects (i.e., those who are unable to purchase assets) does not have a consistent effect on asset prices. That is, the leverage constraint that restricts the participation of indebted subjects does not appear to play a clear role in stabilizing asset prices. Specification (3) shows that contractionary monetary policy in the previous period has a sizeable positive but inconsistent effect on current asset prices. However, when we instead consider the asset price-to-cash ratio, we find that asset prices decrease by 0.85% in response to a 1% increase in the past gross nominal interest rate. This finding is consistent with the fact that the quantity of wealth in the system grows positively with nominal interest rates.

Finally, we consider asset prices in our AT treatment. As in the other asset market treatments, asset prices exhibit a very high degree of serial correlation regardless of whether we control for the money supply. Lagged production growth significantly increases asset prices. When we control for the economy's money supply, past production growth has a much smaller and more inconsistent effect on asset prices, suggesting that past growth increases wealth which in turn can be used for future investment. The share of indebted subjects also does not have any significant or quantitative effect on asset prices. However, in Specification (3) we find that higher lagged nominal interest rates have quite a large and significant contractionary effect on asset prices.

For a 1% increase in lagged gross nominal interest rates, asset prices decrease by roughly 2.6%. Likewise, the asset price-to-cash ratio decreases by roughly 3%. These findings suggest that lagged contractionary policy is highly effective at stabilizing asset prices in the AT treatment. Put another way, recently low interest rates fuel large asset price increases.

Finding 3 *Contrary to our predictions, asset prices do not consistently decrease as a larger share of indebted participants are unable to borrow for speculation due to leverage constraints.*

Finding 4 *Asset prices contract significantly in response to higher interest rates when the central bank responds aggressively to asset price inflation.*

3.2 Production

In this section, we discuss findings associated with individual labor supply, output demand, and aggregate production from play during the experienced-subject phase of the experiment. Summary statistics computed at the session-level for each treatment are presented in Table 4. The distributions of labor supply and output demand decisions are presented in Figure 4 for each treatment where the dashed vertical line labeled SS refers to the steady state predicted individual labor supply of 2.24 hours and output demand of 22.4 units. In the Benchmark (B) treatment, the median labor supply is 2.3 hours. Introducing an asset market into the economy in the NI treatment reduces the labor supply for the bottom half of the distribution and median labor supply decreases to 2 hours. When a leverage constraint is imposed on subjects in the C treatment, labor supply increases relative to the NI treatment across the entire distribution and median labor supply rises to 2.5 hours. Finally, in the AT treatment, median labor supply is 2.3, with its distribution relatively more centered around the steady state prediction than under the NI treatment. Mean labor supply, measured at the session-level, is not significantly different from the steady state prediction in the NI and AT treatments (signed-rank test, $p > 0.68$ in both cases), but is significantly greater in the B treatment ($p = 0.075$) and C treatment ($p = 0.049$). Session-level mean labor supplies do not differ significantly across treatments.

Output demands, by contrast, are significantly greater than the steady state predictions in all treatments. Median output demand is 40 units in the B treatment. Introducing asset markets and leverage constraints in the NI and C treatments decreases the output demands across the majority of the distribution and we observe quite large decreases in the number of participants demanding high levels of output. Median output demands decrease to 30 and 35 units in the NI and C treatments respectively. The median output demand is 40 units in the AT treatment. Mean output demands follow a similar pattern. Signed rank sum tests reject the null hypothesis that mean output demands, measured at the session-level, are identical to the steady state prediction ($p < 0.05$ in all treatments). Session-level mean output demands also do not differ significantly across most treatment comparisons.[23]

While our findings do not support Hypothesis 5—that subjects identically choose the steady state levels of labor supply and output—the differences in results with respect to labor supply and output demand reveal an important insight. While every period of play involves some rationing, we observe that the majority of rationing takes place in the output market. Labor rationing occurs most frequently in the C treatment in approximately 17% of experienced-subject periods while it never occurs in the experienced periods of the AT treatment.

As a result, production is usually determined by subjects' labor supply. Mean production is 242.24 units in the B treatment but is not significantly different from the steady state prediction at the 10% level ($p = 0.116$). In the NI treatment, mean

[23]Session-level mean labor supply in the C treatment is significantly higher than in the AT treatment ($p = 0.028$).

production falls to 206.50 units and is not significantly different from either the steady state prediction or the baseline economy with no asset market. Thus, our evidence is in favor of Hypothesis 6—that the introduction of an asset market has no significant effect on aggregate production. The imposition of the leverage constraint in the C treatment results in a mean production of 237.80 units which is significantly higher than the steady state prediction. Finally, under the asset inflation targeting policy in the AT treatment, mean production is very close to the prediction at 205.50 units.

Output volatility is significantly greater than predicted by the non-stochastic model and signed-rank tests consistently reject the null hypothesis that output volatility is zero ($p < 0.05$ in all treatments). Output volatility is the lowest in the C treatment at 0.11, and the highest in the B and NI treatments at 0.17. Output volatility in the C treatment is also significantly lower than in the NI treatment (p =0.016). We attribute the increased and stable labor supply in the C treatment to increased precautionary saving motives due to the potentially-binding leverage constraint. We also observe a reduction in output volatility in the AT treatment, though the differences are not significant at the 10% level.

Nominal interest rates are governed by output price inflation in the B, NI, and C treatments and, additionally, by asset price inflation in the AT treatment. Nominal interest rates are significantly higher than the steady state prediction in the C treatment where we observe significant production and, consequently, inflation, with an average session-mean of 0.08. By contrast, mean nominal interest rates are the lowest in the NI and AT treatment at 0.034 and 0.032 respectively. It is important to note that there exists considerably greater heterogeneity in nominal interest rates in the NI treatment while interest rates are more tightly distributed around the steady state prediction in the AT treatment.[24] Figure 5 plots the median nominal interest

[24] Session mean interest rates measured over the entirety of the experienced-subject periods range from -0.04 to 0.09 in the NI treatment and 0.008 to 0.04 in the AT treatment. During the first 4

rate over all experienced-subject repetitions of each session for the first ten periods. Nominal interest rates are consistently lower at the start of the AT sequences due to the structure of the monetary policy rule. In responding to asset price inflation, the rule places relatively less weight on output price inflation. Despite insignificant differences in aggregate labor supplies (and subsequent levels of production and output price inflation), nominal interest rates are considerably higher in some sessions of the NI because the central bank responds more aggressively to output price inflation.

Finding 5 *In support of Hypotheses 6, mean labor supply and output demands are not significantly affected by the introduction of an asset market in the NI treatment.*

Finding 6 *In support of Hypothesis 7a, leverage constraints increase labor supply and also considerably increase the frequency of labor rationing relative to that observed in the NI treatment. Production volatility is significantly lower with leverage constraints in place as workers more consistently supply labor from one period to the next.*

Finding 7 *Asset inflation targeting policies slightly reduce average labor supply and lead to large increases in average output demands relative to that observed in the NI treatment. Average production is not significantly affected by the policy.*

While there is considerable heterogeneity among the decisions made by the participants, the labor supply and output demand of the median participants indicates a weak convergence to the competitive equilibrium. Figures 6.a and 6.b present session-level averages of the (per-period) median labor supply and output demand per sequence for each treatment. Unlike output demand, labor supply converges to the steady state value in most of the sessions.[25] Figures 6.c and 6.d show the analysis for individual choices on labor supply and output demand, distinguishing

periods of each experienced repetition, the session mean interest rates range from -0.035 to 0.092 in the NI treatment and 0.004 to 0.032 in the AT treatment.

[25]Detailed outcomes for each session can be found in the Appendix.

between inexperienced-subject and experienced-subject sequences. A similar pattern is observed as labor supply converges to the predicted values for experienced participants.[26]

We next investigate the determinants of the decisions made by participants with respect to labor supply using our rich panel-level data in our asset market treatments.[27] Individual-level data is important to explore as it can shed light on where heterogeneous behavior may arise and influence our aggregate results. We focus on labor supply decisions, rather than on output demand decisions, as these form the key determinant of production in most periods. Our key estimating equations are motivated by the equilibrium inter-and intra-temporal equations (7) and (8) which govern optimal behavior presented in Section 2.2. In addition to the standard determinants of labor supply (expected wage growth, output demand, gross interest rates, and expected inflation), we also control for past labor supply, bank account balances at the beginning of the period, the expected future asset price, the number of assets held, and finally, whether a subject concurrently submitted a bid or ask in the asset market. Subjects are assumed to forecast period $t+1$ wage growth and asset prices naïvely using period $t-1$ realized values. To identify differential responses to each of these explanatory variables across treatments, we include treatment-specific fixed effects and interactions with treatment-specific dummies. We fit our panel data using feasible generalized least squares that corrects for the presence of AR(1) autocorrelation within panels and heteroskedasticity across panels.

Table 5 reports our stratified regression results, where estimated labor supply

[26]To verify whether labor supply and output demand converge to the competitive equilibrium, we follow the econometric procedure proposed by Duffy (Forthcoming). In all sessions weak convergence is obtained for both labor supply and output demand. However, in the case of labor supply, strong convergence is observed in three sessions of the Benchmark, one session of the NI and C, and four sessions of the AT treatments. There is no evidence of strong convergence for the output demand in any of the sessions. The procedure and estimations can be found in the Appendix.

[27]A comprehensive set of regressions involving results from all session are presented in our Appendix.

responses for subjects with positive and negative bank account balances are presented in Specifications (1) and (2) respectively. First, we note that after introducing all of our controls, average labor supply in the two intervention treatments is significantly higher than in the NI treatment by between 0.28 and 0.51 hours. We also note that labor supply has a high and positive serial correlation in all treatments in all treatments. The exception to this correlation is among indebted subjects who, faced with leverage constraints, do not base their labor supply decisions to any significant extent on past decisions.

Labor supply decisions made by subjects who chose to save in the NI treatment respond predictably to many of our explanatory variables. Labor supply responds positively to concurrent output demand and negatively to expected future wage growth and growing bank account balances. Contrary to the predictions proposed by our model, savers had an unexpected response to nominal interest rates and expected inflation. Where our model predicts that the substitution effect dominates labor supply decisions, we find a stronger income effect associated with rising nominal interest rates. NI subjects decreased their labor supply on average 3% in light of a 10% increase in lagged gross nominal interest rates. We also observe subjects responding to expected future inflation by supplying more labor. Both of these labor supply responses are highly heterogeneous across subjects and are not deemed to be statistically significant. Most of our additional asset market controls do not appear to play an important role in shaping labor supply decisions. In particular, lagged asset prices have a negligible positive effect on labor supply decisions. Similarly, traders who are offering to sell their assets concurrently will increase their labor supply by a modest 0.03 additional hours. The labor supply decisions of indebted NI subjects exhibit a noisier response to most of our explanatory variables. Compared to subjects identified as savers, the labor supply of indebted subjects reacts more positively to higher recent nominal interest rates, likely in an effort to avoid further interest costs.

Subjects identified as savers in both of the policy intervention treatments increase their labor supply in response to expected wage growth at a significantly more than their NI counterparts, and they are significantly less responsive to their own concurrent output demands. These same subjects, on average, also increase their labor supply in response to rising past nominal interest rates, with C savers exhibiting a highly significant substitution effect—a 1% increase in the gross nominal interest rate results in C savers increasing their labor supply by nearly 2.4%. Initial bank account balances have little influence on the labor supply decisions of C savers, decisions which are not significantly different from those made by the AT savers. Similarly, asset market balances, prices, or trading decisions do not seem to play a consequential role in the labor supply decisions of savers in the C treatment. The labor supply decisions of the AT savers are significantly less responsive to asset prices than compared to their NI counterparts; their labor supply decreases modestly as asset prices rise. The response by indebted subjects to our explanatory variables in both the C and AT treatments is noisy; we do not observe any noteworthy differences in the behavior of these subjects in any of the treatments.

Finding 8 *All else equal, labor supplies are higher in the presence of a binding leverage constraint. Savers in the C treatment substitute in favor of supplying more labor as nominal interest rates rise.*

Finding 9 *All else being equal, labor supplies are higher in the presence of an asset price targeting policy. Savers in the AT treatment substitute in favor of supplying more labor as nominal interest rates rise.*

4 Discussion

We have presented the results of a novel laboratory experiment that explores the interaction of an asset market in a macroeconomic setting. The experiment extends the popular partial equilibrium asset market environment by allowing for activity in the asset market to influence macroeconomic outcomes and vice versa. Such an environment provides a more robust platform from which to study the implications of macroeconomic policies on individual and aggregate decisions.

We observe that aggregate production is not significantly influenced by the presence of the asset market in our No-Intervention treatment. Moreover, the real side of the economy is, expectedly, unresponsive to changes in asset prices. Our participants are not willing to work considerably more in order to trade an asset with only a modest value if they can borrow in order to speculate. In fact, for much of the distribution of decisions, we observe lower labor supplies when participants have the opportunity to participate in an asset market. Imposing leverage constraints, however, leads to significantly greater labor supply and production, and significantly less volatility in production, as participants deem it necessary to maintain sufficient bank account balances in order to participate in the asset market. Such precautionary saving and debt aversion has also been documented in a laboratory setting by Meissner (2016). As wealth accumulates from increased labor supply, more money is directed into the asset market and asset price deviations from fundamental value become significantly larger and more persistent. Our results complement experimental findings by Caginalp, Porter and Smith (2000) and Haruvy and Noussair (2006), who find that increasing the cash-to-asset ratios in partial equilibrium asset markets increases asset prices and mispricing. In our Leverage Constraint treatment, we prevent subjects from borrowing to speculate in an effort to reduce the cash-to-asset ratio. Subjects in this treatment circumvent potentially binding leverage constraints by working additional costly hours.

We also observe larger asset price amplitudes when the automated central bank targets asset price inflation in its policy rule. This is a consequence of the relatively low interest rate response to output price inflation in the early periods of subjects' lifecycle. Low interest rates create a greater incentive to speculate and generate larger asset price deviations. But, unlike under the leverage constraint policy, asset prices are quickly deflated by rapidly rising interest rates.

Asset price targeting leads to an unintended effect: It enhances the salience and effectiveness of monetary policy. Past contractionary monetary policy that targets asset price inflation is significantly more effective at stabilizing asset prices and labor supply decisions. In this experiment, participants have access to a large set of relevant information about the state of the economy but have limited time to process and submit their decisions. The lack of participant responsiveness to monetary policy in our Benchmark and NI treatments can be related to costs associated with processing and reacting to information, which have been explored in the rational inattention literature. For example, Sims (2003) and Moscarini (2004) assume that agents have limited capacity to process information. In this experiment the information processing cost is mitigated when changes in monetary policy are made more salient by way of more dramatic adjustments, as in the case of the AT treatment.

We have demonstrated that implementing an experimental macroeconomy in the laboratory is feasible. Utilizing appropriate tools, such as automation and visual aids, an experimenter can design an experiment that involves considerable stationary repetition and learning in a reasonable time frame. Our design and results provide a springboard for further experimental research on the effects of macroeconomic mechanisms and policies on individual and market behavior. The environment we devised can easily be expanded to include interaction with additional markets at the expense of less stationary repetition. A natural extension would be to implement a financial accelerator mechanism where macroeconomic cycles are amplified through financial market conditions. Aggregate or idiosyncratic shocks can be incorporated to study behavioral responses and their implied macroeconomic dynamics. One could also consider varying the communication, credibility, and timing of the introduction of policy. Such experimentation can provide potentially useful causal evidence to support the development of further policy and theory.

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Tables and Figures

Table 1: Experimental Treatments

Treatment	Number of Sessions	Asset Market	Borrowing Constraint	Asset Targeting
B	6	No	No	No
NI	6	Yes	No	No
C	6	Yes	Yes	No
AT	6	Yes	No	Yes

Table 2: Session-Level Statistics on Asset Market Variables[I]

Panel A: Statistics in Levels

Treatment	Statistic	Turnover	Ampl. S.S.	Ampl. Dynamic	MV Ampl. S.S.	MV Ampl. Dynamic	RAD S.S.	RAD Dynamic	Volatility
NI	mean	0.77	5.15	4.59	27.72	5.88	1.79	0.51	0.33
	s.d.	0.36	1.96	1.75	23.78	4.03	1.33	0.17	0.10
C	mean	0.72	11.81	17.31	41.45	29.32	4.70	1.19	0.29
	s.d.	0.41	6.49	10.80	49.86	40.51	2.48	0.73	0.13
AT	mean	0.80	9.56	12.25	45.41	18.20	2.30	0.82	0.35
	s.d.	0.37	1.30	3.51	36.50	8.70	0.92	0.51	0.13
NI vs. C	p-value	0.83	0.08	0.08	0.60	0.35	0.05	0.07	0.75
NI vs. AT	p-value	0.75	0.01	0.01	0.35	0.02	0.35	0.17	0.92
C vs. AT	p-value	0.60	0.92	0.60	0.92	0.60	0.17	0.46	0.60

Panel B: Statistics Controlling for Total Wealth in Bonds

Treatment	Statistic	Turnover	Ampl. S.S.	Ampl. Dynamic	MV Ampl. S.S.	MV Ampl. Dynamic	RAD S.S.	RAD Dynamic	Volatility
NI	mean	0.01	0.05	0.03	0.22	0.05	0.01	0.00	0.33
	s.d.	0.00	0.02	0.01	0.19	0.03	0.01	0.00	0.09
C	mean	0.00	0.08	0.10	0.23	0.04	0.02	0.01	0.28
	s.d.	0.00	0.04	0.06	0.22	0.05	0.01	0.01	0.12
AT	mean	0.00	0.08	0.09	0.40	0.14	0.02	0.01	0.36
	s.d.	0.00	0.02	0.03	0.38	0.11	0.01	0.01	0.14
NI vs. C	p-value	0.12	0.08	0.03	0.75	0.92	0.25	0.17	0.92
NI vs. AT	p-value	0.92	0.05	0.01	0.25	0.12	0.35	0.60	0.46
C vs. AT	p-value	0.17	0.75	0.92	0.60	0.05	0.75	0.75	0.35

(I) This table presents session-level statistics on asset market variables. N=5 for each asset market treatment where outlier sessions NC5, C1, and AT1 are removed from the analysis. Turnover measures the trading activity in the market by the total volume of trade divided by the total outstanding stock in the experiment and the number of periods. Amplitude measures the trough-to-peak change in market asset value relative to fundamental value. Market value amplitude measures the normalized market value of trade by weighting period amplitude by the volume of trade. RAD is the relative absolute deviation of asset prices from fundamentals, weighted by the number of periods of trade. Volatility measures the historical volatility of the log-returns. Outlier session (NI5, C1, AT1) are removed from the dataset.

Table 3: Asset Prices - By Treatment[I]

	Naïve Expectations								
	NI Treatment			C Treatment			AT Treatment		
Dep.Var.: $logQ_{j,t}$	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
$log\left(\frac{Y_{j,t-1}}{Y_{j,t-2}}\right)$	-0.144	-0.147		0.305**	0.306**		0.322**	0.319*	
	(0.17)	(0.17)		(0.15)	(0.15)		(0.16)	(0.17)	
$logQ_{j,t-1}$	0.861***	0.858***	0.851***	0.946***	0.944***	0.935***	0.905***	0.898***	0.910***
	(0.04)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
$log(1+\pi_{j,t-1})$	1.453**	1.467**		0.448	0.450		-2.427**	-2.462**	
	(0.63)	(0.66)		(0.49)	(0.57)		(1.17)	(1.19)	
$PercEnteringWithDebt_{j,t}$		-0.006			0.001			0.012	
		(0.13)			(0.12)			(0.12)	
$log(1+i_{j,t-1})$			1.226**			0.442			-2.646***
			(0.51)			(0.43)			(0.69)
α	0.146***	0.149***	0.113***	0.065*	0.067*	0.066	0.076**	0.084**	0.153***
	(0.04)	(0.06)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)
N	168	168	168	213	213	213	244	244	244
N_g	5	5	5	5	5	5	5	5	5
χ^2	802.8	768.3	805.7	2121.4	2052.2	1755.5	1240.0	1118.8	988.6

	Naïve Expectations: Controlling for Cash Balances								
	NI Treatment			C Treatment			AT Treatment		
Dep.Var.: $logQ_{j,t}/B_{j,t}$	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
$log\left(\frac{Y_{j,t-1}}{Y_{j,t-2}}\right)$	0.053	0.060		0.474***	0.475***		0.276	0.271	
	(0.19)	(0.19)		(0.18)	(0.18)		(0.17)	(0.18)	
$log\left(\frac{Q_{j,t-1}}{B_{j,t-1}}\right)$	0.899***	0.904***	0.898***	0.976***	0.975***	0.973***	0.935***	0.931***	0.934***
	(0.04)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
$log(1+\pi_{j,t-1})$	-0.526	-0.616		-0.971*	-0.965		-3.416***	-3.420***	
	(0.59)	(0.61)		(0.56)	(0.63)		(1.29)	(1.32)	
$PercEnteringWithDebt_{j,t}$		-0.086			-0.004			-0.034	
		(0.15)			(0.13)			(0.14)	
$log(1+i_{j,t-1})$			-0.464			-0.848*			-3.046***
			(0.44)			(0.46)			(0.75)
α	-0.447***	-0.395**	-0.434***	-0.159***	-0.164***	-0.136**	-0.330***	-0.340***	-0.240**
	(0.15)	(0.18)	(0.16)	(0.06)	(0.06)	(0.06)	(0.09)	(0.10)	(0.10)
N	168	168	168	213	213	213	244	244	244
N_g	5	5	5	5	5	5	5	5	5
χ^2	581.3	579.8	582.3	3660.3	3499.2	3574.3	2091.3	1862.1	1602.1

(I) This table presents results from panel-data linear models fit using feasible generalized least squares, to allow estimation in the presence of AR(1) autocorrelation with panels and heteroskedasticity across panels. Total output produced, $logY_{t-1}$, is adjusted to account for decisions not submitted on time and group size. Outlier session (NI5, C1, AT1) are removed from the dataset. *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

Table 4: Session-Level Statistics on Production[I]

Treatment	Sessions	Statistic	Mean Labor Supply	Mean Output Demand	Total Output Produced	Freq. Excess Labor Supply†	Output Volatility	Mean Nominal Interest Rate
Steady State			2.24	22.4	201.6	0	0	0.035
B	6	mean	2.76*	49.91**	242.24	0.11	0.17**	0.08
		s.d.	0.76	12.96	63.22	0.17	0.05	0.10
NI	5	mean	2.33	40.31**	206.50	0.09	0.17**	0.03
		s.d.	0.43	17.19	41.54	0.13	0.03	0.05
C	5	mean	2.69*	42.65**	237.80**	0.17*	0.11**	0.08**
		s.d.	0.31	10.04	21.65	0.27	0.03	0.04
AT	5	mean	2.28	50.09**	205.50	0	0.14**	0.03
		s.d.	0.13	8.81	12.06	0	0.04	0.01
B vs. NI		p-value	0.273	0.584	0.273	0.833	1.000	0.465
B vs. C		p-value	0.715	0.361	0.584	0.550	0.018	0.361
B vs. AT		p-value	0.201	0.855	0.361	0.176	0.100	0.715
NI vs. C		p-value	0.174	0.917	0.251	0.738	0.016	0.076
NI vs. AT		p-value	0.917	0.347	0.754	0.136	0.117	0.917
C vs. AT		p-value	0.028	0.347	0.028	0.054	0.175	0.009

(I) Session-level results for experienced participants are presented: total output produced, frequency of excess aggregate labor supply and output volatility. Total output produced is adjusted for the number of participants who submitted their decisions on time. Asterisks indicate the significance of the difference of the mean estimate from its steady state prediction, measured by Wilcoxon signed-rank tests. Outlier session (NI5, C1, AT1) are removed from the dataset. *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.
† All sessions experience rationing in every period.

Table 5: Individual Labor Supply Decisions[I]

$Dep.Var.: logN_{i,t}$	(1)	(2)
$logN_{i,t-1}$	0.372***	0.666***
	(0.03)	(0.03)
$logN_{i,t-1} \times C$	0.146***	0.031
	(0.03)	(0.05)
$logN_{i,t-1} \times AT$	0.226***	0.185***
	(0.03)	(0.04)
$logC_{i,t}$	0.167***	0.165***
	(0.02)	(0.02)
$logC_{i,t} \times C$	-0.130***	-0.059**
	(0.02)	(0.03)
$logC_{i,t} \times AT$	-0.148***	-0.157***
	(0.02)	(0.02)
$log\left(\frac{W_{i,t-1}}{W_{i,t-2}}\right)$	-0.092***	0.093
	(0.04)	(0.07)
$log\left(\frac{W_{i,t-1}}{W_{i,t-2}}\right) \times C$	0.175***	-0.109
	(0.05)	(0.14)
$log\left(\frac{W_{i,t-1}}{W_{i,t-2}}\right) \times AT$	0.073*	-0.087
	(0.04)	(0.08)
$log(1+i_{t-1})$	-0.322	1.017
	(0.65)	(1.01)
$log(1+i_{t-1}) \times C$	2.683***	-1.485
	(0.87)	(1.72)
$log(1+i_{t-1}) \times AT$	0.520	-0.911
	(0.66)	(1.06)
$log(1+\pi_{t-1})$	1.235	-1.647
	(0.81)	(1.44)
$log(1+\pi_{t-1}) \times C$	-3.349***	3.295
	(1.14)	(2.38)
$log(1+\pi_{t-1}) \times AT$	-1.209	1.880
	(0.85)	(1.54)
$Bank_{i,t-1}$	-0.001***	-0.000
	(0.00)	(0.00)
$Bank_{i,t-1} \times C$	0.001**	-0.000
	(0.00)	(0.00)
$Bank_{i,t-1} \times AT$	0.001	0.000
	(0.00)	(0.00)
$Bank^2_{i,t-1}$	0.000**	0.000
	(0.00)	(0.00)
$Bank^2_{i,t-1} \times C$	-0.000**	-0.000
	(0.00)	(0.00)
$Bank^2_{i,t-1} \times AT$	0.000	-0.000
	(0.00)	(0.00)
$logQ_{t-1}$	0.069***	0.029*
	(0.02)	(0.02)
$logQ_{t-1} \times C$	-0.057***	0.015
	(0.02)	(0.02)
$logQ_{t-1} \times AT$	-0.084***	-0.024
	(0.02)	(0.02)
C	0.280***	0.331***
	(0.07)	(0.12)
AT	0.395***	0.512***
	(0.06)	(0.08)
α	-0.113**	-0.440***
	(0.05)	(0.07)
Controls	YES	YES
Type	Savers	Borrowers
N	4362	1141
N_g	130	81
χ^2	3616.4	3920.3

(I) This table presents results from panel-data linear models fit using feasible generalized least squares, to allow estimation in the presence of AR(1) autocorrelation with panels and heteroskedasticity across panels. Total output produced, $logY_{t-1}$, is adjusted to account for decisions not submitted on time and group size. Controls include dummies indicating whether the subject submitted a bid or ask and quantity of assets held at the beginning of the period. Outlier session (NI5, C1, AT1) are removed from the dataset. $^*p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

Figure 1: Asset Prices by Treatment

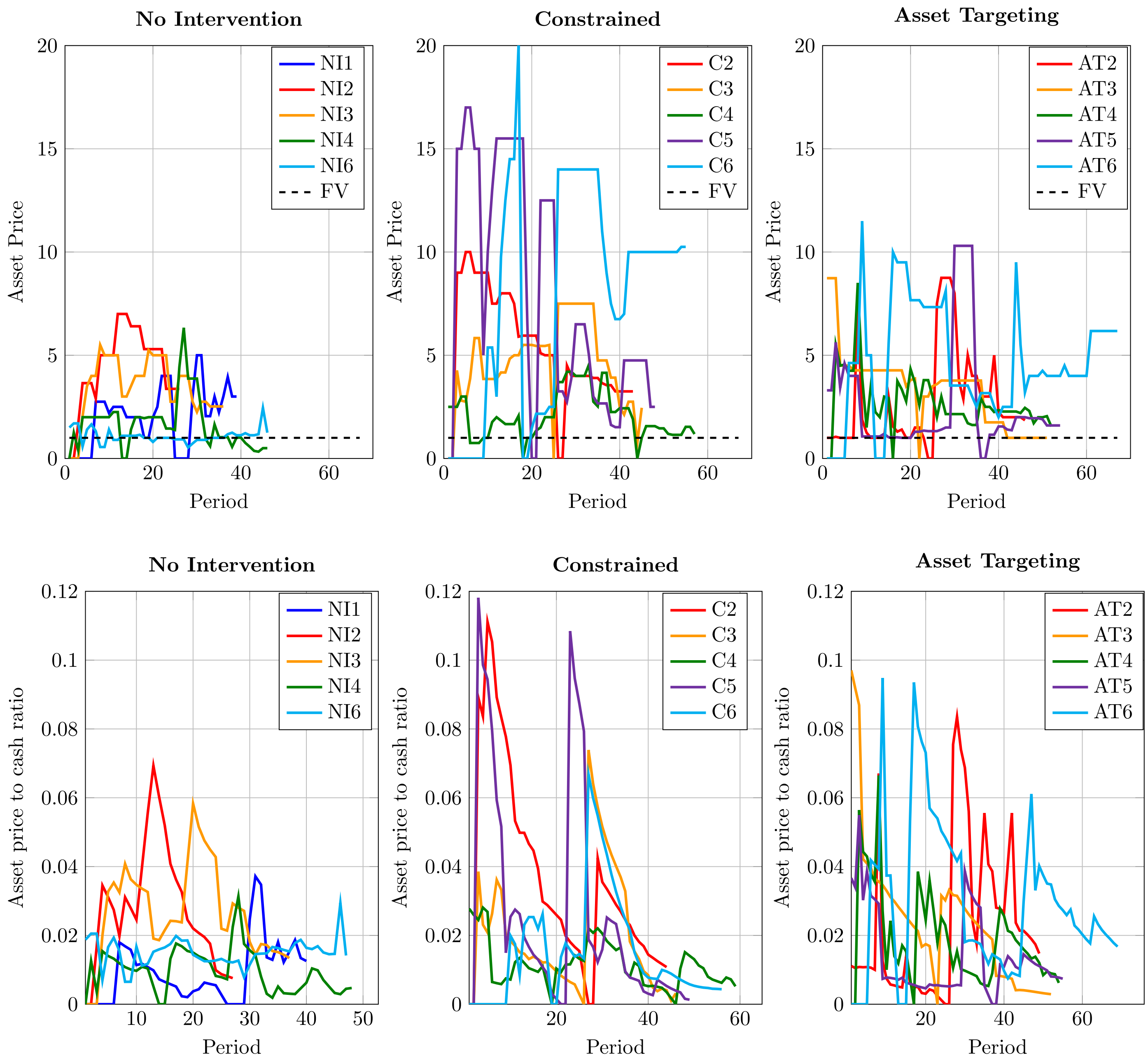


Figure 2: Asset Prices Statistics by Treatment

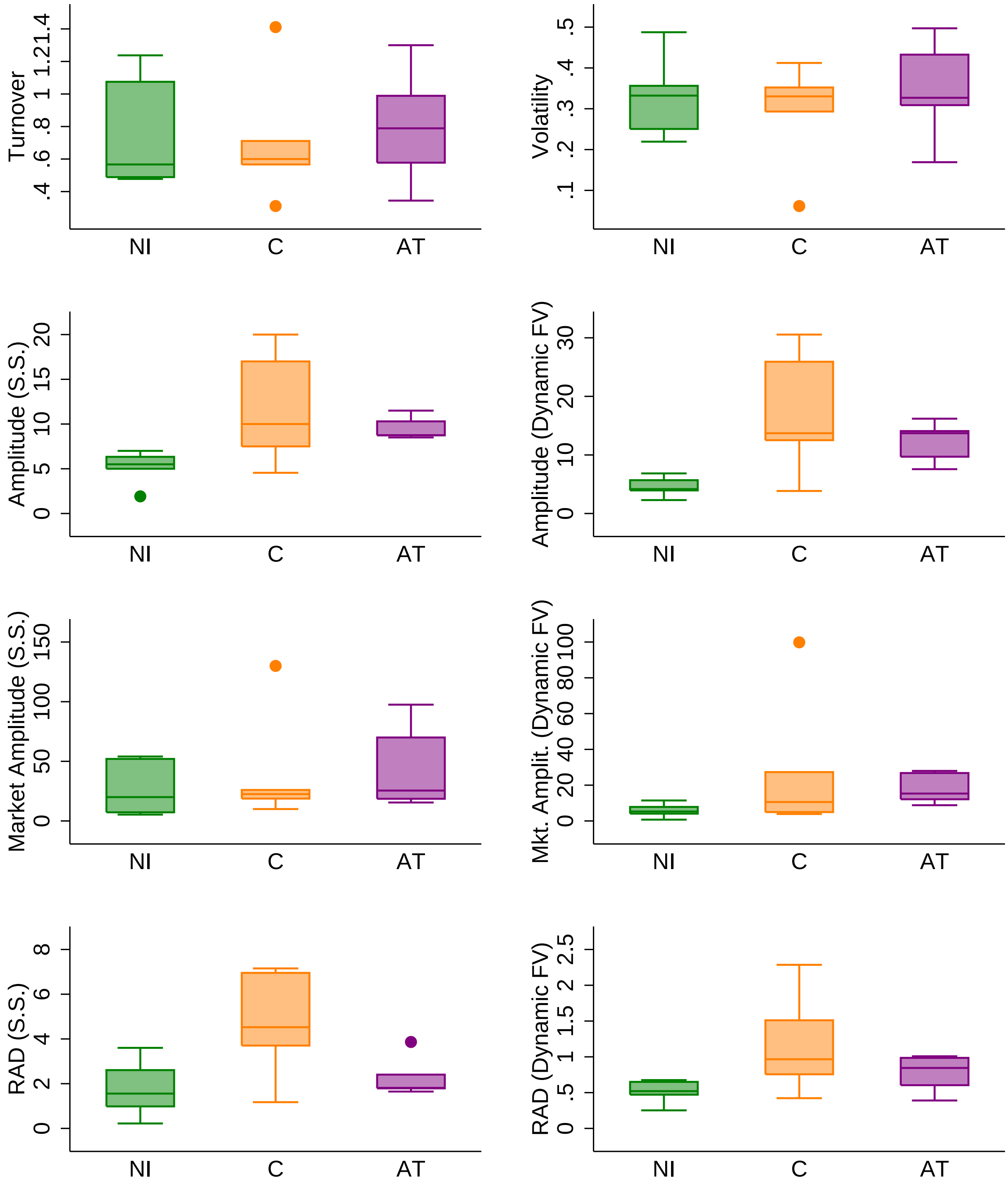


Figure 3: Asset Prices Statistics by Treatment (Controlling for Total Wealth in Bonds)

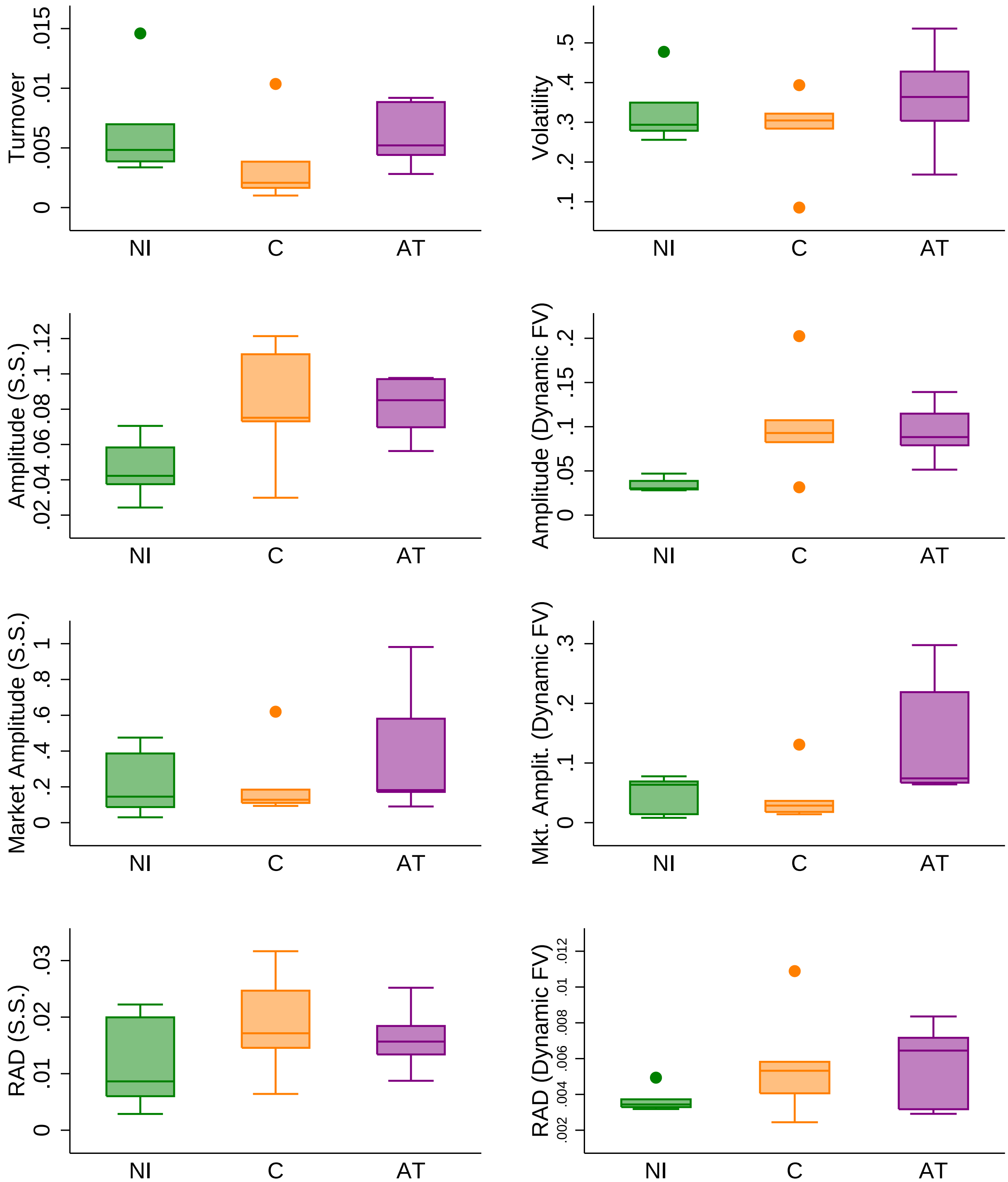
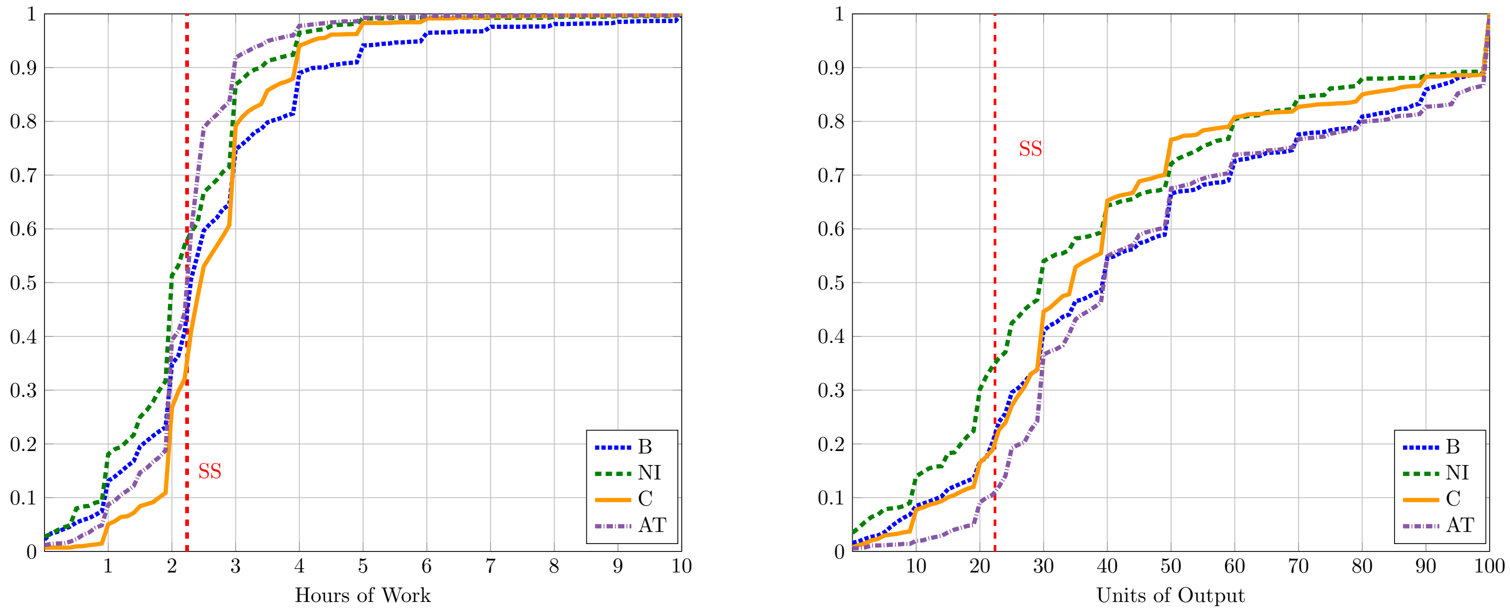


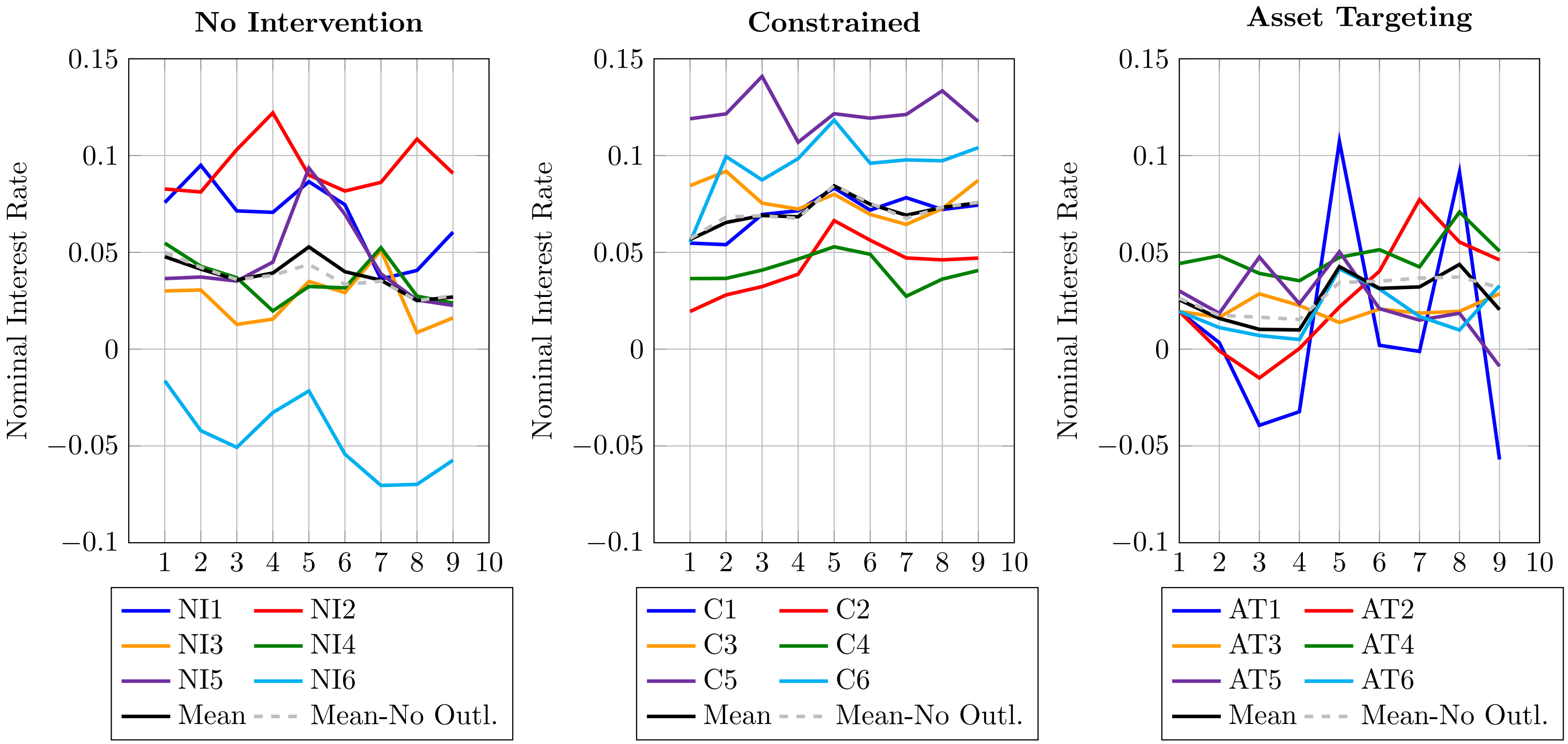
Figure 4: Labor Supply and Output Demand Cumulative Distribution Functions for Experienced Participants

(a) CDF Labor Supply (b) CDF Output Demand



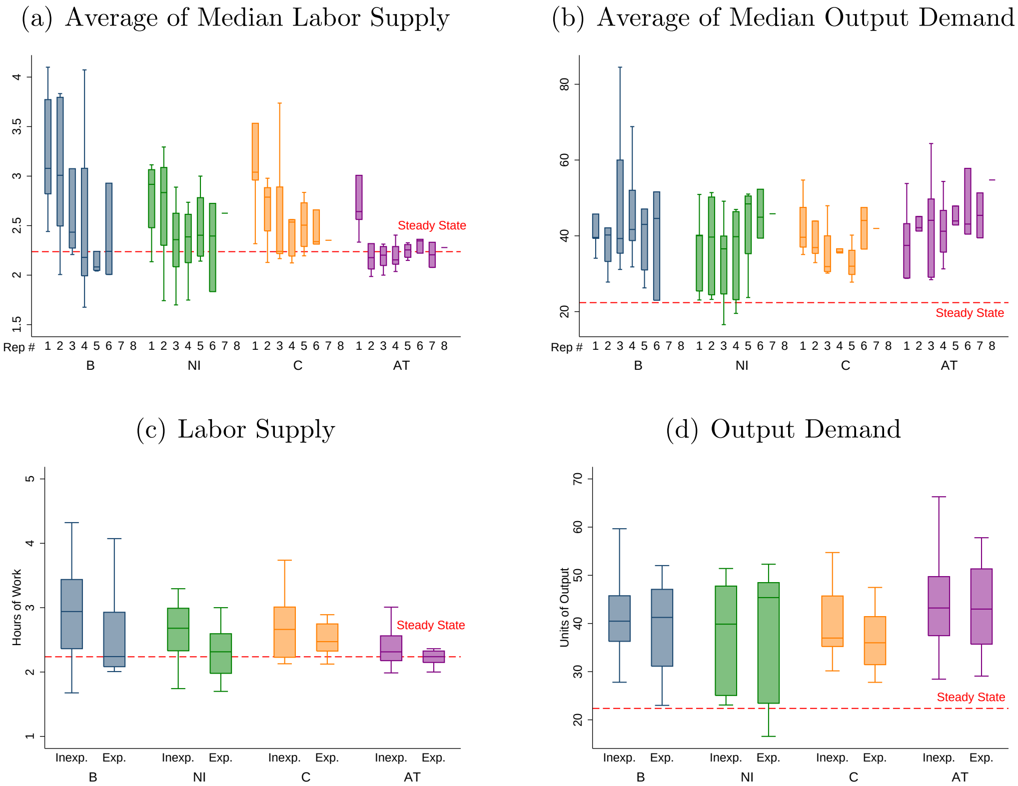
Note: Each display the cumulative distribution function for labor supply (left panel) and output demand (right panel). The red dashed line denotes the steady state prediction.

Figure 5: Median Nominal Interest Rates in Experienced Sequences, by Session



Note: Each line denotes the median interest rate over all experienced sequences of a session for a given period.

Figure 6: Labor Supply and Output Demand



Note: The bottom and top of the box are the first and third quartiles, the band inside the box is the second quartile (the median). The upper (lower) limit of the whisker is the highest (lowest) value within 1.5 interquartile range of the upper (lower) quartile. The red dashed line is the steady state value predicted by the theoretical model.