Asset Trading and Monetary Policy in Production Economies*

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Abstract

This paper studies the effects of monetary policy on asset price bubbles and production in a laboratory economy. Participants play the role of household investors who make consumption, labor, and investment decisions. Introducing asset markets to the economy does not generate significant real effects. Restricting liquidity in asset markets by imposing borrowing constraints on speculation leads to increased precautionary saving through higher, more stable labor supply and smaller bubbles, but increases asset price volatility. In contrast, a "leaning against the wind" interest rate policy improves the salience of monetary policy. Output volatility is modestly reduced, asset prices are quickly stabilized and overall deviations from fundamentals are lower. Indebtedness is an important source of heterogeneity in participants' decisions.

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

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The bubble and subsequent collapse of dot-com technology stocks in 2000 and of housing markets in North America and Europe throughout the last decade have called into question the role 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 great, and largely unresolved, debate.

Proponents of a 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 attractive.[1] This would ideally reduce asset market volatility. An alternative and more controversial response is to adjust interest rates in step with asset price inflation. As asset prices grow, nominal interest rates rise, disincentivizing future investors from borrowing for speculative purposes. Similarly, as asset prices decrease, the central bank will lower saving and borrowing rates to encourage speculative investment in an effort to stabilize asset prices. The interventionist viewpoint is criticized on two fronts.[2]

First, it can be very challenging to identify and measure asset price bub-

[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. Galí (2014) demonstrates within an overlapping generations model with nominal rigidities that "leaning against the wind" policies can lead to greater asset price volatility if the random process driving the bubble component in asset prices moves positively with interest rates.

bles, making central bankers wary to respond to something they are not sure even exists. Only after an asset price crashes we can infer whether it was previously overpriced. It is not clear whether interest rates could effectively reduce asset bubbles. Exuberant and optimistic investors may be willing to speculate regardless of the increased borrowing cost or the higher yield on secure interest-bearing bonds. The consequences of these interventionist policies to the aggregate economy are potentially very large. Given the reluctance to use them, it is difficult to find clear instances in the data where central banks responded aggressively to perceived bubbles; this results in greater uncertainty about the effectiveness of such policies. For these reasons, many argue that policy makers should leave asset markets alone and respond solely to inflation and unemployment fluctuations. By keeping inflation low through the policies currently used, central banks can maintain an environment in which bubbles are less likely to occur. Moreover, if asset bubbles are driven, at least in part, by real and relevant factors in the economy (e.g., increased demand for houses), targeting asset price inflation can have significant negative repercussions on the economy.

Our primary goal is to understand whether monetary policy can attenuate investor exuberance and panic and lead to an overall more stable economy. As a first step, we propose circumventing these empirical shortcomings by studying monetary policies within an innovative laboratory experiment. An experimental testbed can be especially useful in illuminating any unintended or irreversible consequences that policy makers need to consider in their final implementation (Croson (2002)). Compared with computational or theoretical analyses that require agents' expectations to be specified, participants in our experiment bring their heterogeneous preferences and expectations into the laboratory, allowing for a more natural response to our proposed policies. The laboratory provides an exploratory environment for observing whether individual and market behavior is well described by available models of decision making. Experimental evidence allows us to draw qualitative inferences about how an economy populated by human agents would behave under different market and policy scenarios. Moreover, in the laboratory, an asset's fundamental value and the monetary policies set by the central bank are specified by the experimenter, making identification of asset price bubbles and the effects of monetary policy straightforward.[3]

We design and implement an innovative laboratory economy where participants play the role of household investors. We simplify the environment by automating the decisions of firms, banks and the monetary authority, and considering assets with a constant fundamental value. To study the impact of asset markets and policy on real variables, we conduct four treatments. In our baseline economy, participants interact in labor and output markets. In the second treatment, we introduce an opportunity for speculative investment in an asset with a constant dividend. The third and fourth treatments examine the effects of asset price targeting policies. We consider borrowing constraints

[3]See Duffy (2014) and Cornand and Heinemann (2014) for surveys of macroeconomic laboratory experiments. 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) design online experiments for the Bank of Canada to study the importance of monetary policy in influencing the public's expectations about the future state of the economy and whether this expectations channel of monetary policy can be enhanced with improved communication.

for speculative investment and an interest rate policy that responds to asset price inflation. 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)), and the effects of stochastic shocks (Noussair, Pfajfar and Zsiros (2014*a*, 2014*b*); and Petersen (2012)), in that participants' decisions are the sole determinants of aggregate outcomes. As our focus is on household-investor decisions, we simplify these previous frameworks by automating firms and the monetary authority decisions.

This is the first laboratory experiment that combines an asset market and a production economy to study the aggregate implication of speculative trading. While a large number of experiments have been extended the highly influential framework developed by Smith, Suchanek and Williams (1988; SSW henceforth) to explore policies or market features to reduce asset price bubbles, none have investigated how these policies influence labor and consumption decisions.[4] Such decisions critically feed into later investment strategies, and it is essential to map the general equilibrium effects if we are to understand the implications of policy. Indeed, much of the concern about 'leaning against the wind' policies are their potential consequences to the real side of the economy.

[4]Asset price bubbles and crashes are often observed in experimental markets, and much work has explored methods to minimize their occurrence. Mostly closely related to us are the inclusion of an interest-bearing bond (Fischbacher, Hens and Zeisberger (2013)), consumption smoothing motives (Crockett and Duffy (2013)), alternative tasks to speculation (Lei, Noussair and Plott (2001)), and adjusting the available liquidity in the markets (Caginalp, Porter and Smith (2000)).

Our laboratory experiments provide the first experimental evidence of the effects of asset markets and central bank interventionist policies on production and asset market activity. We observe that the presence of an asset market does not distort median or aggregate labor and consumption decisions. This is consistent with our theoretical predictions that real decisions should be unaffected by asset market activity. While asset prices do consistently and significantly inflate above fundamental values, the real decisions of participants are uncorrelated with asset prices. Constraints that prevent investors from borrowing for speculative purposes predictably result in smaller asset price deviations, as less liquidity is immediately available for investing. Asset markets are significantly more volatile when investors face binding budget constraints and are either unable to continue to purchase assets or feel pressured to sell assets as they face debt. Participants in this treatment consistently supply significantly more labor in an effort to precautionarily save, leading to significantly less volatility in production.

By contrast, when nominal interest rates respond to asset price inflation, we do not observe significant effects on the overall level of production or asset market volatility. While asset price amplitudes become significantly larger because of initially cheap credit, prices are quickly dampened by contractionary monetary policy. We attribute this to the fact that interest rates are more aggressively adjusting and become more salient to investors. This is supported by further individual-level evidence that labor and demand decisions better respond to monetary policy when asset-inflation targeting policies are in place. Much of the heterogeneity in participants' decision making is due to differences in indebtedness. Participants with saving consume significantly more as their asset wealth increases. Indebted participants, on the other hand, are more responsive to changes in interest rates and are preoccupied with getting out of debt. These individuals supply more labor while consuming and investing less even as the value of their asset portfolios grow.

1 Experimental Design and Implementation

We begin by describing the experimental design of our Benchmark (B) environment. The experiment was designed to capture key features of the theoretical framework found in our online Appendix. Participants were assigned the role of households that made repeated labor supply, output demand, and in some treatments, investment decisions over multiple sequences of linked periods. In each experimental economy nine participants interacted with automated firms, a commercial bank, and a central bank that responded to their aggregate decisions. Each period, participants earned points from 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 payoff function:

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

To appropriately incentivize participants to take their decisions seriously, the points from all periods were exchanged for cash at a pre-specified rate at the end of the experiment.

In the baseline environment, with only labor and output markets, participants' per-period budget constraint was given by

$$P_tC_t + B_t = (1 + i_{t-1})B_{t-1} + W_tN_t + T_t. \tag{1}$$

Participants received a one-time endowment of 10 units of lab money to make purchases within the sequence. Additional lab money was earned through 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, automatically borrowed from an automated bank. Both savings and debt accrued interest that was added to the balance in the next period.

To induce discounting behavior, we generated indefinite-length sequences in which each period had a constant probability of continuation. As Duffy (2014) explains, this induces exponential discounting of future periods as well as stationarity. To make this 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 periods.

Participants held either positive or negative cash balances at the end of each sequence. 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 an 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 earned more points by consuming more each period than 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. To reinforce this point, we provided participants a supplementary calculation of their adjusted payoffs assuming that the sequence had ended in the previous period.

The monopolistically competitive firms, commercial bank, and central bank were automated to simplify the experiment.[5] A continuum of firms set their prices as a markup over the nominal wage. Each period, a fraction 1-ω were able to update their prices while the remaining ω firms were required to use the previous period's price, resulting 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 market clearing price and wage were calculated using median con-

[5]This simplification allows us to focus on the behavior of participants in the role of household investors and affords us more participants per session. Other experiments such Noussair, Pfajfar and Zsiros (2014*a*) and Petersen (2012) use 3 and 4 participants playing the role of firms, respectively, to generate monopolistic competition opposite the same numbers of worker-consumer participants.Davis and Korenok (2011) employs 6 participants in a firm pricing game with automated consumer demand.

sumption and labor decisions:[6]

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

where

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

The median of participants' labor and consumption decisions is preferred to average choices as 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

[6] See the online appendix for a detailed derivation of the equations.

workers to satisfy demand and produced only a fraction of the output 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. Generally, 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' oversupplying 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 there remaining hours were available because some participants choose to overconsume, these participants would receive a random proportion of those remaining units. No participants ended up with more hours or output than they requested.[7]

The computerized central bank followed a nonlinear nominal interest rate rule that responded more than one-for-one with inflation. In the Benchmark

[7] Fenig and Petersen (2014) 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 egalitarian 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.

environment, the monetary policy rule was given by

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

The interest rate was expressed in percent and could be positive or negative; that is no zero lower bound was imposed). The interest rate was computed at the end of the period after inflation was determined from aggregate outcomes.

Three additional asset market treatments were implemented within the Benchmark environment. In these treatments, participants received 10 nondivisible shares of an asset at the beginning of each sequence. Each share paid a dividend of 0.035 units of lab money. Bids and asks were simultaneously submitted, 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. Participants did not receive any points for holding the asset. Employing a call market for the exchange of assets had many benefits. It allowed us to conduct exchanges relatively faster than under a continuous double auction and at a single market clearing price. 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).

The No-Intervention (NI) treatment introduced an asset market to the Benchmark environment 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 is not linked to economic fundamentals, we would not expect to see the asset trade above fundamental value or 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, beliefs that others will want to buy the asset at a higher price in the future).

We also conducted two interventionist policies to observe their effects on asset market activity and asset price volatility, as well as on labor and consumption decisions. In the Constrained (C) treatment, participants faced a cash-in-advance constraint preventing them from borrowing for investment purposes. Participants wanting to purchase units of the asset required sufficient lab money carried over from the previous period to cover the transaction. Participants were still able to borrow 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 expect 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:

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

where π_t^A is asset price inflation and $\alpha > 0$ represents the the aggressiveness of the central bank when asset prices vary. As asset prices increase, the interest rate increases in lock-step, discouraging investors from borrowing for speculative purposes. Similarly, as asset prices fall, interest rate also falls to encourage more speculative investment. The asset inflation target policy is expected to generate smaller deviations in asset prices from fundamentals and reduced asset price volatility. It is important to note that participants were not informed about the central bank's additional response to asset price inflation. This was to avoid participants' investing speculatively simply to manipulate interest rates and the return on their savings.

The budget constraint of the participants 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:

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

In the C treatment, participants were restricted from borrowing to purchase units of the asset and faced an additional cash-in-advance constraint: $Q_tX_t \leq B_{t-1}$.

The experiment was conducted at the University of British Columbia (four sessions for each treatment) and Simon Fraser University (two sessions for each treatment), where the participant pool consisted of undergraduate students recruited from a wide variety of disciplines. After 30 to 40 minutes of instructions and practice, all participants interacted in the Benchmark treatment for an additional 45 minutes. To establish a thorough understanding of how to make labor and consumption decisions before we introduced an asset market. Once the sequence ended we commenced the experienced sequences. In the Benchmark sessions, participants continued to play in the same environment for the remaining available time (45 minutes). Participants in the asset market sessions were provided additional instructions about the asset market and played for an additional 60 minutes. Six sessions of each treatment were conducted. Nine inexperienced participants interacted in each invited session.[8] Earnings, including a $5.00 show up fee, ranged from $10.00 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, nontechnical language, we explained how they would earn points by purchasing output and lose points by working. We explained how their wages and prices would change based on median labor and consumption decisions, and emphasized that this would reduce the ability of individual participants to manipulate either market. The participants were also given qualitative instructions about how 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

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

be challenging. To facilitate learning, we provided participants with an innovative interactive grid in the experimental software. Two markers on the screen denoted 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. From the second period of each sequence, participants also had access to tables in which they could view the history of their individual decisions as well as market outcomes. Participants in the asset market treatments were able to experiment with different trades to observe the hypothetical change to their bank accounts. Importantly, the software emphasized to them that their points would not change in response to their asset holdings.

2 Aggregate Findings

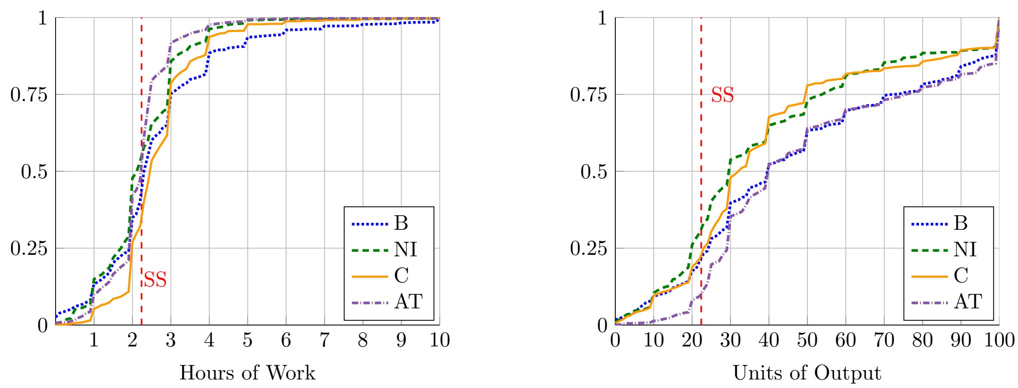
In this section, we summarize our findings across treatments. Our analysis focuses on experienced participants who had interacted in the Benchmark economy for at least two sequences. The data from the experienced sequences are treated as one time series, unless otherwise noted.

2.1 Production

Distributions of labor supply and output demand decisions are presented in Figure 1 for each treatment. 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. Relative to the Benchmark, labor supply decreases across almost the entire distribution when an asset market is introduced in the NI treatment. Mean (median) labor supply is 0.4 (0.17) units higher in the Benchmark treatment. Similarly, median demand for output decreases by more than 10 units when we introduce the asset market, likely due to the presence of an alternative expenditure option.

Summary statistics of production computed at the session-level are presented in Table 1. The policy interventions have considerably different effects on labor supply and output demand. Compared to the NI treatment, mean (median) labor supply across all participants increases by 0.44 (0.4) hours when participants are unable to borrow to purchase assets in the C treatment. A two-sided Wilcoxon rank sum test comparing session-level mean labor hired between the NI and C treatments indicates that this difference is significant at the 10 percent level. As consumption demands do not significantly differ between the NI and C treatments (a session-level rank sum test yields $p = 0.873$), the observed increase in labor supply is likely to finance participation in the asset market. On the other hand, labor supply is not significantly different from the NI treatment when the central bank responds to asset price inflation in the AT treatment. A two-sided Wilcoxon rank sum test comparing session-level mean labor hired fails to reject the null hypothesis of identical

Figure 1: Labor Supply and Output Demand Cumulative Distribution Functions for Experienced Participants



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

distributions ($p = 0.749$).

Table 1: Session-Level Statistics on Production, Prices, and Points[I]

Treatment	Sessions	Statistic	Total Labor Hired	Freq. Excess Labor Supply	Output Volatility	Avg. Points	Av. Points adj. Bank
B	6	mean	23.01	0.106	0.177	5.069	23.265
		s.d.	6.231	0.166	0.044	13.326	7.251
NI	6	mean	19.92	0.078	0.169	7.159	21.297
		s.d.	4.286	0.121	0.019	7.255	2.888
C	6	mean	23.59	0.196	0.106	7.154	21.448
		s.d.	3.2	0.255	0.021	7.493	2.543
AT	6	mean	19.88	0	0.14	7.809	20.445
		s.d.	2.817	0	0.038	6.311	0.816
B vs.NI		p-value	0.262	0.703	0.749	0.149	0.873
B vs. C		p-value	0.423	0.305	0.016	0.149	1
B vs. AT		p-value	0.262	0.14	0.262	0.078	1
NI vs. C		p-value	0.055	0.305	0.006	1	0.873
NI vs. AT		p-value	0.749	0.14	0.262	0.037	1
C vs. AT		p-value	0.01	0.022	0.078	0.262	0.337

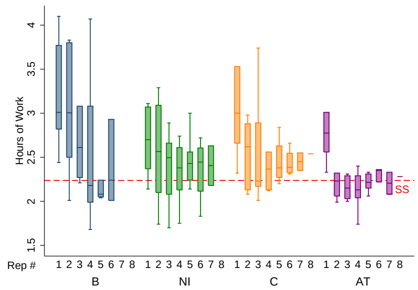
(I) Session-level results for experienced participants are presented: total labor hired, frequency of excess aggregate labor supply, output volatility the average points earned in a period by participants for consumption and labor decisions, and the average points taking into consideration their bank account balance. Total labor is adjusted for the number of participants participating.

Interestingly, we observe significantly higher output demand in the AT treatment, presumably driven by the relatively low interest rates observed in the AT treatments. In addition, labor supply and production are significantly less volatile in the C treatment relative to the other three treatments. Compared to the NI treatment, output volatility is almost 40 percent lower in C ($p < 0.01$). We attribute the increased and stable labor supply to precautionary saving motives.While there is considerable heterogeneity among participants' decisions, the median participant's labor supply and output demand weakly converge to the competitive equilibrium. Figures 2.a and 2.b present session-level averages of the median labor supply and output demand per sequence for each treatment. Unlike output demand, labor supply seems to converge to the steady state value in most of the sessions, even when participants are relatively inexperienced.[9] Figures 2.c and 2.d show the analysis for individual choices on labor supply and output demand, distinguishing between inexperienced and experienced sequences. A similar pattern is observed as labor supply converges to the predicted values for experienced participants.

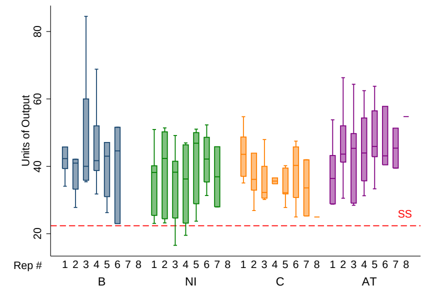
To formally verify whether labor supply and output demand converge to the competitive equilibrium, we followed the econometric procedure proposed in Duffy (2014). As a result, in all the sessions weak convergence is obtained for both labor supply and output demand. However, for the case of labor supply, 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

[9] Detailed outcomes for each session can be found in the online appendix.

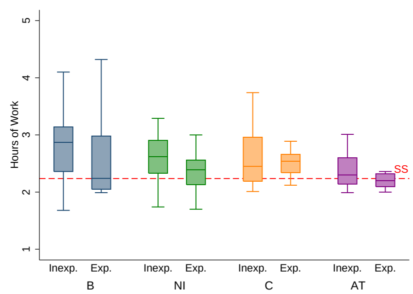
Figure 2: Labor Supply and Output Demand



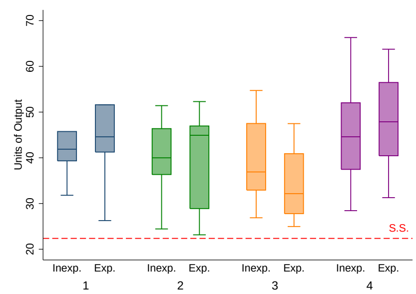
(a) Average of Median Labor Supply



(b) Average of Median Output Demand



(c) Labor Supply



(d) Output Demand

Notes: 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.

evidence of strong convergence for the output demand in any of the sessions.[10]

2.2 Asset Markets

Figure 3 show the path of asset prices and trading activity in each of the experienced sessions. Table 2 presents measures of trading activity and mispricing at the session-level with mean and standard deviation statistics. Two-sided Wilcoxon rank-sum tests are calculated with average measures at the session level, and the associated p-values are presented at the bottom of the table. The

[10]The procedure and estimations can be found in the Online Appendix.

fundamental value of the asset is computed in two ways using the following intertemporal

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

Treatment	Statistic	Turnover	Ampl. S.S.	Ampl. Dynamic	MV Ampl. S.S.	MV Ampl. Dynamic	RAD S.S.	RAD Dynamic	Volatility
NI	mean	1.53	17.38	20.89	36.02	6.60	4.38	3.11	1.17
	s.d.	0.72	30.00	39.62	29.42	6.49	6.45	4.75	0.51
C	mean	1.44	16.07	20.57	49.54	34.25	5.12	4.17	1.60
	s.d.	0.67	11.94	13.11	48.80	38.13	2.44	2.86	0.17
AT	mean	1.35	19.94	28.92	49.70	23.96	2.85	1.55	1.22
	s.d.	0.64	25.47	42.19	34.30	15.75	1.57	0.69	0.22
NI vs. C	p-value	0.87	0.20	0.15	0.52	0.08	0.15	0.20	0.08
NI vs. AT	p-value	0.63	0.06	0.04	0.42	0.02	0.52	0.63	0.88
C vs. AT	p-value	0.87	1.00	0.63	1.00	0.75	0.15	0.06	0.01

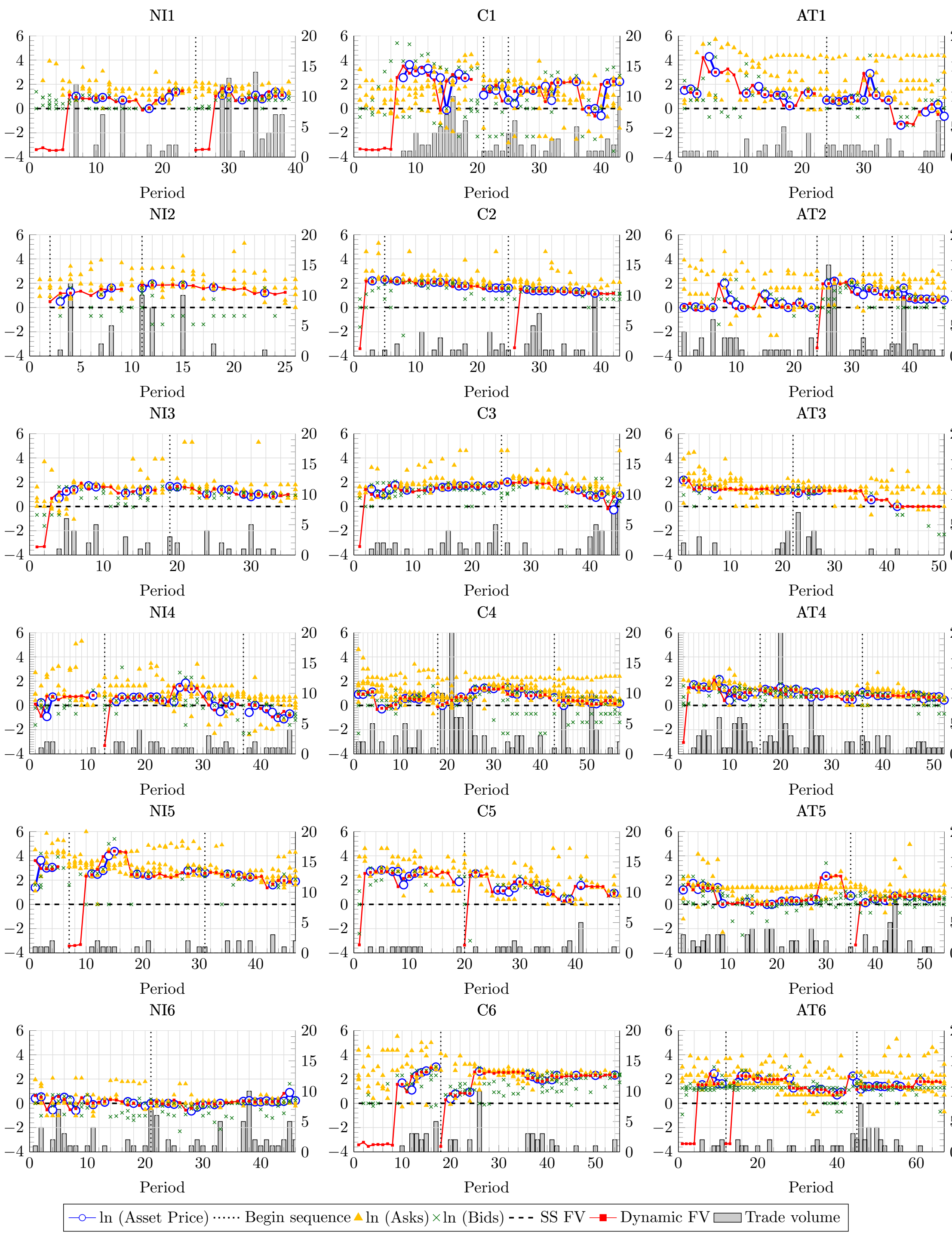
(I) This table presents session-level statistics on asset market variables. Turnover measures the trading activity in the market by the total volume of trade divided by the total outstanding stock in the experiment and the number of periods. Amplitude measures the trough-to-peak change in market asset 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.

tradeoff condition for the asset from the household's optimization problem:

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

We consider a steady-state fundamental value which is calculated as simply the sum of all expected future dividends assuming the economy remains in the steady state, which is simply 1. We also calculate a dynamic fundamental value, where expectations of future variables are set equal to their realized values. This results in different values for measures of the amplitude and relative absolute deviation of asset prices from fundamental value.

Figure 3: Asset Markets per Session (Left Axis: ln(Asset Price), Right Axis: Units of Trade)



Notes: $\ln(Assetprice)$, $\ln(Bids)$, and $\ln(Asks)$ are shown on the left axis. Trade volume is shown on the right axis (grey bars). The red dashed line is the fundamental price of the asset. The vertical dotted black lines represent the beginning of new sequences.

Given that participants were paid primarily on their consumption and labor decisions, it seems reasonable to expect minimal trading activity in the asset market. 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 by $T = \sum_t V_t/S$, where V is the total volume of trade and S is the total stock of outstanding assets in the market. Mean turnover is the highest in the NI treatment (1.527) and lowest in the AT treatment (1.345) and the differences across treatments are not statistically significant ($p > 0.63$ between all treatments). More than two-thirds of the participants submitted a bid during the experiment (76 percent in NI, 81 percent in C, and 79 percent in AT) and almost all participants submitted an ask (98 percent in NI, 92 percent in C, and 87 percent in AT).

The policy interventions did lead to different pricing dynamics. The amplitude of the asset price deviation, measured as the trough-to-peak change in the market asset price relative to its fundamental value, 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. Despite an inability to borrow for speculation, the measures of amplitude decrease only modestly in the C treatment and are not significantly different from the NI treatment ($p > 0.14$ under both specifications of fundamental value). The lack of change in amplitudes is attributed to additional liquidity generated by C participants through their increased labor supply. Counter to our predictions, amplitudes in the AT treatment increase significantly under both specifications of the fundamental value ($p \leq 0.055$ in both cases). Low interest rates in the AT treatment may have encouraged the speculative investment. 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 market value amplitude is higher in both intervention treatments than in the baseline asset market environment, likely driven by greater trade. The increases in market amplitudes are statistically significant at the 10 percent and 5 percent level under the dynamic specification of the fundamental value for the C and AT treatments, respectively.

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. Our results are qualitatively similar when we consider either the steady state or the dynamic fundamental value. Imposing a borrowing constraint in the C treatment raises the average deviations from fundamental value. On the other hand, asset inflation targeting in the AT treatment leads to smaller deviations. While the differences from the NI are not statistically significant, RAD is significantly lower in AT than in C under the dynamic fundamental value specification ($p = 0.055$).

Finally, we consider how volatility in asset markets may change in response to policy interventions. We calculate the historical volatility of the log returns of the asset prices as $Volatility = \sigma$, where σ is the standard deviation of log returns. The price of the asset in a period with no trade is set equal to the last trading price. Under a borrowing constraint, as the investors' budget constraint fluctuates between binding and slackness, prices should adjust more extremely. Our data support this prediction. Volatility increases from an average of 1.168 over all sessions in the NI treatment (ranging from 0.342 to 1.660) to 1.602 in the C treatment (ranging from 1.367 to 1.822), an increase of 37 percent ($p = 0.078$). When we consider only the periods in which assets were successfully traded, volatility increases by 24.5 percent on average but is not statistically significant. By contrast, under asset inflation targeting, nominal interest rates adjust to provide or restrict liquidity to smooth asset price fluctuations. We find that the effects of the policy are negligible. Average volatility slightly increases in the AT treatment to 1.219 (ranging from 0.883 to 1.494), though the differences are not statistically significant ($p = 0.878$). Calculating volatility over only successful trading periods does not change our results qualitatively. As in the NI treatment, volatility is significantly lower under asset inflation targeting than under a borrowing constraint ($p = 0.01$ over all trading periods and $p = 0.055$ under only successful trading periods).

Overall our aggregate results suggest that policy interventions modestly reduce trading activity. The effect on asset prices and their volatility is mixed. The borrowing constraint policy reduces the amplitude of asset price bubbles but increases the overall relative absolute deviation of prices from fundamental values. Importantly, borrowing constraints lead to significantly greater volatility in asset prices. Relative to a situation of no intervention, the asset inflation targeting policy leads to greater amplitudes in asset prices. The high amplitudes in asset prices are quickly minimized, resulting in lower relative absolute deviations and modestly higher levels of volatility.

2.3 General Equilibrium Effects

Table 3 presents results from Granger causality tests conducted at the session-level. Results from a reduced form vector autoregression are provided in the online appendix. Panels 1 to 3 in Table 3 indicate that there are no statistically significant effects of asset price inflation on the amount of labor hired, the level of interest rates, or inflation in the NI, C, or AT treatments. Only in the occasional session does asset price inflation Granger cause either labor supply (NI1), interest rates (AT4), or inflation (NI4 and AT6). Overall, however, the Granger test at the session level does not identify a causal link of asset markets on the real side of the economy. Participants are not offering to supply more labor as the value of assets increases. The fourth panel in the table shows that asset price inflation is occasionally influenced by changes in the macroeconomy. In three of six NI sessions, labor supply Granger causes asset price inflation, where more labor supply last period appears to cause increased asset price inflation today, although as the VAR table in the online appendix suggests, the evidence is mixed, with positive coefficients in some sessions and negative in others. For example, a 1 percent increase in labor supply last period results in a 2.7 percent increase in asset price inflation today in NI1 but a 6.2 percent decrease in NI6. Interestingly, in the C and AT treatments there is no evidence that labor supply Granger causes asset price inflation. In the C treatment, in three out of six sessions, inflation seems to Granger cause asset price inflation, with higher inflation last period leading to less asset price inflation today. In the AT treatment, in three out of six sessions, interest rates and inflation Granger cause asset price inflation, with higher inflation last period leading to higher asset price inflation today and lower last period interest rates leading to higher asset price inflation today. This suggests that asset markets in this treatment significantly respond to monetary policy while in other treatments they do not. Monetary policy appears to have a stabilizing effect on asset prices in that contractionary policy reduces asset price inflation.

Table 3: Outcomes from the Granger Causality Tests[I]

Dep. Var.[II]	$\frac{N-N^{SS}}{N^{SS}}$				$\frac{i-i^{SS}}{i^{SS}}$				π				π^A			
Ind. Var.	$\frac{i-i^{SS}}{i^{SS}}$	π	π^A	Joint	$\frac{N-N^{SS}}{N^{SS}}$	π	π^A	Joint	$\frac{N-N^{SS}}{N^{SS}}$	$\frac{i-i^{SS}}{i^{SS}}$	π^A	Joint	$\frac{N-N^{SS}}{N^{SS}}$	$\frac{i-i^{SS}}{i^{SS}}$	π	Joint.
Sessions: B1	0.26	1.08		0.79	0.88	0.4		0.72	1.43	0.83		1.16				
B2	0.01	0.01		1.02	1.76	0.13		1.09	1.75	1.06		1.33				
B3	0.24	0.3		0.17	1.55	3.12*		2	0.75	2.32		1.72				
B4	1.49	1.49		1.14	1.32	0.91		0.92	1.26	1.2		1.02				
B5	0.21	0.4		0.21	1.59	1.54		1.78	1.07	1.06		1.13				
B6	0.12	0.25		0.53	0.16	0.41		0.22	0.14	1.02		0.56				
NI1	0.46	0.3	2.91*	1.18	1.24	0.4	2.48	1.47	1.25	0.22	2.57	1.33	3.46*	0.75	1.68	1.49
NI2	3.74*	3.77*	1.29	1.61	1.41	0.8	1.19	1.3	1.38	1.03	1.15	1.39	1.44	1.51	2.9	1.52
NI3	2.37	0.16	0.07	2.12	0.75	2.89*	0.86	1.26	0.76	2.87*	0.86	1.28	2.01	0.43	0.46	0.7
NI4	0.91	0.81	2.15	1.13	2.27	1.68	6.69	3.92	2.31	2.38	6.68***	3.95	4.2**	2.08	0.29	1.85
NI5	2.3	1.24	1.01	1.2	0.68	1.18	1.08	0.79	0.66	0.89	1.09	0.9	10.05***	3.08*	1.52	3.96***
NI6	0.1	0.77	0.02	0.77	2.37	4.46**	0.29	1.75	2.39	1.24	0.28	1.47	0.59	1.98	1.77	1
C1	0.24	0.01	0.84	0.57	1.08	2.14	0.75	1.21	1.1	1.89	0.76	1.12	0.81	2.45	4.93**	2.89**
C2	0.13	0.17	1.49	0.92	1.54	0.2	1.62	1.43	1.53	0.46	1.6	1.38	0.18	0.8	3.01*	1.88
C3	0.04	0.13	0.72	0.66	3.06*	0.27	0.02	1.08	3.07*	0.47	0.01	1.1	0.19	0.85	1.84	1.06
C4	1.02	0.97	2.38	1.83	3.31**	0.11	0.56	1.56	3.32**	0.02	0.57	1.51	0.14	0.74	0.91	0.65
C5	12.84***	11.9***	1.7	4.65***	0.67	0.56	0.09	0.38	0.73	0.41	0.1	0.35	0.07	0.26	0.1	0.14
C6	0.98	0.54	1.16	0.86	6.39***	0.11	0.43	2.97**	6.37***	0.1	0.45	2.68**	1.76	3.04*	3.41**	2.35*
AT1	0.04	0.39	0.26	0.42	0.81	1.67	1.14	0.7	0.25	0.17	0.07	0.31	0.92	2.48	0.45	1.2
AT2	1.19	0.62	0.51	0.58	1.21	2.62*	0.8	1.67	0.47	0.07	0.12	0.72	0.85	23.82***	10.433***	11.29***
AT3	0.28	0.25	0.04	0.41	0.27	0.32	0.13	0.33	1.75	1.72	0.66	1.58	0.48	0.05	0.07	0.21
AT4	0.77	0.06	1.18	0.6	1.14	3.02*	4.26**	2.53**	1.04	0.12	0.09	0.4	1.24	20.83***	4.6**	7.56***
AT5	0.43	0.49	0.54	0.86	1.37	0.39	0.04	0.93	0.9	0.1	0.59	0.68	1.13	0.06	0.50	0.53
AT6	0.05	1.45	0.01	0.86	0.78	4.49**	2.24	2.28	0.38	1.69	2.61*	1.15	1.92	5.6**	6.91**	3.41**

(I) $*p < 0.10$, $**p < 0.05$, and $***p < 0.01$. The Granger causality test is based on the null hypothesis that the independent variable does not Granger cause the dependent variable. The table reports the F statistics derived from an underlying regression that includes two lags of the independent variable(s). The label *joint* is based on a null hypothesis that all the independent variables included in the equation, jointly, do not Granger cause the dependent variable.

(II) $\frac{N-N^{SS}}{N^{SS}}$, $\frac{i-i^{SS}}{i^{SS}}$, π, and π^A are percentage deviation of total labor hired from the steady state, percentage deviation of interest rate from the steady state, output price inflation and asset price inflation, respectively.

3 Individual-Level Analysis

In this section we investigate the determinants of participants' behavior in labor, output, and asset markets.

3.1 Labor and Consumption Decisions

To understand how labor and consumption decisions are made, we conduct a series of random effects panel regressions. The results are presented in Table 4. Columns (1)-(4) present results for labor supply decisions, while the remaining columns present output demand decisions. We consider the effects of one-period lagged interest rates and real wages and participation in specific treatments on decisions. The NI treatment is used as a baseline from which we consider the incremental effects of the treatment variation.

Table 4: Individual Labor and Consumption Decisions[I]

	Labor Supply				Output Demand			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i_{t-1}	1.559*	1.586*	0.906**	1.965**	14.705**	13.777*	24.356***	48.545***
	(0.90)	(0.87)	(0.43)	(0.81)	(7.30)	(7.23)	(7.50)	(14.44)
W/P_{t-1}	0.032***	0.031***	0.030***	0.014**	-0.185*	-0.153	-0.132	-0.281**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.10)	(0.10)	(0.10)	(0.11)
B	0.238	0.256	0.246**	0.223*	9.824**	9.344**	9.527**	8.632*
	(0.18)	(0.17)	(0.12)	(0.13)	(4.51)	(4.52)	(4.49)	(4.49)
C	0.228**	0.259***	0.258**	0.112	0.509	-0.288	-0.268	0.209
	(0.11)	(0.10)	(0.12)	(0.13)	(4.50)	(4.51)	(4.48)	(4.46)
AT	-0.054	-0.019	-0.029	0.020	12.439***	11.490**	11.651***	12.661***
	(0.10)	(0.10)	(0.12)	(0.12)	(4.51)	(4.53)	(4.50)	(4.42)
Indebted		0.267***	0.134***	0.129***		-7.071***	-4.984***	-4.976***
		(0.06)	(0.04)	(0.04)		(0.54)	(0.67)	(0.67)
i_{t-1} x Indebted			2.340***	2.364***			-36.830***	-37.631***
			(0.41)	(0.41)			(7.13)	(7.14)
i_{t-1} x B				0.240				2.781
				(0.83)				(15.50)
i_{t-1} x C				1.739**				-14.177
				(0.84)				(14.90)
i_{t-1} x AT				-1.967**				-33.487**
				(0.85)				(15.09)
α	1.953***	1.882***	1.937***	2.047***	41.097***	43.024***	42.183***	42.736***
	(0.11)	(0.11)	(0.10)	(0.10)	(3.33)	(3.34)	(3.32)	(3.29)
N	8710	8710	8710	8710	8710	8710	8710	8710
chi^2	261.5	258.6	340.3	363.1	16.45	187.7	215.0	223.5

(I) This table presents results from random-effects panel regressions. Standard errors are clustered at the session level. $*p < 0.10$, $**p < 0.05$, and $***p < 0.01$.

As real wages and nominal interest rates rise, participants are willing to supply more hours of labor. Consistent with the aggregate level results, individuals in the C treatment work approximately 0.228 hours more than their NI counterparts. There is a slight reduction in labor supply among individuals in the AT treatment, but this difference is not statistically significant. Indebtedness, introduced into our second specification, leads to a significant increase in labor supply. Indebted individuals work an average of 0.27 additional hours, in an effort to stabilize their debts. They are also significantly more responsive to changes in nominal interest rates, working an additional 0.02 hours for every 1 percent increase in the nominal interest rate. We interact nominal interest rates with each treatment in the fourth column to identify differences in the responsiveness of labor supply to monetary policy. Relative to the NI treatment, the increase in labor supply associated with changes in the nominal interest rate are significantly more pronounced when participants face borrowing constraints in the C treatment. The opposite is the case when the central bank targets asset price inflation. Then, contractionary monetary policy leads to a reduction in labor supply.

The next four columns consider the determinants of consumer demand. Contractionary monetary policy is ineffective at reducing consumer demand, with output demands increasing significantly with lagged interest rates. Without an asset market to participate in, participants in the B treatment demand 9.8 more units of output. Consumers in the AT demand on average 12.4 units more than in the NI treatment. This may be due to a relatively lower interest rate caused by low labor supply and production. Both of these treatment effects are significant at the 5 percent level.Indebtedness is again pivotal in overall demand and responsiveness to monetary policy. Indebted participants demand significantly fewer units. Monetary policy is also more effective at stabilizing demand for indebted individuals. In column (7), while a 1 percentage point increase in the nominal interest rate increases output demand by 0.24 units for participants with positive bank account balances, it reduces demand by 0.12 units for indebted individuals. Finally, in column (8) we include the interaction of monetary policy with the various treatments. We observe that consumer demand is significantly more responsive to the monetary policy in the AT treatment. Participation in the various treatments does not lead to significantly different behavior, other than a tendency for NI and C (AT) participants to demand relatively less (more) output, on average. Indebtedness does, however, lead to a significant reduction in demand of between 4.98 and 7.07 units, significant at the 1 percent level. Moreover, indebtedness increases the responsiveness to monetary policy. In column (7), we observe that for a 1 percent increase in nominal interest rates, an indebted consumer's demand will be lower by 0.368 units. Finally, we observe that consumption demand increases by significantly less in response to contractionary monetary policy when participants belong to the AT treatment. In other words, monetary policy is more effective at stabilizing consumer demand in the AT treatment.[11]

[11] The incidence of indebtedness is 26.1 percent in the Benchmark environment. Introducing the asset market in the NI treatment leads to a slightly higher probability of being in debt, 29.4 percent. The incidence of indebtedness increases slightly when the asset market is introduced, as participants now have an opportunity to invest without being required to have sufficient liquidity to cover their speculative purchases. Indebtedness falls considerably under the policy interventions, to 19.6 percent in the C treatment and 16.4 percent in the AT treatment. Some participants never experience indebtedness: 39 percent (21/54) in B, 26 percent (13/50) in NI, 20 percent (11/54) in C, and 38 percent (20/53) in AT. Thus, monetary policy is more effective at stabilizing labor supply and output demand when the incidence of indebtedness is lower.

A series of robustness checks to evaluate whether asset wealth and asset prices are an important determinant of labor supply and output demand in the asset market treatments can be found in the online appendix. While asset wealth and prices are generally not an economically significant determinant of labor supply decisions, they play a significant role in output demand decisions. For a \$1 increase in the value of their risky stocks, individuals with positive bank account balances increase their consumption by 0.011 units. The increase is statistically significant at the 5% level. Indebted individuals, by contrast, decrease their demand by 0.023 units for every \$1 increase in their portfolio value. Qualitatively similar results are obtained when we replace $AssetWealth$ terms with asset price, P_t^A or when we control for the size of participants' bank accounts.

3.2 Asset Trading Behavior

What determines whether a trader submits a bid or an ask? In Table 5 we present results from random-effects probit estimations on the likelihood of submitting bids and asks. We observe that higher nominal interest rates in the previous period lead to a modest but significant decrease in the likelihood of an investor submitting a bid. The marginal effect of a 1 percent increase in the nominal interest rate is a 0.012 decrease in the probability of submitting a bid. The intervention policies lead to somewhat less bidding, but the effects are not statistically significant. Indebtedness, on the other hand, has a much larger effect on bidding behavior, decreasing the probability of bidding by 0.815. In the second column indebtedness is interacted with the individual treatments. Reassuringly, indebtedness in the C treatment leads to a more than 100 percent reduction in the probability of bidding. While indebtedness in the AT treatment does reduce bidding behavior on average, the estimated effect is not statistically significant. Previous changes in prices have a negligible and insignificant effect on bidding behavior. We consider the drivers of selling behavior in the last two columns. Indebtedness again plays an important role, increasing the probability of selling by more than 0.24. The policies lead to a decreased probability of selling. Asset inflation targeting has a large and significant effect, reducing the probability of selling by more than 0.26. As with the bidding behavior, changes in the asset's price do not alter investors' likelihood of selling.

Table 5: Asset Trading Probit[I]

	Pr(Bid)		Pr(Ask)	
	(1)	(2)	(1)	(2)
i_{t-1}	-1.192***	-1.132**	-0.518	-0.508
	(0.46)	(0.45)	(0.54)	(0.56)
P^A_{t-1}	0.001	0.000	0.005	0.005
	(0.00)	(0.00)	(0.00)	(0.00)
Indebted	-0.815***	-0.464**	0.267***	0.244
	(0.18)	(0.19)	(0.09)	(0.15)
C	-0.098	0.065	-0.114	-0.109
	(0.23)	(0.23)	(0.18)	(0.18)
AT	-0.08	-0.011	-0.261**	-0.281**
	(0.24)	(0.23)	(0.13)	(0.12)
Indebted x C		-1.566***		-0.039
		(0.34)		(0.21)
Indebted x AT		-0.199		0.092
		(0.27)		(0.19)
α	-0.932***	-1.018***	-0.182*	-0.176*
	(0.15)	(0.16)	(0.10)	(0.10)
N	7141	7141	7141	7141
χ^2	151.6	133	36.49	37.77

(I) This table presents results from random-effects probit regressions. Standard errors are clustered at the session level. *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

4 Discussion

We have presented a novel experimental design that allows us to observe the interaction of an asset market within a production economy. The experiment extends the conventional partial equilibrium asset market environment, allowing for activity in the asset market to influence macroeconomic outcomes and vice versa. Such an environment provides a more robust platform to study the implications of macroeconomic policies on behavior. We then explore whether borrowing constraints and asset inflation targeting policies can provide greater stability to asset markets and the aggregate economy.

We observe that aggregate production is not significantly influenced by the presence of the asset market. Moreover, in all treatments, the real side of the economy is, expectedly, unresponsive to changes in asset prices. Our participants are not willing to work considerably more to trade an asset with only a modest value if they can borrow for speculation. 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 borrowing constraints leads to greater labor supply and production, and significantly less volatility in production, as participants deem it necessary to maintain sufficient bank account balances for participating in the asset market.Imposing borrowing constraints leads to somewhat lower amplitudes but significantly greater volatility in asset prices.

Asset-inflation targeting leads to an unintended effect: it enhances the salience and effectiveness of monetary policy. In our experiment, asset prices significantly respond to changes in nominal interest rates only when such a policy is in place. Moreover, interest rates are significantly more successful at stabilizing individual decisions. It is worthwhile to notice that in our environment, participants have access to a large set of relevant information about the state of the economy but have limited time to submit their choices. The lack of responsiveness to monetary policy can be related to costs of processing and reacting to information, which have been explored in the rational inattention literature. Some examples are Sims (2003) and Moscarini (2004) that assume that agents have limited capacity to process information, or Reis (2006) who assumes that agents are rational but have to pay some cost in money and time to acquire and process information. In this experiment the processing-cost is mitigated when changes in monetary policy are made more salient through more dramatic adjustments, as in the case of the Asset Inflation Targeting treatment.

The asset inflation targeting policy does not lead to significant differences in overall production but modestly reduces output volatility. This is because labor and demand decisions are more effectively stabilized by monetary policy. Asset prices reach significantly greater extremes but deviations are,quickly tempered and relative absolute deviations from fundamental value are lower. In a related partial equilibrium asset market experiment, Fischbacher, Hens and Zeisberger (2013) extend the SSW framework by introducing an interest bearing bond. In one set of experiments, the interest rate on the bond adjusts in response to persistent trade at prices significantly different from the stock's net present value. The interest rate adjusts discretely and at most once every four rounds. Similar to our procedures, the participants are not informed about the nature of the policy. The authors observe that the "leaning against the wind" policy reduces liquidity in asset markets but is ineffective in terms of offsetting asset price bubbles or reducing asset price volatility. Our findings are similar in that volatility is not significantly affected by the policy, when compared to a No-Intervention environment. We do, however, see the policy working to significantly reduce asset price inflation in half of the sessions and we observe an overall reduction in deviations from fundamental.

The authors conduct a second experiment where participants instead face the possibility of a minimum requirement on saving in the bond account. They restrict holdings in the trading account to 25 percent in earlier rounds and reduce it to as low as 5 percent in later rounds. The treatment is similar to our borrowing constraint policy in that liquidity in the asset market is potentially limited. However, participants in their environment are never shut out of the market, while our participants are if they are in debt. They find that asset price bubbles are significantly smaller when participants are simply informed of the possibility of a reserve requirement, but detect no effect on price volatility. In related work, (Caginalp, Porter and Smith (2000)) observe smaller asset price deviations in response to decreases in market liquidity. We, on the other hand, observe the opposite effect when we impose borrowing constraints in our experiments: only modest decreases in amplitudes and increases in relative absolute deviation of prices form fundamental value. Volatility is significantly higher when participants may face binding budget constraints and an inability to participate in the asset market. These differences stem from the fact that our participants do not face truly binding constraints. They are able to work and earn additional income to loosen their borrowing constraints. Our findings suggest that a policy aimed at reducing asset price bubbles through restrictions on credit is not foolproof.

Crockett and Duffy (2013) introduce a general equilibrium dimension to asset market experiments by incorporating intertemporal consumption smoothing motives into a modified SSW asset experiment with an indefinite horizon. In their environment, participants are endowed each period with laboratory francs to purchase assets. Any francs remaining at the end of a period are consumed and earn the participant points to be exchanged for cash at the end of the experiment. The authors vary the exchange rate: linear (as in SSW) or concave. They observe that the presence of an intertemporal consumption smoothing motive significantly reduces the frequency, magnitude, and duration of asset price bubbles. Higher prices observed in the linear exchange rate treatment are driven by market thinness, a result of high concentration of asset holdings by the most risk-tolerant participants. In the concave exchange rate treatment, the concentration of assets is reduced, as most participants actively trade each period to smooth their consumption. Like Crockett and Duffy, we induce consumption smoothing motives and an indefinite horizon, but allow income to be earned and savings to be carried across periods in the form of one-period bonds. In contrast, we consistently observe persistent positive deviations of asset prices from fundamental value. As in their linear exchange rate treatment, we find that a large concentration of assets are held by a few participants. This is especially the case when we impose a borrowing constraint, and may contribute to the increased volatility observed in that treatment.

Our experimental data provides four distinctive results with respect to labour supply. First, an individual will work more hours if he or she is in debt.

In the context of US-based panel data study of income dynamics, Campbell and Hercowitz (2011) find that a shortage of funds induces indebted households to give up leisure and work more hours to acquire those funds. Second, an individual will tend to work more if last period's interest rates are higher. This is in line with a substitution effect of real interest rate on labor supply. When the nominal interest rate increases, the real interest rate also goes up as prices are sticky in our environment. The increase in the real interest affects the trade-off between current work and future consumption: it makes future consumption less expensive so people can afford to work less in the future if they work more today. Both the macro and the micro empirical evidence is in support of the substitution effect of real interest rate on labor supply (see Hall (1980) for a review of the literature). Third, individuals will work more if they face borrowing constraints which can be attributed to a precautionary saving motive. Domeij and Floden (2006) conduct a panel study on income dynamics data and find that labour supply will increase when households face liquidity constraints. Finally, our results suggest that labour supply decisions are generally insensitive to asset price changes. Similarly, based on a study of a panel of British households, Disney and Gathergood (2013) find little evidence to suggest that hours of work among middle aged individuals are responsive to house price movements. Again analyzing a panel of British households, Benito and Saleheen (2013) find little response of the intensive margin of labor (hours) for financial shocks.

Note that our results are not in line with empirical findings based on field data regarding the equity premium. Mehra and Prescott (1985) observe that investors prefer to hold government bonds even though their safe return is much lower than the expected return on risky stocks. The fact that stocks tend to be much riskier than bonds is not a sufficient explanation for the magnitude of the disparity between the two returns. The economics literature still lacks consensus on reasons for the existence of the equity premium puzzle (see Mehra (2011)). In our experiment, we find that asset prices are consistently higher than the fundamental value predicted by the model. However, in all sessions the average real return on the risky asset is consistently below the average real interest rate.

Our experiment has identified debt as an important source of heterogeneity in real and investment decisions that is not captured by representative agent frameworks. Indebted participants work significantly more, buy significantly less output and assets, and are more likely to liquidate their asset portfolio. Moreover, their decisions are significantly more responsive to changes in the nominal interest rate. This finding is consistent with previous experimental observations of debt-aversion. Meissner (2013) explores the ability of individuals to form optimal intertemporal consumption/saving decisions when borrowing is permitted. In his environment, participants must either save or borrow for optimal consumption. Meissner observes that deviations from optimality are significantly greater when participants must borrow, and he credits this to debt-aversion. Our findings, together with Meissner's, suggest an important role for debt-aversion in the modeling of heterogeneous behavior and the implications of monetary policy on aggregate activity. Attitudes toward debt and the implication for monetary policy may prove to be a fruitful avenue for future research.

Implementing an experimental macroeconomy can be quite simple. Utilizing appropriate automation, an experimenter can design an experiment that involves considerable stationary repetition and learning in a feasible 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 in 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 markets conditions. Aggregate or idiosyncratic shocks can be incorporated to study behavioural responses and their implied macroeconomic dynamics. One can 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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