Asset Prices in Experimental General Equilibrium Economies*

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Abstract

In this paper we demonstrate how an experimental general equilibrium economies can be implemented into a laboratory setting in a simplified, time- and cost-efficient manner. We then introduce an asset market to study speculative behaviour within a general equilibrium setting where subjects’ objective is to maximize their utility from consumption and leisure. Subjects are endowed with units of an asset but are not obliged to participate in the asset market. Asset prices consistently grow above fundamental value and do not decline significantly with learning. Finally, we introduce a policy preventing subjects from borrowing to buy assets. The borrowing constraint does not have any effect on asset prices. Asset market activity has no significant effects on the real economy in either treatment.

JEL classifications: C92, E2, E52, D50, D91
Keywords: Experimental macroeconomics, laboratory experiment, monetary policy, asset price bubbles, general equilibrium, New Keynesian

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1 Introduction

The bubble and subsequent collapse of the dot-com technology stocks in 2000 and U.S. housing market in 2008 has called into question the role central banks can play in reducing speculative investment. One school of thought believes that active and passive intervention by central banks can result in greater macroeconomic stability in the presence of asset market volatility. 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 the possibility of asset price bubbles and the fallout associated with crashes in the asset market.

Others stress that central banks should not use interest rates to rein in speculative investment. Bernanke and Gertler (1999, 2001), Schwartz (2002), Gilchrist and Leahy (2002) believe that an economy can be kept stable by following the conventional monetary policies. First, they posit that it is difficult to identify whether assets such as houses are 'bubbling' above their fundamental values, ex ante. It is only after an asset’s price crashes that we can infer whether it was previously overpriced. And second, it is not even clear whether interest rates could effectively reduce asset bubbles. Exuberant and optimistic investors may be willing to speculate regardless of the increased cost of borrowing or the higher yield on secure interest-bearing bonds. By keeping inflation low through the policies currently used, the Fed and Bank can maintain an environment where 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 of asset price inflation can have significant negative repercussions on the economy. Greenspan (1996) even mentioned in a speech: “We as central bankers need not be concerned if a collapsing financial asset bubble does not threaten to impair the real economy, its production, jobs, and price stability.”

To better understand whether a speculative cap policy is effective at reducing speculative investing and improving economic stability and welfare we study borrowing regulations within a virtual economy where participants play the role of household investors. All subjects are trained for one hour in a benchmark macroeconomy where they participate in labour and output markets. We then introduce the experienced subjects to one of three treatments for a second hour of play: another
benchmark economy, an economy with an asset market, or an economy with an asset market and caps on speculative borrowing. Comparing the performance of economies across treatments, we can identifying the effects of the presence of the asset market and policies on individual consumption, labour, saving, and investment decisions.

Our main finding is that the presence of an asset market does not distort median or aggregate labour and consumption decisions. While asset prices do consistently and significantly inflate above fundamental values, the real decisions of subjects are not correlated with asset prices. The introduction of speculative borrowing caps does not have a significant effect on asset prices or volume of trade. Subjects do not work significantly more in the borrowing cap treatment, but do reduce their indebtedness, allowing them to earn more interest on saving and participate in the asset market.

2 Related Literature

The value and necessity of an experimental testbed of policy is two fold. First, when new policies are being considered, a testbed experiment can illuminate any unintended or irreversible consequences and suggest parameters that policy makers might consider in their final implementation (Croson, 2003). For example, 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 et al., 2011). Kryvtsov and Petersen (2012) design an 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. There have also been an abundance of policy-relevant experiments to aid in the design of spectrum auctions in the U.S. and U.K (Binmore and Klemperer, 2002; Banks et al., 2003), U.S. kidney exchanges and residency matching programs (Roth, 2002), carbon regulation (Buckley et al., 2008), and parallel public and private health care systems in Canada (Buckley et al., 2012a, 2012b).

Second, a problem facing many researchers studying asset markets is that the fundamental (or true) value of assets are generally unknown, making it impossible to empirically determine if prices
of assets are ‘bubbling’ (i.e., exceeding its value). Economics experiments have had exceptional success getting around this problem. Smith et al. (1988) demonstrate how one can preselect the fundamental value of an asset before allowing subjects playing the role of investors to engage in trade. Their pioneering work served as the foundation for hundreds of published research papers on investor speculative behaviour in experimental asset markets.

Asset price bubbles and crashes are consistently found in experimental markets, and much work has explored methods to minimize their occurrence including the introduction of short-selling (Ackert et al., 2002; Haruvy and Noussair, 2006), the presence of futures markets (Porter and Smith, 1995; Noussair and Tucker, 2006), and the existence of traders who had experienced an earlier stock market crash (Dufwenberg et al., 2005). Two more recent papers study the effects of monetary policy on asset trading, Lugovskyy et al. (2012) test the effect of limiting subjects’ asset holdings. They find that caps generally reduce price bubbles in the first periods, but create negative bubbles in later periods. Fischbacher et al. (2013) use Smith et al. (1988) design adding a interest bearing bond. They observe that monetary policy reduces liquidity but it is ineffective in terms of offsetting asset price bubbles.

Experiments based on dynamic general equilibrium models have become popular in the last years (see Crockett, 2013 and Duffy, 2012). This also include experiments based on New Keynesian models (Noussair et al., 2011 and Petersen, 2012). The present experimental framework builds on Petersen (2012) that studies whether the general unresponsiveness to monetary policy in a laboratory production economy is due to firm or consumer-worker behaviour. She finds that while firms react to policy in both the direction and magnitude that theory predicts, consumer behaviour is highly heterogeneous. At the aggregate level, consumer behaviour is largely unaffected by expansionary policy. This finding is consistent with numerous empirical studies suggesting that lowering interest rates monetary policy is ineffective at stimulating economic activity (Weise, 1999; Dolado et al., 2005; Orphanides and Wieland, 1998). On the other hand, contractionary monetary policy halts investment and production and quickly cools off the economy (Morgan, 1993). Given this result, we believe that aggressive contractionary policy may also cool speculative investment, minimize asset price bubbles, and bring about greater economic stability.
3 Theoretical framework

The framework that we use as a basis for our experimental design is a representative agent dynamic stochastic general equilibrium (DSGE) New Keynesian model with sticky prices. Our choice is motivated by the fact that DSGE models are widely used for monetary policy analysis and forecasting among central banks. We adhere to the baseline New Keynesian framework where the economy consists of utility optimizing households, profit maximizing firms and a central bank that stabilizes the economy based on a Taylor rule. Households optimally choose consumption of final goods, labor supply and savings in a one-period nominal risk-free nominal bond. Since we are interested in whether the central bank should stabilize asset prices where we observe asset price bubbles in addition to stabilizing inflation, we have introduced a risky asset which the household can also use for saving. There is a fixed supply of the single, non-reproducible, and infinitely durable asset (trees), each of which yields some stochastic dividend (quantity of fruit) each period. Dividends are nominal and paid at the beginning of each period. Final goods are produced by monoplistically competitive firms who use labor as their only input. Final goods prices are sticky because firms set their prices based on the staggered pricing mechanism a la Calvo. Finally, the central bank sets the nominal interest rate in response to fluctuations in inflation and in the price of the risky asset.

It is important to emphasize that we do not aim to model why asset bubbles arise endogenously. Our question is not why asset bubbles arise but conditional on that they exist whether the central bank should stabilize them above and beyond their effect on the real sector of the economy. Our goal is to introduce a risky asset into the workhorse New Keynesian model used for monetary policy analysis and put it into the lab. Indeed, our agents have no reason to trade the risky asset since they can save in a risk free bond to smooth consumption. But if for some non-fundamental reason, not captured explicitly into the theoretical framework, they choose to trade the asset and exhibit bubble like behavior, which Taylor rule delivers higher welfare, the one with or without asset price inflation.

3.1 Model

In the following section, the model is described in more detail. We begin by characterizing the behavior of households and their optimal decisions. Next, we describe the production and price setting decisions of firms and finally, we show how the central bank conducts monetary policy.
3.1.1 Households

Households maximize the present discounted value of their utilities

\[ \sum_{i=0}^{\infty} \beta^i E_t \left( \frac{C_{t+i}^{1-\sigma} - N_{t+i}^{1+\eta}}{1-\sigma} \right), \]  

where they derive utility from consumption \( C_t \) and disutility from working \( N_t \) hours, \( \sigma \), is the parameter of risk aversion and, \( 1/\eta \), is the elasticity of labor supply.

\[ P_tC_t + B_t + Q_tX_t = (D_t + Q_t) X_{t-1} + (1 + i_{t-1})B_{t-1} + W_t N_t + T_t \]  

Equation 2 is the household’s budget constraint that equates expenditures to income. Households spend on consumption \( C_t \) at price \( P_t \), purchase risk free nominal bonds \( B_t \) and shares in a risky asset \( X_t \) at price \( Q_t \). They obtain income from dividends \( D_t \) earned on past holdings of the risky asset, capital gains \( Q_tX_{t-1} \) from owning shares in last period, interest rate income \( (1 + i_{t-1})B_{t-1} \) on past bond holdings, wage income from working \( W_t N_t \), and transfer from monopolistic firms \( T_t \). \( X_t \) are shares in a fixed supply of an infinitely durable asset (trees), which yield some dividend (fruit) nominal \( D_t \) in amount per period.

The representative household chooses \( C_t, N_t, B_t, X_t \) by optimizing its utility stream 1 to the budget constraint 2. From the household’s first order conditions the following equations can be derived:

\[ \frac{N_t^\eta}{C_t^{-\sigma}} = \frac{W_t}{P_t} = w_t \]  

\[ \beta E_t \left[ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{(1 + i_t)}{1 + \pi_{t+1}} \right] = 1 \]  

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

Equation 3 describes the labor leisure intratemporal trade-off taking the real wage as given. Equation 4 describes the intertemporal tradeoff between current and future consumption in terms of the risk free bond. Equation 5 is an asset pricing equation for the risky asset. Real interest can be defined using the Fisher equation:

\[ 1 + r_t = E_t \left( \frac{1 + i_t}{1 + \pi_{t+1}} \right) \]
3.1.2 Firms

Firms have a linear technology and operate in monoplistically competitive environment. They sell differentiated goods and use labor for production. They set price via a Calvo mechanism where only a fraction $1 - \omega$ is allowed to adjust prices each period.

\[ Y_t = ZN_t. \]  

The demand for each variety is

\[ Y_{it} = \frac{1}{I} \left( \frac{P_{it}}{P_t} \right)^{-\theta} C_t \]  

where $\theta$ is the elasticity of substitution between varieties and $I$ is the number of firms in the economy. $P_t$ is the aggregate price index and is defined as,

\[ P_t \equiv I^{1/\theta} \left\{ \sum_{i=1}^{I} (P_{it})^{1-\theta} \right\}^{1/1-\theta}. \]

If the firms are allowed to adjust prices, they set them at some markup over their marginal cost

\[ \frac{P_t^o}{P_t} = \frac{\theta}{\theta - 1} \frac{\sum_{i=0}^{\infty} \omega^i \beta^i C_{t+i}^{1-\sigma} mc_{t+i} \left( \frac{P_{t+i}}{P_t} \right)^{\theta}}{\sum_{i=0}^{\infty} \omega^i \beta^i C_{t+i}^{1-\sigma} \left( \frac{P_{t+i}}{P_t} \right)^{\theta-1}}. \]

3.1.3 Monetary policy

The central bank targets inflation based on the following Taylor rule:

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

where $\rho$ is natural nominal interest rate. Also important to notice is that when $\gamma > 0$, the central bank exhibits interest rate smoothing behavior.

3.1.4 Market clearing

In order to close the model, we need to impose market clearing conditions on asset markets. Note that the net supply of bonds is zero in equilibrium and the fixed supply of the shares in the risky asset is one:

\[ B_t = 0 \]
\[ X_t = 1. \] 

(12)

We also impose the resource constraint that equates total output produced to total consumption.

\[ Y_t = C_t. \] 

(13)

3.2 Predictions under rational expectations

We simulate the response of the economy to an unrealized expectations shock about the future dividend of the risky asset. Before examining the impulse responses, however, we discuss the parametrization of the model.

3.2.1 Parametrization

We choose standard values for the structural parameters (see Table 4). The model is calibrated in quarterly time. We set the discount factor (framed in our environment as the probability of continuation of the sequence) \( \beta \) equal to 0.965. This implies that a particular sequence of periods would last for an average of 28 periods. The parameter of risk aversion \( \sigma \) is calibrated to be 0.33 while the labour supply parameter \( \eta \) is set to 1.5. The elasticity of substitution between varieties \( \theta \) is 15, implying a markup of 7 percent over marginal cost. The Calvo parameter \( \omega \) is 0.9, implying 10 percent of firms have the ability to update their prices each period. The interest rate smoothing parameter used by the central bank is 0.5, while the Taylor rule parameter indicating how responsive the nominal interest rate is to inflation is \( \delta = 1.5 \). The per-period dividend paid on assets is 0.035 lab dollars, which after an average of 28 periods equals 1 lab dollar.

The model is linearized to the first order and simulated with Dynare. In the steady state, the selected calibrations imply steady state levels of individual consumption and labour of 22.4 and 2.24, respectively. The steady state real wage is set to 9.35 and the steady state nominal rate of return is 0.036.
4 Experimental Design

We developed a computerized experimental environment in which subjects playing the role of households can efficiently interact in multiple markets. Subjects adopt the role of household investors in a computerized virtual economy that consists of automated firms, commercial banks, and a central bank, and interact over a number of trading days. The objective of all subjects is to maximize their points \((U_t)\). They gain points from buying (and automatically consuming) more units of an output good, \(C_t\), and lose points by working more hours, \(N_t\). To work, a subject simply sells some of their available labour hours to firms for a given wage. Specifically, the subjects’ objective is to maximize their present discount value of the utility function:\(^1\)

\[
\sum_{t=0}^{T} \beta^t \left[ \frac{C_t^{1-\sigma} - N_t^{1+\eta}}{1 - \sigma} \right]
\]

To appropriately incentivize subjects to take their decisions seriously, subjects were able to exchange the points they earned for cash at a pre-specified rate at the end of the experiment.

To generate competitive labour and asset markets, 9 subjects participate in each economy. Subjects received a one-time endowment of "lab money" which may be used to make purchases within the game, and units of a tradable asset. Additional lab money could be earned through working, speculative gain or interest on saving. The automated bank was open continuously for subjects to borrow and save. Subjects played for some random number of periods (see Section 4.2), which made up a sequence. When a sequence ended and a subject owed money, she would be required to work the necessary amount of hours to produce the amount of goods that the owed money would purchase. In that case, they would lose \(\frac{1}{1+\eta} \left( \frac{\text{BankAccount}}{P_t} \right)^{1+\eta}\) points. As debts grow large, the disutility of repaying grows exponentially. If, instead, the subject held positive cash balances, she would be required to purchase output at the price set in the last period of the sequence. In that case, she would gain \(\frac{1}{1-\sigma} \left( \frac{\text{BankAccount}}{P_t} \right)^{1-\sigma}\) points. Due to the diminishing marginal utility associated with consumption, a subject with a constant income stream would earn more points by consuming more each period than saving large amount of cash until the end of the sequence. To reinforce this point, we also provide subjects with a payoff calculation taking into consideration their current bank account assuming the current period would be the last.

\(^1\)The parameters that were used can be found in Table 4.
4.1 Asset Markets

In the asset market treatments (C and NC) subjects received 10 shares of an asset at the beginning of each sequence. For each unit held they get a dividend of 0.035 lab dollars at the end of the period. Subjects may buy or sell assets by specifying the units they want to trade and the price. Each period, all bids and asks were sorted to determine a single market clearing price through a call market mechanism. Traders with bids (asks) that are higher (lower) than the clearing price may make exchanges if there are units available.

4.2 Discounting

One approach to implementing infinite horizon models in the lab is to generate indefinite length sequences in which each period have a constant probability of continuation. As Duffy, 2012 demonstrates, this should induce exponential discounting of future periods as well as stationarity. We set the continuation probability at $\beta = 0.965$ which implies an average length of a sequence of 28 periods.\(^2\) When a sequence randomly ends, a new one begins. Subjects’ points, money and asset balances are reset.

4.3 Automation

To simplify our environment, we automate the roles of other agents in the economy, namely monopolistically competitive firms and the central bank.

We assume a continuum of firms that set their prices as a markup over the nominal wage. Each period, a fraction of firms $1 - \omega$ are able to update their prices, while a fraction $\omega$ must continue to price at last period’s price. This creates nominal rigidities in the aggregate price level, and is a key assumption in the New Keynesian framework for obtaining nonneutrality of money. Our approach is to use the consumption and labour decisions of household subjects and equilibrium solutions to calculate the market clearing wage and price level. From the household’s utility maximization problem, we have that $\frac{W}{P} = \frac{N^0}{C^{\frac{1}{2}}}$.\(^3\)

The wage and output price are determined through the median labour and consumption decisions

\(^2\)To avoid credibility problems, each session we brought to the lab a bag that contained 193 blue marbles and 7 green. Each period we drew a marble. If the selected marble was blue then the sequence continued, otherwise the sequence ended.

\(^3\)
each period, using a linearization of the inflation equation. In particular, output prices nominal wages are calculated as:

\[ P_t = P_{t-1} \Pi_t \] (15)

\[ W_t = P_{t-1} \Pi_t \left( \frac{N_{med}}{N_{SS}} \right) \] (16)

Where

\[ \Pi_t = 1 + \gamma c \left( C_{med}^t - C^{SS} \right) + \gamma n \left( N_{med}^t - N^{SS} \right) \] (17)

An automated central bank sets policy according to transparent, pre-specified rules and regulations. By varying these rules across treatments, we can identify the effectiveness of these policies at enhancing welfare and economic stability. In general, the central bank will follow a nominal interest rate rule that responds more than one-for-one with inflation: \[ \beta (1+i_t) = \beta (1+i_{t-1})^{\gamma} \left[ (1+\pi_t)^{\delta} \right]^{1-\gamma}, \]

where \( \beta = \frac{1}{1+\rho} \) and \( \rho \) natural nominal interest rate, \( \pi_t \) is the inflation rate, and parameters \( \gamma \) and \( \delta \) are exogenously selected by the central bank.

4.4 Markets

Each period, subjects submitted their maximum willingness to work and buy output. They had up to 60 seconds to submit their decisions. They may work up to 10 hours and purchase 100 units. Each hour of labour generates 10 units of output. Note that households do not purchase individual varieties, but instead a composite good made up of a fraction of each of the varieties. This simplifies the purchasing task of consumers.

The procedures for allocation of units works as follows:

1. Households specify the maximum hours to work and units of output to purchase. The aggregate demand for the composite good and aggregate labor supply are calculated: \( N_i^S = \sum_{i=1}^N N_i^S \) and \( C_i^P = \sum_{i=1}^C C_i^P \).

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3We used the median of subjects’ labor and consumption decisions because the average choices may be biased due some decisions that were not submitted on time.

4Whenever they did not submit their decisions on time they did not receive any points.
2. Firms will only produce output that can be sold (ie. there is no opportunity for inventories to be produced).

(a) If $C_tD = ZN_t^S$, there is a sufficient supply of labor to produce all the output demanded. All households work and consume the amount they submitted.

(b) If $C_tD < ZN_t^S$, there is an excess supply of labor relative to the amount of output demanded. Firms will only hire up to the amount of workers necessary to produce their output, namely, $N_t^D = C_tD / Z$. All households will receive the units of output they requested, but may not receive as many hours as they would prefer.

(c) If $C_tD > ZN_t^S$, there is an excess demand for output relative to the amount of labor supplied. Firms cannot hire enough workers to satisfy output demand, and so will only produce a fraction of the output requested. $C_t^S = ZN_t^S$ will be produced. All households will receive the labor hours they requested but many not have their output demands satisfied.

Subjects that do not contribute to the excess demand of output or supply of labor will receive all the units of labor and output they requested. If there is an aggregate excess demand for output and a subject is contributing to this excess demand by demanding more units of output than is consistent with their labor supply, that subject will initially receive only the output produced by the labor hours she supplied. If there are any excess units of output available due to other subjects oversupplying labor, the subject may receive a random allocation of the remaining units. Similarly, if there is an excess supply of labor and a subject is contributing to the excess supply of labor, she will obtain only the amount of hours of labor consistent with her consumption decision. And if there are remaining hours available because some subjects choose overconsume, she may receive a random proportion of those remaining units. No subject will end up with more hours or output than they requested.

This quasi-random rationing rule ensures that subjects have an incentive to work. In pilots, we considered random rationing rules where subjects were either able to select from the pool of hours and output according to a random spot in a queue, or randomly allocated units up to their maximum request. We found that many subjects would request many labor hours at the beginning
of sequences, develop a large bank account which would grow interest over later periods, and then attempt to consume 100 units of output and work 0 hours. This free-riding was quickly discovered by the working subjects, who best-responded by cutting their labour supply decisions. This resulted in very low levels of labour supplied and output produced for the remainder of the sequences.

Wages are determined using the intersection of the household’s labour supply curve and the firm’s labour demand curve. Given household’s specified consumption demands and labour supplies, the algorithm determines the inelastic amount of labour to be hired to produce all the output. This allows us to determine the market clearing real wage.

5 Experimental Implementation

The experiments were conducted at the University of British Columbia. The subject pool consisted of undergraduate students recruited from a wide variety of disciplines. Subjects were recruited through ORSEE (Greiner, 2004). No subject participated in more than one treatment. Subjects were invited to participate in sessions that involved 30 minutes of instructions and 120 minutes of game participation.\(^5\) Nine subjects participated in each invited session. Earnings, including a $5 show up fee, ranged from $10 to $39.15, and averaged $25.52. The experiment was programmed in z-Tree (Fischbacher, 2007).

5.1 Procedures

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 lose points by working. We explained how their wages and prices would change based on aggregate labour and consumption decisions. They were able to study the entire payoff space by moving their mouse around a two dimensional grid. They also participated in three practice periods to familiarize themselves with the interface and payoff space.

\(^5\)In the data analysis the first (last) 60 minutes of the the sessions are labeled as sequences in which inexperienced (experienced) subjects participated.
5.2 Learning using the Computer Interface

Understanding how to make optimal labor and consumption decisions can be challenging. To facilitate learning, we provide subjects with an innovative interactive grid in the experimental software. A screen shot of their main screen is given in Figure 10. Two markers are shown on the screen and denote the subject's own decision and the average decision of all the other subjects, respectively. By clicking and moving these dots around, participants can quickly learn how aggregate decisions will affect the wages and prices in the economy, as well as their own payoffs. The structure of the payoffs are significantly easier to comprehend when presented in a visual manner, and avoids the subject having to either search through numerous payoff sheets or use a calculator to conduct a grid search for the decisions associated with the optimal payoffs. From the second period of each sequence subjects also had access to tables in which they could see the history of their individual decisions and performance as well as market outcomes (Figures 11, 12 and 13).

5.3 Treatments

We implemented a combination of between and within subject designs to study how various policies influenced real and speculative behaviour.

The Benchmark treatment allows us to study how subjects make consumption and labour decisions in the experimental economy, and provides a benchmark to observe how an economy would function without an asset market. In this environment we can also assess the extent to which subjects respond to monetary policy. All inexperienced subjects began the experiment participating in the Benchmark treatment. After approximately 1 hour of play, a third of our now-experienced subjects participated in a follow-up hour of the Benchmark treatment.

The other two-thirds of our subjects participated in one of the following two treatments. The No-Constraint (NC) treatment observes the effects of an asset market on participants’ consumption and labour decisions. We can also observe whether there is any significant relationships between real, nominal, and speculative variables. Our null prediction in this treatment is that subjects do not price the asset above its fundamental value. Moreover, since there is limited dividends being paid out to holders of the asset, we do not anticipate subjects to expect to adjust their real decisions significantly to finance their participation in the asset market. Compared to canonical partial equilibrium asset
market experiments, subjects in our environment will be paid based almost entirely on the real decisions that they make. This creates little incentive to participate in the asset market.

Finally, the Constraint (C) treatment prevents subjects from borrowing for speculative purposes. If a subject wishes to buy assets in the asset market, they must have a sufficient balance in their bank accounts to make their requested purchases. Subjects may still borrow to purchase output. Similar to the NC treatment, we expect minimal participation in the asset market. Any speculative behaviour should be dampened relative to the NC treatment by the fact that less liquidity is available for speculation. In the C treatment, subjects are required to engage in additional costly labour in order to finance their asset purchases.

5.4 Findings

In this section, we summarize our findings across treatments. Our analysis focuses on experienced subjects who have all had the opportunity to participate in the benchmark economy. Subjects participated in at least two sequences as experienced subjects. In Session NC2, the first asset sequence randomly ended after one period. We drop this sequence from our analysis as subjects did not have the opportunity to learn the results of that period.

Observation 1

*Consumption and labour decisions weakly converge to the competitive equilibrium in all sessions.*

In Figure 1.a and 1.b the average of the median labor supply and output demand per repetition are shown for each one of the treatments. Unlike output demand, labor supply seems to convergence to the steady state value in most of the treatments. In figure 1.c and 1.d the analysis is done for individual choices of labor supply and output demand distinguishing between the first sequences (inexperienced) and last sequences (experienced) in each one of the treatments. A similar pattern is observed as labor supply converges to the predicted values for experienced subjects.

To formally verify whether labor supply and output demand converge to the competitive equilibrium we followed the econometric procedure suggested in Duffy (2012). For each session $j$ the following equation is estimated:

$$y_{j,t} = \lambda_j y_{j,t-1} + \mu_j + \epsilon_{j,t}$$ (18)

6 In Session NC2, the first asset sequence randomly ended after one period. We drop this sequence from our analysis as subjects did not have the opportunity to learn the results of that period.

7 In Appendix B outcomes for each one of the sessions can be found.
where, $y_{j,t}$ is either the median output demanded or the median labor supplied and $\epsilon_{j,t}$ is a random error term with mean zero. When the equations are estimated it is possible to test for weak convergence if $|\hat{\lambda}_j| \geq 1$ and strong convergence if $\frac{\hat{\mu}_j}{1-\lambda_j}$ is not significant different from the steady state values.

As it can be appreciated in Table 1, in all the sessions weak convergence was obtained for both labor supply and output demand. However, strong convergence was observed in two sessions of the benchmark treatment, 2 sessions of AssetNoConst treatment and only 1 session of AssetConst for the case of labor supply. There is no evidence of strong convergence for the output demand in any of the sessions.
Table 1: Convergence

<table>
<thead>
<tr>
<th>Session</th>
<th>Median Output Demand</th>
<th>Median Labor Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\lambda_j$</td>
<td>$\hat{\mu}_j$</td>
</tr>
<tr>
<td></td>
<td>(Weak Conv.)</td>
<td>(Strong Conv.)</td>
</tr>
</tbody>
</table>

- B1 0.5603* 46.4129 0.4731* 2.2037*
- B2 0.3687* 74.5435 0.3230* 2.1326*
- B3 -0.0030* 42.2383 0.3841* 2.1326*
- B4 0.4232* 29.0705 0.3797* 2.0790
- NC1 0.4902* 46.8682 0.2380* 2.5411
- NC2 0.5577* 45.2297 0.4725* 2.8665
- NC3 0.0904* 23.9117 0.1007* 2.1127
- NC4 0.1834* 48.9095 0.2360* 2.2395*
- C1 0.5510* 29.7346 0.7223* 2.3884
- C2 0.3029* 40.5196 0.1980* 2.2800*
- C3 0.1509* 34.3898 0.3967* 2.6118
- C4 0.5342* 43.4887 0.3994* 2.2836*

(a) The results from the estimation of the $y_{jt} = \lambda_j y_{j,t-1} + \mu_j + \epsilon_{jt}$ are displayed in the table for each session $j$. In columns 2 and 4 for each session, * indicates that we can reject $\hat{\lambda}_j \geq 1$ at 5% level. For strong convergence (columns 3 and 5), * implies that we cannot reject $\frac{\hat{\mu}_j}{1-\hat{\lambda}_j} = SS$ at a 5% level using a Wald Test.

Observation 2

*Interest rates have no significant effect on labour or consumption decisions.*

We present results from a vector auto-regression on our aggregate data. The VARs are conducted at the session level using experienced-subject data. We consider the relationships between percentage changes in labour, interest rates, inflation, and, where applicable, asset price inflation using a two-lag structure. Table 2 presents the results. The results indicate that aggregate outcomes are not significantly affected by changes in lagged interest rates. In only two session (B3 and NC1) does labour hired, output produced, and inflation significantly respond to lagged changes in the nominal interest rate in the correct direction. Otherwise, subjects do not consistently or significantly react to changes in the nominal interest rate. This is further corroborated by questionnaire responses in which X out of Z subjects state that they did not take the nominal interest rate into consideration when making their decisions. The lack of response to monetary policy is consistent with findings by Lian and Plott (1998) who find that subjects do not change their labour supply or consumption decisions in response to changes in the money supply. Similarly, Noussair *et al.* (2011) find in New Keynesian laboratory environments that monetary policy shocks do not have persistent effects on output and inflation in their baseline and low-friction treatments.
Table 2: Outcomes from the VAR\(^a\)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>NC1</th>
<th>NC2</th>
<th>NC3</th>
<th>NC4</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Labor Inflation</strong></td>
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<tr>
<td>Labour inflation(-1)</td>
<td>-1.908</td>
<td>-0.424</td>
<td>-0.136</td>
<td>-0.180</td>
<td>0.227</td>
<td>-0.935</td>
<td>0.829</td>
<td>-1.842</td>
<td>-0.815</td>
<td>-2.070*</td>
<td>-3.176*</td>
<td>1.245</td>
</tr>
<tr>
<td>Labour inflation(-2)</td>
<td>0.019</td>
<td>-0.072</td>
<td>-0.034</td>
<td>0.171</td>
<td>0.500</td>
<td>0.071</td>
<td>-0.295</td>
<td>0.037</td>
<td>-0.114</td>
<td>-0.225</td>
<td>-0.004</td>
<td>-0.213</td>
</tr>
<tr>
<td>Interest Rate Dev.(-2)</td>
<td>-11.08</td>
<td>10.89</td>
<td>-10.18**</td>
<td>5.849</td>
<td>43.38*</td>
<td>-2.294</td>
<td>18.65</td>
<td>7.380</td>
<td>0.360</td>
<td>-9.802</td>
<td>4.700</td>
<td>-10.180</td>
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<tr>
<td>Inflation(-1)</td>
<td>4.446</td>
<td>0.659</td>
<td>-4.181</td>
<td>-2.198</td>
<td>3.992</td>
<td>0.682</td>
<td>-13.25*</td>
<td>8.859</td>
<td>2.469</td>
<td>4.120</td>
<td>11.710</td>
<td>-10.930</td>
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<td>Asset price infl.(-2)</td>
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<tr>
<td><strong>Interest Rate Dev. From SS</strong></td>
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</tr>
<tr>
<td>Labour inflation(-1)</td>
<td>-0.094</td>
<td>-0.001</td>
<td>-0.059</td>
<td>0.003</td>
<td>0.026</td>
<td>-0.016</td>
<td>0.007</td>
<td>-0.058</td>
<td>0.030</td>
<td>-0.085</td>
<td>-0.151</td>
<td>0.048</td>
</tr>
<tr>
<td>Labour inflation(-2)</td>
<td>0.011</td>
<td>-0.001</td>
<td>0.0184</td>
<td>0.011</td>
<td>0.025</td>
<td>0.0164</td>
<td>-0.003</td>
<td>0.005</td>
<td>0.003</td>
<td>-0.003</td>
<td>0.015</td>
<td>-0.006</td>
</tr>
<tr>
<td>Interest Rate Dev.(-1)</td>
<td>1.125</td>
<td>1.115**</td>
<td>1.349***</td>
<td>0.741</td>
<td>-0.848</td>
<td>0.748*</td>
<td>1.507**</td>
<td>0.871</td>
<td>1.001*</td>
<td>1.357*</td>
<td>0.558</td>
<td>1.662**</td>
</tr>
<tr>
<td>Interest Rate Dev.(-2)</td>
<td>-0.232</td>
<td>-0.172</td>
<td>-0.508</td>
<td>0.133</td>
<td>1.777*</td>
<td>0.099</td>
<td>-0.676</td>
<td>0.070</td>
<td>-0.082</td>
<td>-0.457</td>
<td>0.377</td>
<td>-0.721</td>
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<tr>
<td>Inflation(-1)</td>
<td>0.389</td>
<td>-0.0354</td>
<td>0.052</td>
<td>-0.036</td>
<td>0.164</td>
<td>0.030</td>
<td>-0.267</td>
<td>0.319</td>
<td>-0.174</td>
<td>0.235</td>
<td>0.690</td>
<td>-0.421</td>
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<tr>
<td>Inflation(-2)</td>
<td>-0.495</td>
<td>-0.0218</td>
<td>-0.194</td>
<td>-0.092</td>
<td>-0.233</td>
<td>-0.175</td>
<td>0.096</td>
<td>-0.377</td>
<td>0.095</td>
<td>-0.333</td>
<td>-0.750**</td>
<td>0.363</td>
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<tr>
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<tr>
<td>Labour inflation(-1)</td>
<td>-0.390</td>
<td>-0.006</td>
<td>0.0491</td>
<td>-0.004</td>
<td>0.086</td>
<td>-0.154</td>
<td>0.080</td>
<td>-0.259</td>
<td>-0.104</td>
<td>-0.417</td>
<td>-0.783*</td>
<td>0.277</td>
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<tr>
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<td>0.012</td>
<td>-0.006</td>
<td>-0.002</td>
<td>0.045</td>
<td>0.106</td>
<td>0.016</td>
<td>-0.039</td>
<td>0.015</td>
<td>-0.0240</td>
<td>-0.046</td>
<td>0.010</td>
<td>-0.049</td>
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<td>Interest Rate Dev.(-1)</td>
<td>1.167</td>
<td>-1.737</td>
<td>1.754</td>
<td>-2.693</td>
<td>-10.05*</td>
<td>-0.150</td>
<td>2.555</td>
<td>-2.082</td>
<td>-0.221</td>
<td>1.365</td>
<td>-1.819</td>
<td>2.061</td>
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<tr>
<td>Interest Rate Dev.(-2)</td>
<td>-1.726</td>
<td>1.465</td>
<td>-2.565*</td>
<td>2.046</td>
<td>9.685*</td>
<td>-0.548</td>
<td>-3.412</td>
<td>1.777</td>
<td>-0.166</td>
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<td>Inflation(-1)</td>
<td>1.985</td>
<td>0.839</td>
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<td>1.729</td>
<td>0.938</td>
<td>-1.022</td>
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<td>1.142</td>
<td>1.772</td>
<td>3.926*</td>
<td>-1.428</td>
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<td>Inflation(-2)</td>
<td>-1.543</td>
<td>-0.113</td>
<td>0.685</td>
<td>-0.373</td>
<td>-1.081</td>
<td>-0.596</td>
<td>1.155</td>
<td>-1.579</td>
<td>-0.516</td>
<td>-1.271</td>
<td>-3.253</td>
<td>2.147</td>
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<td><strong>Asset price inflation</strong></td>
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<tr>
<td>Labour inflation(-1)</td>
<td>1.757</td>
<td>5.566</td>
<td>1.098</td>
<td>-10.03*</td>
<td>43.83</td>
<td>-0.897</td>
<td>2.240</td>
<td>2.247</td>
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<tr>
<td>Labour inflation(-2)</td>
<td>0.191</td>
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<td>0.381</td>
<td>2.150</td>
<td>3.253</td>
<td>0.208</td>
<td>0.499</td>
<td>1.741*</td>
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<tr>
<td>Interest Rate Dev.(-1)</td>
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<td>-9.731</td>
<td>107.7</td>
<td>-44.13</td>
<td>13.20</td>
<td>3.366</td>
<td>109.4*</td>
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<tr>
<td>Interest Rate Dev.(-2)</td>
<td>0.018</td>
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<td>-8.168</td>
<td>78.25**</td>
<td>-196.4</td>
<td>6.211</td>
<td>-12.470</td>
<td>11.77</td>
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<tr>
<td>Inflation(-1)</td>
<td>3.021</td>
<td>30.23</td>
<td>6.777</td>
<td>-71.05**</td>
<td>173.0</td>
<td>-5.860</td>
<td>9.763</td>
<td>-11.43</td>
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<tr>
<td>Inflation(-2)</td>
<td>0.027</td>
<td>0.138</td>
<td>0.110</td>
<td>-0.124</td>
<td>-0.199</td>
<td>-0.040</td>
<td>-0.376*</td>
<td>-0.012</td>
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<tr>
<td>Asset price infl.(-1)</td>
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</tr>
<tr>
<td><strong>Number of obs.</strong></td>
<td>27</td>
<td>62</td>
<td>28</td>
<td>46</td>
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<td>26</td>
<td>36</td>
<td>46</td>
<td>43</td>
<td>43</td>
<td>45</td>
<td>57</td>
</tr>
</tbody>
</table>

(a) *\(p < 0.05\) and **\(p < 0.01\)
Observation 3

Changes in asset prices do not affect the macroeconomy. Changes in labour supply, interest rates, and inflation have minimal effects on asset markets.

The first three panels of our VAR estimates in Table 2 indicate that there are no statistically significant effects of asset price inflation on the amount of labour hired, output consumed or inflation in the NC and C treatments. Subjects are not offering to supply more labour as the value of assets increase. The fourth panel of our VAR estimates show that asset price inflation is occasionally influenced by changes in the macroeconomy. In NC4, increases in labour supply last period result in a decrease in asset price inflation. Higher inflation in the previous period also leads to higher asset price inflation. In C4, increases in labour supply two periods ago results in significant increases in asset price inflation, while increases in the nominal interest rate last period has the opposite effect. Generally, though, asset prices are not consistently and significantly affected by changes in the real side of the economy.

Observation 4

Asset prices are significantly above fundamental values in all sessions and do not decrease significantly with learning.

Figures 2 and 3 show the path of asset prices in each of the experienced sequences for all of the NC and C, respectively. Asset prices are significantly different from fundamental value in both NC and C treatments in all asset-trading sequences (signed rank test, $p < 0.001$ in all cases).

To compare the levels of mispricing across treatments we calculate the Relative Absolute Deviation (RAD) which is a standard statistic used in asset market experiments (See Stöckl et al. (2010) for details).

$$RAD = \frac{1}{N} \sum_{i=1}^{N} \frac{|p_i - FV|}{FV}$$

There is a weakly significant difference in the relative deviation of asset prices between NC and C treatments in only the first asset sequence (rank sum test, $p=0.083$). When we consider all periods including when no trade occurred or later sequences, there are no significant differences across treatments. This contrasts with findings by Caginalp et al. (2000) and OTHERS that suggest higher liquidity leads to larger asset price bubbles.
Asset price deviations do not disappear with learning. Using a signed rank sum test, we compare the relative deviations across sequences for each treatment in periods where the asset was traded. There are no significant differences for either treatment between the first and second sequences, and the second and third sequences ($p > 0.31$ in all cases). This suggests that asset price deviations do not decrease with substantial learning.

**Observation 5**

*Welfare is higher in the Cap Treatment.*

We consider whether subjects points significantly differ across treatments using two different measurements. *Average points per subject* is computed as the average of an experienced subject’s
points associated with their consumption and labour decisions. *Average total points per subject* is computed as the average of an experienced subject’s points including point associated with their bank account balance. Rank sum tests indicate that there are no statistically significant differences in average points per subject across any of the treatments ($p > 0.2$ in all cases). Evaluating subjects' average total points, we find no statistically significant differences across subjects points between the Benchmark and either the Cap or No-Cap treatments ($p > 0.35$ in all cases).

There are, however, significant differences between the No-Cap and Cap treatments. Subjects in the Cap treatment earn, on average, significantly higher total points per-period, both when we consider all subjects ($p < 0.01$) or only those with a positive bank account on average ($p = 0.022$). The Cap significantly increases a subject’s per-period welfare in the presence of an asset market.
This is not due to subjects working relatively less or consuming more in the Cap treatment ($p > 0.53$ in both cases, whether we consider all subjects or those with positive bank account balances). This is because the bank account balances are significantly larger in the Cap treatment ($p < 0.02$). This is likely due to the fact that subjects need to save in order to participate in the asset market in the Cap treatment.

**Observation 6**

*Macroeconomic variables affect individual labor and consumption decisions. Subjects are highly heterogeneous in their response to real interest rates.*

To the effect of macroeconomic variables on subjects’ labor and consumption decisions we specify the following first difference equations for each subject, $i$ at period $t$:

\[
\Delta N_{i,t} = \Delta N_{i,t-1} + \Delta C_{i,t} + \Delta RW_t + \Delta rr_t + \Delta BB_{i,t} + \Delta Ap_t \tag{20}
\]

\[
\Delta C_{i,t} = \Delta C_{i,t-1} + \Delta N_{i,t} + \Delta RW_t + \Delta rr_t + \Delta BB_{i,t} + \Delta Ap_t \tag{21}
\]

Where $RW$ are the real wages, $BB$ is the bank account balance, $rr$ is the real interest rate $(i_t - \pi_{t+1})^8$ and $Ap$ are the asset prices. We ran regressions for pooled data from all treatments as well that for each one of the treatments. We follow Anderson and Hsiao (1982) and use $N_{t-2}$ and $C_{t-2}$ as instruments for $\Delta N_{i,t-1}$ and $\Delta C_{i,t-1}$ respectively. The results are shown in Table 3. Form the way that goods and hours are allocated in the economy, it is no surprising that consumption and labor decisions are positive correlated at the individual level. There is a positive response in terms of labor supply to higher real wages and no effect in terms of consumption. Labor and consumption react in the expected way to bank account balances. When there is an increase in their bank balances, subjects tend to work less and consume more. Finally, consumption and labor decisions do not respond to the real interest rates or asset prices, confirming Result 2 and 3.

---

8Ideally one should calculate the real interest rates using inflation expectation.
Table 3: Regression on Labor Supply and Output Demand (FD)\(^a\)

<table>
<thead>
<tr>
<th>depvar: (\Delta N_{it})</th>
<th>All</th>
<th>B</th>
<th>NC</th>
<th>C</th>
<th>depvar: (\Delta C_{it})</th>
<th>All</th>
<th>B</th>
<th>NC</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta N_{it-1})</td>
<td>0.131***</td>
<td>0.181***</td>
<td>0.028</td>
<td>0.127*</td>
<td>(\Delta C_{it-1})</td>
<td>0.198***</td>
<td>0.349***</td>
<td>0.005</td>
<td>0.154</td>
</tr>
<tr>
<td>(0.03)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td></td>
<td>(0.05)</td>
<td>(0.09)</td>
<td>(0.08)</td>
<td>(0.08)</td>
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</tr>
<tr>
<td>(\Delta C_t)</td>
<td>0.008***</td>
<td>0.007***</td>
<td>0.015***</td>
<td>0.005***</td>
<td>(\Delta N_t)</td>
<td>2.094***</td>
<td>1.654***</td>
<td>3.776***</td>
<td>1.926***</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td></td>
<td>(0.27)</td>
<td>(0.46)</td>
<td>(0.48)</td>
<td>(0.51)</td>
<td></td>
</tr>
<tr>
<td>(\Delta RW_t)</td>
<td>0.068***</td>
<td>0.080**</td>
<td>0.067***</td>
<td>0.033*</td>
<td>(\Delta RW_t)</td>
<td>0.114</td>
<td>0.073</td>
<td>0.426</td>
<td>-0.343</td>
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<tr>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.01)</td>
<td>(0.02)</td>
<td></td>
<td>(0.18)</td>
<td>(0.38)</td>
<td>(0.24)</td>
<td>(0.30)</td>
<td></td>
</tr>
<tr>
<td>(\Delta rr_t)</td>
<td>-0.096</td>
<td>1.897</td>
<td>-1.430</td>
<td>-0.320</td>
<td>(\Delta rr_t)</td>
<td>6.408</td>
<td>11.629</td>
<td>-12.097</td>
<td>28.608</td>
</tr>
<tr>
<td>(0.65)</td>
<td>(1.41)</td>
<td>(0.90)</td>
<td>(1.04)</td>
<td></td>
<td>(10.45)</td>
<td>(21.48)</td>
<td>(14.15)</td>
<td>(19.36)</td>
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</tr>
<tr>
<td>(\Delta BB_t)</td>
<td>-0.005***</td>
<td>-0.005***</td>
<td>-0.017***</td>
<td>-0.003***</td>
<td>(\Delta BB_t)</td>
<td>0.089***</td>
<td>0.079***</td>
<td>0.226***</td>
<td>0.075***</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td></td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.03)</td>
<td>(0.01)</td>
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</tr>
<tr>
<td>(\Delta Ap_t)</td>
<td>0.013</td>
<td>-0.009</td>
<td>0.004</td>
<td>0.006</td>
<td>(\Delta Ap_t)</td>
<td>-0.893</td>
<td>-0.084</td>
<td>(0.57)</td>
<td>(0.14)</td>
</tr>
<tr>
<td>(0.04)</td>
<td>(0.01)</td>
<td>(0.04)</td>
<td>(0.01)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Cons.</td>
<td>0.001</td>
<td>-0.008</td>
<td>0.004</td>
<td>0.006</td>
<td>Cons.</td>
<td>0.203</td>
<td>0.237</td>
<td>0.316</td>
<td>0.170</td>
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<tr>
<td>(0.02)</td>
<td>(0.05)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td></td>
<td>(0.35)</td>
<td>(0.77)</td>
<td>(0.56)</td>
<td>(0.48)</td>
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</tr>
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</table>

No. obs 4229 1395 1214 1620 No. obs 4229 1395 1214 1620

(a) *\(p < 0.05\), **\(p < 0.01\), ***\(p < 0.001\). This follows Anderson-Hsiao estimator using \(x_{t-2}\) as an instrument for \(\Delta x_{t-1}\).

6 Discussion

Implementing an experimental macroeconomy can be quite simple. Utilizing appropriate automat-
ations, an experimenter can design an experiment that involves considerable stationary repetition and
learning in a feasible time-frame. Our experiments have shed light on how subjects behave within
New Keynesian production economies. While their decisions are sensitive to changes in real wages
and their bank account balances, our subjects do not respond significantly to changes in the nominal
monetary policy. This finding is consistent with earlier experimental macroeconomic results by Lian
and Plott (1998), Petersen (2012) and Noussair et al. (2011) that aggregate behaviour is inelastic to
changes in monetary policy.

Our novel experimental design allowed us to also observe how real behaviour changes in the
presence of an asset market. Relative to the Benchmark economy, we do not find any significant
differences at the aggregate level when we introduce asset markets with or without borrowing con-
straints. Furthermore, we find that real decisions along the business cycle are unaffected by asset
market activity, and vice versa. Welfare does increase when we impose the cap, but this is because
subjects borrow less and are generally less indebted at the end of the experiment. This results in
higher final payouts at the end of the game.

The Active Participation Hypothesis proposed by Lei et al. (2001) suggests that subjects irra-
tionally participate in asset markets when they have no other consequential tasks to occupy their time with. In our experiment, subjects have very salient consumption and labour decisions to make that directly influence their payoffs. They are also well informed that their holding of assets has little to no consequence on their final payouts. Still, subjects actively participate in the asset market even after experiencing asset price bubbles and crashes. Interestingly, reducing the ability to borrow for speculative purposes does not have a significant effect on deviations of asset prices from fundamental values. This is in consistent with Fischbacher et al. (2013) who find that contractionary monetary policies are ineffective at stabilizing asset prices.

Our design and results provide a springboard for further experimental research on macroeconomic policies. The design can easily be extended to elicit expectations to study the relationship between beliefs and decisions. Further treatments involving alternative policy rules, communication methods, payoff functions, and subject pools are just a handful of ways one can test the robustness of our findings. Methodological procedures that could generate real utility payoffs (e.g. real consumption and effort tasks) in a way that would allow for the collection of time series data with sufficient stationary repetition would be another interesting avenue of research.
References


Greiner, B. (2004). "the online recruitment system orsee 2.0- a guide for the organization of experiments in economics, working Paper University of Cologne, Department of Economics.


## A Parametrization

Table 4: Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter Description</th>
<th>Value</th>
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<tr>
<td>$Z$</td>
<td>Productivity level</td>
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</tr>
<tr>
<td>$1 - \omega$</td>
<td>Fraction of firms updating</td>
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</tr>
<tr>
<td>$\delta$</td>
<td>Inflation Target of CB</td>
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<tr>
<td>$\gamma$</td>
<td>Interest smoothing parameter CB</td>
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<tr>
<td>$\kappa$</td>
<td>Slope of NKPC</td>
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</tr>
<tr>
<td>$\theta$</td>
<td>Measure of substitutability</td>
<td>15</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Rate of discounting</td>
<td>0.965</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Natural nominal rate of return</td>
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</tr>
<tr>
<td>$1/\sigma$</td>
<td>Elasticity of intertemporal substitution</td>
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</tr>
<tr>
<td>$1/\eta$</td>
<td>Frisch labor supply elasticity</td>
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</tr>
<tr>
<td>$\mu^*$</td>
<td>Steady state markup ($\theta/(\theta - 1)$)</td>
<td>1.07</td>
</tr>
<tr>
<td>$C^*$</td>
<td>Steady state consumption</td>
<td>22.37</td>
</tr>
<tr>
<td>$N^*$</td>
<td>Steady state labor</td>
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<tr>
<td>$W^*$</td>
<td>Steady state nominal wage</td>
<td>10</td>
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<tr>
<td>$P^*$</td>
<td>Steady state output price</td>
<td>1.07</td>
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</table>
B Labor Supply and Output Demand by Treatment

Figure 4: Median Labor Supply B Treatment
Figure 5: Median Output Demand B Treatment
Figure 6: Median Labor Supply NC treatment

NC1

NC2

NC3

NC4

Med. Lab. Supply  Begin seq.  SS
Figure 7: Median Output Demand NC Treatment

NC1

NC2

NC3

NC4

Med. Out. Demand Begin seq. SS
Figure 8: Median Labor Supply C treatment

C1

C2

C3

C4

Begin seq. Med. Out. Demand SS
Figure 9: Median Output Demand C Treatment

C1

C2

C3

C4

Med. Out. Demand Begin seq. SS
Figure 10: Heat map on the Main Screen of the C Treatment

<table>
<thead>
<tr>
<th># Assets</th>
<th>Units Traded</th>
<th>UnitPrice</th>
<th>Action</th>
</tr>
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<tr>
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</table>
Figure 11: Personal History Screen

Figure 12: Market History Screen
Figure 13: Asset Market History Screen
D Instructions used in the experiment

The instructions distributed to subjects in the all the treatments (B,NC,C) are reproduced on the following pages. They received the same set of instructions except that subjects in the B treatment did not get the last page with the title: "INTRODUCTION OF ASSETS AND ASSET MARKET". Subjects in the NC and C treatments received identical instructions. The only difference was that in the third paragraph of the "INTRODUCTION OF ASSETS AND ASSET MARKET", for the NC treatment said: "You may also borrow money, at the current interest rate, to purchase any assets.". And for the C treatment said: "You will not be able to borrow money to purchase any assets."
INTRODUCTION

You are participating in an economics experiment at the University of British Columbia. The purpose of this experiment is to analyze decision making in experimental markets. If you read these instructions carefully and make appropriate decisions, you may earn a considerable amount of money. At the end of the experiment all the money you earned will be immediately paid out in cash.

Each participant is paid 5 CAD for attending. During the experiment your income will not be calculated in dollars, but in points. All points earned throughout this game will be converted into CAD by applying the exchange rates found on the whiteboard.

During the experiment you are not allowed to communicate with any other participant. If you have any questions, the experimenter(s) will be glad to answer them. If you do not follow these instructions you will be excluded from the experiment and deprived of all payments aside from the minimum payment of 5 CAD for attending.

You will play the role of a household over a sequence of several periods (trading days). You will be interacting with other human consumers. There will be also computerized firms and a central bank operating in this experimental economy.

In this experiment, you will have the opportunity to work and purchase output in two markets. All transactions in all markets will be conducted using laboratory money.

OVERVIEW

The objective of each player is to make as many points as possible. You will receive points for purchasing more units of output in your bank account. You will lose points by working. You may borrow and save at the current interest rate.

LABOR & OUTPUT MARKETS

At the top of the screen you’ll see a graph representing the different combinations of output (x-axis) and labour (y-axis) you can choose. Each of the different combinations defines:

- A current hourly wage
- A current price for a single unit of output

This information will be located on the right hand side of the graph. Notice that these 2 pieces of information are only potential outcomes. The actual outcomes will be computed based on everyone’s actual choices.

You may agree to trade none, some or all of your labor hours to firms in exchange for potential wage. You will input the very maximum you would like to work. You may end up working less than your desired amount, but you will never work more than that. You are able to work a maximum of 10 hours per period and may also work fractions of an hour, up to 1 decimal place, e.g., 4.3 or 7.2 hours. Each worker is able to produce 10 units per hour and this will never change. Wage income will be deposited from your bank account.

You may also choose to purchase output. You will input the very maximum you would like to purchase. You may end up purchasing less than your desired amount. Spending on output will be debited from your bank account. You will also receive a dividend from firms that will also help you to pay for the varieties you will purchase. This is an equal share of the positive or negative profits the firms earned in the current period.

To better understand how your labour and consumption decisions translate into points and how the balance on your bank account changes, you will have the opportunity to move the red dot to your preferred point on the
payoff space. Notice that as you increase the amount of labour, you will lose points at an increasing rate. As you increase the amount of output, you will gain points at a decreasing rate.

Actual wage, output price and the interest rate will be computed based on your choices and everyone else’s choices. That’s why you will be able to move around 2 different dots, the red one that represents your own decisions and the green one that characterizes the average of everyone else’s choices. This way you will visualize different predictions on wages and prices for different combinations of aggregate consumption and aggregate labour.

**You will have an initial balance of 10 experimental units of money on your bank account. Whenever your bank account is negative, i.e. you spent more than you earned, you will owe the bank the remainder PLUS interest in the next period. So long as you pay the interest on your debt, you may continue to borrow. Any money owing at the end of the experiment will be repaid through points. In particular, you will lose: \( \frac{1}{2.5} \left( \frac{\text{Bank Account}}{10+\text{Output Price}} \right)^{2.5} \). Similarly, If your bank account has a positive balance at the end of the experiment you will gain: \( \frac{1}{0.67} \left( \frac{\text{Bank Account}}{\text{Output Price}} \right)^{0.67} \).

**If your bank account is positive, you will receive interest on the saving in your bank account. This will be credited to your account in the next period.

After all subjects submit their labour, consumption, and investment decisions, firms will decide how many hours to hire. Wage and output price will be computed. There will be no unsold output. If the total number of labour hours supplied in the economy is in excess of what is necessary to satisfy consumers’ output demands, firms will hire fewer hours and you may find yourself working a fraction of the hours you requested. Similarly, if the worker supplied hours is insufficient to cover consumer demand, you may find yourself able to purchase only a fraction of the output you requested.

As you purchase more units, you will gain more points but at a decreasing rate. As you work more hours, you will lose more points at an increasing rate. You do NOT obtain points from your holdings of cash.

**Worker Points = (Points Gained from Consuming – Points Lost from Working)**

The interest rate at which you spend or save will depend on inflation. Particularly, for every 1% that prices increase from yesterday, the automated central bank will increase the borrowing and saving rate by more than 1%. Over the long run, the central bank will aim to keep the interest rate around 3.5%, but it will fluctuate as inflation on output occurs. Lower interest rates make it cheaper to borrow but more challenging to accumulate savings, and vice versa.

Notice that interest rate might also be negative. In that case you will lose money by saving and gain money by borrowing.

Each sequence will have a random number of periods determined by a continuation rate of 0.965. That is, there is a 3.5% chance of a period ending at any period. To make the termination rule as transparent as possible, the experimenter will carry a bag containing 200 marbles, 193 of them are blue and only 7 of them are green. Each period a marble will be drawn. If a blue marble is drawn the sequence will end, otherwise the sequence will continue. You will play multiple sequences. On average you will play 28 periods in each sequence.
**Screens**

Throughout the experiment you will have a chance to flip back and forth between 4 different screens:

1) **Action Screen.** - This is the main screen. This screen is divided in two:

   a) On the left hand side of the screen you’ll find a graph that represents all possible combinations of labour and output. On the graph you’ll see two different dots. The red one represents your own choices. By moving around the red dot you will be able to visualize the points you might earn by selecting different combinations of labor and output. The green dot denotes the average values of output and labour of the rest of the participants. By moving around both dots you’ll have a better sense on how your choices as well as everyone else’s decisions affect the potential wage and output price of the economy. Your predicted banking account balance (without interest rate) will be also displayed. Notice that by positioning the dots together you will be assuming that everyone else’s choices are the same as yours.

   b) On the right hand side of the screen (SUBMIT YOUR DECISIONS) you will have to enter your final choices on output and labour. Immediately after everyone submits their decisions, the total amount of output and labour will be computed.

2) **Personal History.** - You will find a summary of your previous decisions on consumption, labour, as well as the points you earned and your bank account balance.

3) **Market History.** - On this screen you will be able to observe information on interest rates and inflation rate from previous periods. Information on total output and labor is also included.
Some useful information

Points = \( \frac{1}{0.67} \times (Output)^{0.67} - \frac{1}{2.5} \times (Labour)^{2.5} \)

Steady State Output = 22.37

Steady State Labour = 2.24
INTRODUCTION OF ASSETS AND ASSET MARKET

All subjects will now receive 10 shares of an asset at the beginning of the next experiment. Each period you will get 3.6 cent of lab currency per asset. That means that the average value of each unit of asset is: 1. At the end of each sequence you will not receive money for the assets you hold. You will incur no cost to holding the asset but no benefits either. Remember the only way you will make points in this experiment is by purchasing the output. All other features of the economy remain identical to the previous experiment.

All subjects may trade this asset costlessly in an asset market. You may specify how many units you wish to buy or sell in the asset at a specified price. Note that you cannot sell more shares that you currently own (i.e. no short-selling). In a given period, you may either buy or sell, but not both. All submitted offers to buy (bids) and offers to sell (asks) will be used to determine a single market clearing price. All offers to buy at a price higher than the clearing price will be transacted at the lower clearing price. Similarly, all offers to sell at a price below the market clearing price will be transacted at the higher clearing price. Earnings from selling units of the asset will be deposited to your bank account. Spending on the asset will be debited from your bank account. You will retain any assets that you hold into the next period.

You may also borrow money, at the current interest rate, to purchase any assets.

The action screen will now include an option for you to preview your asset decisions:

1) **Asset Market.** - On this screen you will find the average number of assets and prices that were offered to buy *(bids)* or to sell *(asks)* in each one of the previous periods. It is important to notice that this information may not coincide with the actual information on prices and traded assets, because the offers might not end up in trading.