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Inflation, Output, and Welfare in the Laboratory

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Abstract

We develop an experimental framework to investigate the quantity theory of money and the real effects of inflation in an economy where money serves as a medium of exchange. We test the classical view that inflation reduces output and welfare by taxing monetary exchange. Inflation is engineered by constant money growth. We conduct three treatments, where the newly issued money is used to finance government spending, lump-sum transfers, and proportional transfers, respectively. Experimental results largely support theoretical predictions. Higher money growth leads to higher inflation. Output and welfare are significantly lower with government spending, and output is significantly lower with lump-sum transfers, while there are no significant real effects with proportional transfers. A deviation from theory is that the detrimental effect of money growth in our framework depends on the implementation scheme and is stronger with government spending than with lump-sum transfers.

Topics: inflation and prices; inflation: costs and benefits; monetary policy

JEL codes: C92, D83, E40

Résumé

Nous élaborons un cadre expérimental pour étudier la théorie quantitative de la monnaie et les effets réels de l'inflation dans une économie où la monnaie sert de moyen d'échange. Nous testons la validité de la perspective classique selon laquelle l'inflation cause une réduction de la production et du bien-être en agissant comme une taxe sur l'utilisation de la monnaie comme moyen d'échange. L'inflation est générée par la croissance constante de la masse monétaire. Nous menons trois expérimentations dans le cadre desquelles de la monnaie nouvellement émise est utilisée pour financer les dépenses publiques, effectuer des transferts forfaitaires et opérer des transferts proportionnels. Les résultats obtenus corroborent dans une large mesure les prévisions théoriques. Une croissance plus élevée de la masse monétaire entraîne une montée de l'inflation. Lorsque la monnaie nouvellement émise sert à financer les dépenses publiques, production et bien-être diminuent de façon significative. Lorsqu'elle sert à effectuer des transferts forfaitaires, la production diminue de façon significative. Lorsqu'elle sert à faire des transferts proportionnels, il n'y a pas d'effet significatif sur la production et le bien-être. Notre cadre se distingue de la théorie en ce que, dans celui-ci, les effets négatifs de la croissance de la masse monétaire dépendent du mécanisme de mise en œuvre et sont plus importants dans le cas des dépenses publiques que dans celui des transferts forfaitaires.

Sujets : Inflation et prix; Inflation : coûts et avantages; Politique monétaire

Codes JEL : C92, D83, E40

1 Introduction

The effects of inflation on output and welfare are central issues in monetary economics and central banking. A classical view, dating back to Bailey (1956), is that inflation acts like a tax on money holdings and disincentivizes monetary exchange. While anticipating inflation, individuals have weaker incentives to acquire real money holdings, which reduces output and welfare. This channel lies at the heart of many monetary models where money is a medium of exchange, including cash-in-advance models such as Lucas (2000) and more microfounded models such as Shi (1997) and Lagos and Wright (2005).

In this paper, we evaluate the inflation tax channel and study the effects of inflation through controlled laboratory experiments. The experimental approach is a useful complement to theoretical and empirical approaches, which have yet to reach a consensus on the effects of inflation, at least for moderate inflation rates.[1] On the theory side, there are several different perspectives on the effects of inflation. One such view is the inflation tax channel that we described above. An opposing view attracting attention in the Great Recession is that higher inflation stimulates spending and output by reducing the real interest rate at the zero lower bound. Similarly, on the empirical side, the evidence on the effects of inflation is mixed. For example, Bullard and Keating (1995) find a permanent shock to inflation is not associated with a permanent change in output in most economies; the effect tends to be negative for high inflation rates while positive for low inflation rates. McCandless and Weber (1995) find no correlation between inflation and real output growth, while Barro (1995) finds a negative correlation.[2]

A key advantage of our experiment is it allows us to focus on evaluating the inflation tax channel and assess the validity of the corresponding theory.[3] As stated by Hommes

[1]In the laboratory, we implement money growth rates of 15% and 30%. These values may appear as high inflation in real life, but may be perceived as moderate by subjects in the lab. We chose these values considering economic salience and earlier findings in the experimental literature. In particular, Duffy and Puzzello (2022) study a similar setting as ours and observed higher production rates with a 16.67% money supply growth rate relative to the case with constant money supply, contrary to theory. We chose comparable (15%) or higher (30%) money growth rates to ensure they would generate salient inflation rates in our environment. An explicit tax of 30% was also used by Anbarci, Dutu, and Feltovich (2015). Given recent events, it also turns out our 15% inflation rate is not too far from current inflation rates even in advanced economies.

[2]There is also a literature that uses survey data to study the effects of inflation expectations. Candia, Coibion, and Gorodnichenko (2020) review this literature and find mixed evidence: higher inflation expectations can lead to either depressed or increased economic activity.

[3]Lucas (2000) and related follow-up papers provide some support for the inflation tax channel, i.e., the demand for real money balances decreases with the nominal interest rate or inflation rate. Our experimental study complements this approach as it yields individual-level data and provides direct evidence on how inflation affects output through real money balances.

(2021), "If a macro theory does not work in a simple controlled laboratory environment, why would it work in reality?" Overall, we find clear support for the inflation tax channel predicted by a wide class of monetary models. The fact that the laboratory institution we develop implements the underlying theory is non-trivial in terms of experimental design and, moreover, provides the assurance that similar settings can be used to study related applications, e.g., unconventional monetary policies and currency competition.

Our experiments are based on the New Monetarist models of Lagos and Wright (2005) and Rocheteau and Wright (2005). In these models, money serves explicitly as a medium of exchange so that inflation erodes money's purchasing power and reduces output and welfare.[4] The model is well suited for laboratory investigation since it is microfounded, and the alternating market structure with quasilinear preferences simplifies the model solution and welfare analysis. In addition, many applications have been studied using this framework – such as open market operations, currency competition, quantitative easing, and forward guidance – so it is possible to extend our design to study a wide range of monetary policies.[5] We adopt the competitive markets version of Rocheteau and Wright (2005) because all subjects observe the same prices, which facilitates the observation of inflation if it occurs in our experimental economies and, in turn, its real effects.[6]

We engineer inflation with a simple monetary policy rule where the money supply grows at a constant rate. We first consider a benchmark treatment where the money supply is constant (Constant Money) and compare prices, output, and welfare in three inflationary treatments with different schemes for money growth — i.e., money injections through government purchases, lump-sum transfers ("helicopter drops"), and proportional transfers to money holdings. In the Government Spending treatment, a computerized robot is preprogrammed to use newly issued money to purchase goods. In the Lump-Sum Transfers treatment, consumers receive a lump-sum transfer of new money. Finally, in the Proportional

[4]Recent work by Lagos and Zhang (2019, 2022) shows that abstracting from money as a medium of exchange is not without loss of generality for cashless monetary models. In addition, quantitative applications of New Monetarist models show their empirical relevance; see e.g. Berentsen, Menzio and Wright (2010), Lagos (2010), Aruoba, Waller, and Wright (2011), Rocheteau, Wright, and Zhang (2018), Lagos and Zhang (2019, 2022), Bethune, Choi, and Wright (2020), among many others.

[5]For applications, see Zhang (2014) for currency competition, Williamson (2012) for unconventional monetary policies, Rocheteau, Wright, and Xiao (2018) for open market operations, and Gu, Han, and Wright (2020) for forward guidance.

[6]This is an important departure from the main setting studied in Duffy and Puzzello (2022) where subjects randomly meet in pairs in the first market and only observe prices within their own matches. Other relevant design departures include our focus on different implementation schemes for money growth and our use of different money growth rates and a higher discount factor (see Sections 2 and 4 for more discussion). Further, the alternating market structure is reminiscent of Bewley (1980) and Townsend (1980) where agents alternate between buyers and sellers. One can interpret the competitive version of Rocheteau and Wright (2005) as a special case of the Bewley-Townsend model with quasilinear preferences in one market.

Transfers treatment, all subjects receive a transfer proportional to their money holdings.

In stationary equilibrium, theory predicts inflation is zero in the Constant Money treatment while positive and equal to the money growth rate in all inflationary treatments. In terms of real effects, money growth through government spending and lump-sum transfers has detrimental effects on output and welfare relative to the Constant Money treatment. In these two environments, agents respond to higher inflation by reducing real cash holdings, and hence consumption and production. With proportional transfers, since the effect of inflation is neutralized by the proportional transfer, output and welfare are identical to the Constant Money treatment. This policy scheme therefore provides an additional test of the inflation tax channel.

Given the sharp predictions from theory, we next explore the following questions with the experimental data: Do anticipated changes in the money supply transfer to prices, in line with the quantity theory of money?[7] If money growth generates inflation, do subjects perceive it like a tax in treatments where money injections are predicted to have detrimental effects on output and welfare?[8] The results of the experiment are largely consistent with theoretical predictions, though we also observe instances departing from theory. First, we find evidence in support of the quantity theory of money: average inflation from the experimental economies is close to the money growth rate in all treatments. Second, in terms of real effects, money growth and inflation reduce output and welfare in the Government Spending treatments and output in the Lump-Sum Transfer treatment but have no real effects under Proportional Transfers. However, in contrast with theory, the detrimental effect of money growth and inflation depends on the implementation scheme, and is stronger with Government Spending than Lump-Sum Transfers.

The remainder of the paper is organized as follows. Section 2 discusses related literature. We introduce the theoretical framework in Section 3. Section 4 describes the experimental design and procedures, and Section 5 discusses the experimental results. We conclude in Section 6.

[7]The quantity theory prediction that prices respond proportionally to changes to the money supply in the long run has received ample confirmation empirically over time and across countries (see e.g., Lucas 1980; Friedman and Schwartz 1987; Rolnick and Weber 1997). Here we provide a complementary empirical investigation in a controlled setting.

[8]Note that the quantity theory of money is conceptually distinct from the inflation tax channel. The quantity theory of money states the price level is proportional to the money supply and is silent on the real effects of money supply changes. In contrast, the inflation tax channel focuses on the impact of inflation on real allocations. In our theoretical setting, the quantity theory holds in all treatments while the inflation tax channel has adverse effects only in the Government Spending and Lump-Sum Transfers treatments. The experiments we design examine predictions from both the quantity theory and the inflation tax channel.

2 Related Literature

Here we discuss papers that are most closely related to our study in order to clarify our contribution relative to the literature. See Duffy (2016) and Hommes (2021) for more comprehensive surveys of experiments studying macroeconomics and monetary policies in the laboratory.

This paper is related to experimental studies on the effects of inflationary monetary policies. The closest study to ours is Duffy and Puzzello (2022), who also use a New Monetarist model to study the effects of monetary policy on output and welfare. The two papers however investigate different questions, use a different experimental framework and design, and find different results. While our main contribution is to study the effects of inflationary monetary policies and different money injection schemes, Duffy and Puzzello (2022)'s main focus is on deflationary policies and different implementations of the Friedman rule through deflation or paying interest on money. While they also consider an inflationary monetary policy, they only study a single implementation through lump-sum transfers and find inflation generates higher output, in contrast with theory and our paper. We conjecture this discrepancy may be in part attributed to different design choices; e.g., our framework is based on the competitive version of Rocheteau and Wright (2005) with fixed trading roles while Duffy and Puzzello (2022) use Lagos and Wright (2005) with pairwise meetings and take-it-or-leave-it-offers, and trading roles are random. Indeed, some of our design choices were in part motivated by the findings of Duffy and Puzzello (2022) and implemented specifically to address factors that may have contributed to departures from theory. We provide more details on other design differences in Section 4.[9]

Our paper also relates to earlier experimental work studying the consequences of hyperinflation in overlapping generation economies (OLG) including Marimon and Sunder (1993, 1994, 1995), Lim, Prescott, and Sunder (1994), and Bernasconi and Kirchkamp (2000). These papers emphasize the role of money as a store of value and focus on analyzing the effects of hyperinflation on price stability and equilibrium selection.[10] Subjects in Marimon and Sunder (1993, 1994, 1995) form inflation forecasts each period which are then used to automate consumption and savings decisions based on an OLG model. Since subjects are

[9]Given all these differences, we leave a more exhaustive exploration of the role of price formation mechanisms (e.g., Nash bargaining versus competitive pricing) and other factors in monetary policy transmission for future research.

[10]For example, Marimon and Sunder (1995) study how price stability is affected by a deficit rule where the real deficit level is fixed and financed by seigniorage and a money growth rule where the money growth rate is fixed and the government deficit adjusts to satisfy it. They find weak evidence that a constant money growth rule helps stabilize prices.

only rewarded based on the accuracy of their inflation forecasts, consumption decisions are not incentivized or chosen explicitly. In contrast, our experiment incentivizes consumption and production explicitly in order to investigate the real effects of inflationary policies on output and welfare.[11] Deck, McCabe, and Porter (2006) study inflationary policies in a finitely repeated double auction and show proportional money injections lead to hyperinflation and trading collapses. Lian and Plott (1998) investigate a static cash-in-advance economy where money supply increases are implemented as unanticipated lump-sum transfers; they document nominal effects due to money supply changes but do not find real effects. We complement this work by considering a *dynamic* environment with an explicit role for money and different money injection schemes. Anbarci, Dutu, and Feltovich (2015) study the effects of an inflation tax in a version of the Lagos and Wright (2005) model with price posting. There are no explicit changes in the money supply and inflation is implemented by asking subjects to pay interest on money borrowed to finance the purchase of consumption. While the inflation tax leads to detrimental effects on output, subjects make static choices and the inflation tax is proxied by an exogenous interest rate. In contrast, our experiment is fully dynamic, subjects can adjust their money holdings over time and therefore prices and inflation are endogenous and evolve over time. Indeed, we find subjects' behavior indicates inflation is perceived as a tax.[12]

This paper also contributes to the experimental literature studying the role of money as a medium of exchange. Studies in this area have focused on a number of questions including equilibrium selection, the essentiality of money, and currency competition. See e.g., Arrieta Vidal et al. (2022), Berentsen, McBride, and Rocheteau (2017), Brown (1996), Camera and Casari (2014), Camera, Noussair, and Tucker (2003), Davis et al. (2022), Ding and Puzzello (2020), Duffy and Ochs (1999, 2002), Duffy and Puzzello (2014a), Jiang, Puzzello and Zhang (2021), Jiang et al. (2021), Jiang and Zhang (2018), Kamiya et al. (2021), and Rietz (2019). In these studies, either prices are exogenous or there is no money growth and hence inflation. By contrast, we use a similar class of models but augmented with endogenous prices and constant money growth in order to study the real effects of different inflationary policies.

Finally, there is also a large experimental literature studying the effects of expected

[11] An advantage of using the Lagos and Wright (2005) or Rocheteau and Wright (2005) model relative to the OLG model is it provides clearer welfare predictions on the effects of money growth (e.g., with OLG models, one must decide the weights attached to different generations for welfare calculations).

[12] Our paper is also related to monetary policy experiments that implement a one-time change in the money supply. Baeriswyl and Cornand (2018) implement one-time monetary injections in a frictionless production environment and find credit expansions distort allocations while lump-sum transfers do not. Closer to what we do, Duffy and Puzzello (2014b) find evidence in support of money neutrality when the money supply is doubled but not when it is halved.

inflation on output using New Keynesian models. These studies typically require delayed responses to shocks, e.g. usually through sticky prices, to generate real effects of monetary policy and therefore do not feature the inflation tax channel that is the focus of our study. See Adam (2007), Pfajfar and Zakelj (2014), Assenza et al. (2021), and references therein. Similar to the learning to forecast OLG experiments, these studies typically focus on subjects' formation of inflation expectations and automate consumption and production decisions to compute output. In contrast, we measure output directly from our experiment since our focus is on evaluating the inflation tax channel rather than inflation expectations. While there are also studies that do not automate consumption and production, the focus is typically on price inertia or menu costs as the main mechanism for real effects of inflation. For recent examples, see Davis and Korenok (2011), Noussair, Pfajfar, and Zsiros (2015, 2021), and references therein. Davis and Korenok (2011) also consider money supply changes and find real effects of monetary policy though this is due to pricing frictions and menu costs rather than the inflation tax channel that is the focus of our study.

To summarize our contribution, while there is work on inflationary monetary policies in laboratory economies, the main novelty of this paper is to document negative real effects of inflation under different money injection schemes in a unified and fully dynamic New Monetarist model. In addition, we focus on the inflation tax channel and show the mechanisms and theoretical predictions are broadly consistent with laboratory evidence.

3 Theoretical Framework

Our experimental economy is based on the New Monetarist model of Lagos and Wright (2005) and Rocheteau and Wright (2005), which provides microfoundations for the use of money as a medium of exchange. In addition, the alternating market structure with quasilinear preferences simplifies the solution and welfare analysis of the model, making it well suited for laboratory implementation.[13] We adopt the competitive market version of Rocheteau and Wright (2005) so that all subjects observe the same price signals in each market in the experimental implementation of the model (see Section 4.2 for more details). Next we describe the environment and use it to derive testable implications on the effects of monetary policy through different schemes for injecting new money.

[13] An important advantage of having the alternating market structure and quasilinear preferences in the model is analytic tractability. These assumptions make the distribution of money holdings degenerate. In our experiment, there are no idiosyncratic shocks so quasilinear preferences are not required for tractability. Nonetheless these preferences simplify the model solution and welfare analysis since we can focus on consumption and output in one market.

3.1 Environment

Time is discrete and continues forever. There are two types of agents, called type A and type B, each of size N. Each period consists of two markets, A and B, that open in sequence. In each market, there is a divisible and perishable good, called good A in market A and good B in market B. In market A (B), type A (B) agents want to consume but cannot produce, while type B (A) agents can produce but do not to consume, i.e., there are gains from trade. All agents discount between periods with a constant discount factor $\beta \in (0,1)$. Instantaneous utilities for type A and B agents are given by:

$$\boldsymbol{U}^A = u(x_A) + x_B,$$

$$\boldsymbol{U}^B = -x_A + v_0 + x_B,$$

where we use the subscript to label the good or market, and the superscript to label the agent's type. In market A, type A agents consume and type B agents produce good A. Type A agents derive utility $u(x_A)$ from consuming x_A units of good A, where $u'(0) > 0, u''(0) < 0$ and $u'(0) = \infty$. Type B agents can produce x_A units of good A by incurring the disutility x_A. In market B, both types can consume or produce good B, and the utility from consuming good B is x_B for type A, and $v_0 + x_B$ for type B (and $x_B < 0$ means net production).[14] The term v_0 is intended to equalize payoffs between type A and type B agents in the laboratory implementation (theory predicts type B earns zero if $v_0 = 0$). Introducing this term does not affect equilibrium predictions. The first-best level of output in market A is x_A^* such that $u'(x_A^*) = 1$.

Lack of commitment, no formal enforcement, and private trading histories restrict the emergence and sustainability of credit arrangements and a lack of double coincidence of wants rules out barter.[15] There is a single intrinsically useless asset, called money, that could serve as a medium of exchange. Money is divisible and storable in any amount, m_t. The money supply at the start of period t is M_t, which grows at a constant gross rate $\gamma \geq 1$, i.e., $\gamma \equiv M_{t+1}/M_t$. New money is injected at the beginning of each market B in one of

[14] In Lagos and Wright (2005) and Rocheteau and Wright (2005), agents have quasilinear preferences in market B; i.e., they derive concave utilities from a general good and linear utilities (disutilities) from leisure (labor). Without loss of generality, we adopt linear preferences to further simplify the environment so that subjects decide only on one object in market B (e.g., Rocheteau and Nosal 2017).

[15] Here only aggregate outcomes, i.e., prices, are observable. Nonetheless, since the population is finite in the laboratory, informal enforcement schemes are theoretically possible (see Aliprantis et al. 2007 and Araujo et al. 2012). However, Duffy and Puzzello (2014a) implement laboratory economies of 6 and 14 subjects and find outcomes are closer to the monetary equilibrium predictions and do not find support for the use of informal enforcement schemes.

three ways: (1) to finance government spending, (2) to finance lump-sum transfers to type B agents (who are consumers in market B), and (3) to finance transfers proportional to money holdings at rate $\tau = \gamma - 1$.[16]

3.2 Monetary Equilibrium

We focus on steady state equilibria where real variables and inflation are constant over time and inflation equals $\gamma - 1$. As in Lagos and Wright (2005) and Rocheteau and Wright (2005), we start backward by first characterizing agents' decision problems in market B and then use that to solve for their choices in market A. We then describe equilibrium allocations and prices across different inflationary regimes.

Market B Optimization Problems

In market B, agents trade good B and money in a competitive market where the price of good B is p_B. The value function of a type i agent who enters market B with money holdings m^i satisfies

$$\begin{aligned} \max_{\hat{m}^i, x_B^i} W(m^i) &= \max_{\hat{m}^i, x_B^i} \left\{ x_B^i + v^i + \beta V^i(\hat{m}^i) \right\} \\ \text{subject to } \hat{m}^i &= -p_B x_B^i + (1+\tau) m^i + T^i, \end{aligned}$$

where τ is the rate of proportional transfers, $v^A = 0, v^B = v_0$, x_B^i is net consumption of good B, $\hat{m}^i$ is the choice of money holdings in the next market A, and T denotes the lump-sum transfer of money by the government, expressed in nominal terms ($T^A = 0$, and T^B is positive if money grows over time).[17] Substituting x_B^i from the budget constraint into the objective function, the value function simplifies to

$$\max_{\hat{m}^i} W(m^i) = \max_{\hat{m}^i} \left\{ \frac{-\hat{m}^i + (1+\tau) m^i + T^i}{p_B} + v^i + \beta V(\hat{m}^i) \right\}.$$

[16]Our focus here is on $\gamma > 1$, i.e., money supply growth. The case where $\gamma < 1$ corresponds to money supply contraction. If the latter is implemented via lump-sum taxation, then it would result in higher output in our context. However, our focus here is on detrimental effects of inflationary monetary policy.

[17]In a monetary equilibrium, x_B^i is positive for type B agents (they consume) and negative for type A agents (they produce). That is, a type B agent is a net consumer in market B and finances her end-of-period money holdings and consumption of good B, with money balances brought in market B inclusive of the proportional transfer. On the other hand, a type A agent is a net producer in market B, finances her end-of-period money holdings with money balances brought in market B (inclusive of proportional transfers) and sales from production of good B.

The optimal choice for $\hat{m}^i$ solves

$$\beta\frac{\partial V(\hat{m}^i)}{\partial \hat{m}^i} - \frac{1}{p_B} \leq 0, \text{ with equality if } \hat{m}^i > 0.$$

As usual in this framework, the value function $W(m)$ is linear in m, and the choice of money holdings next period, $\hat{m}$, is independent of current money holdings m. By the envelope theorem, for both types of agents, we have

$$\frac{\partial W(m)}{\partial m} = \frac{1+\tau}{p_B}.$$

Market A Optimization Problems

Agents in market A can trade good A and money in a competitive market at price p_A. Type B agents, who are producers in market A, incur a linear production cost to produce x_A units of good A. Their decision problem is

$$V^B(m) = \max_{x_A}\left\{-x_A + \frac{(1+\tau)(m + x_A p_A)}{p_B} + W^B(0)\right\}.$$

Notice we used the linearity of the value function $W(m)$, i.e., the envelope result $\partial W(m)/\partial m = (1+\tau)/p_B$, which from the first-order condition of type B's problem implies

$$\frac{(1+\tau)p_A}{p_B} = 1. \tag{1}$$

Type B agents produce and earn money in market A, and spend money to consume in market B. The left-hand side of equation (1) captures the benefit of producing in market A: type B agents acquire p_A units of money for each unit of output A, earn interest at rate τ and purchase good B at price p_B. With linear production function in market A and linear utility in market B, in equilibrium, they adjust the supply of good A and demand for good B such that the price levels in the two markets satisfy equation (1). By the envelope theorem, we have

$$\frac{\partial V^B(m)}{\partial m} = \frac{1+\tau}{p_B}.$$

Type A agents, who are consumers in market A, can buy and consume x_A units of good

A. Their value function in market A is

$$V^A(m) = \max_{x_A} \left\{ u(x_A) + \frac{(1+\tau)(m - p_A x_A)}{p_B} + W^A(0) \right\}$$
$$\text{subject to } p_A x_A \leq m.$$

If the cash constraint does not bind, then $u'(x_A) = (1+\tau)p_A/p_B$, which combined with type B's decision, implies $u'(x_A) = 1$, and hence, $x_A = x_A^*$. Otherwise, $x_A = m/p_A$, and it can be shown that $V^A(m)$ is concave in m. In either case, we have

$$\frac{\partial V^A(m)}{\partial m} = \frac{u'(x_A)}{p_A}.$$

Equilibrium

We now combine agents' decision problems from markets A and B to derive the equations that characterize the monetary equilibrium. For type B agents, the net marginal value of carrying money to the next market A is

$$-\frac{1}{p_B} + \beta \frac{\partial V^B(\hat{m})}{\partial \hat{m}} = -\frac{1}{p_B} + \beta \frac{1+\tau}{\hat{p}_B} = \frac{1}{p_B}\left[-1 + \frac{\beta(1+\tau)}{\gamma}\right] < 0,$$

where the second equality incorporates the result that the inflation rate is equal to γ in the steady state. From the equation above, money carried by type B agents to market A will be idle in market A and can be used to purchase good B in the next market B. Given τ is either 0 or $(\gamma - 1)$ (depending on the inflationary scheme), holding idle balances is costly. As a result, it is optimal for type B agents to spend all their money in market B and enter market A with no money balances.

For type A agents, the net marginal value of carrying money to the next market A is

$$\begin{aligned} -\frac{1}{p_B} + \beta \frac{\partial V^A(\hat{m})}{\partial \hat{m}} &= -\frac{1}{p_B} + \beta \frac{u'(x_A)}{\hat{p}_A} = -\frac{1}{p_B} + \beta(1+\tau)\frac{u'(x_A)}{\hat{p}_B} \\ &= \frac{1}{p_B}\left[-1 + \frac{\beta(1+\tau)}{\gamma}u'(x_A)\right], \end{aligned}$$

where the second equality uses equation (1). Since $u'(0) = \infty$, type A agents bring a positive amount of money to market A in contrast with type B agents. In equilibrium, the net marginal value of carrying money is zero, which implies output in market A (per consumer or producer), x_A, solves

$$\beta u'(x_A)\frac{1+\tau}{\gamma} = 1. \tag{2}$$

If τ is either 0 or $(\gamma - 1)$, type A agents carry just enough money to spend in market A and the cash constraint binds. Equation (2) illustrates the inflation tax channel. Type A agents produce and earn money in market B and spend the proceeds in the following period's market A. With an expected increase in the money supply and price level in the next period's market B, type A agents expect type B to demand a higher price in the next market A. Since type A agents earn money in the current period and spend it at a higher price level, their real earnings from production decrease in response to inflation so they reduce consumption in market A. As a result, inflation, captured by the term γ, acts like a distortionary tax on money holdings and reduces the benefit from holding money, which in turn translates into lower output x_A and welfare. Proportional transfers, captured by the term τ, help to neutralize the inflation tax.

Solving the allocation in market A, x_A (the consumption by each type A agent and the output by each type B agent), we can derive equilibrium price and allocation in market B. The market-clearing price in market A, $p_{A,t}$, is

$$p_{A,t} = \frac{M_t}{N x_A}. \tag{3}$$

In market B, the equilibrium price, $p_{B,t}$, is given by (1), and the amount of consumption by each type B agent, x_B, is

$$x_B^B = \frac{M_t(1+\tau)/N + T_t^B}{p_{B,t}}, \tag{4}$$

and output per producer (type A) is given by

$$x_B^A = \frac{M_{t+1}/N}{p_{B,t}} = \frac{\gamma}{1+\tau} x_A, \tag{5}$$

where the second equality uses equations (1) and (3).[18] Given monetary policy (M_t, τ, T_t^B), a steady state monetary equilibrium is a list of allocations (x_A, x_B^A, x_B^B) and prices $(p_{A,t}, p_{B,t})$ satisfying (1) to (5).

[18] Notice type B agents hold the entire money supply at the beginning of market B and spend all money, including the amounts from proportional and lump-sum transfers. Similarly, type A agents hold all the money at the end of market B.

Table 1: Monetary Policy Schemes

	γ	τ	T_t^B
Constant Money Supply (CM)	$= 1$	0	0
Government Spending (GS)	> 1	0	0
Lump-Sum Transfers (LS)	> 1	0	$(\gamma - 1)M_t/N$
Proportional Transfers (PR)	> 1	$\gamma - 1$	0

3.3 Monetary Policy Schemes

We consider the effect of money growth under three money injection schemes: seigniorage to finance government spending, lump-sum transfers to buyers at the beginning of market B ("helicopter drops"), and transfers proportional to money holdings at the beginning of market B. Table 1 specifies the profile of monetary policies we consider.[19]

4 Experimental Design and Procedures

We first outline our experimental treatments and hypotheses and then describe our implementation of the experiment.

4.1 Treatments and Hypotheses

We consider five treatments to evaluate the effect of the three inflationary policies outlined in Table 1 and two money growth rates. The baseline treatment features a laissez-faire policy with a constant money supply, labeled CM. We then consider three treatments with the same money growth rate $\gamma - 1 = 30\%$, but each with a different scheme for money injection: government spending, lump-sum transfers, or proportional transfers. We label them GS30, LS30, and PR30, respectively. In terms of real effects, money growth implemented by government spending and lump-sum transfers has detrimental effects on output and welfare relative to the Constant Money treatment. In these implementations, inflation should act like a tax on real money holdings. The third policy scheme with proportional transfers provides an additional test of the inflation tax channel. Under this scheme, the

[19]Note that when new money is used to finance government spending, it does not add new terms to agents' choices but it works through inflation. In our treatment LS30, new money is injected with lump-sum transfers to consumers. An opposite policy is to retire money by lump-sum taxes, which would contract money supply, generate deflation and thereby increase output in theory. Such policies are studied by Duffy and Puzzello (2022).

distortionary effect of inflation is neutralized by the proportional transfer, and output and welfare remain the same as in the Constant Money treatment. That is, the proportional transfer compensates agents for the inflation tax, and thus there are no real effects. Finally, to allow for a more exhaustive exploration of the quantity theory of money and the effect of inflation, we run a treatment with a lower money growth rate at $\gamma - 1 = 15\%$, where new money is injected to finance government spending; this treatment is labeled GS15.[20]

Other parameter values are chosen as follows. The discount factor is set to $\beta = 0.9$. The period utility functions for type A and B agents are respectively

$$U^A = \underbrace{A\frac{x_A^{1-\eta}}{1-\eta}}_{\text{market A}} - \underbrace{x_B}_{\text{market B}} \text{ and } U^B = \underbrace{-x_A}_{\text{market A}} + \underbrace{v_0 + x_B}_{\text{market B}};$$

where $A = 2.6563$, $\eta = 0.37851$, and $v_0 = 8$ in CM and PR30 treatments, $v_0 = 6$ in GS15, $v_0 = 5$ in GS30 and $v_0 = 3.5$ in LS30. The parameters A and η were chosen to obtain salient differences in the theoretical predictions and integer values for equilibrium quantities for $\gamma = 1$ and $\gamma = 1.3$. The parameter v_0 was chosen to roughly equalize equilibrium expected payoffs for type A and B subjects.[21]

Table 2 summarizes the steady state equilibrium predictions for output, prices, inflation and welfare for each treatment, which we use to formulate the main hypotheses we test with the experiments. Equilibrium prices and quantities are calculated from equations (1) to (5), and welfare is calculated as the sum of period utilities for all agents. Notice since agents' utilities are linear in market B, welfare is simply the sum of trade surpluses due to consumption by each type A agent. The last column of Table 2 computes the welfare ratio, denoted by $\mathcal{W}$, which measures efficiency relative to the first-best quantity of output in market A, $x_A^* = 13.2$:

$$\mathcal{W} \equiv \frac{\sum_i [u(x_{A,i}) - x_{A,i}]}{N[u(x_A^*) - x_A^*]}.$$

[20] The money growth rates, $\gamma = 1.15$ and $\gamma = 1.3$, are set so that the effects of money growth are salient to subjects. Due to budget concerns, we explored the effect of lower money growth only under the government spending scheme.

[21] Our experimental implementation deviates slightly from the model described in Section 3 regarding market B activities. In the model, both types can consume or produce in market B. In our implementation, type A can only produce and type B can only consume in market B. The purpose of this deviation is to simplify subjects' choice sets; otherwise, they would need to choose both a consumption amount and a production amount. Furthermore, this allows us to pin down consumption and production in market B, rather than net consumption or production. Alternatively, subjects can make a two-step choice where they first decide whether they want to consume or produce and then decide on the amount. Importantly, this modification of market B activities does not change the steady state equilibrium predictions for other variables shown in Table 2.

Table 2: Equilibrium Predictions

Treatment	x_A	x_B	p_{At}	p_{Bt}	Inflation	Welfare Ratio
CM	10	10	0.5	0.5	0	0.98
GS15	6.91	7.95	$0.7233 * 1.15^{t-1}$	$0.7233 * 1.15^{t-1}$	15%	0.91
GS30	5	6.5	1.3^{t-1}	1.3^{t-1}	30%	0.82
LS30	5	6.5	1.3^{t-1}	1.3^{t-1}	30%	0.82
PR30	10	10	$0.5 * 1.3^{t-1}$	$0.5 * 1.3^{t}$	30%	0.98

Theory predicts GS30 and LS30 yield the same stationary equilibrium where inflation equals the constant money growth rate, $100(\gamma - 1)\%$. Quantities traded and welfare for all inflationary treatments are lower than in the CM treatment, except for PR30, where money growth has no real effects. This holds because inflation acts like a tax on real money holdings in GS30 and LS30, while the effect of the inflation tax is neutralized in PR30 by the interest paid on money balances at the rate of inflation. In addition, output and welfare in GS30 should be lower than in GS15.

We explore the following questions with the experimental data: Do anticipated changes in the money supply transfer to prices? If there is inflation, do subjects perceive it like a tax in the Lump-Sum and Government Spending treatments, but realize the inflation tax is neutralized by transfers in the Proportional Transfers treatment? Based on the theoretical predictions in Table 2, we formulate the following hypotheses about inflation, quantities traded, and welfare across treatments. The first hypothesis concerns the quantity theory of money, which states that the general price of goods is directly proportional to the amount of money in circulation. In other words, changes in money growth lead to one-to-one changes in inflation. The second and third hypotheses focus on the real effects of money supply changes on output and welfare, respectively. In the formulation of the hypotheses, for each treatment j, we let π_A^j and π_B^j denote the inflation rate in markets A and B, x_A^j output in market A and $\mathcal{W}^j$ the welfare ratio (for output, we focus on market A because output in market A determines the total welfare).

Hypothesis 1. Higher money growth rates lead to higher inflation rates in markets A and B. Specifically, inflation rates in markets A and B are higher in GS15, GS30, LS30, and PR30 than in the CM treatment. In addition, inflation rates are lower in GS15 than in GS30.

$$\pi_A^{CM} < \pi_A^{GS15} < \pi_A^{GS30} = \pi_A^{LS30} = \pi_A^{PR30},$$

$$\pi_B^{CM} < \pi_B^{GS15} < \pi_B^{GS30} = \pi_B^{LS30} = \pi_B^{PR30}.$$

Hypothesis 2. Output in market A is lower in GS15, GS30, and LS30 relative to the CM and PR30 treatments.

$$x_A^{CM} = x_A^{PR30} > x_A^{GS15} > x_A^{GS30} = x_A^{LS30}.$$

Hypothesis 3. Welfare is lower in GS15, GS30, and LS30 relative to the CM and PR30 treatments.

$$\mathcal{W}^{CM} = \mathcal{W}^{PR30} > \mathcal{W}^{GS15} > \mathcal{W}^{GS30} = \mathcal{W}^{LS30}.$$

4.2 Experimental Procedures

In this subsection, we describe the general experimental procedure and how we implement three ingredients of the model key to our experimental study: infinite horizon with discounting, competitive markets, and money growth.

The experiments in this study were conducted at Purdue University and Indiana University in 2018 and 2019 (see Table 3 for session characteristics). Participants were undergraduate students at Purdue University and Indiana University across genders and majors.[22] We adopt a between-subjects design where each session of the experiment consists of a new group of subjects making decisions under a single parameter set. For each treatment, we conduct four sessions.[23] For each session, the total number of subjects is $2N = 10$, equally split between type A and type B agents, with the exception of one session where $2N = 8$ since fewer subjects showed up for that session. No subject participated in more than one session of the experiment, although some subjects may have participated previously in other economics experiments.

The total length of a session ranged from 100 to 120 minutes, though all subjects were recruited for 2 hours. Participants received a \$5 show-up payment plus earnings from the experiment. Points earned by subjects in the experiments were converted to dollars at the exchange rate 0.15 dollar per point except for three sessions in the GS30 treatment.[24]

[22]The demographic composition of the subjects are very similar across Purdue and Indiana University, except slightly more Liberal Arts majors at Indiana University than Purdue due to the presence of engineering majors at Purdue. The experimental results are not noticeably different across the two universities.

[23]We used theoretical predictions and data from the closest treatment in Duffy and Puzzello (2014a) to compute the power of the test for differences in output between the CM, LS30, and GS30 treatments. For a sample size of 4 sessions per treatment and a probability level of 5%, the power is 78% (details available upon request).

[24]In the Government Spending treatment, the government agents take away resources from the economy so we initially used a slightly higher exchange rate of 0.2 to make subjects' point earnings more commensurate across treatments. We then decided to keep the 0.15 exchange rate constant across subsequent sessions and treatments for the sake of comparability. The exchange rate does not affect our theoretical predictions.

Subjects were paid for all periods of all sequences. Average earnings across all treatments were $25.67.

Table 3: Session Characteristics

Treatment	Session	Date	Subjects	Location	Sequence Lengths
Constant Money	1	8/3/2018	8	Purdue	9, 15
(CM)	2	8/24/2018	10	Indiana	6, 8, 2, 16
	3	8/29/2018	10	Indiana	13, 10, 5
	4	9/5/2018	10	Purdue	5, 6, 4
Government Spending 15	1	3/27/2019	10	Purdue	9, 15
(GS15)	2	3/27/2019	10	Purdue	6, 8, 2
	3	3/27/2019	10	Indiana	13, 10, 5, 11
	4	3/27/2019	10	Indiana	5, 6, 4
Government Spending 30	1	7/25/2018	10	Purdue	9, 15
(GS30)	2	8/27/2018	10	Indiana	6, 8, 2, 16
	3	9/19/2018	10	Purdue	13, 10
	4	9/4/2018	10	Purdue	5, 6, 4, 1
Lump Sum Transfers 30	1	9/26/2018	10	Purdue	9, 15
(LS30)	2	9/27/2018	10	Purdue	6, 8, 2
	3	10/10/2018	10	Purdue	13, 10, 5
	4	10/23/2018	10	Purdue	5, 6, 4
Proportional Transfers 30	1	11/27/2018	10	Purdue	9, 15
(PR30)	2	11/27/2018	10	Purdue	6, 8, 2
	3	12/7/2018	10	Purdue	13, 10
	4	12/7/2018	10	Purdue	5, 6, 4

Each session included instructions, a comprehension quiz on the instructions (see Appendix E for the instructions and quiz), and the experiment. Upon entering the laboratory, participants were assigned a computer station and given a written copy of the instructions. Participants then completed a comprehension quiz about the instructions. After completing the quiz, the experimenter went over the correct answers, answered questions individually, and began the experiment. We purposely spent a large portion of time on this phase of the experiment (typically 45 minutes to an hour) to ensure subjects' comprehension. All parts of the experiment were programmed with z-Tree (Fischbacher 2007).

Further, behavior in the session with the 0.15 exchange rate was comparable with behavior observed in the sessions employing the 0.2 exchange rate.

In the experiments, a period consists of market A followed by market B. The mapping of production and consumption decisions to points is described in detail to subjects in the written instructions and presented to subjects in table form in both the instructions and on their computer screens. Furthermore, subjects can also see previous periods' prices for both markets, which allows them to observe price changes over time. This is an important consideration since price signals are a crucial factor for policy to operate as predicted by theory. In particular, in order for the policy to work as predicted, in the laboratory economy we would need to have that i) money supply changes transfer to price changes (quantity theory holds), ii) subjects see prices, and iii) subjects perceive price increases as a tax in GS and LS treatments. Our implementation with centralized markets and information on price realizations appears to facilitate these steps.[25] See Figure 1 for a sample screenshot.

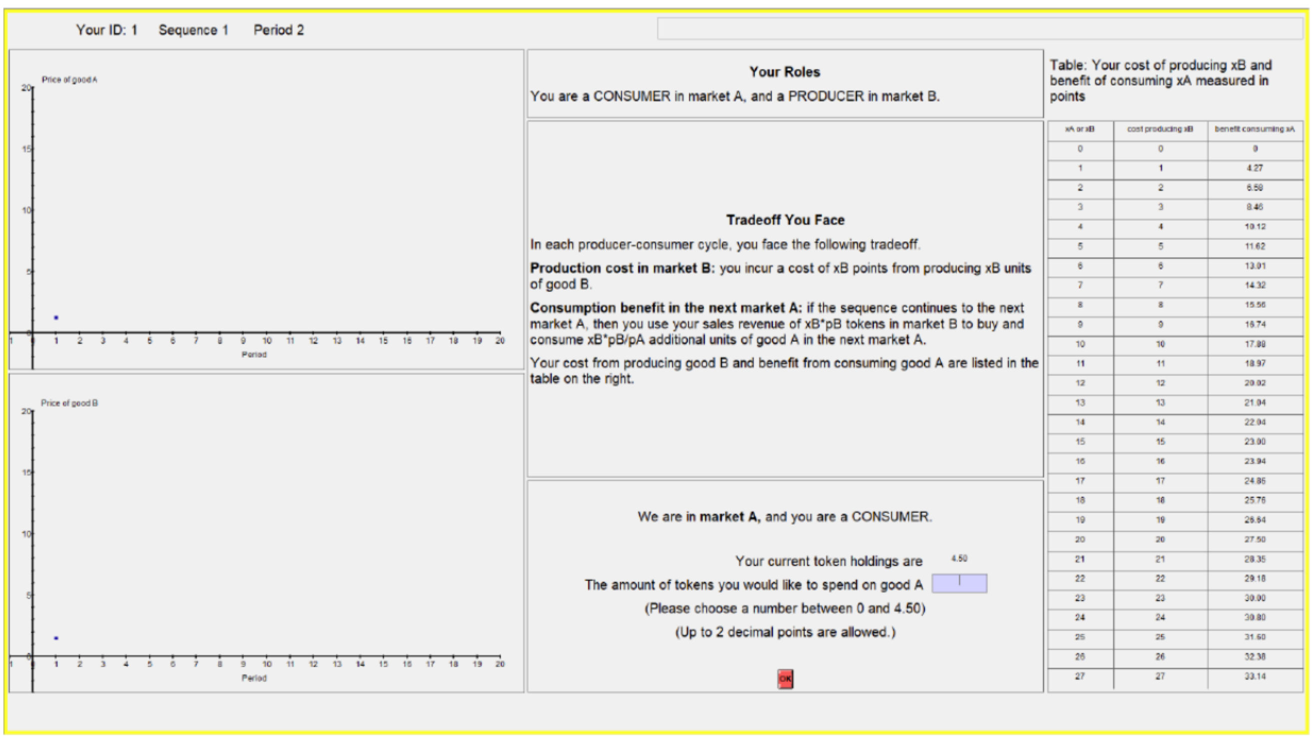

Figure 1: Sample Decision Screen of Experiment

[25]Notice subjects would not be able to observe previous periods' prices if the pricing mechanism was bilateral bargaining. This aspect of our design is an important departure from Duffy and Puzzello (2022), where prices are determined through take-it-or-leave-it-offers by buyers. While this feature does not affect the steady-state theoretical predictions, it may affect behavior, as it generates fragmented price signals in the laboratory. We conjecture this may be one reason why our results are closer to theoretical predictions relative to what Duffy and Puzzello (2022) find.

Indefinite Horizon. Our theoretical model in Section 3 features an infinite horizon where all agents have a constant discount factor β. The standard approach to implementing an infinite horizon in the laboratory follows Roth and Murnighan (1978). Each session consisted of several sequences which in turn consisted of an indefinite number of periods. After each period, the sequence continues with a fixed probability equal to $\beta = 0.9$. We implemented the indefinite horizon with a block random termination procedure similar to Fréchette and Yuksel (2017). Subjects played a "block" 10 periods and were informed about the termination period at the end of the block. If the sequence had ended within the block, then decisions after the termination period were invalid. If the sequence had not ended by period 10, then from period 11 onward, subjects were informed about whether the sequence would continue after each period.[26] Sessions averaged 32.3 total periods with a median of 3 sequences per session. Table 3 summarizes the sequence lengths for each session.[27]

Market Game. Prices are endogenously determined by subjects' decisions in the experiment. This feature allows us to explore whether and how changes in the money supply affect price formation. To implement competitive pricing in markets A and B, subjects participate in a market game as in Shapley and Shubik (1977), which provides non-cooperative foundations to competitive equilibrium outcomes (see e.g., Arifovic 1996; Bernasconi and Kirchkamp 2000; Duffy, Matros, and Temzelides 2011; Ding and Puzzello (2020); Duffy and Puzzello 2014ab, 2022; among others, for implementations of market games in laboratory economies). Another important advantage of the market game is that it allows us to precisely control the injection of money and thus the money supply growth rate. In both markets, producers submit a quantity to produce (x_A or x_B) while consumers submit a bid of tokens for good A or B (b_A or b_B). Subjects make these decisions in isolation and do not observe

[26] Our procedure is slightly different from the one proposed by Fréchette and Yuksel (2017), where subjects would always start a new block after one was over. In our procedure, if the sequence did not terminate by the end of the 10-period block, subjects received feedback, in each period afterwards, on whether the sequence continued or not. That is, we did not start a new 10-period block after the first block was over. We adopted this procedure because it allowed us to potentially fit more sequences in a session: after the first block, the sequence could stop anytime instead of at the end of another 10-period block. The same design is used by Duffy, Jiang, and Xie (2019) in experimental asset markets, and Aoyagi, Fréchette and Yuksel (2021) for repeated games.

[27] In a follow-up project Jiang, Puzzello, and Zhang (2021), we propose a new method for implementing infinite horizon environments in the lab using the discount factor interpretation to back out subjects' continuation value following a period of deterministic length. In a similar set up as in this one but only with a constant money supply, we then compare the results of our new method with the block design and random termination methods commonly used in the literature. We do not find substantial differences across implementation methods. Davis et al. (2022) study finite horizon environments where fiat money is valued, but these environments are not well suited to study inflationary monetary policies.

current actions of other participants. The market price in each market is then computed as

$$p = \frac{\sum_i b_i}{\sum_i x_i} = \frac{\text{Total Tokens Bid}}{\text{Total Amount Produced}},$$

where b_i and x_i are the individual bids and production decisions of consumers and producers, respectively, for subject i. If the total amount of tokens bid or the total amount produced is zero, no trade takes place. If the price is positive, buyers consume an amount equal to their bid divided by the market price and their point total increases as specified by the utility function in each market, while their token total decreases by the amount bid. Producers lose points from production as specified by the production function but their token total increases by the amount produced times the market price.

Schedule of Token Increases. In all treatments, type A agents (who are consumers in market A) are endowed with 5 tokens at the start of a new sequence. In the Constant Money treatment, the total token supply is fixed at $5 \times N$. Otherwise, the token supply increases by $100(\gamma - 1)\%$ in market B of each period (i.e. either 15% or 30%). In the Government Spending treatments, we introduce computerized "robots" in market B that create new tokens and use them to purchase good B. Subjects are informed these robots are pre-programmed and intervene in market B only to create new tokens and use them to buy goods.[28] In the Lump-Sum Transfers treatment, consumers in market B receive a lump-sum transfer of tokens at the start of each market B. In the Proportional Transfers treatment, all agents receive a 30% transfer of tokens proportional to their token holdings at the start of each market B. In all treatments, money injections occur before trading in market B. Importantly, all schemes are publicly known and communicated in detail to subjects in the instructions and reinforced in the follow-up quiz. For example, in the Lump-Sum Transfers treatment, subjects were informed about lump-sum transfer amounts in each period, while in the Government Spending treatment, subjects knew how many tokens robot buyers spent each period. The comprehension quiz on the instructions then tested subjects' knowledge about how a given scheme would impact the supply of tokens (see Appendix E for the instructions and quiz).[29]

[28]In the treatments with government spending, new money is used to purchase output from subjects and the purchased output is not distributed back to subjects. In follow up work, we plan to explore an implementation where subjects' production is redistributed back to subjects via real lump-sum transfers.

[29]We adopt different timing of monetary transfers compared to Duffy and Puzzello (2022) where money supply changes always occur at the end of market B. This is done to achieve a more controlled comparison of different money growth schemes.

5 Experimental Results

We first analyze market-level data in Section 5.1 and present our main results as a series of findings that mirror our hypotheses in the previous section. Section 5.2 presents additional analysis on convergence and learning and summarizes decisions at the individual level.

5.1 Main Results

Here we discuss the impact of changes in the money supply on market-level inflation, output, and welfare.

Finding 1. *Inflation rates in markets A and B are higher in the GS15, GS30, LS30, and PR30 treatments than in the CM treatment; inflation rates are lower in GS15 than in GS30, LS30 and PR30.*

Recall the theoretical steady state inflation rate is 0% in treatment CM, 15% in treatment GS15, and 30% in GS30, LS30, and PR30. To estimate the inflation rate from the experimental data, we regress the natural log of the price level in market A or B on the time period within sequences and its interaction with the treatment dummies to capture differences in inflation from the baseline treatment with constant money supply (see Table A.1 for more details). The coefficient on the time period captures the growth rate of the price level and hence is an estimate of the inflation rate for the CM treatment. We also determine inflation in other treatments by adding the coefficients of the interaction terms. For moderate rates of money growth, the coefficient on the time period can be read directly as an estimate of the inflation rate. Since the money growth rate is substantial in our inflationary treatments, we transform the coefficient on the time period to obtain an estimate of inflation rates. To illustrate, if ψ_1 denotes the coefficient on the time period variable, our estimated inflation rate for the CM treatment is then $e^{\psi_1}-1$. If ψ_2 denotes the coefficient on the interaction term of the time period and dummy variable for the GS15 treatment, then the estimated inflation rate for GS15 is $e^{\psi_1+\psi_2}-1$. A similar logic then applies for the remaining treatments.

Figure 2 shows average estimated inflation rates with 95% confidence intervals for each treatment. Table 4 reports differences in the estimated inflation rate between the baseline CM treatment and other treatments. To compare inflation across treatments, we also estimate pairwise differences in inflation rates and report the results in Appendix A in Table A.2 for market A inflation and Table A.3 for market B inflation.[30]

[30] For more details on individual sessions, see Appendix D. Table D.1 shows estimates of inflation by session

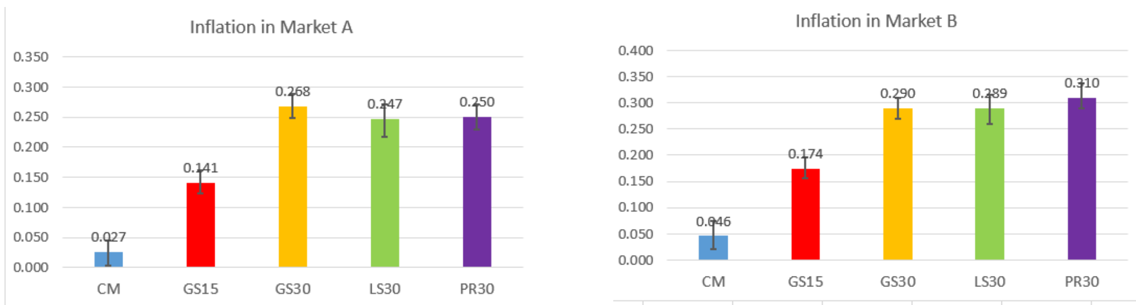

Figure 2: Estimated Average Market Inflation Rates

Notes. (1) Theory predicts inflation in both markets A and B is 0 in CM, 0.15 in GS15, and 0.3 in GS30, LS30 and PR30. (2) The estimates are derived from the regression in Table A.1.

Table 4: Inflation in Market A and Market B, by Treatment

Variables	Market A	Market B
GS15-CM	0.115 ***	0.128***
	(0.013)	(0.016)
GS30-CM	0.241***	0.244***
	(0.014)	(0.014)
LS30-CM	0.220***	0.243***
	(0.016)	(0.018)
PR30-CM	0.223***	0.264***
	(0.014)	(0.017)
CM	0.027 ***	0.045***
	(0.009)	(0.009)

Notes. (1) This table shows the estimated inflation rate for baseline treatment CM, and the difference between other treatments and the CM treatment. The estimates are derived from the regression in Table A.1. (2) Robust standard errors in parentheses. (3) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Consistent with Hypothesis 1 and the quantity theory of money, Figure 2 and Table 4 show higher money growth rates are associated with higher inflation rates in the experimental economies. So, changes in the money supply do transfer to changes in prices, which was not ex-ante obvious, as prices are endogenously determined by subjects' choices. Table 4 shows that average inflation in market A (B) is 11.5% (12.8%) higher in GS15, 24.1% (24.4%) higher in GS30, 22.0% (24.3%) higher in LS30, and 22.3% (26.4%) higher in PR30 relative to the CM treatment, where it is 2.7% (4.5%). Regarding pairwise comparisons across inflationary treatments, as shown in Tables A.2 and A.3 in Appendix A, the inflation rate in market A (B) is 12.7% (11.6%) higher in GS30, 10.5% (11.5%) higher in LS30 and 10.8% (13.6%) higher in PR30 relative to GS15. Inflation rates are not significantly different from each

and Figure D.2 graphs the time paths of prices by session.

other across the three treatments with 30% money growth.

We next discuss whether inflationary policies have real effects on output and welfare. In the following, we focus on market A output since it is the main variable affecting welfare calculations. By linearity, output in market B does not affect welfare so we summarize the results on market B output in Appendix A.

Finding 2. *Market A output is significantly lower in GS15, GS30, and LS30 than in CM. In addition, market A output is significantly lower in GS30 than in LS30.*

To validate Hypothesis 2, we regress market A output averaged across producers within a period on treatment dummies and summarize the results in Table 5. The constant term from the regression is average market A output in the CM treatment while the coefficients on the treatment variables correspond to the marginal effect of the corresponding treatment. Figure 3 summarizes the average quantity produced in markets A across sessions for each treatment where the bands correspond to 95% confidence intervals. Similar to the analysis on inflation, we also estimate pairwise differences in average output between treatments, and report the results in Table A.4 in Appendix A.

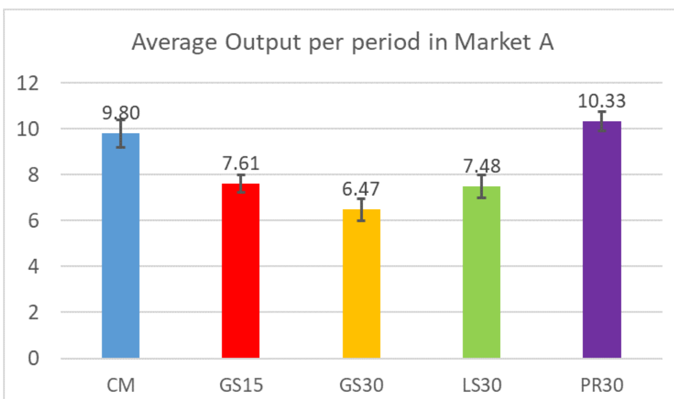

Figure 3: Average Market A Output

Notes. Theory predicts output in market A is 10 in CM and PR30, 6.91 in GS15, and 5 in GS30 and LS30.

Recall theory predicts output in market A is 10 in the CM and PR30 treatments, 6.91 in GS15, and 5 in GS30 and LS30. Regression results confirm market A output is significantly lower in GS15, GS30, and LS30 relative to the CM treatment. In addition, consistent with theory, market A output is not significantly different between PR30 and CM. Further, output in GS30 is significantly lower than in GS15. Taken together, these results are broadly consistent with the directional hypotheses we posed from the theoretical predictions and confirms the adverse effects of inflation on output.

Table 5: Regression of Average Market A Output on Treatment Dummies

Variables	Avg. Market A Output
GS15	-2.193^{***}
	(0.358)
GS30	-3.326^{***}
	(0.389)
LS30	-2.319^{***}
	(0.397)
PR30	0.529
	(0.375)
Constant	9.800^{***}
	(0.303)
Observations	623
R-squared	0.218

Notes. (1) Robust standard errors in parentheses. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

An outcome from the experiments not predicted by theory is that market A output is significantly lower in GS30 than in LS30 (see Figure 3 and Table A.4). This indicates the inflationary implementation scheme matters, as output is affected more adversely in GS30 than in LS30. A potential reason for the higher observed output in LS30 is type B subjects may perceive they are compensated with additional tokens in market B for their production in market A. In theory, the transfers are lump-sum and should not affect production decisions (i.e., type B subjects receive the transfer even if they did not produce in market A). In practice however, it is possible subjects in the laboratory perceive they are compensated for their production in market A which would tame the adverse effect of the inflation tax.[31]

Also notice our results from LS30 differ from the inflationary treatment in Duffy and Puzzello (2022) where money supply changes also occur through lump-sum transfers. Contrary with us, Duffy and Puzzello (2022) higher money growth raises output relative to the constant money case. This difference in results between our two studies may be due to different design features that may impact monetary policy transmission such as the trading protocol and price information provision.[32]

[31] In future work, we plan to include a post-experimental questionnaire to probe into this channel and better understand the underlying mechanisms.

[32] For example, in the main treatments, both market A and B feature competitive pricing in our setting, while market A is decentralized with pairwise bargaining in Duffy and Puzzello (2022). While they observe inflation only in market B, we observe inflation in both markets. We also provide information on price paths to subjects so it was easier for them to observe whether there was inflation. These design differences may have contributed to make monetary policy more potent in our case relative to Duffy and Puzzello (2022). Interaction effects between price formation protocols and the transmission of monetary policy are worthwhile inquiries for further research.

Finding 3. *Welfare is significantly lower in GS15 and GS30 than in CM. Welfare in LS30 is significantly higher than in GS30.*

Figure 4 reports average welfare ratios across treatments where the bands correspond to 95% confidence intervals. We also regress the welfare ratio on treatment dummies and report the results in Table 6. Figure 4 and Table 6 confirm that welfare is significantly lower in GS15 and GS30 than in CM, while welfare in PR30 is not significantly different from CM. Similar to our findings on market A output, welfare in LS30 is significantly higher than in GS30, which suggests inflationary schemes with government spending have stronger real effects than with lump-sum transfers. In addition to lower average output, we also observe higher dispersion in consumption (across buyers and time) in GS30 than in LS30, as captured by a higher coefficient of variation in GS30 (see Table A.10 in Appendix A). Thus, in addition to lower output, higher consumption dispersion may also contribute to generating lower welfare in GS30 than LS30.

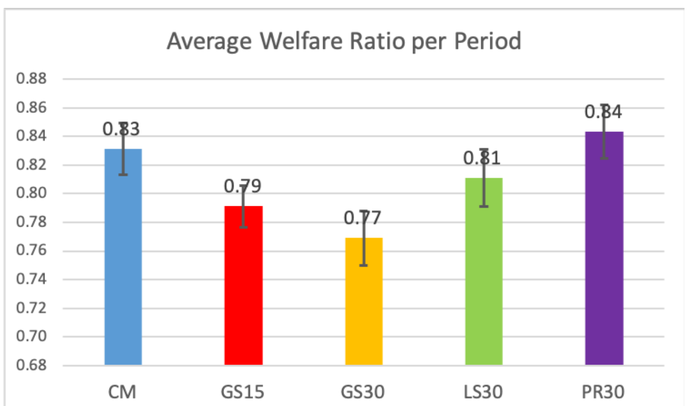

Figure 4: Welfare Ratio

Notes. Theory predicts welfare ratio is 0.98 in CM and PR30, 0.91 in GS15, and 0.82 in GS30 and LS30.

To summarize, we find inflation tends to decrease welfare in treatments predicting detrimental real effects, and the detrimental effect can be attributed to both decreased aggregate output and increased consumption dispersion among consumers. Since welfare is computed by aggregating utilities of all traders, it is decreasing in consumption dispersion due to the concave utility of market A traders. Furthermore, the implementation details of money injections matter, as output and welfare are more adversely affected in treatments with government spending relative to lump sum transfers. This result may be in part explained by a combination of two factors: lower output and higher consumption dispersion in GS30 than in LS30. While higher consumption dispersion is not predicted by the model, we conjecture

Table 6: Regression of Welfare Ratio on Treatment Dummies

Variables	Welfare Ratio
GS15	-0.040^{***}
	(0.012)
GS30	-0.062^{***}
	(0.013)
LS30	-0.020
	(0.014)
PR30	0.012
	(0.013)
Constant	0.827^{***}
	(0.009)
Observations	623
R-squared	0.066

Notes. (1) Robust standard errors in parentheses. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

that it is affected by the implementation method. In contrast with the GS30 treatment, subjects in LS30 receive lump-sum transfers which reduce money holdings dispersion and in turn consumption dispersion.[33]

5.2 Additional Analysis

Overall, our analysis of the market-level data in the previous subsection suggests the experimental evidence supports the key qualitative predictions of the theory.[34] In particular, we find higher money growth leads to higher inflation, consistent with the quantity theory. Evidence in favor of the inflation tax channel is also supported: output and welfare are significantly lower with government spending, output is significantly lower with lump-sum transfers, while there are no significant real effects with proportional transfers. To gain further insight on other aspects of the model and experimental data, we next present additional

[33]We compute the coefficient of variation for money holdings at the start of market A and find it is lower for LS30 (at 1.134) than for GS30 (at 1.387), indicating less money holdings dispersion in the former.

[34]Our regression analysis with market-level data uses robust standard errors. We also explore two options to further control for session effects (see Appendix A.4 for details). In our experiment, each subject participates only in one session. Session effects may arise as the same group of subjects interact for multiple periods (e.g., see Fréchette 2012). We first address dynamic session effects by adding past inflation as additional regressors; the results are similar. We also investigate treatment effects by clustering standard errors at the session level. While results regarding inflation are not much affected, we lose some statistical significance for average output and welfare. Given the trade-off between robustness and efficiency associated with clustering standard errors at the session level and similar results with the addition of lagged variables, it is reasonable to focus on the results without clustering at the session level.

analysis related to convergence and learning and also analyze individual-level decisions, such as production and token spending.[35]

Since subjects in the experiments interact dynamically in competitive markets, it is useful to investigate the dynamics of the laboratory data to see the extent to which subjects learn over time. To measure the extent of convergence and learning over time, we compare the deviation of inflation in both markets and average output in market A from theoretical predictions (in Tables B.1 and B.2). We also conduct two sets of regression analyses for each of these observables to capture potential learning effects.[36] We first compare deviations in the last three periods with earlier periods; this allows us to investigate learning and convergence across periods within a sequence. We also compare deviations in the last sequence with earlier sequences; this allows us to investigate learning across sequences within a session. Results for this analysis are reported in Tables B.3 to B.9 in Appendix B.

Regarding observed deviations from theoretical predictions, the overall inflation rate (see Table B.1) is slightly higher than the point prediction in the CM treatment and slightly lower for market A in the inflationary treatments. Deviations of market B inflation rates tend to be statistically insignificant. Average market A output is strikingly close and not significantly different from the theoretical prediction of 10 in CM and PR30 (see Table B.2). On the other hand, output in inflationary treatments predicted to have real effects, namely GS15, GS30 and LS30, is higher than the theoretical prediction of 6.91 and 5.[37]

In general, we do not find evidence in favor of learning across time within sequences and only find some evidence of learning across sequences. The first set of comparisons suggests no significant differences in the deviation of inflation and average output in market A between the last three periods and earlier periods. Nor do we find deviations in the last three periods are consistently smaller than in earlier periods. From the second set of comparisons, we find in treatments CM, GS30, and PR30, there is no significant difference in the extent of deviation between the last sequence and earlier sequences. In GS15 and LS30, the deviation is significantly smaller in the last sequence.

[35]Theory predicts market A and B prices satisfy equation (1). We check the price ratio against its theoretical prediction in Appendix A.5 and find the deviation is not statistically significant for CM and GS30, but significant for the other three treatments (the deviation is mild at around 10% for GS15 and PR30, and more than 20% for GS30).

[36]See Tables D.1 and D.2 for more details on deviations from theoretical predictions at the session level.

[37]Regarding the welfare ratio, Table A.11 suggests that the estimated value is significantly lower than predicted (except for treatment LS30). This is mainly due to consumption dispersion, which is positive in the experiment while zero in theory. As shown in the last column of Table A.11, removing consumption dispersion and evaluating the welfare ratio assuming every buyer consumes the average output would bring the welfare ratio close to or even higher than the theoretical prediction (recall output in market A tends to be higher than theoretical predictions).

The analysis so far reports results at the aggregate level. We now turn to summarizing additional analysis of the individual-level data. To determine the extent to which our aggregate results on the inflation tax channel is present at the individual level, we regress individual production decisions on the treatment dummies and report the results in Tables C.1 and C.2 in Appendix C. The results indicate the treatment effect on individual production in market A is similar to our findings on period average output. Specifically, individual producers tend to produce less in the inflationary treatments predicted to have adverse effects on output (GS15, GS30, and LS30).

We also look at the token spending ratio across individuals, namely, the fraction of tokens buyers choose to spend out of their token holdings. Table C.3 shows there are no significant treatment effects on the fraction of money holdings subjects spend in the inflationary treatments relative to the CM treatment, in line with theoretical predictions. However, point predictions are not supported as subjects tended not to spend all their money holdings. Similar results are observed in Duffy and Puzzello (2014ab, 2018, 2022), and could be attributed to some precautionary motive and uncertainty in price realizations.

6 Conclusion

We develop an experimental framework to study the real effects of inflation. In particular, we test the classical view that inflation has detrimental effects on allocations and welfare by taxing monetary exchange. Inflation is implemented by anticipated changes in the money supply, and we examine three schemes to engineer money growth: government spending, lump-sum transfers (or helicopter drops), and proportional transfers. According to the quantity theory, changes in money growth should translate one-to-one to inflation. In terms of real effects, theory predicts money growth through government spending and lump-sum transfers have the same detrimental effects on output and welfare while inflation under proportional transfers is neutralized by the transfer so has no real effects.

Our findings from the experiments are largely consistent with theory, though we also obtain results that depart from the model's predictions. First, we find broad support for the quantity theory of money, i.e., inflation rates endogenously determined in the laboratory track money growth rates across time. Output and welfare are significantly lower with government spending, output is significantly lower with lump-sum transfers, while there are no significant real effects with proportional transfers. A deviation from theory is that output and welfare are lower with government spending than with lump sum transfers, which suggests the real effects of inflation depend on the particular money injection scheme.

Given the opposing theoretical views on the effects of inflation and the challenge of empirically identifying particular channels in field data, our experimental approach serves as a useful complement by isolating a channel of interest and gathering insight about the validity of the corresponding monetary theory. The inflation tax channel is supported by our experimental data. In addition, the consistency between the experimental data and theoretical predictions suggests the experimental framework we developed can serve as a foundation to study other important questions in monetary economics in the lab. For example, while we focus on the inflation tax channel in this paper, we can enrich the current experimental setting to incorporate unconventional monetary policies to test the real interest rate channel and see how these two channels interact.[38] We can also juxtapose the inflation tax channel and other channels to gain insight on the relative importance of different channels. Furthermore, we can use the framework developed here to study open market operations, different trading institutions, currency competition, etc. We view the agenda of conducting monetary policy experiments in the lab as having the potential of becoming an additional tool for policymakers to isolate and analyze the interactions of different policy channels before implementing policies in the field.

References

Adam, Klaus (2007). "Experimental Evidence on the Persistence of Output and Inflation." *Economic Journal*, 117, 603–636.

Aliprantis, Charalambos, Gabriele Camera, and Daniela Puzzello (2007). "Contagion Equilibria in a Monetary Model." *Econometrica*, 75, 277-282.

Anbarci, Nejat, Rirchard Dutu, and Nick Feltovich (2015). "Inflation Tax in the Lab: a Theoretical and Experimental Study of Competitive Search Equilibrium with Inflation." *Journal of Economic Dynamics and Control*, 61, 17-33.

Aoyagi, Masaki, Guillaume Fréchette and Sevgi Yuksel. " Beliefs in Repeated Games." *ISER DP No. 1119*

Araujo, Luis, Braz Camargo, Raoul Minetti, and Daniela Puzzello (2012). "The Essentiality of Money in Environments with Centralized Trade." *Journal of Monetary Economics*, 59, 612-621.

[38] Arifovic and Petersen (2017) and Hommes et al. (2019) conduct learning-to-forecast experiments in a New Keynesian framework to study the effectiveness of monetary and fiscal policies with a zero lower bound on the interest rate. It would be fruitful to investigate the effects of monetary policies in a zero-lower-bound environment using a framework where money serves explicitly as a medium of exchange where subjects make explicit consumption and production decisions.

Arifovic, Jasmina (1996). "The Behavior of the Exchange Rate in the Genetic Algorithm and Experimental Economies." *Journal of Political Economy*, 104, 510–541.

Arifovic, Jasmina and Luba Petersen (2017). "Stabilizing expectations at the zero lower bound: Experimental evidence." *Journal of Economic Dynamics and Control*, 82, 21–43.

Arrieta Vidal, Johar, David Florián Hoyle, Kristian López Vargas, Valeria Morales Vásquez (2022). "Policies for Transactional De-dollarization: A Laboratory Study." *Journal of Economic Behavior and Organization*, 200, 31-54.

Aruoba, Boragan, Christopher Waller, and Randall Wright (2011). "Money and Capital." *Journal of Monetary Economics*, 21, 105-124.

Assenza, Tiziana, Peter Heemeijer, Cars Hommes, and Domenico Massaro (2021). "Managing self-organization of expectations through monetary policy: A macro experiment." *Journal of Monetary Economics*, 117, 170-186.

Baeriswyl, Romain and Camille Cornand (2018). "The Distortionary Effect of Monetary Policy: Credit Expansion vs. Lump-sum Transfers in the Lab." *B.E. Journal of Macroeconomics*, 18, 1-30.

Bailey, Martin J. (1956). "The Welfare Cost of Inflationary Finance." *Journal of Political Economy*, 64, 93–110.

Barro, Robert. (1995). "Inflation and Economic Growth." Bank of England Quarterly Bulletin, May issue, 39–52.

Berentsen, Aleksander, Guido Menzio, and Randall Wright. (2011). "Inflation and Unemployment in the Long Run." *American Economic Review*, 101, 371-98.

Berentsen, Aleksander, Michael McBride, and Guillaume Rocheteau (2017). "Limelight on Dark Markets: Theory and Experimental Evidence on Liquidity and Information." *Journal of Economic Dynamics and Control*, 5, 70-90.

Bernanke, Ben. (2020). "The New Tools of Monetary Policy." *American Economic Review*, 110, 943-983.

Bernasconi, Michele and Oliver Kirchkamp (2000). "Why Do Monetary Policies Matter? An Experimental Study of Saving and Inflation in an Overlapping Generations Model." *Journal of Monetary Economics*, 46, 315–343.

Bethune, Zachary, Michael Choi, and Randall Wright (2020). "Frictional Goods Markets: Theory and Applications." *Review of Economic Studies*, 87, 691-720.

Bewley, Truman (1980). "The Optimum Quantity of Money." In *Models of Monetary Economies*, ed. by J. H. Kareken and Neil Wallace, 169–210.

Brown, Paul (1996). "Experimental Evidence on Money as a Medium of Exchange." *Journal of Economic Dynamics and Control*, 20, 583-600.

Bullard, James and John Keating (1995). "The Long-Run Relationship Between Inflation and Output in Postwar Economies." *Journal of Monetary Economics*, 36, 477-496.

Burdett, Kenneth, Shouyong Shi, and Randall Wright (2001). "Pricing and Matching with Frictions." *Journal of Political Economy*, 109, 1060–1085.

Camera, Gabriele and Marco Casari (2014). "The Coordination Value of Monetary Exchange: Experimental Evidence." *American Economic Journal: Microeconomics*, 6, 629–660.

Camera, Gabriele, Charles Noussair, and Steven Tucker (2003). "Rate-of-return Dominance and Efficiency in an Experimental Economy." *Economic Theory*, 22, 629-660.

Candia, Bernardo, Olivier Coibion, and Yuriy Gorodnichenko (2020). "Communication and the Beliefs of Agents." in Navigating the Decade Ahead: Implications for Monetary Policy, Economic Policy Symposium (Jackson Hole, WY) Proceedings, Federal Reserve Bank of Kansas City.

Davis, Douglas and Oleg Korenok (2011). "Nominal Shocks in Monopolistically Competitive Markets: An Experimental Analysis." *Journal of Monetary Economics*, 58, 578-589.

Davis, Douglas, Oleg Korenok, Peter Norman, Bruno Sultanum, and Randall Wright (2022). "Playing with Money." *Journal of Economic Behavior and Organization*, 200, 1221-1239.

Deck, Cary, Kevin McCabe, and David Porter (2006). "Why Stable Fiat Money Hyperinflates: Results from an Experimental Economy." *Journal of Economic Behavior and Organization*, 61, 471-486.

Ding, Shuze and Daniela Puzzello (2020). "Legal Restrictions and International Currencies: An Experimental Approach." *Journal of International Economics*, 126, 103342.

Duffy, John (2016). "Macroeconomics: A Survey of Laboratory Research." In *Macroeconomics: A Survey of Laboratory Research*, edited by Kagel, John H., and Alvin E. Roth, Princeton University Press.

Duffy, John, Janet Hua Jiang, and Huan Xie (2019). "Pricing Indefinitely Lived Assets: Experimental Evidence." Available at SSRN: https://ssrn.com/abstract=3420184.

Duffy, John and Jack Ochs (1999). "Emergence of Money as a Medium of Exchange: An Experimental Study." *American Economic Review*, 89, 847–877.

Duffy, John and Jack Ochs (2002). "Intrinsically Worthless Objects as Media of Exchange: Experimental Evidence." *International Economic Review*, 43, 637–673.

Duffy, John, Alexander Matros, and Ted Temzelides (2011). "Competitive Behavior in Market Games: Evidence and Theory." *Journal of Economic Theory*, 146, 1437-1463.

Duffy, John and Daniela Puzzello (2014*a*). "Gift Exchange versus Monetary Exchange: Experimental Evidence." *American Economic Review*, 104, 1735–1776.

Duffy, John, and Daniela Puzzello (2014*b*). "Experimental Evidence on the Essentiality and Neutrality of Money in a Search Model." *Experiments in Macroeconomics* vol 17, Binley, UK: Emerald Group Publishing Ltd.

Duffy, John, and Daniela Puzzello (2022). "The Friedman Rule: Experimental Evidence." *International Economic Review*, 63(2), 671 – 698.

Fischbacher, Urs (2007). "Z-Tree: Toolbox for Ready-Made Economic Experiments." *Experimental Economics*, 10, 171–178.

Fréchette, Guillaume (2012). "Session-effects in the Laboratory." *Experimental Economics*, 15, 485–498.

Fréchette, Guillaume and Sevgi Yuksel (2017). "Infinitely repeated games in the laboratory: four perspectives on discounting and random termination." *Experimental Economics*, 20, 279-308.

Friedman, Milton and Anna Schwartz (1981). *Monetary Trends in the United States and United Kingdom: Their Relation to Income, Prices, and Interest Rates.* University of Chicago Press for the NBER.

Gu, Chao, Han Han, and Randall Wright (2020). "The Effects of News When Liquidity Matters." *International Economic Review*, 61(4), 1411-1435.

Hommes, Cars (2021). "Behavioral and Experimental Macroeconomics and Policy Analysis: a Complex Systems Approach." *Journal of Economic Literature*, 59(1), 149-219.

Hommes, Cars, Domenico Massaro, and Isabelle Salle (2019). "Monetary and fiscal policy design at the zero lower bound: Evidence from the lab." *Economic Inquiry*, 57(2), 1120–1140.

Jiang, Janet Hua, Peter Norman, Daniela Puzzello, Bruno Sultanum, and Randall Wright (2021). "Is Money Essential? An Experimental Approach." *Federal Reserve Bank of Richmond Working paper No. 21-12.*

Jiang, Janet Hua, Daniela Puzzello, and Cathy Zhang (2021). "How Long is Forever in the Laboratory? Three Implementations of an Infinite-Horizon Monetary Economy" *Journal of Economic Behavior and Organization*, 184, 278-301.

Jiang, Janet Hua and Cathy Zhang (2018). "Competing Currencies in the Laboratory." *Journal of Economic Behavior and Organization*, 154, 253-280.

Kamiya, Kazuya, Hajime Kobayashi, Tatsuhiro Shichijo and Takashi Shimizu (2021). "On the Monetary Exchange with Multiple Equilibrium Money Holdings Distributions: An Experimental Approach." *Journal of Economic Behavior and Organization*, 183, 206-232.

Lagos, Ricardo (2010). "Asset Prices and Liquidity in an Exchange Economy." *Journal of Monetary Economics*, 57(8), 913-930.

Lagos, Ricardo and Randall Wright (2005). "A Unified Framework for Monetary Theory and Policy Analysis." *Journal of Political Economy*, 113, 463–486.

Lagos, Ricardo and Shengxing Zhang (2019). "The Limits of Onetary Economics: On

Money as a Medium of Exchange in Near-Cashless Credit Economies." Available at SSRN: http://dx.doi.org/10.2139/ssrn.3141226

Lagos, Ricardo and Shengxing Zhang (2020). "Turnover Liquidity and the Transmission of Monetary Policy." *American Economic Review*, 110, 1635-72.

Lagos, Ricardo and Shengxing Zhang (2022). "The Limits of Onetary Economics: On Money as a Constraint on Market Power." *Econometrica*, 90(3), 1177-1204.

Lian, Peng and Charles Plott (1998). "Markets, Macroeconomics and Money in a Laboratory Experimental Environment." *Economic Theory*, 12, 21-75.

Lim, Suk S., Edward C. Prescott, and Shyam Sunder (1994). "Stationary Solution to the Overlapping generations model of fiat money: experimental evidence." *Empirical Economics*, 19, 255-277.

Lucas, Robert E. (1980)."Two Illustrations of the Quantity Theory of Money." *American Economic Review*, 70, 1005-14.

Lucas, Robert E. (2000). "Inflation and Welfare." *Econometrica*, 68(2), 247–274.

Marimon, Ramon and Shyam Sunder (1993). "Indeterminacy of Equilibria in a Hyperinflationary World: Experimental Evidence." *Econometrica*, 61, 1073-107.

Marimon, Ramon and Shyam Sunder (1994). "Expectations and learning under alternative monetary regimes: an experimental approach." *Economic Theory*, 4, 131-162.

Marimon, Ramon and Shyam Sunder (1995). "Does a Constant Money Growth Rule Help Stabilize Inflation?: Experimental Evidence." *Carnegie-Rochester Conference Series on Public Policy*, 43, 111-156.

McCandless, George and Warren Weber (1995). "Some Monetary Facts." *Quarterly Review*, 19, 2-11.

Noussair, Charles, Damjan Pfajfar, and Janos Zsiros (2015). "Pricing Decisions in an Experimental Dynamic Stochastic General Equilibrium Economy." *Journal of Economic Behavior and Organization*, 109, 188-202.

Noussair, Charles, Damjan Pfajfar, and Janos Zsiros (2021). "Frictions in an Experimental Dynamic Stochastic General Equilibrium Economy." *Journal of Money, Credit, and Banking*, 53, 555-587.

Pfajfar, Damjan and Blaz Zakelj (2014). "Experimental Evidence on Inflation Expectation Formation." *Journal of Economic Dynamics and Control.* 44, 147-168.

Rietz, Justin (2019). "Secondary Currency Acceptance: Experimental Evidence with a Dual Currency Search Model." *Journal of Economic Behavior and Organization*, 166, 403-431.

Rocheteau, Guillaume and Ed Nosal (2017). *Money, Payments and Liquidity*, MIT Press.

Rocheteau, Guillaume and Randall Wright (2005). "Money in Search Equilibrium, in

Competitive Equilibrium, and in Competitive Search Equilibrium." *Econometrica*, 73, 175-202.

Rocheteau, Guillaume, Randall Wright and Sylvia Xiao (2018). "Open Market Operations." *Journal of Monetary Economics* 98, 114-128.

Rocheteau, Guillaume, Randall Wright, and Cathy Zhang (2018). "Corporate Finance and Monetary Policy." *American Economic Review*, 108, 1147-1186.

Rolnick, Arthur J. and Warren E. Weber (1997). "Money, Inflation, and Output under Fiat and Commodity Standards." *Journal of Political Economy*, 105, 1308-321.

Roth, Alvin and Keith Murnighan (1978). "Equilibrium Behavior and Repeated Play of the Prisoner's Dilemma." *Journal of Mathematical Psychology*, 17, 189–198.

Shapley, Lloyd, and Martin Shubik (1977). "Trade Using One Commodity as a Means of Payment." *Journal of Political Economy*, 85, 937-968.

Shi, Shouyong (1997). "A Divisible Search Model of Fiat Money." *Econometrica*, 65(1), 75-102.

Townsend, Robert (1980). "Models of Money with Spatially Separated Agents." In *Models of Monetary Economies*, ed. by J. H. Kareken and Neil Wallace, 265–304.

Williamson, Stephen (2012). "Liquidity, Monetary Policy, and the Financial Crisis: A New Monetarist Approach." *American Economic Review* 102, 2570-2605.

Zhang, Cathy (2014). "An Information-Based Theory of International Currency." *Journal of International Economics*, 93(2), 286-301.

INFLATION, OUTPUT AND WELFARE IN THE LABORATORY
APPENDIX FOR ONLINE PUBLICATION

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Appendix A Additional Tables to Capture Treatment Differences

In this appendix, we report additional findings on treatment differences in inflation, output, and welfare, using aggregate level data.

A.1 Inflation

We present additional tables reporting on regression results on inflation: specifications used to estimate inflation rates (Table A.1), pairwise comparisons across treatments (A.2 and A.3), and deviations of the inflation estimate from theoretical predictions (B.1).

Table A.1: Regression Specifications for Estimation of Inflation Rates

Variables	$ln(p_A)$	$ln(p_B)$
Period	0.026 ***	0.045***
	(0.009)	(0.009)
Period x GS15	0.106 ***	0.116***
	(0.012)	(0.014)
Period x GS30	0.211***	0.210***
	(0.012)	(0.012)
Period x LS30	0.194***	0.209***
	(0.014)	0.015
Period x PR30	0.196***	0.225***
	(0.013)	0.014
Observations	623	623
R-squared	0.916	0.917

Notes. (1) GS15, GS30, LS30 and PR30 denote treatment dummies. The regression specifications include session-sequence dummies to allow each sequence to have a potentially different price level. For brevity, we suppress the coefficients of these dummies. (2) Robust standard errors in parentheses. (3) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table A.2: Pairwise Comparison of Estimated Inflation Rates in Market A

	GS30	LS30	PR30
GS15	0.127***	0.105***	0.108***
	(0.015)	(0.016)	(0.015)
GS30		−0.021	−0.018
		(0.017)	(0.016)
LS30			0.003
			(0.017)

Notes. (1) Each entry in a cell represents the estimate of the inflation rate in the column treatment minus the inflation rate in the row treatment. (2) Robust standard errors in parentheses. (3) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table A.3: Pairwise Comparison of Estimated Inflation Rates in Market B

	GS30	LS30	PR30
GS15	0.116***	0.115***	0.136***
	(0.016)	(0.020)	(0.019)
GS30		−0.001	0.020
		(0.018)	(0.017)
LS30			0.021
			(0.021)

Notes. (1) Each entry in a cell represents the estimate of the inflation rate in the column treatment minus the inflation rate in the row treatment. (2) Robust standard errors in parentheses. (3) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

A.2 Output

A.2.1 Output in Market A

Table A.4 shows the estimated difference in average market A output across treatments. Table B.2 shows the average market A output for each session and the deviation from theoretical predictions. Table A.5 reports output A's trend within sequences. Average output in Market A is fairly stable with the exception of the CM treatment.

Table A.4: Estimated Difference in Average Market A Output

	GS30	LS30	PR30
GS15	-1.133^{***}	-0.126	2.721^{***}
	(0.310)	(0.320)	(0.292)
GS30		1.007^{***}	3.854^{***}
		(0.354)	(0.330)
LS30			2.847^{***}
			(0.339)

Notes. (1) Each entry in a cell represents the estimate of the average market A output in the column treatment minus the average market A output in the row treatment. (2) Robust standard errors in parentheses. (3) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. (4) Note that the difference in average output between the CM and other treatments can be directly read from Table 5.

Table A.5: Time Trend in Average Market A Output

	Obs.	Coef.	Robust Std. Err.
CM	134	-0.234 ***	0.085
GS15	129	0.060	0.057
GS30	134	0.019	0.069
LS30	118	0.126	0.078
PR30	108	0.103	0.068

Notes. (1) Robust standard errors in parentheses. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

A.2.2 Output in Market B

Figure A.1 graphs the average output per period in market B, with 95% confidence intervals. Tables A.6 examines the treatment effect on average market B output relative to the CM treatment. Table A.7 reports pairwise comparisons between inflationary treatments. Table A.8 reports the time trend of average market B output.

Average output in market B is broadly consistent with the directional hypotheses based on theoretical predictions, e.g., output in market B is significantly lower in GS15, GS30, and LS30 than in CM and PR30. However, there is one exception as output in GS30 is not significantly lower than output in GS15.

Perhaps not surprisingly, point predictions are not fully supported by the data. Market B average output in the CM and PR30 (neutral) treatments tends to be slightly lower than the theoretical prediction, while output in GS30 tends to be higher than predicted. Specifically, average output levels in CM and PR30 are equal to 8.69 and 8.60, and significantly lower than the theoretical prediction of 10. Average output in GS30 is equal to 7.60, which is significantly higher than the theoretical prediction of 6.5. Average output in GS15 is equal to 7.56 which is not significantly different from 7.95. Similarly average output in LS30 at 6.55 is very close and not significantly different from the theoretical prediction of 6.5.

There is no significant time trend except for PR30, which exhibited a downward trend.

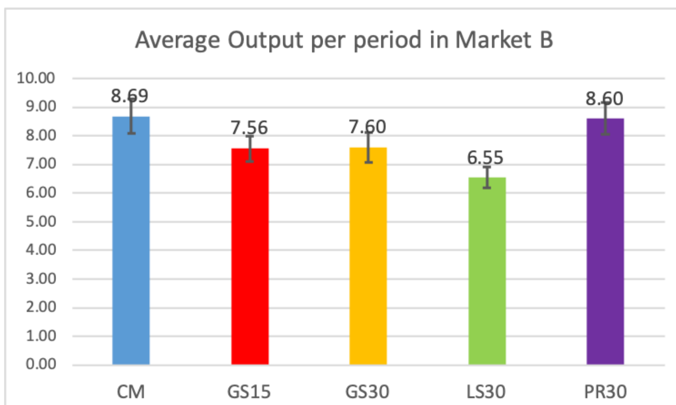

Figure A.1: Average Market B Output

Notes. Theory predicts output in market B is 10 in CM and PR30, 7.95 in GS15, and 6.5 in GS30 and LS30.

Table A.6: Regression of Average Market B Output on Treatment Dummies

Variables	Avg. Market B Output
GS15	-1.124^{***}
	(0.375)
GS30	-1.088^{***}
	(0.397)
LS30	-2.142^{***}
	(0.352)
PR30	-0.086
	(0.412)
Constant	8.688^{***}
	(0.301)
Observations	623
R-squared	0.069

Notes. (1) Robust standard errors in parentheses. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table A.7: Estimated Difference in Average Market B Output

	GS30	LS30	PR30
GS15	0.036	-1.019^{***}	1.038^{***}
	(0.342)	(0.289)	(0.359)
GS30		-1.055^{***}	1.002^{***}
		(0.316)	(0.382)
LS30			2.056^{***}
			(0.335)

Notes. (1) Robust standard errors in parentheses. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table A.8: Time Trend in Average Market B Output

	Obs.	Coef.	Robust Std. Err.
CM	134	-0.091	0.095
GS15	129	-0.007	0.062
GS30	134	0.039	0.071
LS30	118	0.062	0.056
PR30	108	-0.197**	0.083

Notes. (1) The dependent variable is average market B output, and the regressors are period and the constant. We report only the coefficient for period. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

A.3 Welfare

Here we report results related to welfare analysis. Table A.9 reports pairwise comparisons across treatments. Table A.10 reports on consumption dispersion.

Table A.9: Estimated Difference in Welfare Ratio

	GS30	LS30	PR30
GS15	-0.022^{*}	0.020	0.052^{***}
	(0.012)	(0.012)	(0.012)
GS30		0.042^{***}	0.074^{***}
		(0.014)	(0.013)
LS30			0.032^{**}
			(0.014)

Notes. (1) Each entry in a cell represents the estimate of the welfare ratio in the column treatment minus the welfare ratio in the row treatment. (2) Robust standard errors in parentheses. (3) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. (4) Note that the difference in average welfare ratio between the CM and other treatments can be also directly read from Table 6.

Table A.10: Individual Consumption in Market A: Summary Statistics, by Treatment

Treatment	Obs.	Mean	std	CoV.
Baseline	645	9.687	6.763	0.698
GS15	645	7.607	6.253	0.822
GS30	670	6.474	5.311	0.820
LS30	590	7.481	5.358	0.716
PR30	540	10.329	7.485	0.725

Table A.11 reports deviations from theoretical predictions by treatment. We see that point predictions from the theory are not supported as welfare is significantly lower than predicted (see Table A.11 for estimated welfare ratio and deviation from theoretical point predictions for each session and treatment), with the exception of the LS30 treatment where welfare is not significantly different from the theoretical prediction of 0.82. Notice the low level of welfare relative to theory is mainly due to consumption dispersion (i.e. dispersion is positive in the experiment while zero in theory). As shown in the last column of Table A.11, removing consumption dispersion and evaluating the welfare ratio assuming every buyer consumes the average output would bring the welfare ratio close to or even higher than the theoretical prediction (recall output in market A tends to be higher than theoretical predictions; see Table B.2).

A.4 Analysis to Control for Session Effects

In our regression analysis with aggregate market-level data, we use robust standard errors. We also explore two options to further control for session effects. In our experiment, each

Table A.11: Welfare Ratio and Deviations from Theoretical Point Predictions, by Treatment

Session	Obs.	Welfare Ratio	Welfare Ratio - Steady State Estimate		Robust Std. Err	Welfare Ratio at Avg. Output
CM	134	0.827	-0.152	***	0.009	0.976
GS15	129	0.787	-0.120	***	0.007	0.929
GS30	134	0.765	-0.058	***	0.009	0.891
LS30	118	0.807	-0.016		0.010	0.926
PR30	108	0.839	-0.140	***	0.009	0.984

Notes. (1)* p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. (2) The steady state welfare ratio is 0.98 for CM and PR30, 0.91 for GS15, and 0.82 for GS30 and LS30.

subject participates only in one session. Session effects arise as the same group of subjects interact for multiple periods in a session.

As suggested by Fréchette (2012), to address dynamic session effects where subjects' choices are affected by outcomes in the past, it may be sufficient to control for that instead of clustering errors at the session level. In our experiment, past outcomes are well summarized by past prices (and subjects observe the price trajectories on their decision screen). To investigate session effects, we first regressed average output in market A and market B on treatment dummies and added past inflation in market A and in market B as additional regressors. The results are reported in Tables A.12 and A.13. The results are similar to our original regression (the only notable difference is that output in market A in PR30 becomes marginally statistically higher than the baseline but the magnitude is still small at 0.8).

We also investigate the treatment effects on inflation, market A output, and welfare with errors clustered at the session level. Regarding inflation (see Table A.14), the results are not much affected: higher money growth rates lead to significantly higher inflation. For average output in market A (see Table A.15), we still see significant treatment effects for the two government spending treatments GS15 and GS30. For the lump-sum treatment, the p-value is 12.6% so becomes marginally insignificant at the 10% level. Money growth/inflation is still neutral in the treatment with proportional transfers (PR30). For welfare, the results are no longer statistically significant.

In terms of clustering standard errors, it is common to report standard errors clustered at the subject level while regressing with individual data. There is much less agreement in the experimental literature on whether to cluster errors at the session level. One reason is most experimental studies have only a small number of sessions, and there is a nontrivial trade-off between robustness and efficiency. Given this trade-off and that results with the addition of lagged variables appeared to be robust, we think it is reasonable to focus on the results without clustering at the session level.

Table A.12: Regression of Average Market A Output with Lagged Inflation

GS15	-1.943***
	(0.402)
GS30	-3.224***
	(0.441)
LS30	-2.043***
	(0.447)
PR30	0.810*
	(0.433)
ln(lagInflationA)	0.258
	(0.311)
ln(lagInflationB)	0.092
	(0.308)

Notes.
(1) Robust standard errors in parentheses.
(2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table A.13: Regression of Average Market B Output with Lagged Inflation

GS15	-0.993**
	(0.433)
GS30	-1.190***
	(0.446)
LS30	-2.016***
	(0.406)
PR30	-0.203
	(0.482)
ln(lagInflationA)	0.128
	(0.340)
ln(lagInflationB)	0.303
	(0.326)

Notes.
(1) Robust standard errors in parentheses.
(2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table A.14: Inflation in Market A and Market B, by Treatment, with Errors Clustered at Session Level

Variables	π_A	π_B
GS15-CM	0.115 ***	0.128***
	(0.014)	(0.028)
GS30-CM	0.241***	0.244***
	(0.008)	(0.018)
LS30-CM	0.220***	0.243***
	(0.024)	(0.032)
PR30-CM	0.223***	0.264***
	(0.024)	(0.023)
CM	0.027 ***	0.045***
	(0.007)	(0.017)

Notes.
(1) This table shows the estimated inflation rate for baseline treatment CM, and the difference between other treatments and the CM treatment. (2) Errors clustered at the session level in parentheses. (3) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table A.15: Regression of Average Market A Output on Treatment Dummies

Variables	robust err.	err. clustered at session level
GS15	−2.193***	−2.193*
	(0.358)	(1.203)
GS30	−3.326***	−3.326**
	(0.389)	(1.400)
LS30	−2.319***	−2.319
	(0.397)	(1.448)
PR30	0.529	0.529
	(0.375)	(1.229)
Constant	9.800***	9.800***
	(0.303)	(1.108)
Observations	623	623
R-squared	0.218	0.218

Notes.
(1) Robust standard errors in parentheses.
(2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table A.16: Regression of Welfare Ratio on Treatment Dummies

Variables	robust err.	err. clustered at session level
GS15	-0.040^{***}	-0.040
	(0.012)	(0.045)
GS30	-0.062^{***}	-0.062
	(0.013)	(0.052)
LS30	-0.020	-0.020
	(0.014)	(0.056)
PR30	0.012	0.012
	(0.013)	(0.044)
Constant	0.827^{***}	0.827^{***}
	(0.009)	(0.040)
Observations	623	623
R-squared	0.066	0.066

Notes.
(1) Robust standard errors in parentheses.
(2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

A.5 Relative Price in Market A and Market B

Theory predicts the prices in the two markets satisfy equation (1). In Table A.17 below, we show the price ratio in the two markets, defined as p_A/p_B for all treatments, the theoretical prediction, and the deviation from theory. Prices in market A tend to be lower than in market B. While deviations from theory are not statistically significant in CM and GS30, they are in the other three treatments.[39]

Table A.17: Price Equality Test by Treatment

Variables	CM	GS15	GS30	LS30	PR30
theory	1	1	1	1	0.769
mean	0.961	0.896	0.943	0.698	0.712
dev	-0.038	-0.104^{***}	-0.057	-0.302^{***}	-0.075^{**}
std	(0.033)	(0.038)	(0.036)	(0.036)	(0.037)
Obs.	134	129	134	118	108

Notes. (1) Standard errors in parentheses. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

[39]For GS15 and PR30, the deviation is not very large and is around 10%. The deviation is larger for LS30. One possible reason is that in LS30, subjects tend to spend more in market B relative to market A because they receive money transfers at the beginning of market B.

Appendix B Convergence and Learning

In this Appendix we present results on the deviation from theoretical point predictions and capture potential learning effects by comparing the deviations in the last three periods (sequences) with earlier periods (sequences).

Tables B.1 and B.2 show the deviation of inflation and average market A output by treatment. Tables B.3 to B.5 compare the last three periods with earlier periods. Tables B.6 to B.9 compare the last sequence versus earlier sequences. A significant negative coefficient on the variable "Diff" indicates the deviation from theory is significantly smaller in the last three periods (sequences) and can be interpreted as evidence of learning across periods within sequences (across sequences within sessions).

Overall, as mentioned in the main body of the paper, there are no significant differences between the last three periods and earlier periods, and weak evidence of learning between earlier sequences and the last sequence.

Table B.1: Estimated Inflation and Deviations from Theoretical Point Predictions, by Treatment

		Market A				Market B			
			Deviation from ss				Deviation from ss		
		Estimated			robust	Estimated			robust
	Obs.	Inflation	Estimate		std. err.	Inflation	Estimate		std. err.
CM	134	0.027	0.027	***	0.009	0.046	0.046	***	0.010
GS15	129	0.141	-0.009		0.010	0.174	0.024	*	0.013
GS30	134	0.268	-0.032	***	0.011	0.290	-0.010		0.010
LS30	118	0.247	-0.053	***	0.013	0.289	-0.011		0.015
PR30	108	0.250	-0.050	***	0.011	0.310	0.010		0.014

Notes.(1) Inflation is estimated from regressing ln(Price) on Period with robust standard errors. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table B.2: Average Market A Output and Deviations from Theoretical Point Predictions, by Treatment

Session	Obs.	Ave. Output A	Ave. Output A -SS		
			Estimate		Robust Std. Err.
CM	134	9.800	-0.200		0.303
GS15	129	7.607	0.694	***	0.191
GS30	134	6.474	1.474	***	0.244
LS30	118	7.481	2.481	***	0.257
PR30	108	10.329	0.329		0.221

Notes. (1)* p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. (2) Steady-state market A output is 10 in treatments CM and PR30, 6.91 in treatment GS15, and 5 in treatments GS30 and LS30.

Table B.3: Market A Inflation Deviation from Theory, Last 3 Periods versus Earlier Periods, by Treatment

	CM	GS15	GS30	LS30	PR30
Earlier periods	0.014	-0.013	-0.036**	-0.045**	-0.044**
	(0.013)	(0.016)	(0.017)	(0.020)	(0.019)
Last 3 periods	0.026***	-0.009	-0.032***	-0.053***	-0.050***
	(0.009)	(0.010)	(0.011)	(0.013)	(0.011)
Diff	0.012	-0.004	-0.004	0.007	0.006
	(0.008)	(0.009)	(0.011)	(0.014)	(0.013)

Table B.4: Market B Inflation Deviation from Theory, Last 3 Periods versus Earlier Periods, by Treatment

	CM	GS15	GS30	LS30	PR30
Earlier periods	0.041***	0.013	-0.002	-0.031	0.010
	(0.012)	(0.015)	(0.016)	(0.019)	(0.022)
Last 3 periods	0.046***	0.023*	-0.010	-0.012	0.010
	(0.010)	(0.012)	(0.010)	(0.015)	(0.014)
Diff	0.004	0.010	0.008	-0.019	0.000
	(0.009)	(0.011)	(0.011)	(0.013)	(0.015)

Table B.5: Market A Output Deviation from Theory, Last 3 Periods versus Earlier Periods, by Treatment

	CM	GS15	GS30	LS30	PR30
Earlier periods	0.123	0.626***	1.525***	2.353***	0.125
	(0.357)	(0.232)	(0.270)	(0.293)	(0.267)
Last 3 periods	-1.080*	0.872***	1.336**	2.810***	0.858**
	(0.557)	(0.335)	(0.542)	(0.524)	(0.379)
Diff	0.957	0.247	-0.189	0.457	0.733
	(0.662)	(0.407)	(0.605)	(0.600)	(0.463)

Table B.6: Learning Regression for Inflation, Last Sequence versus Earlier Sequences

CM	$e^{(\beta_1+\beta_3)} - e^{\beta_1}$
GS15	$e^{(\beta_1+\beta_{2,GS15}+\beta_3+\beta_{4,GS15})} - e^{(\beta_1+\beta_{2,GS15})}$

Notes. To compare inflation in the last sequence with earlier sequences, we regress the natural logarithm of the price level in market A or B on a constant (α), Period (β_1), Period x Treatment dummies ($\beta_{2,GS15,..,PR30}$), Period x LastSeq dummy (β_3), and Period x treatment dummies x LastSeq dummy ($\beta_{4,GS15,..,PR30}$). We include session-sequence dummies to capture potentially different price levels between sequences. This table shows how we estimate the difference between the last sequence versus earlier sequences for different treatments (we illustrate it for GS15 but a similar procedure applies to other treatments).

Table B.7: Market A Inflation, Deviation from Theory - Last Sequence versus Earlier Sequences, by Treatment

	CM	GS15	GS30	LS30	PR30
Earlier seq	0.028**	-0.001	-0.021	-0.076***	-0.044***
	(0.013)	(0.016)	(0.015)	(0.015)	(0.016)
Last seq	0.025**	-0.018*	-0.042***	-0.013	-0.057***
	(0.013)	(0.010)	(0.016)	(0.019)	(0.015)
Diff	-0.003	0.017	0.020	-0.063***	0.013
	(0.018)	(0.019)	(0.022)	(0.024)	(0.022)

Table B.8: Market B Inflation, Deviation from Theory - Last Sequence versus Earlier Sequences, by Treatment

	CM	GS15	GS30	LS30	PR30
Earlier seq	0.064***	0.020	0.014	-0.003	0.015
	(0.016)	(0.014)	(0.015)	(0.020)	(0.023)
Last seq	0.028***	0.029	-0.033***	-0.025***	0.004
	(0.010)	(0.023)	(0.011)	(0.023)	(0.014)
Diff	-0.036*	0.008	0.019	0.022	-0.011
	(0.019)	(0.027)	(0.019)	(0.030)	(0.027)

Table B.9: Market A Output, Deviation from Theory - Last Sequence versus Earlier Sequences, by Treatment

	CM	GS15	GS30	LS30	PR30
Earlier seq	0.499	1.378***	1.625***	2.958***	0.768***
	(0.335)	(0.234)	(0.320)	(0.311)	(0.284)
Last seq	-1.338**	-0.538**	1.229***	1.351***	-0.287
	(0.549)	(0.243)	(0.377)	(0.398)	(0.334)
Diff	0.839	-0.839**	-0.396	-1.607***	-0.481
	(0.643)	(0.337)	(0.494)	(0.505)	(0.438)

Appendix C Analysis of Individual Data

Here we report findings on individual behavior. Table C.1 and C.2 report treatment effects on individual production decisions. Table C.3 reports on individual spending decisions.

The treatment effect on individual output in market A is similar to our findings in the main text on period average output. Specifically, individual producers tend to produce less in the inflationary treatments predicted to have adverse effects on output (GS15, GS30 and LS30) (see Table C.1). Regarding market B, the treatment effect is in the same direction as at the aggregate level, but it is not significant (see Table C.2).

The regression in Table C.3 shows there are no significant treatment effects on the fraction of money holdings subjects spent in the inflationary treatments relative to the CM treatment; this is qualitatively consistent with theoretical predictions. However, point predictions are not supported as subjects tended not to spend all their money holdings. Similar results are observed in Duffy and Puzzello (2014ab, 2018, 2022), and could be attributed to some precautionary motive and uncertainty in the price realization.

Table C.1: Regression of Individual Market A Output on Treatment Dummies

Variables	Market A Output
GS15	-2.080^{*}
	(1.225)
GS30	-3.212^{**}
	(1.222)
LS30	-2.206^{*}
	(1.203)
PR30	0.642
	(1.512)
Constant	9.687^{***}
	(0.817)
Observations	3,090
R-squared	0.051

Notes. (1) Standard errors clustered at the subject level are in parentheses. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table C.2: Regression of Individual Market B Output on Treatment Dummies

Variables	Market B Output
GS15	-0.955
	(1.636)
GS30	-0.919
	(1.439)
LS30	-1.974
	(1.259)
PR30	0.082
	(1.375)
Constant	8.519
	(1.047)
Observations	3,090
R-squared	0.014

Notes. (1) Standard errors clustered at the subject level are in parentheses. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table C.3: Regression of Individual Token Spending Ratio on Treatment Dummies

Variables	Market A Spending Ratio	Market B Spending Ratio
GS15	0.029	0.055
	(0.056)	(0.048)
GS30	0.091	-0.045
	(0.062)	(0.065)
LS30	-0.081	-0.027
	(0.058)	(0.057)
PR30	0.048	-0.014
	(0.057)	(0.056)
Constant	0.716***	0.754***
	(0.043)	(0.038)
Observations	3,074	3,073
R-squared	0.047	0.015

Notes. (1) Standard errors are clustered at the subject level. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. (3) Note that some subjects enter the market with a zero token balance; we omit those observations in the regression.

Appendix D Individual Sessions

In this section, we provide information on individual sessions. Tables D.1 to D.3 show the estimated inflation, average output in market A, and welfare ratio, and the deviations from theoretical predictions for each individual session. Figures D.1 and D.2 show the time paths for average Market A output and price levels, for each session of each treatment.

Table D.1: Estimated Inflation and Deviations from Theoretical Point Predictions, by Session

		Market A				Market B			
			Deviation from ss				Deviation from ss		
		Estimated			robust	Estimated			robust
	Obs.	Inflation	Estimate		std. err.	Inflation	Estimate		std. err.
CM1	25	0.005	0.005		0.011	0.001	0.001		0.012
CM2	46	0.028	0.028	**	0.014	0.076	0.076	***	0.015
CM3	33	0.033	0.033		0.027	0.040	0.040	**	0.018
CM4	30	0.046	0.046	**	0.021	0.050	0.050	*	0.030
GS15-1	25	0.148	-0.002		0.010	0.151	0.001		0.013
GS15-2	30	0.184	0.034		0.022	0.150	0.000		0.021
GS15-3	44	0.119	-0.031		0.021	0.154	0.004		0.014
GS15-4	30	0.131	-0.019		0.017	0.272	0.122	**	0.048
GS30-1	25	0.264	-0.036		0.029	0.280	-0.020	*	0.012
GS30-2	46	0.271	-0.029	**	0.014	0.290	-0.010		0.017
GS30-3	23	0.279	-0.021		0.028	0.315	0.015		0.022
GS30-4	40	0.258	-0.042	**	0.021	0.280	-0.020		0.029
LS30-1	25	0.296	-0.004		0.020	0.278	-0.022		0.027
LS30-2	30	0.184	-0.116	***	0.013	0.243	-0.057	**	0.023
LS30-3	33	0.223	-0.077	***	0.018	0.259	-0.041	***	0.015
LS30-4	30	0.274	-0.026		0.038	0.399	0.099	**	0.049
PR30-1	25	0.214	-0.086	***	0.015	0.273	-0.027		0.020
PR30-2	30	0.222	-0.078	***	0.023	0.325	0.025		0.038
PR30-3	23	0.257	-0.043	*	0.022	0.321	0.034		0.021
PR30-4	30	0.325	0.025		0.016	0.338	0.038	**	0.018

Notes. (1) Inflation is estimated from regressing ln(Price) on Period with robust standard errors. Sequences dummies are included in the regressions, and their coefficients are suppressed for brevity. (2) * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

Table D.2: Average Market A Output and Deviations from Theoretical Point Predictions, by Session

Session	Obs.	Ave. Output A	Ave. Output A -SS		
			Estimate		Robust Std. Err.
CM-1	25	12.711	2.711	***	0.506
CM-2	46	7.484	-2.516	***	0.476
CM-3	33	11.594	1.594	***	0.528
CM-4	30	8.950	-1.050	**	0.391
GS15-1	25	7.432	0.519		0.365
GS15-2	30	8.561	1.649	***	0.377
GS15-3	44	8.108	1.195	***	0.308
GS15-4	30	6.064	-0.848	**	0.352
GS30-1	25	8.956	3.956	***	0.559
GS30-2	46	6.701	1.701	***	0.317
GS30-3	23	7.245	2.245	***	0.422
GS30-4	40	4.218	-0.782	**	0.360
LS30-1	25	8.123	3.122	***	0.369
LS30-2	30	4.436	-0.564	***	0.200
LS30-4	33	8.598	3.598	***	0.439
LS30-4	30	8.763	3.763	***	0.493
PR30-1	25	10.317	0.317		0.443
PR30-2	30	11.779	1.779	***	0.353
PR30-3	23	8.869	-1.131	**	0.444
PR30-4	30	10.006	0.006		0.378

Notes. (1)* p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. (2) Steady state market A output is 10 in treatments CM and PR30, 6.9126 in treatment GS15, and 5 in treatments GS30 and LS30.

Table D.3: Welfare Ratio and Deviations from Theoretical Point Predictions, by Session

Session	Obs.	Welfare Ratio	Welfare Ratio - Steady State Estimate		Welfare Ratio - Steady State Robust Std. Err	Welfare Ratio at Avg. Output
CM-1	25	0.898	-0.081	***	0.008	1.000
CM-2	46	0.731	-0.248	***	0.015	0.926
CM-3	33	0.887	-0.093	***	0.011	0.995
CM-4	30	0.850	-0.129	***	0.013	0.962
GS15-1	25	0.777	-0.131	***	0.018	0.924
GS15-2	30	0.861	-0.046	***	0.012	0.954
GS15-3	44	0.757	-0.151	***	0.009	0.943
GS15-4	30	0.768	-0.140	***	0.015	0.875
GS30-1	25	0.808	-0.015		0.016	0.962
GS30-2	46	0.804	-0.018	*	0.010	0.900
GS30-3	23	0.797	-0.026		0.017	0.918
GS30-4	40	0.675	-0.148	***	0.02	0.775
LS30-1	25	0.845	0.022		0.020	0.943
LS30-2	30	0.680	-0.143	***	0.010	0.789
LS30-4	33	0.861	0.038	***	0.012	0.954
LS30-4	30	0.844	0.021		0.015	0.958
PR30-1	25	0.872	-0.108	***	0.016	0.983
PR30-2	30	0.825	-0.154	***	0.017	0.996
PR30-3	23	0.776	-0.204	***	0.018	0.960
PR30-4	30	0.876	-0.104	***	0.017	0.979

Notes. (1)* p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. (2) The steady state welfare ratio is 0.979 for CM and PR30, 0.907 for GS15, and 0.823 for GS30 and LS30.

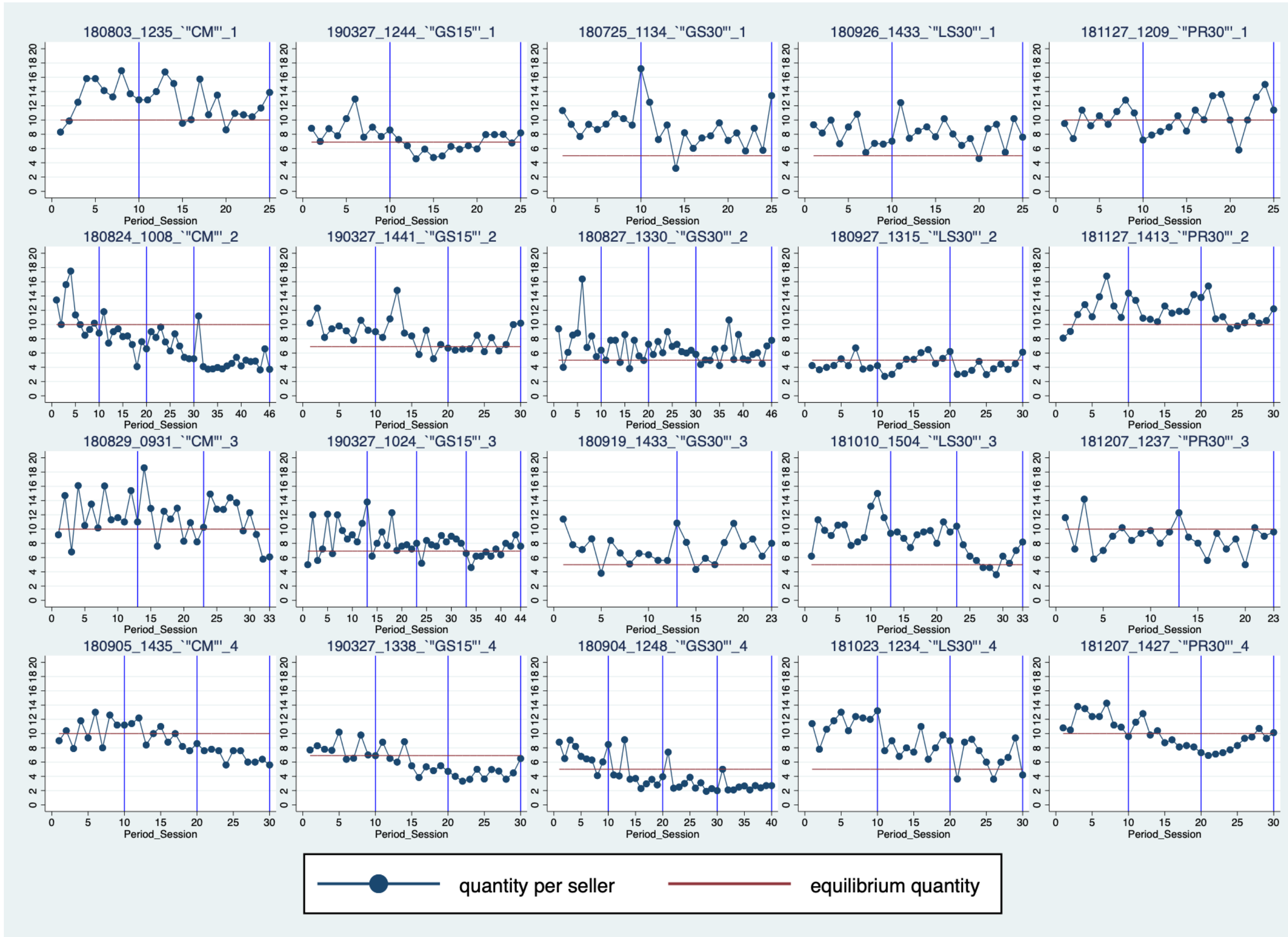

Figure D.1: Output in Market A by Session

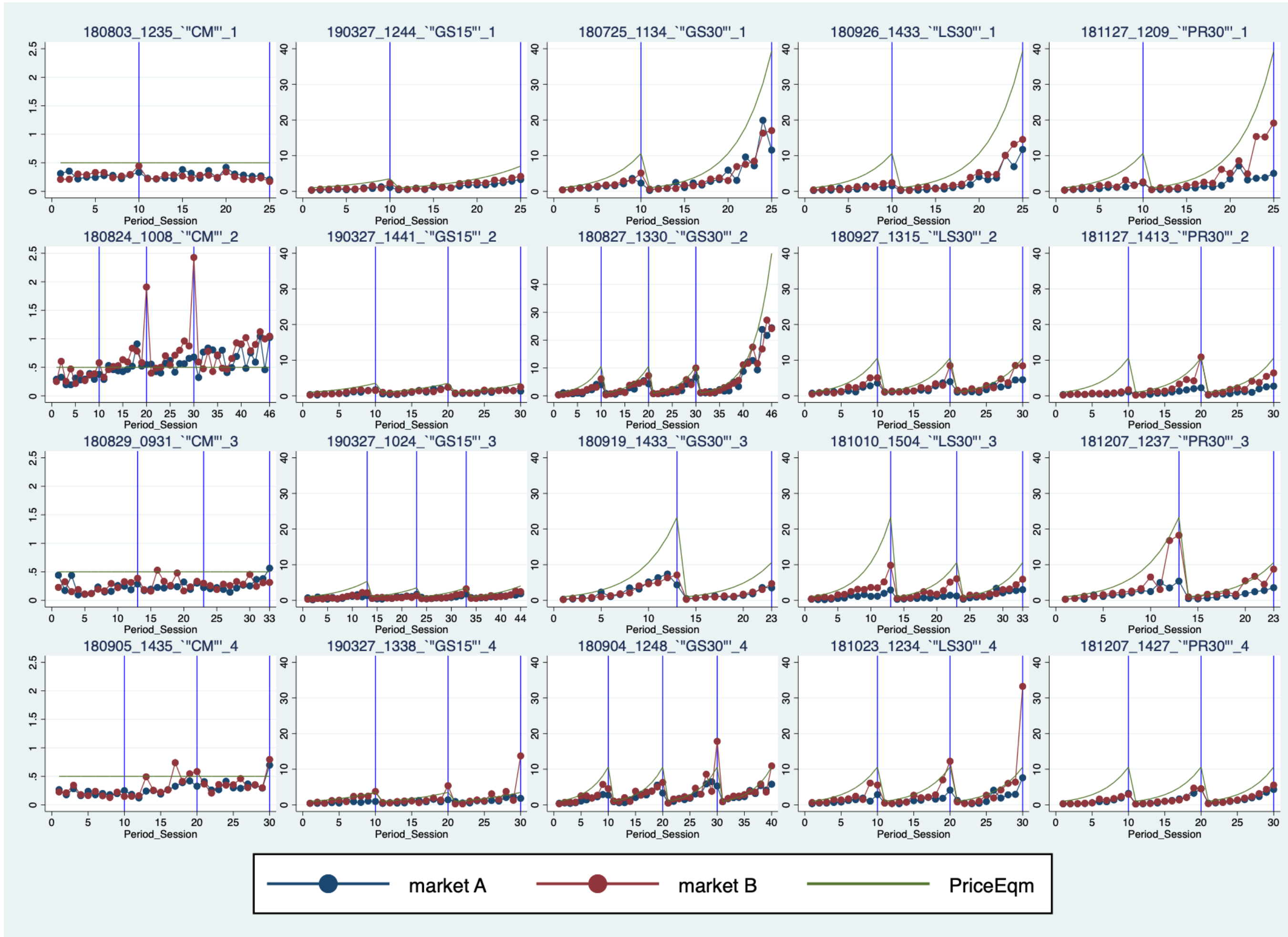

Figure D.2: Price Level in Market A and Market B by Session