

Why stable fiat money hyperinflates: Results from an experimental economy

Cary A. Deck^{a,*}, Kevin A. McCabe^{b,1}, David P. Porter^{b,1}

^a Department of Economics, 425 WCOB, Sam M. Walton College of Business, University of Arkansas, Fayetteville, AR 72701, USA

^b Interdisciplinary Center for Economic Science, 4400 University Drive, MSN 1B2, George Mason University, Fairfax, VA 22030, USA

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Abstract

Experiments are used to study acceptance of a fiat money as a medium of exchange. In these finite horizon markets, people trade valuable goods for intrinsically worthless money. However, when a public sector capable of printing money is introduced, the private sector is crowded out, producing dramatic hyperinflations and collapses in trading. This economic failure is found to be a consequence of the public sector undermining the market's ability to coordinate trade. The inefficiency associated with the hyperinflation is found not to be a purely monetary phenomenon resulting from an increasing money supply.

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Fiat money is a convention that allows individuals to complete trades without relying on the coincidence of wants or diverting valuable commodities to serve as money. In order for individuals to accept intrinsically worthless fiat money in exchange for valuable goods, the agents must believe that the money can be used to complete subsequent purchases of other goods or services. Thus, standard theory predicts that fiat money will not circulate under a finite horizon.² McCabe (1989)

* Corresponding author. Tel.: +1 479 575 6226; fax: +1 479 575 3241.

E-mail addresses: cdeck@walton.uark.edu (C.A. Deck), kmccabe@gmu.edu (K.A. McCabe), dporter4@gmu.edu (D.P. Porter).

¹ Tel.: +1 703 993 4850, fax: +1 703 993 4851.

² Kovenock and De Vries (2002) develop a finite horizon model of helicopter money. In their model fiat money is accepted in a fixed sequence of transactions because the agents do not know how many subsequent trades remain in the sequence.

demonstrated in a simple environment that a finite trading horizon causes money's acceptance to unravel immediately, but only after subjects have experience with the end of horizon. Lian and Plott (1998) examine money in a more complex circular flow environment, also finding that subjects were in fact able to coordinate trades and achieve a high level of efficiency in a finite horizon.

Many diverse models have been constructed to demonstrate how an intrinsically worthless currency can circulate within an economy. Beginning with Clower (1967), cash-in-advance models have been used to support fiat money's acceptance by placing restrictions on the timing of transactions; see Svensson (1985), Lucas and Stokey (1987), and Hayashi and Matsui (1996). An alternative approach is based on the overlapping generations (OLG) model of Samuelson (1958) in which the young accept fiat money with the expectation that it can be used when the agent is older. Experimental evidence by Marimon and Sunder (1993), Lim et al. (1994), and Camera et al. (2003) demonstrates that within the OLG framework agents are able to conduct trade using a type of fiat money.³ Kiyotaki and Wright (1989) create another type of model where fiat money has a role as a medium of exchange due to its sufficiently low holding cost; see Brown (1996) and Duffy and Ochs (1999) for related experimental work.

In these models, markets serve to coordinate behavior by determining relative prices. With functioning markets generating price information, agents can pursue a series of advantageous trades. While examples of stable fiat monies abound, including national currencies and privately issued Internet monies, an economic collapse can occur when agents lose faith in the money's ability to make future purchases. In fact fiat money can rapidly become unstable as evidenced by observed hyperinflationary episodes.

Multiple explanations for such collapses have been offered. Capie (1986) finds three common elements of hyperinflations: the use of a fiat money, government spending financed through the use of the printing press, and civil unrest. Based upon historic data, Sargent (1982) finds evidence suggesting that it is the government injecting newly created money into the private economy that causes hyperinflation. Government activity of this form actually includes two factors that could cause the hyperinflation. First is the purely monetary phenomenon of too much money chasing too few goods. The second way government spending impacts a fiat money economy is by interfering with the determination of prices in the market. As the government competes for real goods, the market's ability to coordinate behavior through nominal price information is weakened.

The autarky that results from a loss of faith in the currency leaves market participants worse off than if everyone had continued to accept the money. Hence, there are two countervailing forces affecting money's acceptability: a desire to reap the gains from trade and a fear of lost confidence. Through the use of controlled laboratory experiments, this work explores the factors affecting a fiat money's stability as a medium of exchange in the sense of maintaining relative prices, thereby allowing economic agents to coordinate activity and conduct transactions. Unlike studies based on field data, the use of laboratory methods also affords disentanglement of an increase in the money supply with the disruption of markets that occurs when governments finance expenditures by printing money.

³ The money in these OLG experiments is not a pure fiat money as the currency was converted into salient payoffs at the conclusion of the experiment based upon either predicted future prices or previously observed prices. Thus the money had no value of its own, but an agent would always be able to use the money to trade for valuable commodities.

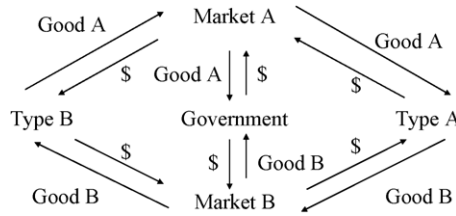


Fig. 1. Experimental economy.

1. Experimental design

The goal of this paper is to explore what impacts a fiat money's ability to circulate. As hyperinflations are a clear example of money's collapse, the experimental design is based in part on the common hyperinflation traits identified by Capie. The first two traits refer to the level of government involvement in the economy, which serves as one of the dimensions for the experimental design. In total four levels of government involvement are considered: an economy using backed money, an economy required to use fiat money, an economy using fiat money with a government that can create money to make purchases, and an economy using fiat money that has exogenous growth of the money supply at the same rate as with an active government. A comparison of the first two conditions reveals the effect of using fiat money. The impact of government spending is obtainable from a comparison of second and third conditions. The fourth condition serves to determine whether the difference between the fiat money and active government conditions is due to the level of the money supply.

The fact that most historical hyperinflations have occurred during periods of extreme civil unrest may mean that hyperinflations are the result of agents' expectations that the money will have a short-lived future. Once the money is not expected to last indefinitely, theoretical models would suggest that the money's acceptability should collapse. If this is in fact the cause for the hyperinflation, then a finite horizon should not be able to support a fiat money. However, as shown by McCabe (1989), backwards induction does not cause money to collapse immediately; instead it fails only as individuals gain experience with the end of the horizon. To account for this backwards induction failure, the second dimension of the experimental design is the trading horizon that is either short or long, but finite in both cases. If it turns out that fiat money is not accepted in trade, it would then be necessary to conduct experiments in which the trading horizon was not fixed⁴ to determine whether the finite horizon caused the autarky.

1.1. Experimental economy

The experimental economy is described by the simple circular flow diagram shown in Fig. 1. Type A agents purchase units of good A with the experimental currency called "tickets." To raise the necessary tickets, type A agents can sell their endowed units of good B for tickets. Similarly, type B agents purchase units of good B paying with tickets and sell units of good A in return for tickets.⁵ In the treatments involving an active government, type G agents, the central links of the economy are added. Type G agents demand both goods but supply neither good. While types A

⁴ For example, in some previous experiments trading continues for another period with some strictly positive probability.

⁵ This design is an extension of preliminary work reported in McCabe (1987).

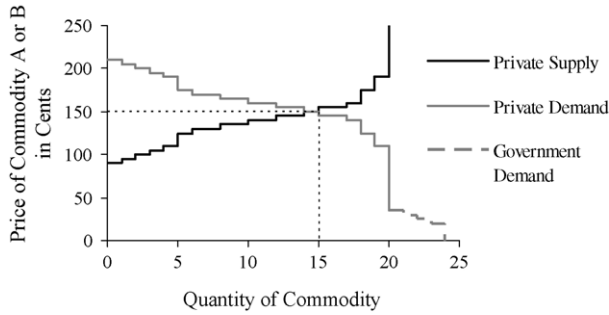


Fig. 2. Supply and demand per day.

and B agents are endowed with some money, they face a liquidity constraint forcing them to sell their endowment good in order to acquire additional money with which to make purchases. Type G agents face no such restriction, instead being able to create an unlimited supply of money.

Real market conditions for both goods are characterized by the induced demand and supply curves depicted in Fig. 2. The height of the demand curve represents the induced value in US cents of a unit of good A or B and the height of the supply curve represents the induced cost in US cents of a unit of the good. Table 1 lists the steps along the demand and supply curves for each agent. The real market clearing price, US\$ 1.50, and equilibrium quantity, 15, are readily observable from Fig. 2. However, nominal prices are dependent upon λ , the rate at which tickets can be converted into US cents. The exchange rate, λ , was common information among all market participants before trading commenced. The equilibrium nominal price for both goods is $150/\lambda$, when $\lambda > 0$. When a fiat money was in use, $\lambda = 0$, agents should not be willing to sell. The use of a 0 exchange rate is a key difference between this study and the related work of Lian and Plott. In that paper, money was converted into payoffs at a rate determined by the average prices observed in the final period. The total surplus is US\$ 7.50 in each market and it is distributed evenly among the five types A and B agents in the economy. Hence, in equilibrium types A and

Table 1
Induced market conditions by agent

Agent	Steps on market A demand curve (US\$)	Steps on market A supply curve (US\$)	Steps on market B demand curve (US\$)	Steps on market B supply curve (US\$)
A1	2.10, 1.65, 1.50, 1.0	–	–	0.90, 1.35, 1.50, 1.75
A2	2.05, 1.65, 1.55, 1.25	–	–	0.95, 1.35, 1.45, 1.75
A3	2.00, 1.70, 1.55, 1.40	–	–	1.00, 1.30, 1.45, 1.60
A4	1.95, 1.70, 1.60, 1.45	–	–	1.05, 1.30, 1.40, 1.55
A5	1.90, 1.75, 1.60, 1.45	–	–	1.10, 1.25, 1.40, 1.55
B1	–	0.90, 1.35, 1.50, 1.75	2.10, 1.65, 1.50, 1.10	–
B2	–	0.95, 1.35, 1.45, 1.75	2.05, 1.65, 1.55, 1.25	–
B3	–	1.00, 1.30, 1.45, 1.60	2.00, 1.70, 1.55, 1.40	–
B4	–	1.05, 1.30, 1.40, 1.55	1.95, 1.70, 1.60, 1.45	–
B5	–	1.10, 1.25, 1.40, 1.55	1.90, 1.75, 1.60, 1.45	–
G1	0.35, 0.20	–	0.30, 0.25	–
G2	0.30, 0.25	–	0.35, 0.20	–

B agents each earn US\$ 1.50 trading profit, calculated as the value of goods purchased minus the cost of goods sold, per day. The units demanded by the government agents are not produced in equilibrium. Since the worth of the government's most valuable unit is below the lowest cost of any seller, there is necessarily an efficiency loss whenever a government agent makes a purchase.⁶

Agents bought and sold goods through double auction institutions⁷ operating simultaneously in each market by posting willingnesses to buy or sell in nominal ticket prices. Each trading period is referred to as a "day." A subject's values and costs, which were always in cents, were reinitialized at the beginning of each day; that is, subjects could buy and sell the same units each trading day. Subjects retained the same locations along the demand and supply curves throughout the experiment.⁸ Tickets circulated in the economy for a given number of days, which was referred to as a "week." The length of a week was publicly specified before trading commenced.⁹ At the beginning of a week, types A and B subjects were given an endowment, ω , of tickets. As subjects traded, their ticket balances reflected these transactions. Types A and B agents were not allowed to hold negative ticket balances at any point in the experiment. A subject's ticket balance was carried forward until the completion of the last trading day of the week at which time the remaining balances were converted into monetary payoffs at the exogenously determined rate λ . Thus, when the exchange rate is positive, tickets are a commodity or backed money, but when $\lambda = 0$, the currency is a pure fiat money. Type G agents were not endowed with money and instead could create money at a cost of λ per ticket.¹⁰

In the experiments, a short horizon regime lasted for a 2-day week, while a long horizon regime endured for 8 days.¹¹ In the inactive government treatments, only the five types A and B agents conducted trade in the economy. The active government was introduced into the experiments by including two additional subjects, each demanding two units in each market, as shown in Table 1. The role of government was split between two subjects to reflect the problems that national governments routinely have in controlling their spending.¹² During the experiments no references were made to government, the printing press, or money to avoid any influence from preconceived notions the subjects may have had about these institutions.

⁶ The losses imposed by the level of government demand are taken into account in subsequent analysis. By making the government's units not part of the equilibrium, the private markets remain identical across treatments with respect to number of agents and the values and costs per agent.

⁷ A double auction institution was employed due to its demonstrated success in achieving equilibrium in other market situations. See Smith and Williams (1982), Ketcham et al. (1984), Williams et al. (2000) and Deck (2001). A double auction also provides to market participants considerable feedback in the form of willingnesses to trade. In this sense, a double auction gives fiat money an increased chance of being successful as medium of exchange even though theoretically the worthless money should not circulate.

⁸ Retaining market location speeds convergence towards equilibrium pricing in single market double auctions with backed money. This feature was implemented to give fiat money a greater chance of success at determining relative prices and helping subjects to understand the potential gains from trade.

⁹ The known trading horizon is a second major design difference between the current study and the related study of Lian and Plott. In their study the end of horizon was not announced until the penultimate trading period.

¹⁰ As the endowment of tickets represents a loan from the experimenter, the US\$ value of the endowment was deducted from subjects' payoffs at the end of the week. The loan, equal to $\lambda \times \omega$, was identical for all types A and B agents each week. Type G agents did not have a loan repayment.

¹¹ All long horizon sessions went to an 8-day week after an initial backed money phase. Time constraints then dictated the duration of the remaining weeks, which in some cases were reduced to 4 days.

¹² As is commonly exploited in market experiments, having multiple agents in each role also reduces the effect of any one subject on the overall economy.

1.2. Procedures

Seventeen computerized experiments were conducted at the Economic Science Laboratory using University of Arizona undergraduate students as subjects. Each computerized experiment ran for a total of 4 h over the course of two calendar days. On the first calendar day, subjects read instructions¹³ and participated in a training session consisting of one day trading horizons. During the training session subjects experienced ticket redemption values varying between $\lambda = 0.25$ and 2.0 US cents per ticket. By varying λ , behavioral changes that occur when the money's backing is removed are attributable to the use of fiat money and not simply an exchange rate change.

The second calendar day consisted of subjects rereading the instructions and then participating in the experiment. In every experiment the initial weeks consisted of 2 days with the value of a ticket backed at the rate $\lambda = 1$. All sessions quickly converged towards the equilibrium prediction, $P_A = P_B = 150$. Therefore, each session had the same initial conditions, and the impact of the various treatments can be interpreted as deviations away from this focal point. The money endowment, ω , was set equal to 400 tickets for every types A and B agent each time a regime was initiated.

At the conclusion of the experiment subjects were privately paid their earnings from the training session and the actual experiment¹⁴ as well as a US\$ 15.00 participation fee. A subject's earnings consisted of the summation of weekly profits from both the experiment and the training session, thus alleviating the impact that negative period profits might have on subject incentives.

2. Qualitative results

The data consist of bids, asks, and acceptances in both markets for each of the sessions, three sessions under each of the five fiat money treatments and two backed money sessions. [Figs. 3 and 4](#) display the daily average nominal contract price by treatment for the long and short horizons, respectively.

Using backed money, the average prices remain near the equilibrium level regardless of the horizon. In the fiat money long horizon treatment, the average nominal prices also remain nearly constant throughout the experiment. Notice that these prices are centered on the equilibrium price from the initial weeks with backed money even though nominal prices are irrelevant in this setting. This is likely the result of subjects having discovered that prices in this range allowed them to reap the gains from trade in the initial backed money weeks. However, when the monetary horizon is short, nominal prices do begin to increase, but only after participants experienced the termination of multiple fiat regimes, similar to behavior observed by [McCabe \(1989\)](#). From the figures it is evident that fiat money can provide a stable medium of exchange but that the level of inflation is dependent on the horizon. [Table 2](#) shows the total number of trades each day, averaged across sessions, for all seven treatments. Recalling that the equilibrium quantity under backed money is thirty units, the same pattern is again discernible where fiat money serves as medium of exchange, allowing agents to coordinate and complete the same desired real transactions as in the backed money regimes. This ability is hampered under the short horizon. However, even repeated experience with the end of the horizon is not sufficient to force the economy to unravel fully.

[Figs. 5 and 6](#) graph average efficiency by treatment for the long and short horizons, respectively. Both backed money regimes and the fiat money long horizon regime attain high levels of efficiency

¹³ A copy of the directions is available from the authors upon request.

¹⁴ Salient payoffs for the actual experiment on calendar day 2 averaged US\$ 14.30. There was considerable variability across treatments as hyperinflationary episodes necessarily resulted in extremely low profits.

Table 2
Average number of contracts comparison by treatment averaged by session

Day	Backed money long horizon	Backed money short horizon	Fiat money long horizon	Fiat money short horizon	Active government long horizon	Active government short horizon	Exogenous money growth
1	22	29	21	24	24	21	19
2	25	31	23	27	25	22	23
3	25	30	25	26	26	22	24
4	24	33	25	26	25	22	24
5	24	32	21	20	25	20	20
6	24	30	20	18	27	20	23
7	26	29	18	19	28	22	24
8	26	31	19	15	25	17	20
9	25	29	23	18	28	20	17
10	27	30	22	15	24	14	13
11	27	29	26	18	21	11	15
12	26	30	22	16	14	3	15
13	29	30	27	18	22		17
14	29	29	24	14	15		17
15	30	29	26	16	5		19
16	29	30	23	9	2		16
17	29	27		22			
18	28	29		15			
19	28	28		21			
20	28	28		12			

The first four market days of each session employed backed money at a rate $\lambda = 1$.

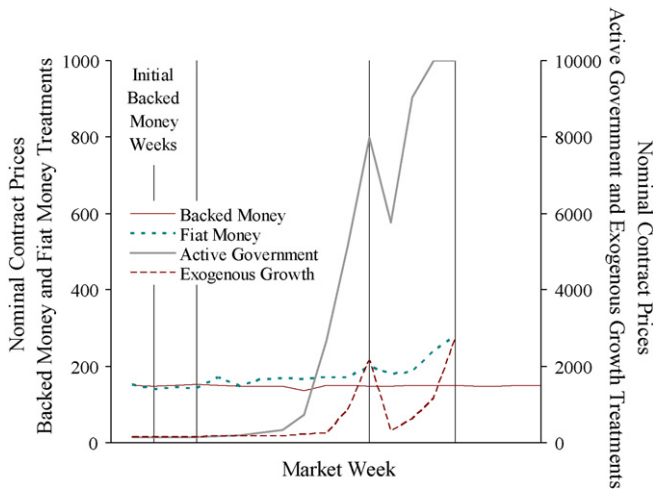


Fig. 3. Quantity weighted average contract prices by treatment in long horizon.

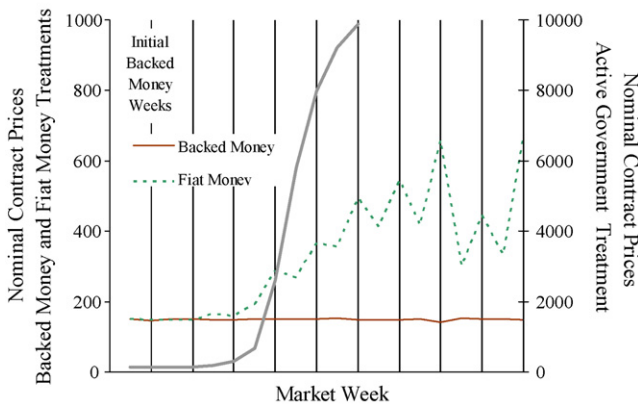


Fig. 4. Quantity weighted average contract prices by treatment in short horizon.

throughout the experiment. Again, a short horizon fiat money regime slightly destabilizes the economy, with observed efficiency around 65%. The success of fiat money under the long horizon is consistent with previous results reported by Lian and Plott.

In contrast, when an active government is printing money to finance expenditures, the economy experiences hyperinflation. Nominal prices experience tremendous increases, sometimes in the range of 2,000% between trading periods¹⁵; see Figs. 3 and 4. Rapid growth in nominal prices is not debilitating if agents are able to sustain the real economy. Transaction prices do not affect

¹⁵ This nominal behavior is comparable to historical field data. For example, German wholesale prices grew by 1.36×10^{14} between 1914 and 1924 and retail prices in Austria increased by 24,167% in the three and a half year period starting in January 1921.

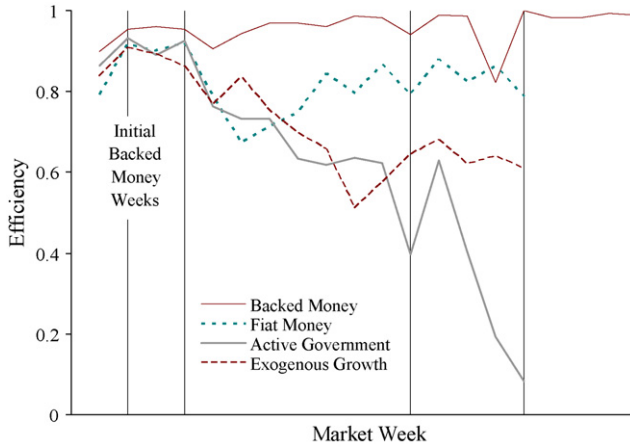


Fig. 5. Average efficiency by treatment in long horizon.

achieved surplus regardless of the money’s backing. Even when trading occurs with backed money, contracts at nominal prices different from the theoretical prediction represent a transfer of surplus between agents, not a change in the level of surplus.

However, the presence of a government also causes a dramatic collapse in the number of contracts, independent of the duration of the monetary regime as shown in Table 2. The same conclusions can be drawn from the efficiency measures; see Figs. 5 and 6. Efficiency analysis for the treatments without an active government is straightforward. However, the market conditions employed in this experiment are admittedly such that any trade by the government involves efficiency losses. Further, the level of government values arbitrarily determines the absolute size of this loss. Therefore, a more appropriate measure of the economy’s performance is the private efficiency, which is what is presented in Figs. 5 and 6 for the active government treatments. This rate is calculated as the percentage of the potential surplus available after the government crowding that the private sector of the economy is actually able to achieve. Formally, adjusted

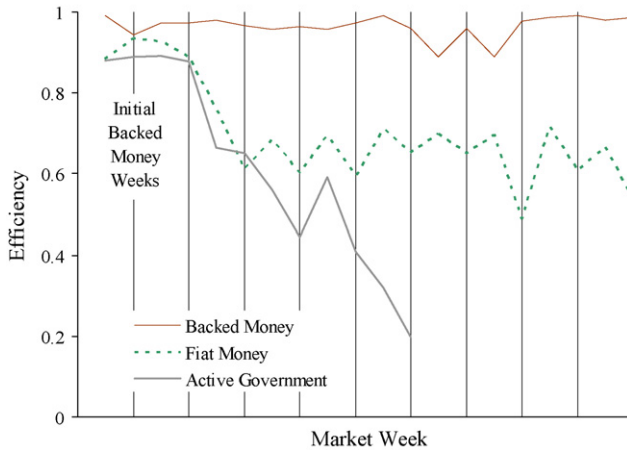


Fig. 6. Average efficiency by treatment in short horizon.

potential surplus is calculated by first removing from the supply curve the steps associated with units traded to the government. This adjusted supply curve is then compared to private demand to determine the potential private surplus.

The impact government spending has on the economy is quite clear; prices escalate while trade volume and efficiency plummet. However, there are two effects that an active government has on the economy. One is the pure monetary phenomenon of an increase in the money supply caused by the use of the printing press. The second effect is the erratic way the government introduces money into the economy and its disruption of the market's ability to convey relative price information. Based upon the results of the exogenous money growth treatment,¹⁶ the hyperinflations of the active governments are not caused simply by the increasing amount of money in the economy. The economies in the exogenous growth treatment experienced the same overall rate of increase in the money supply as did the active government sessions. Even with the rapid monetary growth, the number of contracts and the efficiency pattern are comparable to a short horizon, no government fiat money regime as shown in Table 2 and Figs. 5 and 6. However, the increase in the money supply does generate inflation; see Fig. 3.¹⁷

In order to maintain economic activity, individual private agents must use the fiat money to conduct trades in the one real market in this economy: units of good A for units of good B. The nominal bid in market A represents a willingness to spend money for good A, while the nominal ask in market B represents a willingness to sell good B for money. Therefore, the ratio of the nominal ask in market B to the nominal bid in market A represents the willingness of market participants to purchase good A with units of good B, the real bid. Similarly, the determination of the real asking price for good A in terms of good B is the ratio of the bid in market A to the ask in market B. Fig. 7 plots real bids and asks for 1 day in one session of each of the four long horizon treatments.¹⁸

When money is backed participants are actively seeking out the real price, which is 1 in equilibrium based upon the market conditions presented in Table 1. When subjects have gained experience trading in fiat money and there is no active government, the price discovery process is similar to the backed money environment. However, when the government is active the trading process breaks down; nominal prices no longer convey information about relative prices. Since the government stands ready to purchase regardless of the market price, there is no pressure on relative prices to remain in equilibrium. Thus, the way government injects money disrupts the market's ability to coordinate trade.

3. Quantitative results

The main qualitative results are (1) that prices are higher and that efficiencies are lower in the short horizon than in the long horizon when fiat money is used, (2) regardless of

¹⁶ Exogenous growth was only studied in the long horizon as this duration provided the greatest separation between the presence and absence of an active government. In the exogenous growth treatment, each agent's money holdings were increased daily by a multiplier based on the observed growth rate of money in the long horizon active government treatment.

¹⁷ This result that the level of the money supply does not impact real performance strengthens the finding of Lian and Plott who compared economies with different levels of a fixed money supply.

¹⁸ At some points in time there were no standing bids or asks in a market, so the most recent nominal price quotes were used to calculate the real bids and asks, which were truncated for values above two. It is the absence of a standing nominal bid or ask that allows the real bid to exceed the real ask.

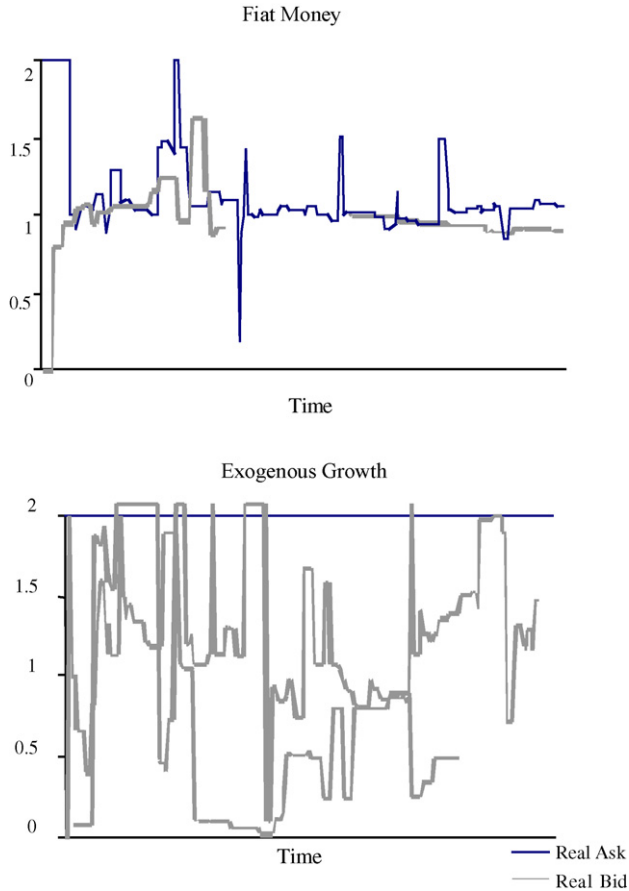


Fig. 7. Real bids and asks for a day in long horizon treatments, given that the real bids and asks are the ratios of the nominal bids and asks in the two markets, real bids and asks are bounded by 0 and Ψ . As the real price is 1 in equilibrium, real bids and asks are truncated at 2.

the horizon, an active government leads to higher prices and lower efficiency, and (3) the real performance of the exogenous growth economy is superior to the active government economy.

A series of non-parametric tests are offered in support of the findings. For each of the tests the unit of observation is a session average. In comparing the short and long horizons with a fixed supply of fiat money and no active government, the Mann-Whitney (MW) test statistics are 15 (p -value = 0.050) for both prices and efficiency, the most extreme value possible with three sessions in each treatment. Hence the null hypotheses of no horizon effect can be rejected in favor of the appropriate one-sided alternative. To quantify the second finding, a Mack Skillings (MS) test that controls for any horizon effect is used. The MS test statistics are 7.74 (p -value < 0.0150) and 6.095 (p -value = 0.0150) for the null hypotheses of no price and no efficiency effect, respectively, against the one-sided alternative that the active government hurts performance. The superior performance of the exogenous growth economies relative to the active government economies is supported by

a MW test of the null hypothesis of no treatment effect.¹⁹ With a MW test statistic of 15 (p -value = 0.050), the null is rejected in favor of the alternative that exogenous growth generates greater efficiency.

Having established the relative performance of the economies, the analysis turns to the long run stability of the various regimes. Econometric analysis based on the time series data for private efficiency again confirms that while fiat money economies are not as stable as backed money systems, these economies outperform unrestrained active government regimes. Formally, each regime type is independently modeled as

$$\Pi_t = \alpha + \beta\Pi_{t-1} + \delta\text{Initial}_t + \varepsilon_t. \quad (1)$$

Π_t denotes the efficiency at time t , Initial_t , a dummy variable indicating the first trading day of a new monetary horizon, and ε_t is assumed to be a random i.i.d. $N(0, \sigma^2)$ variable. The decision to include a dummy for the initial period²⁰ is based on previous public goods experiments with voluntary contribution mechanisms. Fiat money has the public good characteristic that society is better off if everyone accepts fiat money even though each individual agent would prefer to defect and not accept it. With standard public goods, experiments routinely find individual contributions increase when a new public good is introduced even as contributions decrease when the same public good is repeated; see [Marwell and Ames \(1985\)](#) and [Isaac and Walker \(1988\)](#).

[Table 3](#) reports the estimation of the model parameters for each of the seven treatments. Also reported in [Table 3](#) are the p -value associated with the modified Breusch Godfrey test²¹ that asks whether the coefficient on e_{t-1} is different from zero in a linear projection of e_t on Π_{t-1} , S_t , e_{t-1} , and a constant term, where e_t is the time t residual from the estimated model. Based on this test, the hypothesis that there is no autocorrelation in the residuals cannot be rejected for any of the treatments.

The estimated point of the convergence for a particular series is $\alpha/(1 - \beta)$.²² To determine the tendencies of each treatment, two separate hypothesis tests are conducted. One hypothesis tested is that the economy was converging to zero efficiency. This is equivalent to an α of 0 in Eq. (1). Based on the p -value associated with α reported in [Table 3](#), only in the two active government sessions can the null hypothesis that $\alpha = 0$ not be rejected at the 5% significance level.

The second hypothesis tested is that private economy was converging to full efficiency or equivalently that $\alpha/(1 - \beta) = 1$. This point of convergence is well defined because the Modified Breusch Pagan test rejects that $\beta = 1$ for each treatment. Using a likelihood ratio test, the hypothesis of convergence to 100% private efficiency cannot be rejected at the 1% significance level for either backed money treatment. For the remaining treatments the hypothesis is rejected for all standard significance levels. These results are reported in [Table 4](#).

¹⁹ As the exogenous growth condition was only implemented with a long horizon, the comparison is restricted to the long horizon active government treatment, thus necessitating the use of a Mann-Whitney test rather than a Mack Skillings test.

²⁰ One could alternatively include a dummy variable for the final period in which money is in circulation. In the short horizon, the conclusions would be identical as there are only initial and final periods. However, given the public goods results and the lack of any obvious end of week effect in the individual sessions, an initial dummy and not a final dummy was included.

²¹ The commonly employed Durbin-Watson test for autocorrelation has a potential bias towards finding no autocorrelation when lagged values of the dependent variable are included as an independent variable. See [Greene \(1997\)](#).

²² Due to lagged dependent variables in the set of regressors the estimates are biased, however, the technique does generate consistent estimates.

Table 3
Parametric time series models by treatment

Estimated Model: $\Pi_t = \alpha + \beta\Pi_{t-1} + \delta\text{Initial}_t + \varepsilon_t$

Treatment	Backed money long horizon	Backed money short horizon	Fiat money long horizon	Fiat money short horizon	Active government long horizon	Active government short horizon	Exogenous money growth
α	1.1067 ^a [0.001]	0.7422 ^a [0.013]	0.4884 ^a [0.001]	0.2700 ^a [0.005]	0.0928 [0.310]	0.0781 [0.416]	0.2307 ^a [0.014]
β	-0.1488 [0.601]	0.2410 [0.391]	0.3871 ^a [0.023]	0.4636 ^a [0.001]	0.6912 ^a [>0.001]	0.6502 ^a [>0.001]	0.6288 ^a [>0.001]
δ	-0.0032 [0.918]	-0.0224 [0.184]	0.0264 [0.571]	0.1331 ^a [>0.001]	0.1471 [0.101]	0.0689 [0.278]	0.0189 [0.708]
Number of observations	16	16	34	40	34	24	36
Estimated point of convergence $\alpha/(1 - \beta)$	0.9633	0.9779	0.7968	0.5034	0.3007	0.2232	0.6215
<i>p</i> -Value for modified Breusch Godfrey test (Ho: no autocorrelation in residuals)	[0.761]	[0.898]	[0.380]	[0.905]	[0.416]	[0.390]	[0.357]

Π_t denotes private efficiency at time t and Initial_t is a dummy indicating a regime's initial period. Numbers in brackets are the *p*-value associated with a test of the null hypothesis. The null hypothesis for the parameter estimates of α , β , and δ is that the parameter is zero vs. the two-sided alternative.

^a Indicates a rejection of the null at the 5% significance level.

Table 4
Hypothesis tests for convergence to full private efficiency

Treatment	Backed money long horizon	Backed money short horizon	Fiat money long horizon	Fiat money short horizon	Active government long horizon	Active government short horizon	Exogenous money growth
Ho: series converges to full efficiency, $\alpha/(1 - \beta) = 1$ restricted model: $\Pi_t - 1 = \beta(\Pi_{t-1} - 1) + \delta \text{Initial}_t + \varepsilon_t$							
Unrestricted estimate of $\alpha/(1 - \beta)$	0.9633	0.9779	0.7968	0.5034	0.3007	0.2232	0.6215
Sum of squares unrestricted model	0.029	0.012	0.306	0.430	1.242	0.470	0.396
Sum of squares restricted model	0.043	0.013	0.419	0.866	1.642	0.700	0.504
Likelihood ratio test statistic	6.066	1.212	10.719 ^a	27.992 ^a	10.056 ^a	9.560 ^a	8.740 ^a
p-Value	0.014	0.271	0.001	>0.001	0.002	0.002	0.003

Π_t denotes private efficiency at time t and Initial _{t} is a dummy indicating a regime's initial period. The test statistic has a χ^2 (1) distribution.

^a Indicates a rejection of the null at the 1% significance level.

This analysis demonstrates that fiat money in a long horizon regime with no growth in the money supply and both long and short horizon regimes with backed money provide stable mediums of exchange in an economy converging to a high level of efficiency, ≈ 80 , ≈ 100 , and $\approx 100\%$, respectively. Short horizon fiat money regimes with no money growth and long horizon exogenous money growth regimes can sustain trade, thereby allowing more than 50% of the maximum surplus to be attained. In contrast, economies with an active government collapse, converging to private zero efficiency.

Anecdotal evidence also exists that supports the claim that an active government leads to extremely low private efficiency. The smaller number of trading days in the active government sessions was endogenously determined. All experimental sessions were designed to last 20 trading periods. Some sessions were forced to end before all periods occurred due to time constraints; however, in the active government sessions the shortened time was the result of subject upheaval. In one extreme case a subject caused a scene demanding to leave the experiment after repeated days of low trade volume and hence low profits. This subject's behavior was anticipated by Keynes (1932) who said "There is no subtler, no surer means of overturning the existing basis of society than to debauch the currency" (p. 78).

4. Conclusions

A primary finding of this research is that individuals are able to coordinate and achieve a high proportion of the gains from trade using pure fiat money as a medium of exchange in decentralized finite horizon markets. The price level, trade volume, and market efficiency are comparable to those of economies using backed money. Uncertainty about the money's termination theoretically weakens the hyperinflationary pressure. As behaviorally such pressure is already observed to be low under a finite horizon, one would expect even greater stability in more indefinite horizon situations. While repeated experience with the termination of a fiat money regime, such as in the short horizon, does result in lower levels of efficiency and moderate inflation, the economy still remains active especially in comparison to the no trade prediction of the standard economic model.

This work also demonstrates that an active government injecting newly printed money into the private economy can lead to a hyperinflation. Further, the experiments reveal that such a collapse is not due solely to the increasing money supply. However, an inherent aspect of government spending is that the money goes in lump sums to individual private sellers. It remains to be determined whether the collapse caused by government is due to the government competing in the private markets or the erratic way in which the government introduces the newly printed money. The current experimental results suggest that the collapse is due at least in part to the government's actions in the market. Without an active government, a set of stable prices is found by the agents. When the government makes purchases, there is a coordination failure because agents are unable to use the markets to determine relative prices.

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References

- Brown, P., 1996. Experimental evidence on money as a medium of exchange. *Journal of Economic Dynamics and Control* 20, 583–600.
- Camera, G., Noussair, C., Tucker, S., 2003. Rate-of-return dominance and efficiency in an experimental economy. *Economic Theory* 22, 629–660.
- Capie, F., 1986. Conditions in which very rapid inflation has appeared. *Carnegie-Rochester Conference Series on Public Policy* 24, 115–168.
- Clower, R., 1967. A Reconsideration of the microfoundations of Monetary theory. *Western Economic Journal* 6, 1–9.
- Deck, C., 2001. Double auction performance in a circular flow economy. Working paper, University of Arkansas.
- Duffy, J., Ochs, J., 1999. Emergence of money as a medium of exchange: an experimental study. *American Economic Review* 89, 847–877.
- Greene, W., 1997. *Econometric Analysis*, 3rd ed. Prentice Hall, Upper Saddle River.
- Hayashi, F., Matsui, A., 1996. A model of fiat money and barter. *Journal of Economic Theory* 68, 111–132.
- Isaac, R.M., Walker, J., 1988. Group size effects in public goods provision: the voluntary contributions mechanism. *Quarterly Journal of Economics* 103, 179–199.
- Ketcham, J., Smith, V., Williams, A., 1984. A comparison of posted-offer and double auction pricing institutions. *Review of Economic Studies* 51, 595–614.
- Keynes, J.M., 1932. *Essays in Persuasion*. Harcourt, Brace and Company, New York.
- Kiyotaki, N., Wright, R., 1989. On money as a medium of exchange. *Journal of Political Economy* 97, 927–954.
- Kovenock, D., De Vries, C., 2002. Fiat exchange in finite economies. *Economic Inquiry* 40, 147–157.
- Lian, P., Plott, C., 1998. General equilibrium, markets, macroeconomics and money in a laboratory experimental economy. *Economic Theory* 12, 21–75.
- Lim, S., Prescott, E., Sunder, S., 1994. Stationary solution to the overlapping generations model of fiat money: experimental evidence. *Empirical Economics* 19, 255–277.
- Lucas, R., Stokey, N., 1987. Money and interest in a cash-in-advance economy. *Econometrica* 55, 491–513.
- Marimon, R., Sunder, S., 1993. Indeterminacy of equilibria in a hyperinflationary world: experimental evidence. *Econometrica* 61, 1073–1077.
- Marwell, G., Ames, R.E., 1985. Economists free ride: does anyone else? *Journal of Public Economics* 26, 51–74.
- McCabe, K.A., 1987. Hyperinflation in experimental double auctions. Working paper, Washington University.
- McCabe, K.A., 1989. Fiat money as a store of value in an experimental market. *Journal of Economic Behavior and Organization* 12, 215–231.
- Samuelson, P., 1958. An exact consumption-loan model of interest with or without the social contrivance of money. *Journal of Political Economy* 66, 457–482.
- Sargent, T.J., 1982. The ends of four big inflations. In: Hall, R.E. (Ed.), *Inflation: Causes and Effects*. University of Chicago Press, Chicago, pp. 41–97.
- Smith, V.L., Williams, A.W., 1982. The effects of rent asymmetries in experimental auction markets. *Journal of Economic Behavior and Organization* 3, 99–116.
- Svensson, L., 1985. Money and asset prices in a cash-in-advance economy. *Journal of Political Economy* 93, 919–944.
- Williams, A., Smith, V., Ledyard, J., Gjerstad, S., 2000. Concurrent trading in two experimental markets with demand interdependence. *Economic Theory* 16, 511–528.