The Effects of News When Liquidity Matters*

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Abstract

This paper analyzes the impact of news (information shocks) in economies where liquidity matters, including those with endogenous debt limits, and those with currency or other assets serving as exchange media or collateral. While we also consider news about productivity and credit conditions, a leading case concerns monetary policy announcements. Real or monetary news has big effects on goods, equity, housing, credit and foreign exchange markets, causing cyclic and boom-bust responses. Different from theories of self-fulfilling prophecies, we focus on the unique transition consistent with stationarity after information shocks. Still, even news about neutral policies leads to complicated dynamics. Policy announcements can induce rather than reduce volatility, with ambiguous welfare implications.

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Bernanke Speaks, and Shares Tumble; New York Times (6/6/6)

1 Introduction

There has been much recent interest in the effects of news – i.e., information shocks – in macroeconomics. As Krusell and McKay (2010) say, "An example of a negative news shock would be the sudden arrival of information indicating that future productivity will not be as high as previously thought ... [or] a government announcement about a policy change to be implemented on a future date, say, that taxes will be raised beginning next year." This is exactly what we analyze. Actually what matters would be expectations, but the premise is that these are affected by news. As Beaudry and Portier (2014) say, "There is a widespread belief that changes in expectations may be an important independent driver of economic fluctuations." This is exactly what we formalize, in a way that is different from previous work in the area.[1]

Precisely, we show how news at date t_0 about an event at t_1 leads to intricate dynamics between t_0 and t_1, whether the news concerns productivity or policy, and, in the latter case, even if the policy is neutral in a classical sense. As special cases, if $t_0 = t_1$ the event is totally unexpected, and if t_0 is the beginning of time, there is perfect foresight. For those that dislike surprises, for any $t_0 < t_1$ the outcome between t_0 and t_1 is identical if the news arrives even sooner, at $t < t_0$. In particular, while the main conclusions hold with perfect foresight, we are also happy to consider t_0 after the beginning of time (more on this in fn. 3). The presentation uses a series of examples showing how the impact of news can differ from conventional wisdom. These examples all use theory that takes liquidity seriously, with cash or other assets facilitating intertemporal transactions, and with reputation supporting unsecured credit.

[1] Cochrane (1994) is an early advocate for the importance of news about productivity, policy, energy prices, and other factors. Many papers since try to identify news shocks in data and use them as impulses in macro models – indeed, too many to discuss individually, and so we refer readers to the Beaudry and Portier (2014) survey.

A reason to highlight liquidity is this: while we also study news about real factors, one application concerns monetary policy announcements, since it is often said that Fed news has a big impact on Wall Street and Main Street. Rosa (2011*a,b*,2013), e.g., shows that markets for stocks, bonds and foreign exchange all react to FOMC announcements: when news comes out, they display spikes in volatility that are economically and statistically significant. As he summarizes: "First, the Fed is able to move the stock market by using either monetary policy or news shocks. Second, the level of equity prices seems to quickly incorporate monetary news. Third, only the surprise component of the Fed's statement [matters]. Fourth, central bank communication has remained an important monetary policy tool." Similar results obtain for announcements by other central banks and other types of news (see Andersen and Bollerslev 1998, Gilbert et al. 2017 and references therein). Thus, we highlight liquidity because it is generally accepted that it is closely related to monetary policy.

Four settings where liquidity matters are discussed: an OLG (overlapping generations) model of currency from Azariadis (1993); the search-based framework recently surveyed by Lagos et al. (2017); a standard model of unsecured credit based on Kehoe and Levine (1993), and, in an Appendix, a cash-in-advance model. Similar results emerge in each, even if the economic forces are different. Importantly, *the dynamics here are not the same as the self-fulfilling prophecies* that occur in some related models.[2] Those models have many cyclic, chaotic or stochastic equilibria, even when fundamentals are constant, but there always coexists a stationary equilibrium. We focus on the unique equilibrium that is stationary when exogenous variables are constant and study the transition between the news and the event. This transition can look dramatically different depending on parameters, but is uniquely determined by backward induction. In fact, while we typically start the induction at the stationary equilibrium at t_1, the

[2] One can see Azariadis (1993), Rocheteau and Wright (2013), and Gu et al. (2013) for details in OLG, search, and credit models, but we sketch the ideas in Section 2.

methods are more general: given *any* equilibrium selection at t_1 we can construct the unique transition back to t_0, and the substantive conclusions apply.

As an illustration, consider an economy in stationary equilibrium where agents think exogenous variables follow a particular path. At t_0 they update to believe something will change at $t_1 \geq t_0$, then at t_1 it changes and we revert to the stationary equilibrium.[3] We construct the transition from t_0 to t_1, and show it can involve booms, busts, and cycles with amplitudes that increase or decrease over time, even for the most elementary news. Moreover, this does not rely on sticky prices or disparate beliefs (as in, e.g., Michelacci and Paciello 2016 or Holden 2017), nor on multiple equilibria with news helping to coordinate expectations (as in, e.g., Andolfatto and Martin 2013). Given market-clearing prices and homogeneous beliefs, the unique transition yields complicated and interesting dynamics that may resemble those due to self-fulfilling prophecies in the short run, although not in the long run, and for different economic reasons.

Our goal is not to prove theorems but, in the spirit of the suggestion that the role of theory is to provide counterexamples, we frame the results as a series of *lessons* motivated by substantive issues. First we show even the simplest news can lead to runups, crashes and oscillations in prices and quantities. A rudimentary example is a one-time increase in the money supply M at t_1 that is classically neutral: if it is a surprise then prices rise proportionally and real variables stay the same. Yet if it is announced at $t_0 < t_1$ there are big real effects between t_0 and t_1. This is a counterexample to the New Classical Macro view that money shocks have real effects if and only if they are unanticipated. That view, going

[3] As mentioned, perfect foresight is a special case where the substantive conclusions all apply, but we are also happy to have news come as a surprise at t_0, and do not worry about a tension between that and rational expectations. The force of rational expectations is that one should not model repeated changes as repeatedly unanticipated – e.g., it is unreasonable to say inflation is above average on average, as one must in order to argue that Friedman's (1968) expectation-augmented Phillips curve provides an exploitable policy menu. Yet no less a proponent of rational expectations than Sargent (1993) says this does not mean we can never entertain the possibility of a surprise. In our simplest experiments agents' priors put 0 probability on an event, then update to put positive probability on it, but we show the methods and results still apply when agents know future events are random and get signals before the realization.

back to David Hume, appears in Friedman (1968), Phelps (1968), Lucas (1972) and Sargent and Wallace (1975). Of course, they all had something else in mind, like signal-extraction problems, and in context they are correct; we show that in another context M shocks matter if and only if they are anticipated.

More generally, regarding central bank policy, financial analysts spend plenty of resources trying to figure out what the Fed is up to – as Kurov (2012) says, "Market participants analyze every word of Fed officials for clues of possible directions of monetary policy because monetary policy affects asset prices, particularly stock prices." This bears on the notion of *forward guidance*, defined as efforts by central banks to influence expectations about the future path of policy (D'Amico and King 2017 provide many references). The usual rationale is that early announcements avoid big reactions when policy changes actually occur. Yet we show they can accentuate rather than attenuate volatility.

To be clear, the claim is not that advance warning always induces volatility, but that it might, counter to conventional wisdom as illustrated by Blinder et al. (2009): "central bank talk increases the predictability of central bank actions, which should in turn reduce volatility in financial markets." Similarly, Matsumotoa et al. (2011) say "providing more information about future fundamentals ... (i.e., more information about the exogenous stochastic processes) would reduce asset price volatility." That may be true in some circumstances, but not in general. Also, perhaps surprisingly, news-induced volatility can improve welfare, and even if the news is bad. This is contrary to the idea that one should not release bad information early, where in related models such a view can be gleaned from, e.g., Andolfatto et al. (2014) or Dang et al. (2014). In any case, while news-induced volatility can improve welfare in principle, we would not recommend it in practice, because the results are very sensitive to timing and parameters.

Before proceeding, we mention that some people will probably think we have too many examples, and would prefer one main message. While we like having multiple applications, here is one leading case. Consider the injection of M at t_1

that, as described above, is classically neutral. If it is anticipated at $t_0 < t_1$, real variables are affected between t_0 and t_1 in a big way that is uniquely determined by the theory but can be complicated and highly parameter dependent. One thing that always happens, however, is that when the injection occurs at t_1 output goes up while prices do not. While this looks like a failure of neutrality, it is important to understand this: output did not go up because prices failed to adjust, and in fact prices were already high and output already low at $t_1 - 1$ because agents knew the injection was coming. Hence it is hard to test neutrality (the quantity theory of money) in the data, because crucial factors include what people knew and when they knew it. That seems a point worth emphasizing.

The rest of the paper is organized as follows. Section 2 shows how to solve for transitions in a simple OLG model. Section 3 applies the methods to models where we can more easily generate a transaction role for assets in addition to money, including stocks, foreign currency and home equity. Section 4 and 5 consider unsecured credit and alternative monetary policies. Section 6 concludes.

2 An Overlapping Generations Model

2.1 Environment and Equilibrium

Time is indexed by $t = 1, 2...$ At each t, a $[0, 1]$ continuum of agents are born and live two periods, except for the initial old who are around only at $t = 1$. There is one nonstorable good x_t at every t. Agents can convert labor ℓ_t into x_t at a one-for-one rate when young, but only value consumption when old. The initial old are endowed with fiat money. Injections (or extractions) of money in any period can be engineered through lump-sum transfers to (or taxes on) the old. Agents trade in competitive markets. If born at $t \geq 1$ they maximize utility by producing when young and selling the output for cash that buys consumption when old; the initial old simply spend their cash endowment.[4]

[4]This environment, which is basically Azariadis (1993), can be easily generalized on many dimensions, but the goal here is to show how complex outcomes obtain in simple models.

The problem of an agent born at $t \geq 1$ is

$$\max_{x_{t+1},\ell_t,m_t} \{-\ell_t + \beta u(x_{t+1})\} \tag{1}$$
$$\text{st } \ell_t = \phi_t m_t \text{ and } x_{t+1} = \phi_{t+1}(m_t + \tau_{t+1}),$$

where m_t is money demand, ϕ_t is the price of money in term of x_t, τ_{t+1} is the transfer, or tax if negative, and $\beta \in (0,1)$ is a parameter that could be subsumed in the notation, but including it explicitly facilitates comparison with other models discussed below. Assume that u is twice continuously differentiable with $u' > 0$ and $u'' < 0$. Then the FOC for $m_t > 0$ is

$$-\phi_t + \beta u'(x_{t+1}) \phi_{t+1} = 0 \tag{2}$$

equating the marginal cost of cash to the marginal benefit.

The aggregate money supply at t is M_t, where $\mu_t > -1$ is the rate of monetary expansion, so $M_t = (1+\mu_t) M_{t-1}$, and the government budget constraint is $\tau_{t+1} = \mu_{t+1} M_t$. Let real balances be $z_t \equiv \phi_t m_t$, and note that money market clearing entails $m_t = M_t$. Then, multiplying the LHS of (2) by M_t and the RHS by $M_{t+1}/\left(1+\mu_{t+1}\right)$, we get a difference equation

$$z_t = f_{t+1}(z_{t+1}) \equiv \frac{\beta u'(z_{t+1}) z_{t+1}}{1+\mu_{t+1}}. \tag{3}$$

Thus, the real value of money – which in this economy is total liquidity – at t depends on its value at $t+1$, a forward-looking dynamical system.

It is standard to define equilibrium as a positive bounded path for z_t satisfying (3). Obviously, $z_t = 0$ $\forall t$ is an equilibrium. We are interested in monetary equilibrium, where $z_t > 0$ $\forall t$. If $\mu_t = \mu$ is time invariant then under standard conditions there exists a unique SME (stationary monetary equilibrium), which is a steady state of (3), $\beta u'(\bar{z}) = 1 + \mu$. The left column of Figure 1 plots three examples (all Figures are at the end). In the top panel f is monotone increasing; in the middle panel it is decreasing at steady state with $|f'(\bar{z})| < 1$; and in the bottom panel it is decreasing at steady state with $|f'(\bar{z})| > 1$. The potential nonmonotonicity of f is relevant because it affects transitional dynamics.

While this paper is *not* about multiple equilibria or self-fulfilling prophecies, to make that clear we mention a few standard results. First, when SME exists there coexist a continuum of nonstationary monetary equilibria that start at any $z_0 > 0$ in some range and entail $z_t \to 0$. If $f(z)$ is monotone then z_0 is bounded above by steady state, since starting at $z_0 > \bar{z}$ generates an unbounded path, and convergence to 0 is monotone. If $f'(\bar{z}) \in (-1, 0)$ then we can start at any $z_0 \neq \bar{z}$ that is not too high, but can be above $\bar{z}$, and again $z_t \to 0$ with convergence that is not necessarily monotone. If $f'(\bar{z}) < -1$ there are still equilibria starting at $z_0 \neq \bar{z}$ where $z_t \to 0$, but in addition there are cyclic equilibria.

In particular, standard theorems (see Azariadis 1993) tell us that $f'(\bar{z}) < -1$ implies the existence of a period 2 cycle, a solution to (3) where z oscillates between z_L and $z_H > z_L$. This means $z_L = f(z_H)$ and $z_H = f(z_L)$, so a 2 cycle is a fixed point of the composite $f^2(z) = f \circ f(z)$. In examples it is easy to generate 2 cycles by making the curvature of $u(x)$ moderately high. As we make it slightly higher, cycles of greater periodicity emerge, including eventually 3 cycles. Standard theorems imply that when there are 3-cycles there are n-cycles $\forall n$, plus chaotic solutions to (3) interpretable as cycles of period ∞. However, it is also standard to show that when there are cycle there are also stochastic equilibria, or sunspot equilibria, where z fluctuates randomly. All these equilibria generate fluctuations as a self-fulfilling prophecy.

As this is all well known, we do not dwell on either the mathematics or the economics, but emphasize that when these dynamic equilibria exist there coexists a SME where $z_t = \bar{z}\ \forall t$. Indeed, the literature uses these kinds of results to illustrate how monetary economies are subject to instability: even when fundamentals are constant, there are multiple equilibria and in many of them endogenous variables vary over time simply because people expect them to vary. While this is a good point, we concentrate instead on asking what happens in the SME when parameters change. There is a unique answer to that question, but it will depend on what agents know and when they know it.

The results do not pertain only to fiat money. Thus, replace M_t with a real asset A_t, a "tree" that each period yields "fruit" as a dividend $\rho > 0$ in units of numeraire x_t, as in standard asset pricing theory following Lucas (1978). Assume the supply A and ρ are constant. Then for the young the budget constraint is $\ell_t = \psi_t a_t$, where ψ_t is the price and a_t is asset demand, while for the old it is $x_{t+1} = \left(\psi_{t+1} + \rho\right) a_t$. Equilibrium is still described by $z_t = f\left(z_{t+1}\right)$, but now

$$f\left(z_{t+1}\right) = \rho A + \beta u'\left(z_{t+1}\right) z_{t+1}. \tag{4}$$

where $z_t = \left(\psi_t + \rho\right) A$. It is easy to make assumptions implying there is a unique equilibrium, not only a unique steady state. Yet by continuity transitions with $\rho > 0$, but not too big, are similar to those with $\rho = 0$. Hence, our news effects can give complicated dynamics even if there is a unique equilibrium – the construction and conclusions do not require the multiplicity that occurs when $\rho = 0$.

2.2 Transitions After News

Our first experiment is a one-time increase in M above trend.[5] Initially, agents take μ as fixed and the economy is in its unique SME. Then at date t_0 it is announced – or otherwise comes to be believed – that μ will change at $t_1 \geq t_0$ to $\mu' > \mu$, then revert to $\mu_t = \mu\ \forall t > t_1$, when we go back to the SME. Hence there is a fixed terminal condition, $z_{t_1+1} = \bar{z}$, that pins down the transition by backward induction. The easiest case is $t_0 = t_1$, a complete surprise, where ϕ drops when M rises to leave $z = \phi M$ and all other real variables the same: classical neutrality.

For a more interesting case, consider $t_1 > t_0$, so the event is anticipated, still assuming we go back to $\bar{z}$ after t_1. Pursuing induction using (3) and $\mu_{t_1} = \mu'$, at the penultimate point in the transition we have

$$z_{t_1-1} = \beta\frac{\bar{z}u'(\bar{z})}{1+\mu'} = \frac{1+\mu}{1+\mu'}\bar{z} < \bar{z}. \tag{5}$$

[5] One can similarly consider decreases in M, but for consistency here we always use increases. When we take up productivity changes we use decreases, because lower productivity is in some sense similar to raising – debasing, if you will – the money stock.

At the antepenultimate point, z_{t_1-2} is given by (3), and so on back to $t = t_0$ for the entire path.

The left panels of Figure 1 plot the transitions when $t_1 - t_0 = 5$. Graphically, start at $z_{t_1} = \bar{z}$ and use (5) to get $z_{t_1-1} < z_{t_1}$; locate z_{t_1-1} on the horizontal axis and use $f(z)$ to get z_{t_1-2}, z_{t_1-3} and z_{t_1-4}. For news further in advance, keep on iterating, possibly so far back that there is perfect foresight about the event, and that this does not at all affect z_{t_1}, z_{t_1-1}, z_{t_1-2}. In any case, the arrows in the left panels of Figure 1 show time moving backward from t_1 to t_0, and panels on the right show the paths moving forward in t. In the top panel, z_t falls monotonically until t_1 when jumps back to $\bar{z}$. In middle panel, z_t displays increasing oscillations before finishing up at $\bar{z}$. In the bottom, z_t displays decreasing oscillations. So while the transition is uniquely determined, it can display a wide range of patterns.

We emphasize several features. First, when oscillations decrease with t they increase the further back we go, but not forever, because the paths are bounded. So the oscillations do not get huge when the news comes much further in advance, as is the case if one uses linear approximations to the system around $\bar{z}$ instead of the exact global dynamics. Second, we started the induction at the stationary equilibrium at t_1, but that is not necessary – select any equilibrium path at t_1, and the construction of the transition is the same. Third, while oscillations during the transition may be interesting, we think monotone transitions are at least as interesting, since z can display significant deviations from $\bar{z}$ after the news, which can also be described as volatility.

Also notice in all the rows of Figure 1 there is the sizable rise in z_t from $t_1 - 1$ to t_1. The intuition is simple: at $t_1 - 1$, producers (the young) anticipate the M increase at t_1, and hence require more money to produce the same x_t; but before the extra money is injected, buyers (the old) don't have more money, so production falls. Anticipating the price impact at $t_1 - 1$, there are effects at $t_1 - 2$, $t_1 - 3$... When the injection eventually occurs at t_1, liquidity and output go up, which looks like a failure of neutrality, or the quantity theory, but it is important to understand the reason. It is not that ϕ cannot adjust when M is injected, as assumed in Keynesian sticky price models; it is because ϕ has already adjusted. A naive observer seeing a jump in M at T leading to a jump in liquidity and output with no jump in prices could understandably jump to the wrong conclusion. As mentioned in the Introduction, we think this is a point worth emphasizing.

One can also consider permanent changes in μ, changes in productivity, multiple or staggered announcements, etc. We do these below in the context of different environments, but first summarize the above results as follows:

Lesson 1: *In OLG models, responses to news about* simple *policy changes can be complicated and highly parameter dependent, despite having a fixed terminal condition. This is true even for policy that is neutral.*

3 A New Monetarist Model

3.1 Environment and Equilibrium

In this environment, at each date $t = 1, 2, ...$ two markets convene sequentially: a decentralized market, or DM, with frictions detailed below; then a frictionless centralized market, or CM. There are two types of infinitely-lived agents called buyers and sellers. In the CM they all work, consume and adjust asset positions. In the DM sellers can provide something buyers want, perhaps goods or services if they are households, productive inputs if they are firms, or assets if they are financial institutions, and we are agnostic about that because the same equations apply to each interpretation, and all have been deployed to good effect in the literature. A novelty over the OLG model is that here the DM features bilateral meetings, where α is the probability a buyer meets a seller, and so $n\alpha$ is the probability a seller meets a buyer, where n is the buyer-seller ratio.[6]

[6] This alternating CM-DM structure, based on Lagos and Wright (2005), is a way to combine elements of search and general equilibrium theory. While much of the action takes place in the DM, having the CM greatly enhances tractability, making it about as easy as OLG models even

Period payoffs of buyers and sellers are

$$U^b(q,x,\ell) = u(q) + U(x) - \ell \text{ and } U^s(q,x,\ell) = -c(q) + U(x) - \ell, \tag{6}$$

where q is the object being traded in the DM, while x is the CM numeraire and ℓ is CM labor. Here $u(q)$ can be the utility from consuming q and $c(q)$ the disutility of producing it, or $u(q)$ can be output of x from using q as an asset/input and $c(q)$ the opportunity cost of giving it up. Assume U, u and c are twice continuously differentiable with $U', u', c' > 0$ and $U'', u'' < 0 \leq c''$. Also, $u(0) = c(0) = 0$, and $u'(q^*) = c'(q^*)$ define the efficient q.

Agents discount between the CM and DM at $\beta \in (0,1)$, but not between the DM and next CM. In the DM, they are anonymous and lack commitment, precluding credit for now (this relaxed below). This implies an essential role for assets as payment instruments. Given x and q are nonstorable, the only candidate for this role is fiat money (this too is relaxed below). As in Section 2, the money supply per buyer satisfies $M_t = (1+\mu_t) M_{t-1}$, where only buyers pay taxes or get transfers, and again x_t is produced using ℓ_t at a one-for-one rate.

Letting $W_t(m_t)$ be buyers' value function in the CM, we have

$$\begin{aligned} W_t(m_t) &= \max_{x_t,\ell_t,\hat{m}_{t+1}} \{U(x_t) - \ell_t + \beta V_{t+1}(\hat{m}_{t+1})\} \\ \text{st } x_t &= \ell_t + \phi_t (m_t + \tau_t) - \phi_t \hat{m}_{t+1}, \end{aligned} \tag{7}$$

where as above ϕ_t is the price of money and τ_t is the transfer, but now $V_{t+1}(\hat{m}_{t+1})$ is the continuation value in the next DM. Here we distinguish between m_t, money taken into the CM at t, and $\hat{m}_{t+1}$, money taken out. The FOC for $\hat{m}_{t+1} > 0$ is

$$\phi_t = \beta V'_{t+1}(\hat{m}_{t+1}), \tag{8}$$

which implies $\hat{m}_{t+1}$ is independent of m_t, while $W'_t(m_t) = \phi_t$ implies the CM payoff is linear. Sellers' problem is omitted, but similar, except they set $\hat{m}_{t+1} = 0$ unless the nominal interest rate (defined below) is $i = 0$.

while adding ingredients like market tightness, alternative bargaining solutions, etc. It is also also easier to add other assets, compared to OLG models, which imply different assets must have the same return (the law of one price). It is also easier to analyze welfare, because there is no intergenerational heterogeneity. And it is easier to more realistically set parameters.

When buyers and sellers meet in the DM they trade (p_t, q_t), where p_t is the payment, not to be confused with the unit price $P_t = p_t/q_t$, subject to $p_t \leq \phi_t \hat{m}_t$. We need a mechanism to determine the terms of trade. In most of what follows it suffices to set $c(q_t) = q_t$ and $p_t = q_t = \phi_t \hat{m}_t$, consistent with bargaining when buyers having share $\theta = 1$, or with competitive price taking (for the latter interpretation one may prefer the version of the model with multilateral meetings in Rocheteau and Wright 2005). However, in many applications, more generality can be interesting, so we follow Gu and Wright (2016) and allow any mechanism satisfying

$$p_t = \begin{cases} \phi_t \hat{m}_t & \text{if } \phi_t \hat{m}_t < p_t^* \\ p_t^* & \text{otherwise} \end{cases} \quad \text{and } q_t = \begin{cases} v_t^{-1}(\phi_t \hat{m}_t) & \text{if } \phi_t \hat{m}_t < p_t^* \\ q^* & \text{otherwise} \end{cases} \tag{9}$$

where p_t^* is the payment needed to get q^*, and $v_t(q)$ is a strictly increasing function with $v_t(0) = 0$ and $v_t(q^*) = p_t^*$. Different v's correspond to various bargaining solutions, perfectly or imperfectly competitive pricing, and more exotic mechanisms. For now all we need is (9).[7]

By the linearity of $W_t(m_t)$, buyers' DM value function is

$$V_t(\hat{m}_t) = W_t(\hat{m}_t) + \alpha [u(q_t) - v(q_t)], \tag{10}$$

where the first term is the no-trade payoff and the second is the expected trade surplus. From (9), $\partial q_t / \partial \hat{m}_t = \phi_t / v'(q_t)$ if $\phi_t \hat{m}_t < p^*$ and $\partial q_t / \partial \hat{m}_t = 0$ otherwise. Given this, differentiate (10) and use (8) to get

$$\phi_{t-1} = \beta \phi_t \left\{ 1 + \alpha \left[\frac{u'(q_t)}{v'(q_t)} - 1 \right] \right\}. \tag{11}$$

It is convenient to use the Fisher equation to define a nominal interest rate between the CM at $t-1$ and the CM at t by $1 + i_t = (1 + r_t)\phi_{t-1}/\phi_t$, where ϕ_{t-1}/ϕ_t is gross inflation and r_t is the real interest rate given by $1 + r_t = 1/\beta$.

[7] It is also convenient to make $v(q)$ twice differentiable almost everywhere and stationary. Stationarity avoids dynamics due to, say, shifts in bargaining power, like stationarity of $u(q)$ or $c(q)$ avoids dynamics due to shifts in tastes or technology, to focus on dynamics due to news.

Thus, i_t and r_t are respectively the returns in the next CM agents require to give up in this CM a unit of m or x. Then (11) reduces to

$$\frac{u'(q_t)}{v'(q_t)} - 1 = \frac{i_t}{\alpha}. \tag{12}$$

Gu and Wright (2016) prove the q_t solving (12) is generically unique and decreasing in i_t. Let $q_0 \leq q^*$ be the solution at $i_t = 0$. Then $i_t > 0$ implies buyers bring $\phi_t \hat{m}_t = v(q_t) < v(q_0)$ to the DM, while $i_t = 0$ implies they bring $\phi_t \hat{m}_t = v(q_0)$, and in the latter case, if their money demand does not exhaust supply, the excess is held by sellers.

Again denote real balances by $z_t \equiv \phi_t M_t$, and write the LHS of (12) as

$$L(z_t) \equiv \begin{cases} \dfrac{u' \circ v^{-1}(z_t)}{v' \circ v^{-1}(z_t)} - 1 & \text{if } z_t < v(q_0) \\ 0 & \text{otherwise} \end{cases} \tag{13}$$

where $L(z_t)$ is the Lagrange multiplier on $p_t \leq z_t$, also called the liquidity premium. Then multiply the LHS of (11) by M_{t-1} and the RHS by $M_t/(1+\mu_t)$ and use (13) to get the difference equation

$$z_{t-1} = f_t(z_t) \equiv \frac{\beta z_t [1 + \alpha L(z_t)]}{1 + \mu_t}. \tag{14}$$

A monetary equilibrium is a bounded path $z_t > 0$ satisfying (14).

With $\mu_t = \mu$ constant, a SME solves $\bar{z} = f(\bar{z}) > 0$. As is standard, we impose $\mu > \beta - 1$, or $i > 0$, but also consider the Friedman rule $\mu \to \beta - 1$, or $i \to 0$. Then $\bar{z} = f(\bar{z})$ simplifies to $i = \alpha L(\bar{z})$. One can show a solution $\bar{z} > 0$ exists iff i is below some threshold. It is generically unique, and $\bar{z} \leq v(q_0)$ with $\partial \bar{z}/\partial i < 0$ when $\bar{z} < v(q_0)$ (Gu and Wright 2016). Notice that (14) is similar to (5), and in fact, $\alpha = 1$ and $v(q) = q$ implies the two are qualitatively the same $\forall z < q^*$. However, now $f(z) = \beta z/(1+\mu)$ is linear $\forall z > v(q_0)$, since agents can bring money out of the DM and into the next CM, different from the OLG model where agents with money are on death's doorstep. This is shown in Figure 2, where again the rows correspond to $f'(\bar{z}) > 0$, $f'(\bar{z}) \in (-1, 0)$ and $f'(\bar{z}) < -1$, but different from Figure 1 notice f now has a linear branch.

3.2 Transitions After News

Again the simplest experiment is a one-time injection of M, and the same method gives the transition, shown in Figure 2. As in Figure 1, transitions display various patterns depending on f, but now f has a linear term $\beta z/(1+\mu)$ representing the value of cash as a savings vehicle, plus a nonlinear term $\beta\alpha zL(z)/(1+\mu)$ representing the value of liquidity, which can be decreasing in z. If the latter term dominates the former term, oscillations arise, although we emphasize again that cyclic patterns are not our exclusive focus, and a slow decline followed by rapid recovery as in the top row of Figure 2 is at least as interesting.

While the qualitative results are similar to OLG models, it is more reasonable here to quantify them. Consider the functional forms

$$c(q) = \frac{q^{1+\sigma}}{1+\sigma} \text{ and } u(q) = A\frac{(q+b)^{1-\gamma} - b^{1-\gamma}}{1-\gamma}.$$

As a benchmark, let $\sigma = 0$, $A = 1$, $b = 0.1$. Then consider three values of γ, $\gamma_L = 0.5$, $\gamma_M = 4$ and $\gamma_H = 8$, which imply $f'(\bar{z}) > 0$, $f'(\bar{z}) \in (0, -1)$ and $f'(\bar{z}) < -1$, respectively. While other period lengths are considered, usually it is a month, with $\beta = 0.9959$ and $\mu = 0.0041$ to get annual real interest and inflation rates of 5% in SME. The mechanism is usually $v(q) = c(q)$, and buyers' DM trading probability is $\alpha = 0.5$. Appendix A summarizes parameters for all the experiments, and while they are not calibrated, but set for the sake of illustration, the values are all reasonable.[8]

Again consider a one-period change from μ to μ' at t_1, announced at t_0, generating a 1% jump in M at t_1 above trend. This is shown in the left column of Figure 3, where the rows are for the γ, and there are 12 months between the announcement and event. Shown are liquidity z_t, plus the life-time DM surplus S_t,

[8] As one way to judge this, with $\gamma = 0.5$, 4 or 8, at 5% annual inflation q is 3.54%, 0.55% or 0.18% below q^* in SME. For the same γ's, at 10% inflation q is 5.18%, 0.66% and 0.33% below q^*. The implied elasticities are not extreme. If one worries that $\alpha = 0.5$ is too low, simply think of households as collections of many agents as in Shi (1997), so the representative family trades as often as one likes in the DM. See Aruoba (2011) and Aruoba and Schorfheide (2011), e.g., for much more on calibrating and estimating similar models.

which is our welfare criterion (it is equivalent to a change in consumption of x that affects payoffs the same, and to be clear it measures discounted life-time payoffs). Units are normalized so that $\bar{z} = \bar{S} = 1$. To get a feel for magnitudes, z_t and S_t both change roughly 1% at their peak over the transition. Thus, for reasonable parameters, news about an upcoming change in M generates significant effects.

To consider a nonneutral policy, the right column of Figure 3 depicts a permanent change in μ from 5% to 6%, which lowers $\bar{z}$ and $\bar{S}$ in the long run. Notice the variations in z_t and S_t are smaller than in the left column, because an injection that increases M by 1% corresponds to a bigger one-period jump in M. Another difference is that z_t is more oscillatory, especially in the middle row. Heuristically, this is because a smaller one-period jump in M means z_t does not stray as far from $\bar{z}$, and so the economy spends less time on the linear branch of $f(z)$. Still, the implication is that news about nonneutral policy can also generate complicated parameter-dependent effects.

To further investigate magnitudes, Figure 4 shows smaller changes, a 0.05% temporary increase in μ in the left column and a 0.001% permanent increase in μ in the right. The overall results are similar, but there is one result worth emphasizing: in the bottom left of Figure 4, S_t is above its steady state in the antepenultimate period. Thus, if the timing is right we can improve welfare by announcing a one-time cash injection, even though this generates volatility, or indeed precisely because it generates volatility. Heuristically, inflation is harmful as it taxes DM trade, and the example shows that a gradual inflation can be worse than an erratic path. This is because the latter has higher q during its deflationary phases, and while it also has lower q during its inflationary phases, the net impact can be positive.

In the top rows of Figures 3-4 there is no welfare gain, as z_t falls monotonically before jumping back to $\bar{z}$, and the welfare loss is minimized by revealing a plan to increase M as late as possible. Symmetrically, in such cases the welfare gain is maximized by revealing a plan to decrease M as soon as possible. This sounds like a sound principle – if you plan to do something good (bad), tell people (keep it to yourself). It is not, however, general. In the bottom left of Figure 4 it is better to announce at $t < t_1$ that M will increase at t_1. Since that is true for policy that is neutral in the long run, by continuity it can be true for policies that are somewhat bad in the long run.

Figure 5 reports the results of a temporary increase in μ with β reset to quarterly (left) and daily (right) period length. The transitions are similar in the quarterly and monthly models, but there is less volatility in the daily model, mainly because buyers hold cash for less time on average, so the inflation wedge is smaller (we could offset that by lowering α but did not in this experiment). Also, injecting the same M in a shorter period constitutes a bigger shock and moves z further from $\bar{z}$ (we could offset that by lowering μ' but did not). So period length matters, but the general idea is robust. Before reporting other experiments, we catalogue a few results:

Lesson 2: *In New Monetarist models, responses to news about neutral or non-neutral policy changes can be complicated and highly parameter dependent, and the quantitative the effects are not small. News-induced volatility can improve welfare, but this is sensitive to timing and parameters.*

3.3 More Experiments

Now consider a monetary injection with a promise to reverse it later (somewhat similar to Berentsen and Waller 2011). Thus, announce at t_0 that at $t_1 \geq t_0$ there will be an increase in M, then at $t_2 > t_1$ there will be an offsetting decrease; as a special case, if $t_1 = t_0$ the announcement and initial injection come together. Given we return to SME, backward induction yields the transition. Notice $z_{t_2-1} > \bar{z}$ since at t_2-1 buyers flush with cash trade at relatively low prices, commensurate with the low μ at t_2; and $z_{t_1-1} < \bar{z}$ since at $t_1 - 1$ buyers short of cash trade at high prices, commensurate with the high μ at $t_1 > 0$.

The left column of Figure 6 shows results with $t_1 = t_0$, so the initial injection is a surprise, but the future extraction is known. Observe the initial injection does not increase prices in proportion, so real balances increase. In the top row, z_t and S_t jump up at the news, then the former continues to rise while the latter falls until t_2. This makes the policy look good, with liquidity, output and welfare all rising, but it is important to understand that the benefit comes from committing to withdraw M at t_2; the injection at $t_1 = t_0$ is neutral here.

The right column of Figure 6 shows $t_1 > 0$, so the initial injection is not a total surprise. Here it takes S_t a while to peak at t_1, and z_t first falls before starting an upswing at t_1. Consistent with Section 3.2, the middle and bottom rows display complicated paths as news accentuates volatility. But in all cases, a key point is that there is no obvious impact on trend inflation starting at t_1. This is interesting because people find it remarkable that money injections during the great recession did not raise prices – Feldstein (2015) dubs it *the inflation puzzle*.[9] It is a puzzle because it ostensibly violates the quantity theory, but here, where the quantity theory holds by construction, it is not easy to see it in the simulations because of the impact of announcements or anticipations.

The above case has two announcements occurring simultaneously. What if they are staggered? Suppose at t_0 agents hear that at t_2 there will be a one-period change to μ' but otherwise it's business as usual; then at $t_1 < t_2$ they hear that instead of the change at t_2 there will be a one-period change to μ'' at t_3. This is shown in the left column of Figure 7.[10] In the top case, with $f' > 0$, liquidity falls at the first announcement, jumps at the second, with a direction and magnitude that depend on the exact timing and parameters, and then falls again before recovering to $\bar{z}$. Obviously with staggered announcements we do not

[9] As Hayes (2016) says: "When QE was first put on the table... many people feared that it would ultimately lead to runaway inflation like the kind seen in Zimbabwe (and its 1 trillion dollar bill), Argentina, Hungary or the German Weimar Republic... Prices did rise modestly during that period, but by historical measures inflation was subdued."

[10] The experiment uses $t_0 = 0$, $t_1 = 4$, $t_2 = 8$, $t_3 = 12$, $\mu' = 0.0191$ and $\mu'' = 0.0091$. To get the transition, construct two sequences from (14), one with $z_{t_2-1} = \bar{z}(1+\mu)/(1+\mu')$ and the other with $z_{t_3-1} = \bar{z}(1+\mu)/(1+\mu'')$. Between $t = t_0 + 1$ to t_1, z_t comes from the first sequence; between $t = t_1 + 1$ to $t_3 - 1$ it comes from the second.

need $f'(\bar{z}) < 0$ to generate cyclic trajectories.

To address a potential concern with these experiments, let $\mu_t \sim G_t(\mu)$ be a stochastic process, with μ_t realized in the CM. Letting $z_t = \hat{m}_t \mathbb{E}_t \phi_t$, one can show the generalization of (14) is

$$z_{t-1} = f_t(z_t) = \beta z_t [1 + \alpha L(z_t)] \mathbb{E}_t (1 + \mu_t)^{-1}, \tag{15}$$

so the model displays a form of certainty equivalence. If agents initially believe $G_t(\mu) = G(\mu)\ \forall t$ then $z_t = \bar{z}$ is constant. Suppose news arrives at t_0 that μ_{t_1} will be drawn from a different distribution. If $\mathbb{E}\left(1 + \mu_{t_1}\right)^{-1}$ changes then z_t follows the path implied by (15). As a special case, news can be that $\mu_{t_1} = \mu'$ will take a given value in the support of μ. Different from our earlier experiments, here μ' is in the support of the prior belief distribution, but the methods and insights are basically the same.

We can also allow cases where agents know at $t < t_0$ that an announcement is coming at t_0, but do not know what it will be. By the law of iterated expectations, this is equivalent to not knowing the news is coming. Hence, we usually assume the news itself, and not just its content, is unexpected. An example is shown in the right column of Figure 7, where μ_t follows a two-point distribution: M_t increases by 0.615% or 0.205% with equal probability. At t_0 agents learn $\mu_{t_1} = 0.615\%$ with probability 1. The transition is similar to earlier results. We summarize as follows:

Lesson 3: *Multiple or staggered news induce even more intricate dynamics. This is true whether news concerns values of μ not in the support of prior beliefs or realizations from a stochastic process. News of future decreases in M temper current increases in M, which is desirable, but the beneficial impact is due to the future decrease not the initial increase.*

3.4 Other Assets and Secured Credit

Here we introduce real assets, multiple currencies and residential capital. First, as sketched in Section 2, cash is replaced with a real asset in fixed supply $A = 1$

per buyer, with price ψ_t and dividend $\rho_t > 0$. Notice ρ_t measures productivity in terms of output per asset. Moreover, we now reinterpret the model in terms of secured credit and introduce a pledgeability parameter $\chi \leq 1$, following Kiyotaki and Moore (1997). This means buyers in the DM promise sellers a payment in next CM but, because of limited commitment, debt must be collateralized, and only a fraction χ of one's assets can be used (the usual story is that assets are seized if buyers default, but they can abscond with a fraction $1 - \chi$ of them). Hence, buyers' DM liquidity is $z_t = \chi \hat{a}_t (\psi_t + \rho_t)$.

In this setting, with $\rho_t > 0$, the constraint $p_t \leq z_t$ may not bind, but the above methods still yield the analogue of (14),

$$z_{t-1} = f_t(z) \equiv \beta z [1 + \alpha \chi L(z)] + \chi \rho_{t-1}. \tag{16}$$

Equilibrium is a path satisfying (16). If $\rho_t = \rho\ \forall t$ then SME solves $\bar{z} = f(\bar{z})$. It is standard to show it exists uniquely and has properties that depend on $\rho_0 \equiv v(q_0) r / \chi (1 + r)$: if $\rho \geq \rho_0$ then $\bar{q} = q_0$ and $\bar{\psi} = \psi_0$, where $\psi_0 = \rho / r$ is called the fundamental price; and if $\rho < \rho_0$ then $\bar{q} < q_0$ and $\bar{\psi} > \psi_0$. Thus, when pledgeable assets are scarce, they command a liquidity premium.

Now suppose agents learn at t_0 that there will be a one-time productivity drop to $\rho' < \rho$ at t_1. Given we are back in SME at $t_1 + 1$, $z_{t_1} = z_{t_1+1} - \rho + \rho' < z_{t_1+1}$, and we iterate on (16) as usual. Assuming $\rho < \rho_0$, the transition can be intricate. We do not show it, but with $\rho' = 0.8\rho$, the results are virtually identical to Figure 3. Hence, when real assets convey liquidity news about dividends generates paths similar to monetary news in the benchmark model.

With both fiat money and real assets the CM budget equation is

$$x_t = \ell_t + (\psi_t + \rho_t) a_t + \phi_t (m_t + \tau_t) - \psi_t \hat{a}_{t+1} - \phi_t \hat{m}_{t+1}. \tag{17}$$

In Geromichalos et al. (2007), the first paper to study this setup, m and a are perfect substitutes. That implies an essential role for money iff $\rho < \rho_0$, but m and a must have the same return. Lester et al. (2012) assume a and m are not equally acceptable in the DM: α_m is the probability of meeting a seller who accepts only m, α_a is the probability of meeting one who accepts only a, and α_b is the probability of meeting one who accepts both.[11]

Consider the natural case $\alpha_a = 0$ and $\chi_m = 1$, and let $z_t^m = \phi_t m_t$, $z_t^a = \chi(\psi_t + \rho_t)\hat{a}_t$ and $z_t^b = z_t^m + z_t^a$. Then the Euler equations for $\hat{m}$ and $\hat{a}$ yield a two-dimensional system:

$$z_{t-1}^m = \frac{\beta z_t^m \left[1 + \alpha_m L(z_t^m) + \alpha_b L\left(z_t^b\right)\right]}{1 + \mu_t} \tag{18}$$

$$z_{t-1}^a = \beta z_t^a \left[1 + \chi \alpha_b L\left(z_t^b\right)\right] + \chi \rho_{t-1} \tag{19}$$

Let q_t^j be the quantity traded in type-j DM meetings, and assume the liquidity constraints bind in all meetings, $v\left(\bar{q}^j\right) = \bar{z}^j$, which is true when ρ is not too big. It is now interesting to ask what news about money does to the value of equity and vice versa.

Figure 8 shows a 1% one-time increase in M_{t_1} announced at t_0, with z_t^m and z_t^a in the left column and z_t^b and S_t in the right (the price ψ_t is not shown but it basically tracks z_t^a). Clearly, monetary policy news affects the value of assets in intricate ways, even when money is neutral. In the top row, there is an initial jump in z_t^a (and ψ_t) as agents compete for other assets to compensate for the fall in z_t^m, then both decline, until z_t^a reaches $\bar{z}^a$ and z_t^m jumps back to $\bar{z}^m$. The other rows are similar but with oscillations. Also, news about a one-time fall in ρ looks like Figure 8 with the patterns in z_t^m and z_t^a reversed. So asset market news affects the value of money, in intricate ways, too.

Now consider foreign exchange markets, which as remarked above are also affected by Fed announcements. Following Zhang (2014), suppose there are two currencies, M_1 and M_2, accepted by sellers with some probabilities. Details are in Appendix B, but in Figure 9, news arrives at t_0 of a one-time jump in M_1 at t_1. At t_0, M_1 immediately depreciates against M_2, then both transition back to the original SME. For these parameters, α_1 and α_2 are small compared to α_b, so the

[11] Lester et al. (2012) endogenize the α's using private information, similar to the way Li et al. (2012) endogenize pledgeability, χ.

two monies are close to perfect substitutes; different parameterizations display different patterns. In any case, this shows how news travels across countries and generates complex patterns for exchange rates.

Now as in He et al. (2015) consider housing that provides direct utility as a consumer durable, plus liquidity, because home equity loans can be used to get cash for the DM. The Appendix again has details, but Figure 10 shows the results of news about a one-time 1% increase in μ. Depending on parameters, this can lead to a jump in house prices with a long monotone correction, or a slower rise with varying degrees of cyclicality, followed by a late surge and fall back to the original steady state. This shows how announcing monetary policy changes can lead to booms, crashes and cycles in housing markets.

It is worth repeating that we do not claim announcements always destabilize the economy, but they can. While we have multiple assets on the table, we can give is an example where news is stabilizing in an economy with a and m. For simplicity, set $\alpha_b = \chi_m = \chi_a = 1$, so m and a are perfect substitutes; with $\rho > 0$ this implies both can be valued iff $\mu < 0$. Then let $\bar{z}^m$, $\bar{z}^a$ and $\bar{\ell}$ be real balances, asset liquidity and labor in SME. Suppose agents learn at the end of $t_1 - 1$ that $\rho_{t_1} < \rho$, but then $\rho_t = \rho$ for $t > t_1$. Without intervention, we are back in SME in $t_1 + 1$, but $z^a_{t_1} = \bar{z}^a - \rho + \rho_{t_1} < \bar{z}^a$, and $z^m_{t_1} = \bar{z}^m$. This means DM trade at t_1 decreases, while CM output stays the same, and labor increases to $\ell_{t_1} = \bar{\ell} + \rho - \rho_{t_1}$ in response to the fall in ρ.

To counteract the ρ shock, a central bank can implement a one-time extraction of M at $t_1 + 1$, announced at the end of $t_1 - 1$. If

$$\mu_{t_1+1} = \frac{\bar{z}^m (1 + \mu)}{\bar{z}^m + \rho - \rho_{t_1}} - 1,$$

then total liquidity and DM output are unchanged. This policy sterilizes the ρ shock iff it is announced in advance. So it is easy to come up with scenarios where announcements attenuate volatility; our other examples show they might accentuate volatility.

Lesson 4: *Productivity and policy news induces* intricate *dynamics in output and prices in goods, equity, foreign exchange and housing markets, including booms, crashes and cycles. This is true whether assets are used as payment instruments or collateral.*

4 Unsecured Credit

Now consider unsecured credit as in Kehoe and Levine (1993), with limited commitment, but repayment incentivized by punishing those who default by not allowing them any more credit. The presentation here follows Gu et al. (2013), which is relatively simple and facilitates comparison to the models presented above. A reason for including this is to show that our methods also apply to pure credit economies.

At each t there are two subperiods, and two divisible goods X and Y. Agents called debtors produce Y and consume X in the first subperiod; agents called creditors produce X in the first subperiod but want to consume Y only in the second. The producers of Y can store or otherwise invest it at return R across subperiods; the consumers of Y cannot store it across subperiods. Agents meet randomly each period, either bilaterally or multilaterally in different versions, where α is the meeting probability of a debtor. A desirable arrangement is for a creditor to produce X for a debtor in the first subperiod in exchange for a promise to deliver RY in the second. The payoffs trading arrangement from this are $RY - c(X)$ and $u(X) - Y$ for the creditor and debtor.

To parameterize the incentive problem, let debtors get an extra payoff λ for each unit of their own output they consume, where $\lambda = 0$ implies a promise to deliver the goods is perfectly credible, while $\lambda > 0$ implies a temptation to renege similar to the model in Biais et al. (2007) or Demarzo and Fishman (2007). Assume $\lambda R < 1$, so debtors do not want to produce Y for their own consumption ex ante, even if they may want to opportunistically do so ex post. Also, if a debtor behaves opportunistically, assume he gets caught (monitored or recorded) with probability $\pi \leq 1$, and if caught he is punished by taking away future credit, meaning autarky with a payoff normalized to 0.

The incentive condition at t for a debtor to honor his obligation is

$$\beta V_{t+1} \geq \lambda R_t Y_t + (1 - \pi_t)\, \beta V_{t+1}, \tag{20}$$

where V_{t+1} is the continuation value as long as he has never been caught misbehaving – i.e., as long as he has a reputation for honoring his obligations. Rewrite this as $R_t Y_t \leq D_t$, where $D_t \equiv \beta \pi_t V_{t+1}/\lambda$ is the endogenous debt limit. The outcome depends in interesting ways on the mechanism determining the terms of trade, but here it suffices to use Walrasian price taking. Then a debtor, who has both a budget and a repayment constraint, solves

$$\begin{aligned} V_t = \max_{X_t, Y_t} \{\alpha\, [u\,(X_t) - Y_t] + \beta V_{t+1}\} \\ \text{st } P_t X_t = R_t Y_t \text{ and } R_t Y_t \leq D_t, \end{aligned} \tag{21}$$

where P_t is the unit price and $p_t = P_t X_t$ is the total payment. Clearly, $u'(X_t) = P_t/R_t$ if $P_t X_t < D_t$ and $X_t = D_t/P_t$ otherwise. For a creditor, who faces no repayment constraint, $c'(X_t) = P_t$.

Let X_t^* solve $u'(X_t^*) = c'(X_t^*)/R_t$ and let $p_t^* = c'(X_t^*)\, X_t^*$. Then, in equilibrium, $X_t = X_t^*$ and $Y_t = p_t^*/R_t$ if $D_t \geq p_t^*$, while $X_t = D_t/c'(X_t)$ and $Y_t = D_t/R_t$ if $D_t < P_t^*$. Write $X_t = g(D_t)$ in the latter case, and use $D_t = \beta \pi_t V_{t+1}^b/\lambda$ and (21) to write

$$D_t = f(D_{t+1}) \equiv \beta \frac{\alpha \pi_t}{\lambda} S(D_{t+1}; R_{t+1}) + \beta \frac{\pi_t}{\pi_{t+1}} D_{t+1}, \tag{22}$$

where a debtor's trade surplus is:

$$S(D_t; R_t) = \begin{cases} u \circ g(D_t) - D_t/R_t & \text{if } D_t < p_t^* \\ u(X_t^*) - p_t^*/R_t & \text{if } D_t \geq p_t^* \end{cases}$$

Suppose agents initially believe $\pi_t = \pi$ and $R_t = R\ \forall t$, and the economy is in steady state at D with a binding debt limit (which must be true for some parameters, e.g., β or π small). Then at t_0 they learn that at $t_1 > t_0$, for one period only, the monitoring probability will fall, making it harder to identify and punish defaulters. This implies $D_{t_1} < D$, and the transition back to t_0 is determined by iterating on (22). Figure 11 shows the results. In the middle (bottom) row, news that credit conditions will deteriorate in the future sets off oscillations in D_t with increasing (decreasing) amplitude before recovery to D. The right panel shows results for news about future productivity, now captured by lower R. In both experiments, along with D_t, the terms and amount of lending as well as output vary over the transition. So pure credit economies, not only monetary economies, are dynamically sensitive to news.

We can also integrate money and credit. Assume buyers can produce the CM numeraire x in DM meetings, but sellers have no use for it until the next CM, and only buyers can store it with $R = 1$ for simplicity. As in the pure credit economy, buyers produce x in the DM and promise to deliver it in the CM, but again buyers can opportunistically divert a fraction λ. This captures the main features of the credit model, but lets agents top up their debt limits with cash.[12]

On the equilibrium path the value function $W(m_t)$ is still given by (7). Given any debt limit D_t, the DM problem is

$$V_t(\hat{m}_t) = \alpha [u(q_t) - p_t] + W_t(\hat{m}_t),$$

where $p_t = d_t + \phi_t \hat{m}_t$ and $d_t \leq D_t$. Deriving the Euler equation for $\hat{m}_{t+1}$ we get

$$z_{t-1} = f_t(D_t, z_t) \equiv \frac{\beta z_t [1 + \alpha L(D_t + z_t)]}{1 + \mu_t}. \tag{23}$$

When λ is time invariant, the credit constraint reduces to

$$d_t \leq \frac{\pi_t}{\lambda} W_t(0) = \frac{\pi_t}{\lambda} [-\phi_t m_t + \beta V_{t+1}(\hat{m}_{t+1})] \equiv D_t.$$

Emulating the analysis of the pure-credit model, we arrive at

$$D_t + \frac{\pi_t}{\lambda} z_t = \beta \frac{\alpha \pi_t}{\lambda} S(D_{t+1} + z_{t+1}) + \beta \frac{\pi_t}{\pi_{t+1}} D_{t+1} + \beta \frac{\pi_t}{\lambda} z_{t+1} \tag{24}$$

[12] It is not trivial to combine money and credit in ways that respect microfoundations and lead to interesting results. See Gu et al. (2016) for details, but note that in that paper changes in credit conditions are neutral because real money balances adjust endogenously to leave total liquidity the same. That is not true here because the result applies to steady states and not necessarily transitions.

Figure 12 shows the impact news about a one-time 1% increase in μ. The transition for z_t again displays intricate dynamics, but now monetary policy news also induces dynamics in D_t. Similarly, news about credit conditions due to changes in π_t or R_t induces dynamics in z_t. Yet there is an asymmetry: news leading to lower D_t tends to increase z_t as agents try to substitute out of credit and into cash, while news leading to lower z_t tends to decrease D_t because lower z_t reduces equilibrium payoffs and that tightens the endogenous debt limit, at least for some parameters. We summarize as follows:

Lesson 5: *News about future credit conditions can induce intricate dynamics in the amount and terms of lending. Bad news about money tends to tighten credit while bad news about credit tends to boost the value of money.*

5 Alternative Monetary Policies

Above we took the monetary policy instrument to be μ. In SME, targeting μ is the same as targeting i, since $1 + i = \mu/\beta$, but they are not the same during transitions, where ϕ_t and i_t can vary with t even if μ_t does not. The earlier experiments can be interpreted as the Fed announcing at t_0 a change in μ_t at t_1 to determine i_t in the long run, but letting the market determine ϕ_t and i_t in the short run. Here we instead peg i and let M_t adjust endogenously in the transition. The results are different. From (12) and (13), z_t and q_t are pinned down by i_t $\forall t$. Hence, if we announce at t_0 that i_t will remain the same between t_0 and t_1, and then change to $i_{t_1} \neq i$, during the transition z_t and q_t only react when policy actually changes.

With multiple assets, however, news about interest rate policy still induces complex dynamics. With money and real assets, e.g., under a nominal interest rate peg (18)-(19) become

$$
\begin{aligned}
i_t &= \alpha_m L(z_t^m) + \alpha_b L\left(z_t^b\right) && (25) \\
z_{t-1}^a &= \beta z_t^a \left[1 + \chi \alpha_b L\left(z_t^b\right)\right] + \chi \rho_{t-1}. && (26)
\end{aligned}
$$

Suppose $i_t = i \; \forall t \neq t_1$ and $i_{t_1} > i$. Assuming we go back to SME at $t_1 + 1$, as usual, iterating on (25)-(26) yields the transition. In Figure 13, the news at t_0 is that $i_{t_1} = 0.0182$ and $i_t = 0.0082 \; \forall t \neq t_1$. This generates a boom in z_t^a and asset prices when the news is released, followed by a return to the original SME. Similarly, nontrivial transitions arise after news about productivity.

While these patterns are interesting, in examples we found it harder (in terms of finding parameter values) to generate oscillations, even with two monies or money and credit. It is easier to get oscillations with money and housing, because a model with housing has more nonlinearity, with h_t entering utility functions and not only the constraints. Figure 14 shows the same experiment, $i_{t_1} = 0.0182$ and $i_t = 0.0082 \; \forall t \neq t_1$, announced at t_0 with money and housing. Here the values of the two liquid assets move in opposite directions, and there are at least mild oscillations in both, with volatility increasing in t.

Lesson 6: *Under interest rate rules productivity or policy news can induce dynamics in goods and asset prices, and credit market news can induce dynamics in the value of money and debt limits. It is harder to get oscillations under interest rate rules, but it is possible with money and housing.*

6 Conclusion

This paper studied dynamics in response to news (information shocks) in economies where liquidity plays a role. One motivation was the way monetary policy announcements affect markets, but we also considered news about productivity and credit conditions. The results were summarized as a series of Lessons. In short, news can send shock waves through goods, equity, housing and other markets, affecting prices, quantities and welfare, with transitions that can involve cycles or boom-bust patterns, even for news about classically neutral policy changes. Our methods and results apply in a large class of standard models of money and credit. Also, we reiterate that the transition is unique for any equilibrium selection after the event occurs, and thus do not depend on multiple equilibria.

In a version of the theory with, e.g., real assets replacing fiat currency equilibrium (and not only steady state) can be unique, yet news still entails interesting dynamics.

To put this in perspective, recall that Friedman was famously concerned about the efficacy of policy due to *long and variable lags* between implementation and impact. We instead focused on *long and variable leads* between announcements and events. Probably both are relevant.

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Appendix A: Parameters for Experiments

In all cases $t_0 = 0$ and $t_1 = 12$, except Figures 6 and 7; $\beta = 0.9959$, except the right column of Figure 5; and $\sigma = 0$, except Figure 11. The other parameters are set as follows:

Table 1: Parameters for Experiments

Common Values for Figures 3-5(L) and 6-7: $\alpha = 0.5$, $A = 1$, $b = 0.1$, $\gamma = 0.5, 4, 8$.	
Figure 3	$\mu = 0.0041$, $\mu' = 0.0141$ (L), 0.0049 (R).
Figure 4	$\mu = 0.0041$, $\mu' = 0.0046$ (L), 0.00411 (R).
Figure 5	(L) $\beta = 0.9879$, $\mu = 0.0123$, $\mu' = 0.0223$,
	(R) $\beta = 0.9999$, $\alpha = 1$, $A = 0.25$, $b = 0.45$, $\gamma = 3$, 4.7 or 7, $\mu = 0.1368 \times 10^{-4}$, $\mu' = 0.0101$.
Figure 6	$\mu = 0.0041$, $\mu_{t_1} = 0.0141$, $\mu_{t_2} = -0.0059$, $t_2 = 12$, $t_1 = 0$ (L), 6 (R).
Figure 7	(L) $t_0 = 0$, $t_1 = 4$, $t_2 = 8$, $t_3 = 12$, $\mu = 0.0041$, $\mu' = 0.0191$, $\mu'' = 0.0091$,
	(R) $\Pr(\mu_t = 0.00615) = \Pr(\mu_t = 0.00205) = 0.5$. $\Pr(\mu_{12} = 0.00615) = 1$
Common Values for Figures 8-9: $A = 0.25$, $b = 0.45$, $\gamma = 3, 6, 9$.	
Figure 8	$\alpha_m = 0.01, 0.001, 1 \times 10^{-4}$, $\alpha_b = 0.5$, $\chi_a = 1$. $\mu = 0.0041$, $\rho = 2 \times 10^{-4}$, $\mu' = 0.0141$.
Figure 9	$\alpha_1 = 0.01, 0.001$, 1×10^{-4}, $\alpha_2 = 0.1\alpha_1$, $\alpha_b = 0.5$, $\mu^1 = \mu^2 = 0.0041$, $\mu^{1\prime} = 0.0141$.
Figure 10	$A = 0.25$, $b = 0.45$, $\gamma = 3$, 6, 9, $U(x_t, h_t) = x_t^{\delta} h_t^{1-\delta}$, $\delta = 0.4$, $\chi_h = 0.5$, $h = 0.001, \alpha_m = 0.01$, $0.001, 1 \times 10^{-4}$, $\alpha_b = 0.5$, $\mu = 0.0041$, $\mu' = 0.0141$.
Figure 11	$\alpha = 0.5$, $A = 1$, $b = 0.1$, $\sigma = 0.2, 0.5, 0.8$, $\gamma = 0$, $\lambda = 0.1$, $\pi = 0.99$, $R = 0.9$, $\pi^{'} = 0.98$, $R' = 0.89$.
Figure 12	$\alpha = 0.5$, $A = 0.1$, $b = 0.15$, $\gamma = 2, 4$ or 6, $\lambda = 1$, $\pi = 2 \times 10^{-4}$, 2×10^{-5} or 2×10^{-6}, $\mu = 0.0041$, $\mu' = 0.0141$.
Figure 13	$i = 0.0082$, $i' = 0.0182$, the rest follow Figure 8.
Figure 14	$A = 0.25$, $b = 0.05$, $\delta = 0.4$, $\gamma = 6, 9$ or 12, $\alpha_m = 1 \times 10^{-3}$, 1×10^{-4},
	or 1×10^{-5}, $\alpha_b = 0.5$, $\chi_h = 0.5$, $h = 0.001$, $i = 0.0082$, $i' = 0.0182$.

Appendix B: More on Multiple Assets

First consider two currencies. As with money and equity, suppose a random seller in the DM accepts only currency j with probability α_j and accepts both with probability α_b, and consider $\chi_j = 1$. With $z^b = z^1 + z^2$, the Euler equations yield

$$\begin{aligned} z_{t-1}^1 &= \frac{\beta z_t^1 \left[1 + \alpha_1 L\left(z_t^1\right) + \alpha_b L(z_t^b)\right]}{1 + \mu_t^1} \\ z_{t-1}^2 &= \frac{\beta z_t^2 \left[1 + \alpha_2 L\left(z_t^2\right) + \alpha_b L(z_t^b)\right]}{1 + \mu_t^2}. \end{aligned}$$

Equilibrium is defined in the obvious way. In SME, for standard mechanisms agents are liquidity constrained in type-1 and type-2 meetings, but may or may not be in type-b meetings.

Now consider money and housing. Let h_t be housing at t, and assume buyers derive direct utility from h_t, plus can pledge it to get liquidity in the DM. Their CM problem is then

$$W_t(m_t, h_t) = \max_{x_t, \ell_t, \hat{m}_{t+1}, \hat{h}_{t+1}} \left\{ U(x_t, h_t) - \ell_t + \beta V_{t+1}(\hat{m}_{t+1}, \hat{h}_{t+1}) \right\}$$
$$\text{st } x_t = \phi_t (m_t + \tau_t) - \phi_t \hat{m}_{t+1} + \eta_t h_t - \eta_t \hat{h}_{t+1} + \ell_t,$$

where η_t is the price of h_t. The FOC for x_t is $U_1(x_t, h_t) = 1$, which means $x_t = X(h_t)$ is pinned down by h_t. While having an endogenous housing supply is interesting, as it adds one more equation, for the sake of illustration let us fix it here at a normalized supply of 1.

The probability a buyer meets a seller who accepts only m is α_m and the probability he meets one who accepts m and h is α_b. Then the Euler equations yield

$$z^m_{t-1} = \frac{\beta z^m_t \left[1 + \alpha_m L(z^m_t) + \alpha_b L\left(z^b_t\right)\right]}{1 + \mu_t} \tag{27}$$
$$z^h_{t-1} = \beta z^h_t \left[1 + \chi_h \alpha_b L\left(z^b_t\right)\right] + \beta \chi_h U_2 \left[X(1), 1\right]. \tag{28}$$

In type-m meetings the constraint $v(\bar{q}^m) \leq \bar{z}^m$ binds in SME, so $\bar{q}^m < q_0$. In type-b meetings, if $\chi_h U_2 [x(1), 1]/r > v(q_0)$ the constraint does not bind, so $\bar{q}^b = q_0$ and housing is priced fundamentally at $\eta = U_2 [x(1), 1]/r$; otherwise $\bar{q}^b < q_0$ and $\eta > U_2 [x(1), 1]/r$.

Appendix C: A Cash-in-Advance Model

Consider an economy with two goods each period: c_1 is a cash good and c_2 is a credit good. Agents are endowed with one unit of labor that can be transformed one-for-one into either good, so they have the same price. Money satisfies $M_t = (1 + \mu_t) M_{t-1}$ as in the other models. To simplify the presentation, let the utility function be linear in c_2. The the representative agent's problem is given by

$$V(m_t) = \max_{c_{1t}, c_{2t}, m_{t+1}} \left\{ u(c_{1t}) + c_{2t} + \beta V(m_{t+1}) \right\}$$
$$\text{st } c_{1t} + c_{2t} = 1 + \phi_t (m_t + \tau_t) - \phi_t m_{t+1} \text{ and } c_{1t} \leq \phi_t (m_t + \tau_t).$$

where inequality is the cash-in-advance constraint.

The FOC's for c_{1t} and m_{t+1} are

$$\begin{aligned} u'(c_{1t}) - 1 - \lambda_t &= 0 \\ -\phi_t + \beta V'(m_{t+1}) &= 0 \end{aligned}$$

where λ_t is the multiplier on $c_{1t} \leq \phi_t (m_t + \tau_t)$. If it does not bind, $\lambda_t = 0$ and $c_{1t} = c^*$ where c^* solves $u'(c^*) = 1$. If it binds, $\lambda_t > 0$ and $c_{1t} < c^*$. The envelope condition is $V'(m_t) = \phi_t (1 + \lambda_t)$. Combine this with the FOC's and to get

$$z_t = f(z_{t+1}) \equiv \frac{\beta z_{t+1}}{1 + \mu_{t+1}} L(z_{t+1}),$$

where $z_t = \phi_t M_t$, $L(z) = u'(z)$ if $z < c^*$ and $L(z) = 0$ if $z \geq c^*$. This equation is a special case of the New Monetarist model with $\alpha = 1$ and $v'(q) = 1$, and hence exhibits qualitatively similar dynamics.

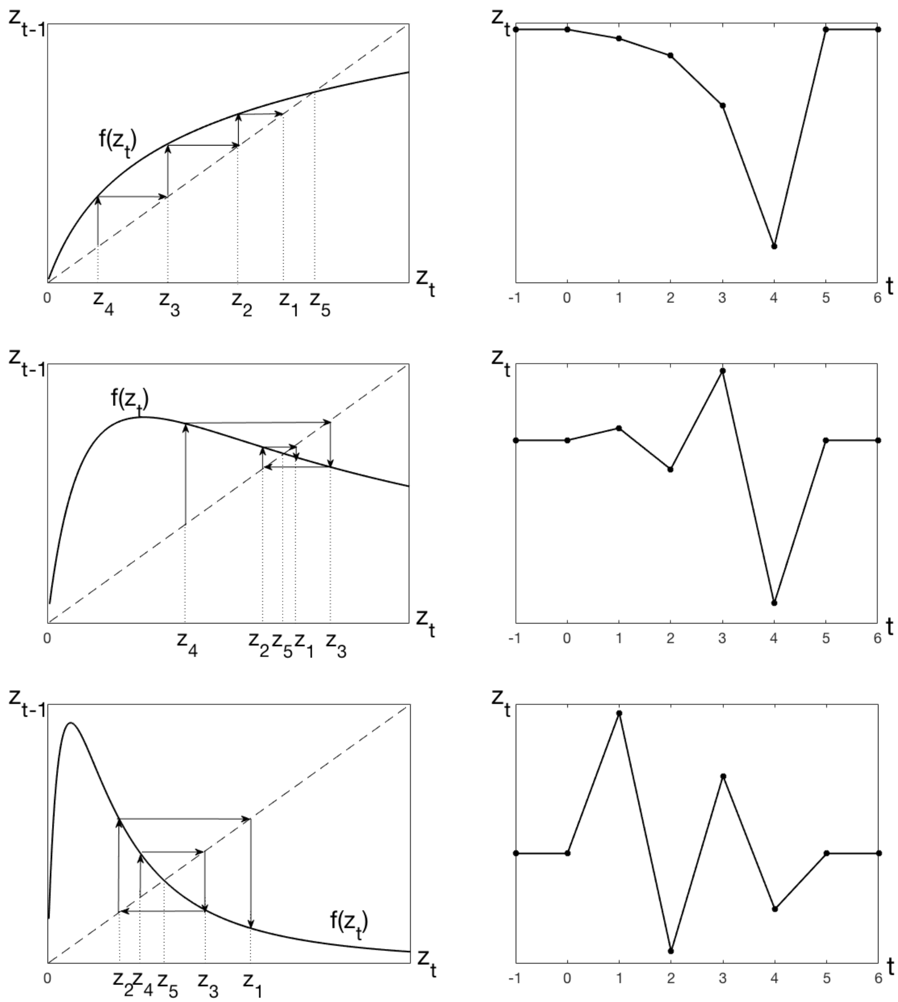

Figure 1: Phase Dynamics and Transition Paths (OLG model)

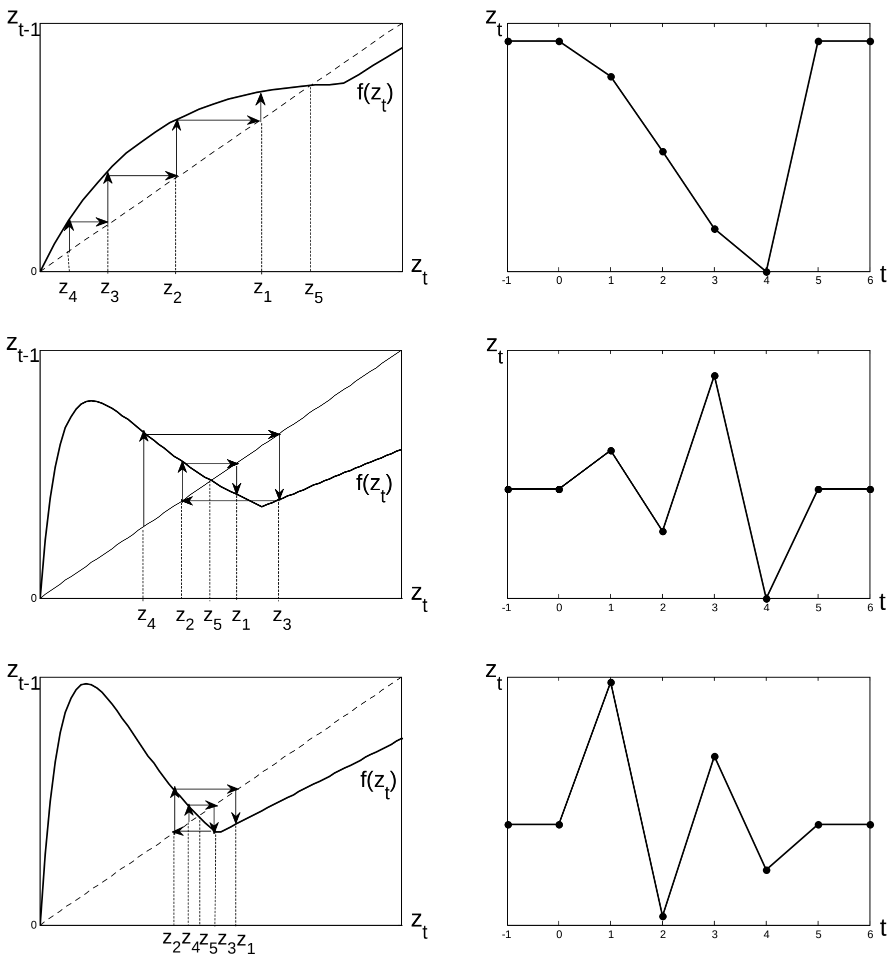

Figure 2: Phase Dynamics and Transition Paths (New Monetarist Model)

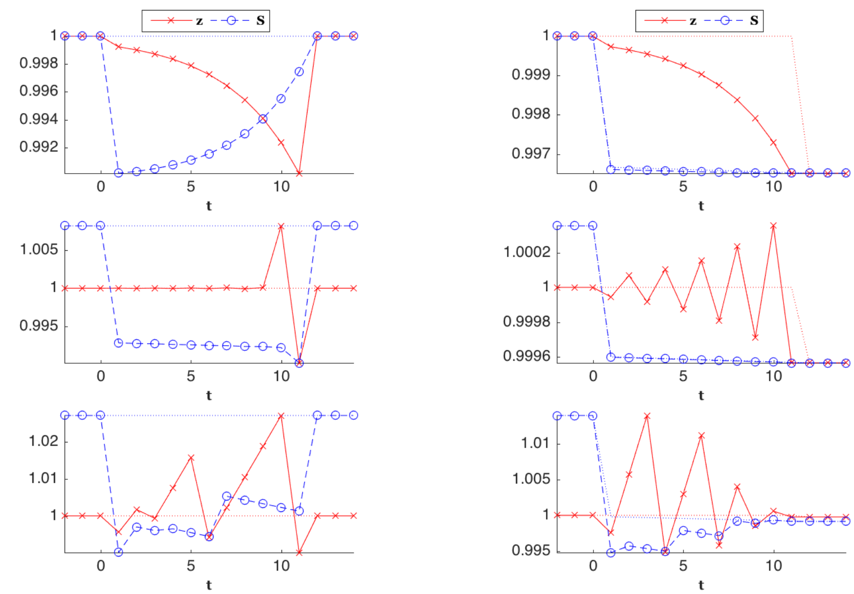

Figure 3: Temporary (left) and Permanent (right) Increase in μ

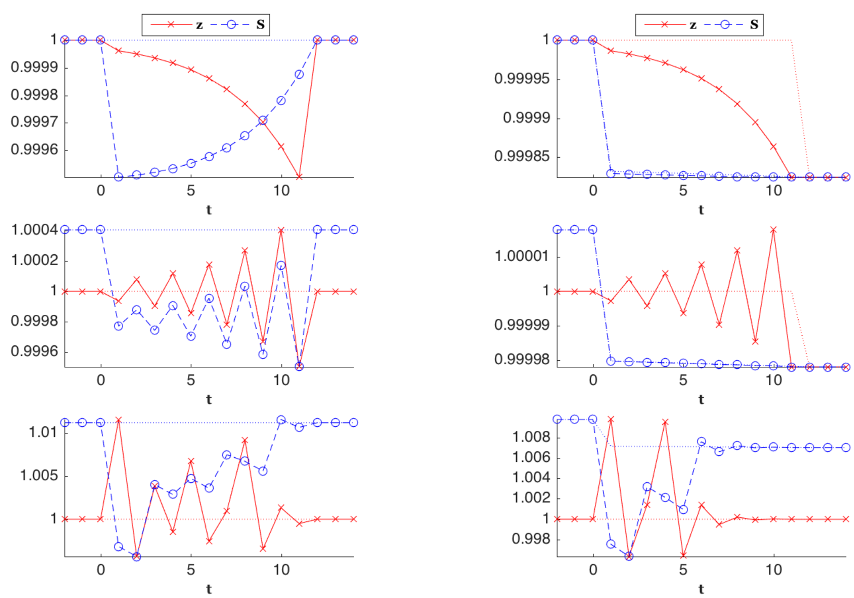

Figure 4: Temporary (left) and Permanent (right) Small Increase in μ

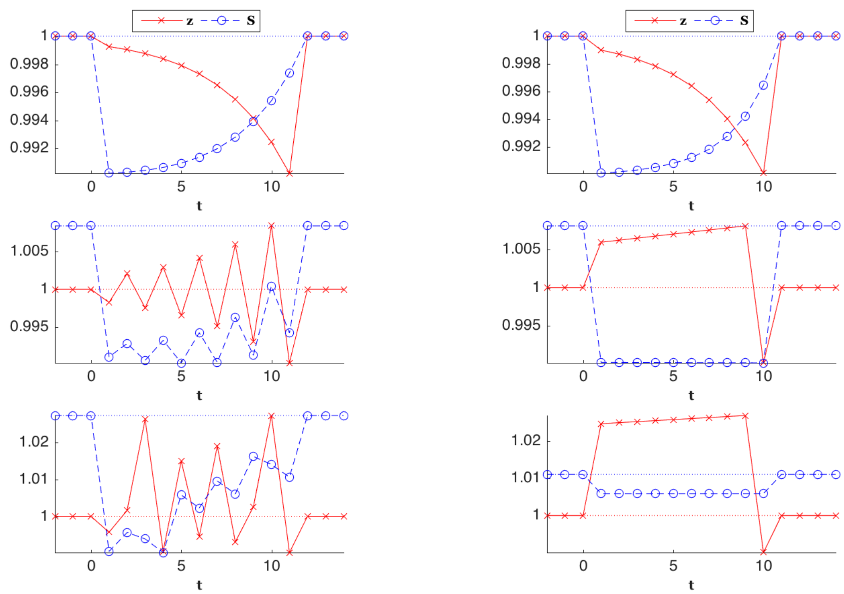

Figure 5: Temporary Increase in μ, Quarterly (left) and Daily (right)

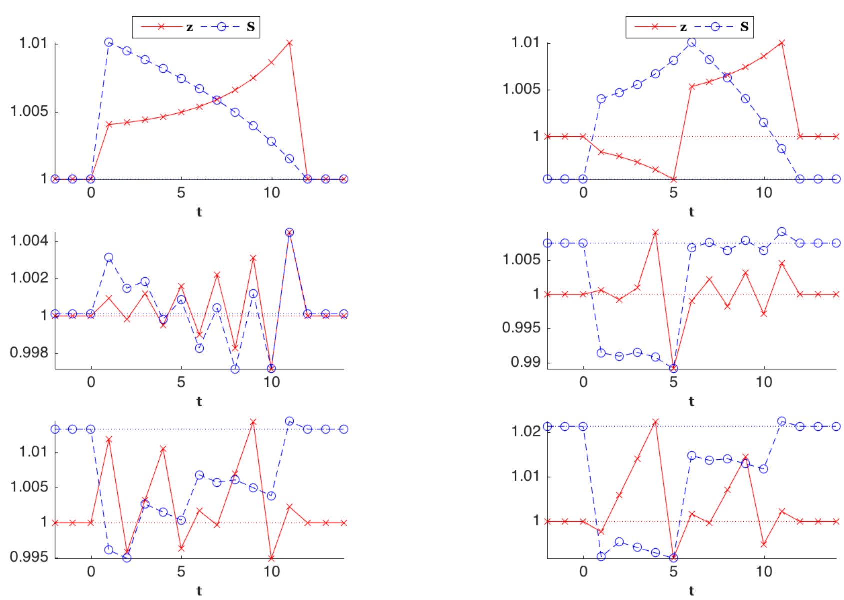

Figure 6: Injection w/ Future Extraction, $t_1 = t_0$ (left) and $t_1 > t_0$ (right)

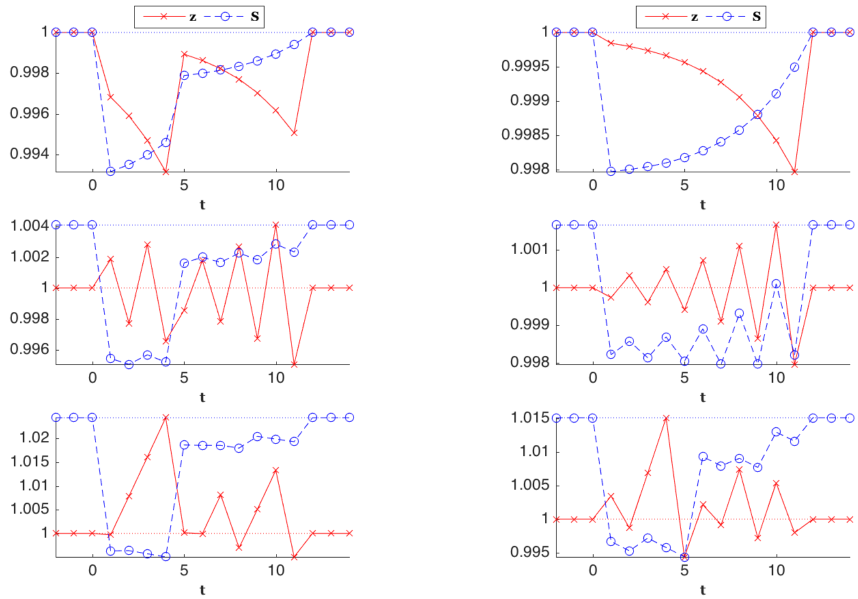

Figure 7: Staggered News (left) and Random News (right)

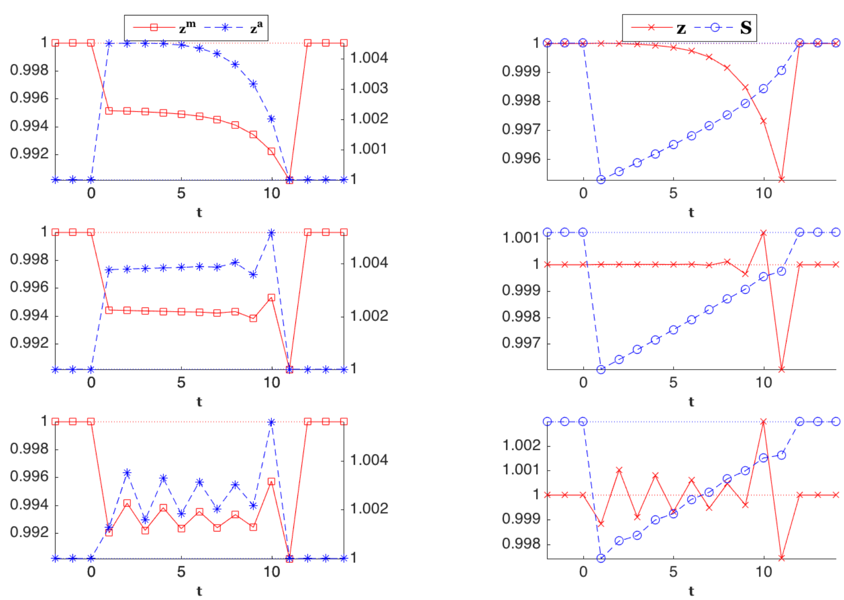

Figure 8: Money-and-Asset Economy, Temporary Increase in μ

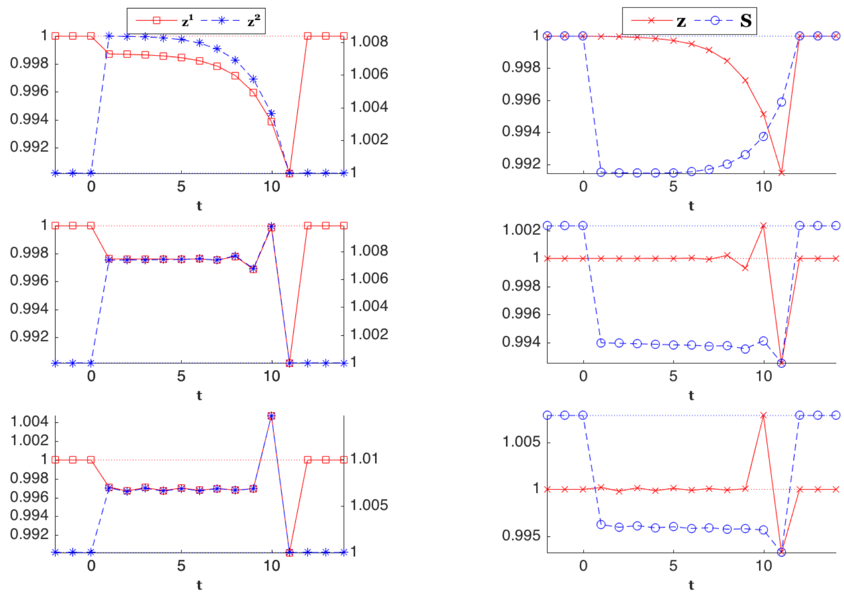

Figure 9: Two-Money Economy, Temporary Increase in μ^1

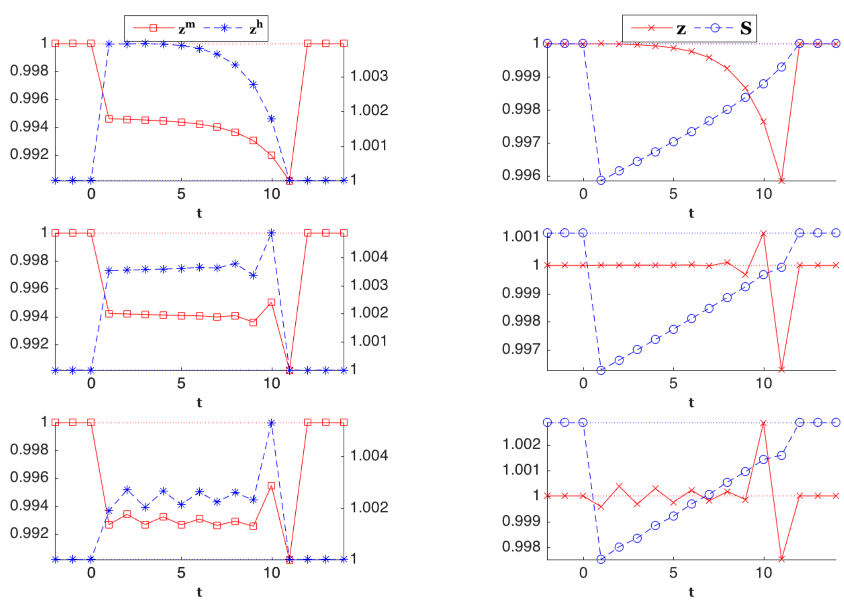

Figure 10: Housing-and-Money Economy, Temporary Increase in μ

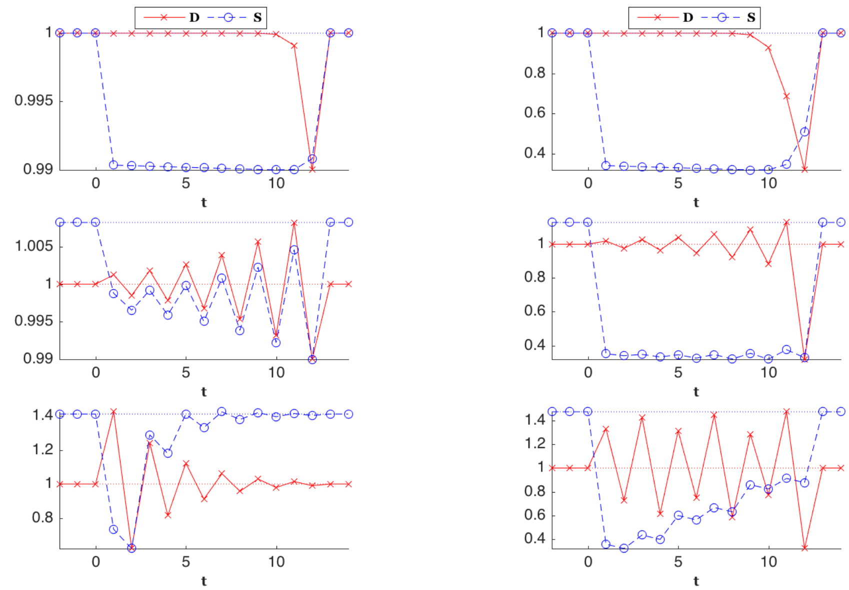

Figure 11: Credit Economy, Temporary Decrease in π (left) and R (right)

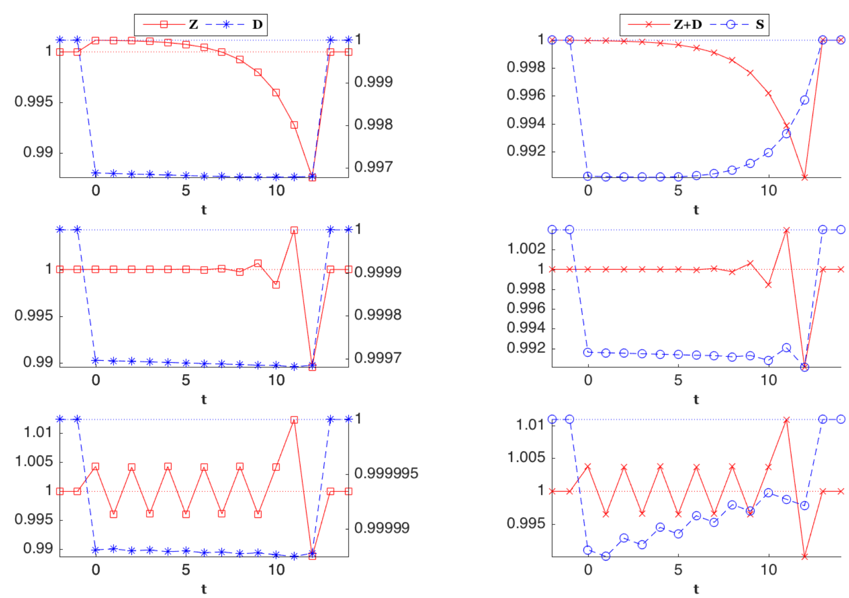

Figure 12: Money-and-Credit Economy, Temporary Increase in μ

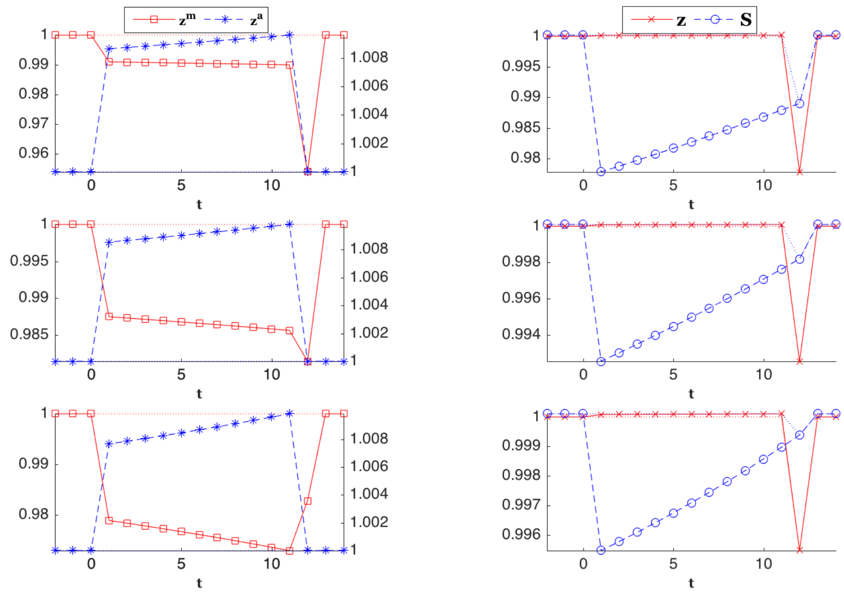

Figure 13: Money-and-Asset Economy, Interest Target, Increase in i

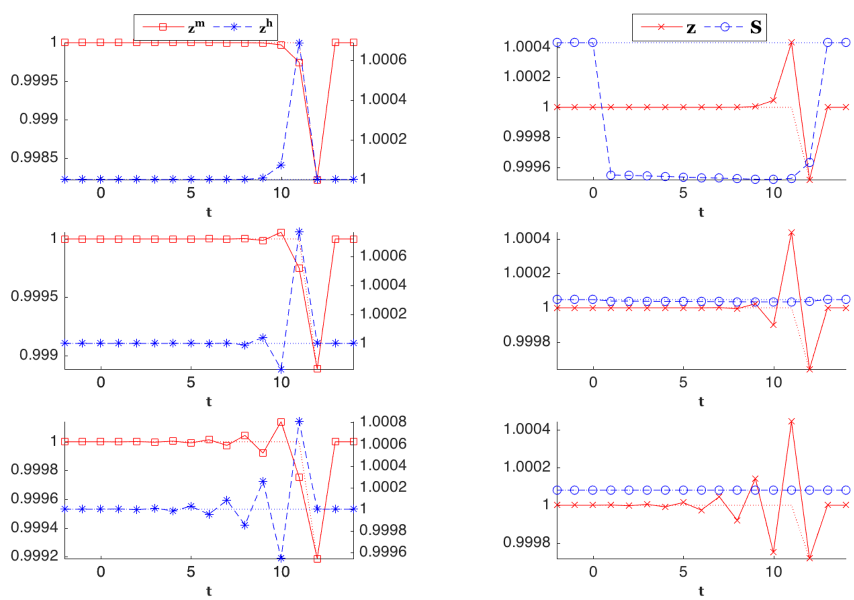

Figure 14: Housing-and-Money Economy, Interest Target, Increase in i