The Effects of Monetary Policy and Other Announcements*

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Abstract

We analyze the impact of news (information shocks) in economies where liquidity plays a role. While we also consider news about real factors, like productivity, one motivation is that central bank announcements evidently affect markets, as taken for granted by advocates of forward guidance policy. The dynamic effects can be complicated, with information about monetary policy or real factors affecting markets for goods, equity, housing, credit and foreign exchange. Even news about neutral policy can induce cyclic or boom-bust responses. More generally, we show that central bank announcements can induce rather than reduce volatility, and might increase or decrease welfare.

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"Bernanke Speaks, and Shares Tumble" New York Times (06/06/06).

1 Introduction

We analyze the impact of news (information shocks) in economies where assets provide liquidity, including economies with fiat currencies, real assets or both. While we also consider news about real economic conditions, one motivation is that central bank announcements evidently have an impact on Wall Street and Main Street, something taken for granted when contemplating forward guidance as a policy tool. To look first at Fed policy, Figure 1 from Rosa (2011a) shows the response of different stock indices to FOMC announcements on four illustrative dates (the author describes why these days are interesting). News has an impact. More generally, as he says, empirical work uncovers four findings: "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, rather than the change in its tone, affects equity indices. Fourth, central bank communication has remained an important monetary policy tool."

Figure 2, from Rosa (2013), shows how asset markets react to news on average, as opposed to on particular days. The top four panels give standard deviations just before and after FOMC statement releases in markets for two- and ten-year treasuries, the S&P 500, and Euro/Dollar exchange. Clearly these markets react to monetary policy news, with a spike in volatility immediately after an announcement that is economically and statistically significant. Similar effects arise from announcements from the ECB, the Bank of England and other policy-making institutions. To show this is also true for other types of information, the bottom four panels in Figure 2 show the effects of news about Nonfarm Payrolls, referred to as the "king" of announcements by Andersen and Bollerslev (1998). This again triggers reactions. So does news about output or productivity.

Moreover, news affects trading volume, not only prices. See Rosa (2011a,b, 2013) and references therein for more details.

Our goal is not to focus on high-frequency financial data, but these facts are meant to motivate generally that it is interesting to study the impact of information about monetary or real factors using dynamic economic theory. We use a microfounded model of liquidity sometimes called the New Monetarist framework.[1] This approach adopts elements of general equilibrium theory, but also borrows from search theory by modeling exchange as a process where agents trade with each other, and not merely along budget lines. The agents can be households, firms or financial institutions, and what they exchange can be goods, inputs or assets. What is important is that they trade explicitly with counterparties, allowing us to ask questions like: Do they use barter, money or credit? If they use a medium of exchange, is it a fiat currency or a real asset? If they use credit, is it secured, and if so by what? This provides a natural laboratory within which to study the impact of monetary policy.

One way to capture changes in policy or other variables is to have them follow stochastic processes and trace out responses to different realizations. While this is standard, we want to consider changes that are to a degree unanticipated, despite some people disparaging this as a violation of rational expectations. To us, the force of the rational expectations hypothesis is that one should not model repeated changes as repeatedly unanticipated – e.g., it is unreasonable to say that inflation is above average on average, as one must to argue that Friedman's (1968) expectation-augmented Phillips curve provides an exploitable policy menu. Yet despite being a leading proponent of rational expectations, Sargent (1993) argues that it does not mean we should never entertain the possibility of a surprise. Here events at t_1 are anticipated as of time $t_0 \leq t_1$, but not at $t < t_0$, capturing totally

[1] For surveys, see Nosal and Rocheteau (2011) or Lagos et al. (2016); for some recent work concerned especially with central bank policy, see Williamson (2012,2016), Andolfatto et al. (2014,2016), Geromichalos et al. (2016) and Rocheteau et al. (2016).

unexpected events ($t_0 = t_1$) and perfect foresight ($t_0 \to -\infty$) as special cases, if not necessarily the most interesting cases.

The results may be surprising: in simple standard models, news at t_0 can induce complicated dynamics, including booms, busts and cycles with amplitudes that increase or decrease as we approach t_1. This does not rely on sticky prices or disparate beliefs as in some Keynesian models (e.g., Michelacci and Paciello 2016), or on multiple equilibria and agents using news to coordinate beliefs (e.g., Andolfatto and Martin 2013). We focus on the unique stationary equilibrium after the change, and construct the transition from t_0 to t_1 by backward induction. This path can look very different depending on parameters, and can involve runups, crashes and oscillations in prices and quantities. As may also be surprising, this can happen for news about policies that are neutral in the long run, or even in the short run, if not for the announcement, including a one-time increase in the money supply. This is the opposite of a classical view that money injections are nonneutral iff unanticipated (see Mishkin 1982 for a discussion and references), and implies that market reactions to Fed news does not constitute conclusive evidence that money is not neutral in the usual sense.

There are also implications for the notion of forward guidance, defined as efforts by central banks to manage expectations using press conferences, speeches, the release of statements or minutes, etc.[2] The relevance of this practice is typically taken for granted: "the view that monetary policy is, at least in part, about managing expectations is by now standard fare both in academia and in central banking circles" (Blinder et al. 2009). Moreover, "Market participants analyze every word of Fed officials for clues of possible directions of monetary

[2]Wikipedia puts it quite well: "Forward guidance is a tool used by a central bank to... guide expectations of market participants about the future path of policy. The strategy can be implemented in an explicit way, expressed through communication of forecasts and future intentions, sometimes known as Odyssean forward guidance. Implied forward guidance also exists, sometimes referred to as Delphic forward guidance... Among the main central banks, Delphic forward guidance dominates, although there are a couple of exceptions such as the US Federal Reserve, which makes quite specific but still conditional statements."

policy because monetary policy affects asset prices, particularly stock prices... Therefore, it is important for central bankers to understand what determines the market's reaction to their statements" (Kurov 2012). While the usual motive for announcing changes in advance is to avoid big reactions when they occur, we find policy news induces rather than reduces volatility. To be clear, the claim is not that advance warning always causes volatility, but that it might.[3]

It is perhaps also surprisingly that news-induced volatility may improve welfare, even for policies that are neutral, or even for those that are unambiguously bad, in the long run. However, while this form of guidance may enhance welfare in theory, exploiting it is very sensitive to timing and parameter values, and hence may be unmanageable in practice. Note also that the news does not have to be about a change happening in the future: the actual change could happen now, but the effects might only kick in after a while. A policy of printing currency can be implemented immediately, e.g., but there could be long and variable lags as the new cash works its way into the system via government expenditures, transfers, tax cuts or open market operations. That would make the timing especially delicate. Additionally, note that no news, or the lack of an announcement, can be just as important as news, depending on what was anticipated.

There has been much recent interest in news 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... Another kind of news shock would be a government announcement about a policy change to be implemented on a future date (say, that taxes will be raised beginning next year)." These are exactly the phenomena we analyze, although our use of New Monetarist theory differentiates the

[3]As evidence that this goes against conventional wisdom, consider Blinder et al. (2009): "central bank talk increases the predictability of central bank actions, which should in turn reduce volatility in financial markets." Or consider Matsumotoa et al. (2011): "one might conjecture that providing more information about future fundamentals in DSGE models (i.e., more information about the exogenous stochastic processes) would reduce asset price volatility." We provide clear counterexamples to such conjectures.

approach from past work. Still, there is a common thread. As Beaudry and Portier (2014) put it, "There is a widespread belief that changes in expectations may be an important independent driver of economic fluctuations," and our intended contribution is simply focusing on a particular channel.[4]

The paper is organized as follows. Section 2 presents a benchmark model, and Section 3 shows how to construct transitions after information innovations. Section 4 provides simple examples illustrating different effects. Section 5 contains more examples, including an analysis of quantitative easing. Section 6 adds equity, multiple currencies and residential capital to study stock markets, exchange rates and housing. Section 7 considers other extensions, including the impact of news in pure-credit or money-and-credit economics, and alternative policy rules. Section 8 concludes.

2 The Baseline Model

As in Lagos and Wright (2005), at each t in discrete time two markets convene sequentially: first there is a decentralized market, or DM, with frictions detailed below; then there is a frictionless centralized market, or CM. There are two permanently different types of agents, called buyers and sellers. In the CM all agents 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; we are agnostic about this since the same equations apply to any of the interpretations and all have been successfully deployed in the literature. Traders meet bilaterally in the DM, where α is the probability a buyer meets a seller, and $n\alpha$ is the probability a seller meets a buyer, with n the buyer-seller ratio.

[4] Cochrane (1994) is an early advocate for the importance of news about productivity, policy, energy prices, regulation, international factors and sectoral shifts. Beaudry and Portier (2004,2006,2007) focus on productivity, try to identify news shocks, and use them as impulses in maro models. As there is too much other good work to discuss here we refer readers to the Beaudry and Portier (2014) survey, with apologies for not citing all individual contributors

Period payoffs of buyers and sellers are

$$\mathcal{U}^b(q,x,\ell) = u(q) + U(x) - \ell \text{ and } \mathcal{U}^s(q,x,\ell) = -c(q) + U(x) - \ell, \tag{1}$$

where q is the object being traded in the DM, x is the CM numeraire and ℓ is 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. There is a constraint $\ell \in [0,1]$, but as long as it is slack, having ℓ enter linearly in (1) guarantees all buyers have the same asset demand and makes CM value functions linear, as shown below. 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 $u'(q^*) = c'(q^*)$ defines 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, following Kocherlakota (1998), agents are anonymous and lack commitment, precluding credit for now (this is relaxed below). This implies an essential role for assets as payment instruments. Also, for now x and q are nonstorable, so the only candidate for this role is fiat money (this is also relaxed below). The money supply per buyer at t is M_t, where $M_t = (1+\mu_t) M_{t-1}$. Changes in M_t can be accomplished by lump sum CM transfers if $\mu_t > 0$ or taxes if $\mu_t < 0$. However, the main results are the same if the consolidated monetary-fiscal authority simply puts newly-issued currency into, or takes newly-retired currency out of, general revenue. They are also the same if we add illiquid bonds and adjust M_t by OMO's (open market operations) as in Rocheteau et al. (2016).[5]

Purely for ease of notation, assume buyers but not sellers pay taxes or get transfers, and x is produced one-for-one with ℓ to make the CM wage 1. Then,

[5] It is easy to incorporate real and/or nominal bonds as in Rocheteau et al. (2016), but for our purposes that would only add notation. Still, the idea is simple: if bonds are illiquid then changing their supply does not matter for the variables of interest, so the effect of increasing M by OMO is the same as giving it out by transfers. This is not true when bonds are liquid, however. As an extreme, suppose as in Wallace (1981) bonds are as liquid as cash. Then OMO's have no real or nominal impact, just like swapping a 10-dollar bill for two fives.

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

$$\begin{aligned} W_t(m_t) &= \max_{x_t,\ell_t,\hat{m}_{t+1}} \{U(x_t) - \ell_t + \beta V_{t+1}(\hat{m}_{t+1})\} \\ \text{st } x_t &= \ell_t + \phi_t m_t - \phi_t \hat{m}_{t+1} + \tau_t, \end{aligned} \tag{2}$$

where ϕ_t is the price of money in terms of x_t, τ_t is the transfer, and $V_{t+1}(\hat{m}_{t+1})$ is the continuation value in the next DM. Notice we distinguish between m_t, money taken into the CM at t, and $\hat{m}_t$, money taken into the DM at t. The FOC for $x_t > 0$ is $U'(x^*) = 1$. The FOC for $\hat{m}_{t+1} > 0$ is

$$\phi_t = \beta V'_{t+1}(\hat{m}_{t+1}), \tag{3}$$

implying $\hat{m}_{t+1}$ is independent of m_t. Also, $W'_t(m_t) = \phi_t$, implying the CM payoff is linear. Sellers' problem (omitted) is similar, and their CM payoff is linear, but for them we know $\hat{m}_{t+1} = 0$ in all but one exceptional situation discussed below.

When buyers and sellers meet in the DM they trade (p_t, q_t), where p_t is a real 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, $\Gamma_t : \phi_t \hat{m}_t \to (p_t, q_t)$. 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 buyers having bargaining power $\theta = 1$, or with competitive price taking (for this interpretation one may prefer the version of the model with multilateral meetings in Rocheteau and Wright 2005). However, more generality can be interesting (see Section 7.1). So consider any Γ_t satisfying resource feasibility, individually rationality, bilateral efficiency, and $p'_t > p_t \Leftrightarrow q'_t > q_t \ \forall (p_t, q_t)$. Gu and Wright (2016) show this implies Γ_t must take the following form:

$$p_t = \begin{cases} \phi_t \hat{m}_t & \text{if } \phi_t \hat{m}_t < p_t^* \\ p_t^* & \text{otherwise} \end{cases} \quad \text{and } q_t = \begin{cases} v_t^{-1}(\phi_t \hat{m}_t) & \text{if } \phi_t \hat{m}_t < p_t^* \\ q^* & \text{otherwise} \end{cases} \tag{4}$$

where p_t^* is the minimum payment that gets q^*, and $v_t(q)$ is a strictly increasing function with $v_t(0) = 0$ and $v_t(q^*) = p_t^*$. They also show different v's correspond to various bargaining solutions, perfectly or imperfectly competitive pricing, and more exotic mechanisms. A simple example is Kalai's (1977) proportional bargaining solution, $v(q) = \theta c(q) + (1-\theta) u(q)$.

While we study special cases below, for now nothing about the mechanism is used except (4), plus the assumption that $v(q)$ is stationary and almost-everywhere twice differentiable. Stationarity of $v(q)$ 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, allowing us to focus on the impact of news. Now using the linearity of $W_t(m_t)$, we write buyers' DM value function as

$$V_t(\hat{m}_t) = W_t(\hat{m}_t) + \alpha [u(q_t) - v(q_t)], \tag{5}$$

where the first term is the default payoff and the second the expected surplus from trade. From (4), notice $\partial q_t / \partial \hat{m}_t = \phi_t / v'(q_t)$ if $\phi_t \hat{m}_t < p^*$ and $\partial q_t / \partial \hat{m}_t = 0$ otherwise. Given this, differentiate (5) and use (3) to get the Euler equation

$$\phi_{t-1} = \beta \phi_t \left\{ 1 + \alpha \left[\frac{u'(q_t)}{v'(q_t)} - 1 \right] \right\}. \tag{6}$$

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 $1 + r_t = 1/\beta$ in the benchmark model. Thus, i_t and r_t are returns in the CM that agents require to give up a unit of m or x in the previous CM, and such trades can be priced whether or not they occur in equilibrium. With this notation (6) reduces to

$$\frac{u'(q_t)}{v'(q_t)} - 1 = \frac{i_t}{\alpha}. \tag{7}$$

Gu and Wright (2016) show the q_t solving (7) is generically unique and strictly 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 if in the latter case this does not exhaust the money supply, the excess is held by sellers, since $i_t = 0$ is the above-mentioned exceptional situation where they are willing to carry cash out of the CM.

It is also convenient to denote real balances by $z_t \equiv \phi_t M_t$, and eliminate $q = v^{-1}(z)$, to write the demand for real balances as:[6]

$$L(z_t) \equiv \begin{cases} \dfrac{u' \circ v^{-1}(z_t)}{v' \circ v^{-1}(z_t)} - 1 & \text{if } z_t < v(q_0) \\ 0 & \text{otherwise} \end{cases} \tag{8}$$

Note $L(z_t)$ is the Lagrange multiplier on $p_t \leq z_t$, or the liquidity premium. Whatever one calls it, we multiply the LHS of (6) by M_{t-1} and the RHS by $M_t/(1+\mu_t)$, then use (8) to arrive at a forward-looking difference equation

$$z_{t-1} = f_t(z) \equiv \frac{\beta z [1 + \alpha L(z)]}{1 + \mu_t}. \tag{9}$$

A *monetary equilibrium* is a path $z_t > 0$ satisfying (9) and $\beta^t z_t \to 0$, the latter being a standard TVC (transversality condition) as discussed, e.g., in Rocheteau and Wright (2013). From z_t we get $q_t = v^{-1}(z_t)$, $\phi_t = z_t/M_t$, $1 + i_t = \phi_{t-1}/\phi_t\beta$ and other variables of interest.

If $\mu_t = \mu$ is time invariant then so is $f_t(z) = f(z)$ and we define *stationary monetary equilibrium*, or SME, as a steady state $\bar{z} = f(\bar{z}) > 0$. As completely standard, for SME 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 $i = \alpha L(\bar{z})$, where RHS is the expected marginal benefit of liquidity and the LHS is the cost. From this standard results follow: (a) SME exists iff $i < \hat{\imath}$, where $\hat{\imath} > 0$ under mild conditions; (b) it is generically unique; (c) $\bar{z} \leq v(q_0)$; and (d) $\bar{z} < v(q_0) \Rightarrow \partial \bar{z}/\partial i < 0$.[7]

In what follows, the plan is to go beyond these standard results by analyzing transitions after news at t_0 about events at $t_1 > t_0$, given we are in SME before

[6] Note that market demand is single valued even in the nongeneric situation where individual demand is not, because agents can randomize if there are multiple solutions to (7). See Gu and Wright (2016) for details

[7] Since $L(z) = 0 < i \; \forall z > v(q_0)$, SME exists if $L(0) > i$. With Kalai bargaining, one can show $L'(z) < 0$ and $L(0) = \theta/(1-\theta)$ under standard Inada conditions, so existence obtains iff $i < \hat{\imath} = \alpha L(0)$, where $\hat{\imath} < \infty \; \forall \theta < 1$ and $\hat{\imath} > 0 \; \forall \theta > 0$. With Nash bargaining, one can show $L(0) = \infty \; \forall \theta > 0$, and so $\hat{\imath} = \infty$ under standard Inada conditions. A minimal assumption to guarantee $\hat{\imath} > 0$ is $u(q) > v(q)$ for some q (ruling out $\theta = 0$ in the above examples). One can also show generic uniqueness even if $L(z)$ is not monotone. Hu et al. (2007) show how to design mechanisms that imply $q = q^*$ for $i > 0$ as long as i is not too big; if i is too big then $q < q^*$ for any reasonable mechanism. See Gu and Wright (2016) for details.

t_0 and after t_1. Again, this is distinct from self-fulfilling dynamic prophecies that can exist in this and many other monetary models. While we are not averse to these kinds of dynamics, the goal here is to see how far we can go with the discipline of imposing stationarity for fixed parameters. What we will show is that the transition is unique, but even with discipline, it can be complex, and changes qualitatively as parameters vary.

3 Transitions from News

Consider as a most rudimentary example a one-time level increase in M. Initially everyone takes μ as fixed, the economy is in its unique SME, and let us suppose $\bar{z} < v(q_0)$, as is usually the case for $i > 0$ (see fn. 7); this simply means agents are not satiated in liquidity. Then at some date normalized to $t = 0$ it is announced – and, obviously crucially, believed – that μ will change at $t = T \geq 0$ to $\mu' > \mu$, then revert to $\mu_t = \mu \; \forall t > T$. As discussed above, we assume the economy goes back to the unique SME after T. What is the reaction to the news? In the special case $T = 0$, which means a complete surprise, the reaction is not very exciting: ϕ jumps with the M change to leave $z = \phi M$ and all other real variables the same. This is classical neutrality.[8]

Now consider $T > 0$, so the injection is anticipated. Upon implementation at T we settle into SME at $\bar{z} < v(q_0)$. Starting the induction using (9) and $\mu_T = \mu' > 0$, at the penultimate point in the transition, we have

$$z_{T-1} = \frac{\beta z_T \left[1 + \alpha L(z_T)\right]}{1 + \mu'} = \frac{(1 + \mu)\bar{z}}{1 + \mu'} < \bar{z}. \tag{10}$$

At the antepenultimate point, z_{T-2} is again described by (9), and so on back to $t = 0$. From the z_t path we get the paths for q_t, ϕ_t and i_t. Notice that $\bar{z} < v(q_0)$

[8]Exact neutrality holds if the surprise transfer occurs after agents have adjusted m to $\hat{m}$ (say, at the start of the DM) since then all buyers are the same. If the transfer occurs before m is adjusted, however, there is a distributional effect, but it only lasts one period and only affects individual leisure. This is due to quasi-linear utility, but our goal is to show certain results are possible, and if we get can interesting news effects with special preferences a fortiori we can get them with general preferences. See Martin (2012, 2013) for more discussion.

in SME does not mean $z_t < v(q_0)$ along the entire path; for some t it could be that $z_t > v(q_0)$, at which point q_t hits its upper bound q_0 and i_t hits its lower bound 0, as liquidity is not scarce that period.

The left column of Figure 3 shows $f(z)$. In general, we know $f(0) = 0$, $f(z) = \beta z/(1+\mu)$ is linear $\forall z > v(q_0)$, and $\bar{z} = f(\bar{z}) > 0$ is unique. As the rows indicate, $f'(\bar{z}) > 0$, $f'(\bar{z}) \in (-1, 0)$ and $f'(\bar{z}) < -1$ are all possible. In each case transitions are shown for $T = 5$, constructed as follows: start with $z_5 = \bar{z}$ and use (10) to get $z_4 < z_5$; locate z_4 on the horizontal axis and use $f(z)$ to get z_3, z_2 and z_1 (for news further in advance, keep iterating). The arrows show time moving backward from $t = T$ to 0; the paths in real time are shown in the right column. In the first row, with $f'(\bar{z}) > 0$, z_t falls monotonically until T, then jumps back to $\bar{z}$. In the second row, with $f'(\bar{z}) \in (-1, 0)$, z_t displays increasing oscillations before finishing up at $\bar{z}$. In the third row, with $f'(\bar{z}) < -1$, z_t displays decreasing oscillations. The fourth row is the same as the third, except that it uses a larger μ'. That makes z_t stray further from $\bar{z}$, and that makes z_t stay on the linear branch longer, increasing from $t = 1$ to 3, before crashing at 4 and recovering at 5.

We conclude that responses to information innovations about simple events can be complicated, and highly dependent on parameters, despite being anchored by a fixed terminal condition $z_T = \bar{z}$. This is true even though the policy here is neutral in the standard sense that surprise changes in M, corresponding to the usual comparative static exercises, have no real effect (we consider nonneutral changes below). Intuitively, when the injection happens, sellers know the value of money is lower but buyers have more of it; in the period before, sellers know the value of money will be lower the next time they can use it, but buyers do not yet have more of it. In other words the currency is effectively debased before being injected. Then, at $t = T-2, T-3...$ real balances can move in various ways due to the nonlinear and potentially nonmonotone nature of liquidity.

To understand this better, observe that $f(z)$ has an increasing linear term $\beta z/(1+\mu)$ representing the value of money as a savings vehicle, plus a nonlinear term $\beta\alpha z L(z)/(1+\mu)$ that tends to decrease with z. Heuristically, when the value of money is falling liquidity will soon be scarce, propping up current currency demand, and when the value of money is rising liquidity will soon be plentiful, depressing current demand. This can yield oscillations when it dominates the linear term.[9] However, while cyclic patterns induced by information revelation are relevant because they show how announcements can exacerbate rather than ameliorate volatility, they are not our exclusive focus – the slow decline and rapid recovery in the top row of Figure 3 is also interesting.

4 Simple Experiments in the Baseline Model

Given the economic intuition developed above, the next step is to consider numerical examples. Consider as a benchmark

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

with $\sigma \geq 0$, $A > 0$, $\gamma > 0$ and $b \geq 0$. While $b = 0$ is CRRA utility, we allow $b > 0$ so that $u(0) = 0$ even if $\gamma > 1$. As a benchmark we use $\sigma = 0$, $A = 1$, $b = 0.1$, and three values of γ, $\gamma_L = 0.5$, $\gamma_M = 4$ and $\gamma_H = 8$, to get $f'(\bar{z}) > 0$, $f'(\bar{z}) \in (0, -1)$ and $-1 > f'(\bar{z})$. Other period lengths are considered, but 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. Buyers' DM trading probability is $\alpha = 0.5$. The mechanism is usually $v(q) = c(q)$, which again follows from bargaining with $\theta = 1$, and from competitive pricing with $\sigma = 0$. The Appendix summarizes the parameters for

[9] This story is not new. As in other dynamical systems, $f'(\bar{z}) < 0$ implies nonmonotone z paths, $f'(\bar{z}) < -1$ implies two-cycles where $z_2 = f(z_1)$ and $z_1 = f(z_2)$, with $z_2 > \bar{z} > z_1$; and further decreases in $f'(\bar{z})$ imply cycles of higher order, chaos, and sunspot equilibria (e.g., Azariadis 1993). While we do not consider dynamics due to self-fulfilling prophecies in this paper, the intuition behind a nonlinear or nonmonotone liquidity premium is similar to papers that do (e.g., Rocheteau and Wright 2013, Gu et al. 2013b and references therein). The novelty in this paper is that we apply the logic to transitions generated by news shocks.

all experiments. While they are not calibrated, and set mainly for the sake of illustration, the values are arguably very reasonable.[10]

The first experiment is a temporary change from μ to μ' that generates a 1% jump in M at $t = T$ over its value along the path with μ fixed, announced at $t = 0$. This is shown in the left column of Figure 4, where the three rows are for the different values of γ, and $T = 12$ (months) between the announcement and implementation; for shorter durations simply start at $t \in (0, T)$. Shown are liquidity z_t and welfare S_t measured by the DM surplus, which is equivalent to a change in consumption of numeraire x that affects payoffs the same, normalizing $\bar{z} = \bar{S} = 1$. To get a feel for the magnitudes, z_t and S_t both change roughly 1% at their peak over the transitions. These numerical results are in line with the analytics shown in Figure 3, but it is useful to see how they play out with reasonable parameters. What we see is this: for a policy change that is neutral in the long-run, and in the short run if it is a surprise, news about an upcoming change is not neutral and the effects are not quantitatively trivial.

While the responses are different in the three rows, there is always a sizable jump in z_t from $T - 1$ to T, because the cash is injected at T but the price level already increased at $T - 1$. In other words, increasing the nominal currency stock at T increases liquidity at T, as predicted by many macroeconomics textbooks and policy commentators, and as mentioned above it does not matter here, by design, how if we increase M. This looks like a quantitatively significant failure of the quantity theory, but it is important to emphasize why this happens – it is *not because prices are sticky* when M is injected, it is *because prices already changed.* Without understanding this, a naive observer seeing a jump in M at T leading to

[10] 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 if anything conservative. As is well know, bigger elasticities and nonlinearities arise for, e.g., Nash bargaining with $\theta < 1$. Also, while the results below are independent of CM utility, it is standard to use $\log x - B\ell$, so that $x^* = 1$ (a normalization), and B can be set to match average labor hours. For more on calibrating or estimating similar models, e.g., see Aruoba (2011), Aruoba and Schorfheide (2011) and Aruoba et al. (2011).

a jump in real balances and output, but not prices, could understandably jump to the wrong conclusion.

We are not wed to neutral policies. The right column of Figure 4 depicts a permanent change in μ that raises inflation, from 5% to 6%, which lowers $\bar{z}$ and $\bar{S}$. This is perhaps closer to actual practice: the central bank announces at $t = 0$ a higher nominal rate i starting at $T > 0$, which ultimately requires a higher μ by the no-arbitrage condition underlying the Fisher equation. Here we let market equilibrium determine the endogenous variables, including i, between 0 and T, while in Section 7.2 we peg i during the transition, not just in the long run, but both experiments seem interesting. Notice the variations in z_t and S_t are smaller than in the left column, because an injection that increases M between $T - 1$ and T 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 that z_t does not stray as far from $\bar{z}$, and hence the economy spends less time on the linear branch of $f(z)$. Still, the overall conclusions are similar: news about nonneutral policy can also generate complicated effects that depend a lot on parameter values.

To further investigate how magnitudes matter Figure 5 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 to before, but there is a difference worth emphasizing: in the bottom left of Figure 5, S_t is above its SME level at $t = 10$, which did happen in the previous experiments. Hence if the timing is just right, we can increase welfare by announcing a one-time cash injection even though this generates volatility – or, to be more accurate, because it generates volatility. To see this, first note that inflation is harmful since it taxes DM trade. The example shows a gradual inflation might be worse than an erratic price path because the latter has higher DM output at least in its deflationary phases.

That does not happen when z_t falls monotonically before jumping back to $\bar{z}$, as in the top rows of Figures 4-5. In those cases the welfare loss is minimized by revealing a plan to increase M as late as possible. Symmetrically, in those cases the welfare gain is maximized by revealing a plan to decrease M as soon as possible. This may sound like a general principle – if one is going to do something good (bad), tell people (keep it to oneself) – but in fact it is not general: in the bottom left of Figure 5 it is better to announce at $t < T$ that M will increase at T. Since that is true for policy that is neutral in the long run, it can be true for policies that are somewhat bad in the long run. Now it may well be impractical in reality to know the parameters exactly and to get the timing just right, but this is at least an example of how it could work in theory. Also, to be clear, this discussion does not reflect myopia: S_t measures discounted life-time utility under perfect foresight $\forall t > 0$.

Figure 6 reports the effects of a temporary increase in μ with β reset to quarterly (left) and daily (right) periods. The transitions are similar in the quarterly and monthly models, but there is less volatility in the daily model, presumably 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 do so 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 can matter, but the general idea is robust. Before pursuing other experiments, let us catalogue a few results, as we do throughout the presentation, to keep track of the many applications and extensions.

Lesson 1: *Monetary policy announcements can induce intricate dynamics before implementation. This is true whether the policy is neutral or nonneutral in the usual sense. For longer periods or smaller changes, news is more likely to generate oscillations. News-induced volatility can improve welfare, but that depends delicately on the timing and parameter values.*

5 Other Experiments in the Baseline Model

As a slightly more complicated but very relevant application, consider QE (quantitative easing). The idea is not to contemplate central banks trading in mortgage-backed securities or long-term debt, as opposed to T-bills. The idea instead is to capture a monetary injection with a promise to undo it later. Thus, announce at $t = 0$ that at $T_1 \geq 0$ there will be an increase in M, then at $T_2 > T_1$ there will be an offsetting decrease. As a special case, $T_1 = 0$ means the announcement and initial injection occur simultaneously. Assuming as usual that we return to SME, backward induction pins down 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. Symmetrically, $z_{T_1-1} < \bar{z}$ 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 7 shows results with $T_1 = 0$, so the initial injection is a surprise, but the future extraction is announced and, crucially, believed. Observe the initial injection does not increase prices in proportion, so z_t increases. In the top row, e.g., liquidity z_t and welfare S_t jump up at the news, then the former continues to rise while the latter falls until T_2 when we implement our exit strategy. This makes QE look pretty good, with liquidity, output and welfare all rising, but it is important to understand why. The beneficial effects come from a commitment to withdraw M at T_2; the injection at T_1 is neutral without restrictions on nominal price adjustment that we do not impose.

The right column of Figure 7 shows $T_1 > 0$, so the initial injection is not a complete surprise. In the top row the outcome is not as good as in the left column: it takes S_t a while to reach its peak at T_1, and z_t first falls before starting to rise at T_1. Consistent with Section 4, the middle and bottom rows display complicated paths as announcements accentuate rather than attenuate volatility. But in all cases, a key point is that there is no obvious impact on trend inflation starting at T_1. It is key because many people find it remarkable that

QE's increases in the money supply did not raise prices much – indeed, Feldstein (2015) dubs this *The Inflation Puzzle*.[11] It is a puzzle presumably because it ostensibly flies in the face of the quantity theory. Even though the quantity theory holds by construction here, it is not easy to see it in the simulations when so much depends on announcements and anticipations.

The QE application has two announcements occurring simultaneously. What if they are staggered? Suppose at t_1 agents hear that at T_1 there will be a one-period change to μ' but otherwise it's business as usual; then at $t_2 < T_1$ they hear that instead of the change at T_1 there will be a one-period change to μ'' at T_2. This is shown in the left column of Figure 8.[12] In the top chart, with $f' > 0$, liquidity falls at the first announcement, jumps at the second with a direction and size that depend on the μ's and the timing, and then falls again until recovering to $\bar{z}$. Thus, with multiple announcements, we do not need $f'(\bar{z}) < 0$ to generate cyclic transitions, although $f'(\bar{z}) < 0$ implies z_t also fluctuates between announcement dates, as in the middle and bottom rows. As a general message, it is no surprise that markets follow circuitous paths as information filters in over time.

As a twist on the above experiments, and to address a potential concern with them, suppose now that $\mu_t \sim G_t(\mu)$ is a stochastic process, with μ_t realized in the CM at t. Letting $z_t = \hat{m}_t \mathbb{E}_t \phi_t$, in this application, it is standard to show the DM liquidity constraint is still $v(q_t) \leq z_t$ and the generalization of (9) is

$$z_{t-1} = f_t(z_t) = \beta z_t \left[1 + \alpha L(z_t)\right] \mathbb{E}_t \left(\frac{1}{1+\mu_t}\right). \tag{11}$$

[11] As regards the proverbial man on the street, at least Wall Street, consider: "In speaking with investors I hear time and time again that the Fed's relentless printing of money is increasing the supply of dollars, which will result in massive inflation, if not hyperinflation." (Kerkhoff 2013). Similarly, consider: "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." (Hayes 2016).

[12] The experiment uses $t_1 = 0$, $t_2 = 4$, $T_1 = 8$, $T_2 = 12$, $\mu' = 0.0191$ and $\mu'' = 0.0091$. To get the transition, construct two sequences from (9), one with $z_{T_1-1} = \bar{z}(1+\mu)/(1+\mu')$ and the other with $z_{T_2-1} = \bar{z}(1+\mu)/(1+\mu'')$. Between $t = t_1 + 1$ to t_2, z_t comes from the first sequence; between $t = t_2 + 1$ to $T_2 - 1$ it comes from the second.

If agents initially believe $G_t(\mu) = G(\mu)\ \forall t$ then $z_t = \bar{z}$ is constant. Now suppose news arrives at $t = 0$ that μ_T will be drawn from a different distribution. If $\mathbb{E}(1/1 + \mu_T)$ changes then z_t follows a path implied by (11), as in the baseline model. As a special case, the news can be that $\mu_T = \mu'$ will take a particular value in the support of μ. This is different from the earlier experiments, where μ' was not in the support of the original belief distribution (agents took $\mu \neq \mu'$ to be constant with probability 1). Whether or not this is a concern, the methods and insights are basically the same.

We can also easily accommodate cases where agents know at $t < 0$ 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 announcement is coming. Hence, without loss of generality we usually assume the announcement itself, and not just its content, is unexpected. An example is shown in the right column of Figure 8, 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 $\mu_T = 0.615\%$ with probability 1. The transition is similar to earlier results, but it is good to know we can easily extend the approach to stochastic economies.

Lesson 2*: Multiple and staggered announcements can induce even more intricate dynamics. This is true when news is a value of μ not in the support of prior beliefs, or a particular realization of μ from a stochastic process. Apropos QE, news of future decreases in M temper the effects of current increases. While QE can produce desirable results, they come mainly from the future decrease and not the initial increase in M.*

6 Other Assets

The next step is to consider real assets, multiple currencies and residential capital. While similar extensions of the baseline model already appear in the literature, we consider the effects of news motivated by substantive economic issues.

6.1 Equity Markets

Following Geromichalos et al. (2007), consider introducing a real asset in fixed supply normalized to 1 unit per buyer. Its price is ψ_t and it bears a dividend $\rho_t > 0$, both in terms of CM numeraire. As in Lucas' (1978) standard equity-pricing model, ρ_t is productivity measured as output per asset. We begin without fiat money and re-introduce it below. The buyers' CM problem is then similar, except a replaces m as the state, and the budget equation becomes

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

Also, following Kiyotaki and Moore (1997), we introduce a pledgeability parameter $\chi \leq 1$, meaning that buyers can only use a fraction χ of their assets in DM transactions. While $\chi = 1$ works fine, we allow $\chi < 1$ to make contact with the literature on secured credit.

To be clear about this, many papers interpret pledgeability in terms of limited commitment, so credit (here, between the DM and CM) must be secured by $\hat{a}$, and defaulters can abscond with a fraction $1 - \chi$ of the collateral. But the equations are the same whether $\hat{a}$ serves as collateral or a medium of exchange as long as sellers only accept a fraction. Also note that χ can be endogenized using information frictions as in Li et al. (2012). Rather than absconding with $\hat{a}$, they let buyers produce low-quality versions, e.g., counterfeits, that are hard for sellers to detect, and show it is an equilibrium outcome that buyers holding $\hat{a}$ can only use a fraction $\chi\hat{a}$ in the DM, either as a means of payment in spot trade, or as collateral in support of settlement deferred to the CM.

Given this, a buyer's DM liquidity is $z_t = \chi \hat{a}_t(\psi_t + \rho_t)$, as this is the most value he can pay/pledge to a seller. Different from fiat currency, $p_t \leq z_t$ does not necessarily bind for real assets, but we can still mimic the methods in the baseline model to get the analog of (9)

$$z_{t-1} = f_t(z) \equiv \beta z \left[1 + \alpha\chi L(z)\right] + \chi\rho_{t-1}. \tag{12}$$

Equilibrium is a path $z_t > 0$ satisfying (12) and TVC. If $\rho_t = \rho\ \forall t$ then SME solves $\bar{z} = f(\bar{z})$, from which we get $\bar{q}$ and $\bar{\psi}$. SME is unique, but now its properties 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 the asset's fundamental price; if $\rho < \rho_0$ then $\bar{q} < q_0$ and $\bar{\psi} > \psi_0$.[13]

Now suppose at $t = 0$ agents become aware there will be a one-time drop to $\rho' < \rho$ at $t = T$. By (12), we are back in SME at $T+1$, but $z_T = z_{T+1} - \rho + \rho' < z_{T+1}$. Then iterate on (12) to get the rest of the path. If $\rho, \rho' > \rho_0$, so liquidity considerations are inoperative and assets are priced fundamentally, then z_t falls monotonically during the transition. If $\rho < \rho_0$, however, liquidity effects come into play and the transition path can be quite complicated. This is not shown, but with $\rho' = 0.8\rho$, which is bad news in the same way $\mu' > \mu$ is bad news with fiat money, the results are virtually the same as Figure 4. Hence, when real assets convey liquidity. news about productivity/dividends can generate paths similar to news about monetary policy in the benchmark model, with this caveat: changes in ρ are never neutral, and the DM surplus S_t is not a true measure of welfare, since ρ affects CM payoffs.

Having established this, let us combine fiat currency and real assets, so that the CM budget equation becomes

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

In Geromichalos et al. (2007), m and a are perfect substitutes in the DM. This means there is an essential role for currency iff $\rho < \rho_0$, since then the liquidity embodied in real assets is scarce, but m and a must have the same return. In a

[13] Since the model with $\rho > 0$ may be less well known, here are a few details: First, $f(0) > 0$ implies the analog of the nonmonetary equilibrium that always exists with fiat money does not exist with $\rho > 0$. Second, if $f'(\bar{z}) > -1$, we can show as in He and Wright (2016) that equilibrium and not only steady state is unique, making it all the more clear that our results do not rely on multiplicity. However, if $f'(\bar{z}) < -1$, there is still a unique SME but there are also cyclic equilibra as mentioned in fn. 9. Third, as in Han et al. (2016) we can let $\rho < 0$ and still have equilibria with the asset valued, for its liquidity, iff $|\rho|$ is not too big. Fourth, when the liquidity constraint binds, $\bar{z}$ and $\bar{q}$ are increasing in ρ and χ, the but effects on $\bar{\psi}$ are ambiguous, illustrating another nonmonotonicity associated with liquidity.

generalization by Lester et al. (2012), a and m are imperfect substitutes because they 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; α_b is the probability of meeting one who accepts both; and buyers do not know who they will meet until the CM has closed. Lester et al. (2012) also endogenize the α's using private information, similar to the way Li et al. (2012) endogenize the χ's, but for these experiments we take them as given.

Consider the special but natural specification $\alpha_a = 0$ 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 $z_t^b = z_t^m + z_t^a$. Generalizing the previous analyses, the Euler equations for $\hat{m}$ and $\hat{a}$ now yield a two-dimensional system:

$$z_{t-1}^m = \frac{\beta z_t^m \left[1 + \alpha_m L(z_t^m) + \alpha_b L\left(z_t^b\right)\right]}{1+\mu_t} \tag{13}$$

$$z_{t-1}^a = \beta z_t^a \left[1 + \chi \alpha_b L\left(z_t^b\right)\right] + \chi \rho_{t-1} \tag{14}$$

Also, let q_t^j be the quantity traded in type-j DM meetings. In SME, in type-m meetings the constraint $v\left(\bar{q}^m\right) \leq \bar{z}^m$ binds for standard mechanisms like price taking or bargaining, and hence $\bar{q}^m < q_0$. In type-b meetings, ρ small implies $v\left(\bar{q}^b\right) \leq \bar{z}^b$ binds, so $\bar{q}^b < q_0$ and $\psi > \psi_0$, while ρ big implies $v\left(\bar{q}^b\right) \leq \bar{z}^b$ is slack, so $\bar{q}^b = q_0$ and $\psi = \psi_0$.

Consider news at $t = 0$ of a one-time increase in μ at T. If ρ is big, so the liquidity embodied in a is abundant, z_t^a may not be affected. If ρ is smaller, so the liquidity embodied in a is relatively scarce, z_t^m and z_t^a are both affected along the transition. Figure 9 is drawn for a 1% one-time increase in M_T, with z_t^m and z_t^a in the left column and z_t^b and S_t in the right, normalized so $\bar{z}^m = \bar{z}^a = 1$ (the asset price ψ_t is not shown, but it moves in sync with z_t^a for a given ρ_t). For the parameters shown, $\bar{q}^b < q_0$ and $\bar{\psi} > \psi_0$. The transitions for z_t^m and S_t are similar to the baseline model, except now policy news affects the real asset market. In the top row there is an initial jump in z_t^a (and hence ψ_t) as agents compete for other assets to compensate for the drop in z_t^m, then both decline until z_t^a reaches $\bar{z}^a$ and z_t^m jumps back to $\bar{z}^m$ after bottoming out. The other rows are similar but display oscillations, with the bottom row especially volatile.

In a stylized way, this corresponds to equity markets responding to news about monetary policy, one of our main motivating observations. News about a one-time fall in ρ (not shown) looks similar to Figure 9 with the patterns in z_t^m and z_t^a reversed. So not only does news about μ affect z^a, news about ρ affects z^m.

Lesson 3: *Without money, when liquidity is scarce productivity news can induce intricate dynamics in prices and output. With money, productivity or monetary policy news can induce intricate dynamics in prices and output. This is true whether the policy is neutral or nonneutral, and whether assets are used as payment instruments or collateral in deferred settlement.*

6.2 Exchange Rates

Another motivating observation is that Fed announcements affect exchange markets, as Rosa (2011b,2013) documents in more detail. Hence, following Zhang (2014) and references therein, consider two currencies m_1 and m_2, with prices ϕ^1 and ϕ^2 in terms of x. As with money and equity, a random seller in the DM accepts only currency j with probability α_j and accepts both with probability α_b, and we set $\chi_j = 1$. It is natural to imagine two countries, each with its own DM, where some sellers in country j accept the currency of country j' while others do not, say because they cannot recognize it.

With $z^b = z^1 + z^2$, the Euler equations now yield the system:

$$z_{t-1}^1 = \frac{\beta z_t^1 \left[1 + \alpha_1 L\left(z_t^1\right) + \alpha_b L(z_t^b)\right]}{1 + \mu_t^1} \tag{15}$$

$$z_{t-1}^2 = \frac{\beta z_t^2 \left[1 + \alpha_2 L\left(z_t^2\right) + \alpha_b L(z_t^b)\right]}{1 + \mu_t^2} \tag{16}$$

Equilibrium is defined in the obvious way.[14] In SME, for standard mechanisms agents are liquidity constrained in type-1 and type-2 meetings, but may or may

[14]Similar to money and equity, when $\alpha_1 = \alpha_2 = 0$ the two monies are perfect substitutes, so if both are valued their returns must be the same. In this case there exist a continuum of SME where the exchange rate is indeterminate (a generalization of Kareken and Wallace 1981), and there effectively is only one currency.

not be in type-b meetings. Hence, there are two possible cases: $\bar{z}^b < v(q_0)$ and $L\left(z_t^b\right) > 0$; or $\bar{z}^b \geq v(q_0)$ and $L\left(z_t^b\right) = 0$.

Figure 10 has news at $t = 0$ of a one-time jump in M_1 at T for parameters such that $L\left(z_t^b\right) > 0\ \forall t$. At the announcement, the news immediately depreciates M_1 against M_2, then both follow transitions back to the original SME. In this example α_1 and α_2 are small compared to α_b, so the two monies are close to perfect substitutes; alternative parameterizations display quite different patterns. We also tried permanent changes in μ_j, and changes in ρ after re-introducing real assets, but this should suffice to make the point.

Lesson 4: *News about monetary policy or real factors in one country can induce dynamics in both countries' prices, output, interest and exchange rates. This is true whether policy is neutral or nonneutral.*

6.3 Housing

As in He et al. (2015), consider a version with housing, h_t, where in addition to providing direct utility, houses are used to secure home-equity loans or lines of credit. For simplicity, we use the version of their model where buyers get direct credit from sellers by pledging home equity, instead of the more realistic one where they get cash loans from banks and use those to buy DM goods.[15]

The buyer's CM problem becomes

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

where η_t is the price of housing. 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. Also, while having an endogenous housing

[15] Integrating housing and money may be interesting for its own sake, since it is commonly thought that monetary polcy has an impact on housing markets; it is also useful in Section 7 when we analyze alternative policy rules. Also, our remarks about the equations being the same whether assets are used as media of exchange or collateral still apply, but it is obviously less natural to imagine a buyer turning over part of his house in a spot trade.

supply is feasible and interesting, it complicates matters slightly by adding one more equation. So assume for the sake of illustration that supply is fixed at $h_t = 1$.

Assume the probability a buyer meets a seller who accepts only m is α_m and the probability he meets one who accepts both is α_b. Then equilibrium is defined in the obvious way, and the Euler equations for $\hat{h}_{t+1}$ and $\hat{m}_{t+1}$ lead to:

$$z_{t-1}^m = \frac{\beta z_t^m \left[1 + \alpha_m L(z_t^m) + \alpha_b L\left(z_t^b\right)\right]}{1+\mu_t} \tag{17}$$

$$z_{t-1}^h = \beta z_t^h \left[1 + \chi_h \alpha_b L\left(z_t^b\right)\right] + \beta \chi_h U_2 \left[X(1), 1\right] \tag{18}$$

As in Section 6.1, in type-m meetings, the constraint $v(\bar{q}^m) \leq \bar{z}^m$ binds in SME and hence $\bar{q}^m < q_0$. In type-b meetings, if $\chi_h U_2 [x(1), 1]/r > v(q_0)$ the constraint does not bind, so we have $\bar{q}^b = q_0$ and housing is priced fundamentally at $\eta = U_2 [x(1), 1]/r$; otherwise we have $\bar{q}^b < q_0$ and $\eta > U_2 [x(1), 1]/r$.

Suppose agents initially believe $\mu_t = \mu \ \forall t$, and announce at $t = 0$ a one-period increase to μ' at T. Figure 11 shows the results for parameters such that the constraints bind in all DM meetings, using $U(x_t, h_t) = x_t^\delta h_t^{1-\delta}$. For a 1% increase in μ, for different parameters, the news can lead to a jump in house prices with a long monotone correction, or to a slower rise with varying degrees of cyclicality, followed by a late surge and then a crash back to the original state. One can also consider permanent changes with similar results. As discussed in He et al. (2015) and references therein, some people argue that policy should have increased nominal rates during the house-price boom to dampen demand. As this experiment shows, simply announcing such a policy can lead to booms, crashes and cycles.

Lesson 5: *When liquidity is scarce and housing can be used as collateral, monetary policy or productivity news can induce intricate dynamics in house prices, including booms, crashes and cycles, as well as goods prices and output. This is true whether policy is neutral or nonneutral.*

7 Other Extensions

Here we consider other contexts in which news might matter, including unsecured credit markets, as well as alternative specifications for policy.

7.1 Unsecured Credit

In Kehoe and Levine (1993), Alvarez and Jermann (2000) and much related work on credit with limited commitment, defaulters are punished by taking away their future credit (as opposed to taking away their assets as in Kiyotaki and Moore 1997). Here we present the version of Kehoe and Levine (1993) in Gu et al. (2013a,b) to facilitate comparison to our baseline monetary model. In this version, 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; other 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 for a unit 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 of the model), where α is the meeting probability of a debtor. Given preferences and technology, a desirable arrangement is for a creditor to produce X for a debtor in the first subperiod, in exchange for a promise that a debtor will deliver RY in the second. Although this can be generalized, for simplicity let the payoff from the arrangement be $RY - c(X)$ for the creditor, and $u(X) - Y$ for the debtor if he does not consume any of his own output. To parameterize the incentive problem, assume that there is limited commitment, and that a debtor can get extra utility λRY if he consumes RY units of his own output; $\lambda = 0$ implies a debtor's promise to deliver the goods is more credible, as his production cost is sunk, but if $\lambda > 0$ he may be tempted to renege.

Assume $\lambda R < 1$, so that it is not in a debtor's interest in the first subperiod to produce Y for his own consumption, but he may opportunistically consume it in the second subperiod, as in the "cash diversion" models of Biais et al. (2007) or Demarzo and Fishman (2007). If he does so, reneging on his promise, he gets caught (monitored or recorded) with probability π, and if caught he is punished by taking away future credit, which is equivalent to autarky, with a payoff normalized to 0.[16] The incentive condition at t for a debtor to honor his obligation, called the repayment constraint, is

$$\beta V_{t+1} \geq \lambda R_t Y_t + (1 - \pi_t) \beta V_{t+1}, \tag{19}$$

where V_{t+1} is the continuation value as long as he has never been caught reneging. 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*.

Gu et al. (2013b) show the outcome depends on the mechanism determining the terms of trade: complicated dynamics can emerge with Walrasian pricing, and with generalized Nash bargaining if $\theta < 1$ but not $\theta = 1$, and not with Kalai bargaining for any θ. For the sake of illustration consider Walrasian price taking (again, for this one may want to interpret meetings as multilateral). Then for a debtor, who has both a budget and a repayment constraint,

$$V_t = \max_{X_t, Y_t} \{\alpha [u(X_t) - Y_t] + \beta V_{t+1}\} \text{ st } P_t X_t = R_t Y_t \text{ and } R_t Y_t \leq D_t, \tag{20}$$

where P_t is the unit (Walrasian) price, and $p_t = P_t X_t$ is the total payment, as in the baseline model. 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 $X_t = g(D_t)$ when $D_t \leq P_t^*$ binds. Then use $D_t = \beta \pi_t V_{t+1}^b / \lambda$ and (20) to write

$$D_t = f(D_{t+1}) \equiv \beta \frac{\alpha \pi_t}{\lambda} S(D_{t+1}; R_{t+1}) + \beta \frac{\pi_t}{\pi_{t+1}} D_{t+1}, \tag{21}$$

[16] There are several reasons to have imperfect punishments (monitoring or record keeping), as captured by $\pi < 1$, including the fact that this is necessary for money to be essential in the model (see Proposition 5 in Gu et al. 2016, which is an extension of Kocherlakota 1998). We consider money below, but want to first see how news matters in a pure credit economy.

where a debtor's trade surplus is:

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

This is a standard recursive formulation of the endogenous debt limit, as in Alvarez and Jermann (2000) and Gu et al. (2013b), where one can find results on existence, uniqueness versus multiplicity, etc.

To consider news, suppose agents initially believe $\pi_t=\bar{\pi}$ and $R_t=\bar{R}\ \forall t$ and the economy is in steady state with $D=\bar{D}$, then they hear at $t=0$ that at $T>0$ for one period the monitoring probability π_T will be lower, making it harder to identify and punish defaulters. This implies $D_T<\bar{D}$, and the transition back to $t=0$ is determined by iterating on (21).[17] The left column of Figure 12 shows the results for parameters such that the debt limit binds. In the middle (bottom) row, e.g., news that credit conditions will deteriorate in the future sets off oscillations in D_t with increasing (decreasing) amplitude, before a recovery to $\bar{D}$. The right panel shows similar results for news about future productivity, in this case captured by a drop in R, for parameters such that the debt limit binds. In both experiments, along with D_t, the terms and amount of lending as well as output vary during the transition. Hence pure-credit economies, not only monetary economies, have interesting dynamics induced by information innovations.

Gu et al. (2016) and references therein argue that it is important to study interactions between money and credit. To this end, we integrate the key elements of our credit economy into the baseline money model. Assume buyers can produce

[17]Nonmonotone dynamics occur if $f'\left(\bar{D}\right)<0$, which is similar to our benchmark model, but the economics is different. In the benchmark, as discussed, it is due to the liquidity premium decreasing in liquidity. In the credit model, with Walrasian pricing it is due to competition raising the loan rate for buyers, reducing their surplus and tightening the current repayment constraint when future credit constraints are looser. Alternatively, with Nash bargaining and $\theta<1$ it is due to debtor's surplus decreasing when the debt limit is looser. This explains why there is no nonmonotonicity with Kalai bargaining: one of his axioms is that the surplus of both parties, not just the total surplus, must increase with the gains from trade. Indeed, it was the nonmonotonicity of generalized Nash bargaining that motivated Kalai's alternative axioms.

the CM numeraire x in DM meetings, but sellers have no use for it until the next CM, and only buyers can store it (at a return set to $R = 1$ here to ease notation). As in the pure-credit economy, buyers produce x in the DM and promise to deliver it to a seller in the CM, and such promises can be more credible if the production cost is sunk. But again we let buyers opportunistically divert a fraction λ of the produced good. This captures the main features of Kehoe-Levine credit in the benchmark environment, where money might still have a role.

The CM problem is

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

where d_t is debt and x_t^D is the good produced in the previous DM. Given any debt limit D_t, we have

$$V_t\left(\hat{m}_t\right) = \alpha\left[u\left(q_t\right) - p_t\right] + W_t\left(\hat{m}_t, 0, 0\right),$$

where $p_t = d_t + \phi_t \hat{m}_t$ and $d_t \leq \min\left\{D_t, x_t^D\right\}$. It is without loss of generality to set $x_t^D = d_t$, so the buyer is indifferent to producing d_t or more in the DM. This makes the CM problem is the same as (2).

The Euler equation for $\hat{m}_{t+1}$ leads to

$$z_{t-1} = f_t\left(D_t, z_t\right) \equiv \frac{\beta z_t\left[1 + \alpha L\left(D_t + z_t\right)\right]}{1 + \mu_t}. \tag{22}$$

When λ is time invariant, the repayment constraint in the CM is

$$W_t(m_t) \geq \lambda d_t + \left(1 - \pi_t\right) W_t\left(m_t\right) + \pi \phi_t m_t,$$

which reduces to

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

Emulating the analysis of the pure-credit model, we rewrite V_{t+1} using D_t as

$$D_t + \frac{\pi_t}{\lambda} z_t = \beta \frac{\alpha \pi_t}{\lambda} S\left(D_{t+1} + z_{t+1}\right) + \beta \frac{\pi_t}{\pi_{t+1}} D_{t+1} + \beta \frac{\pi_t}{\lambda} z_{t+1} \tag{23}$$

There is always a nonmonetary equilibrium, which reduces to a pure-credit model, and there can exist monetary equilibria. Focusing on the latter, transitions after news are complicated by the interactions between money and credit. Figure 13 shows the impact news about a one-time 1% increase in μ. The transition for z_t again displays intricate dynamics, depending on the parameters, and now news about monetary policy also induces dynamics in D_t. Similarly, news about changes in future credit conditions due to changes in π_t or R_t (not shown) can lead to dynamics in z_t as well as D_t. This is related to Section 6, where assets and cash are also substitutes in the payment process, like money and credit, but there is a difference: here news that leads to lower D_t tends to increase z_t, as agents substitute across payment methods; but news that leads to lower z_t tends to decrease D_t. The latter effect occurs because lower z_t reduces equilibrium payoffs, which tightens the debt limit for some, if not all, parameters. In particular, real credit conditions – the amount and terms or lending – can depend in complicated ways on news about changes in monetary policy even if the changes are neutral in the usual sense.[18]

Lesson 6: *Without money, news about credit conditions or productivity can induce intricate dynamics in debt limits, the amount and terms of lending, goods prices and output. With money, news about monetary policy or credit conditions can induce dynamics in these variables whether or not policy is neutral. Bad news about money tends to hurt credit markets, while bad news about credit conditions tends to boost the value of money.*

7.2 Interest Rate Targeting

The experiments presented above can be interpreted as changes in the money growth rate target. In the long run, this is the same as targeting the inflation

[18] There are some subtleties here. Gu et al. (2016) prove that changes in credit conditions are actually neutral in steady state equilibrium, because real money balances adjust endogenously to leave total liquidity the same, but that result does not apply to equilibrium transitions.

rate, since ϕ_t falls at the same rate that M_t grows, or the nominal interest rate, since $1 + i_t = \phi_t/\beta\phi_{t+1}$. It is not the same in the short run, since ϕ_t varies over time for a fixed μ_t during transitions, and although the Fisher equation always holds, the same is true for i_t during transitions. One interpretation is that the central bank announces at $t = 0$ a temporary or permanent change in μ_t at T to determine i_t in the long run, but lets the market determine ϕ_t and i_t in the short run. What if instead we peg the nominal rate at every date and let M_t adjust endogenously? The results can be quite different. From (7) and (8), z_t and q_t are pinned down by i_t at every date. Hence, if we announce at $t = 0$ that i_t will remain fixed between now and $T > 0$, then change, z_t and q_t remain fixed during the transition and only react when i_t actually changes.[19]

However, with multiple assets news can still have significant effects. With money and real assets, e.g., under interest rate targeting (13)-(14) become as

$$i_t = \alpha_m L(z_t^m) + \alpha_b L\left(z_t^b\right) \tag{24}$$

$$z_{t-1}^a = \beta z_t^a\left[1 + \chi\alpha_b L\left(z_t^b\right)\right] + \chi\rho_{t-1} \tag{25}$$

Suppose $i_t = i\ \forall t \neq T$ and $i_T > i$. Assuming we are back in SME $T + 1$, as always, $z_T^a = \bar{z}^a$ and $z_T^m < \bar{z}^m$, and we can iterate on (24)-(25) to generate a nontrivial transition after monetary policy news. Figure 14 shows the case where $i_T = 0.0182$ and $i_t = 0.0082$ for $t \neq T$, corresponding to an increase in μ from 0.0041 to 0.0141 in steady state. This generate a boom in the stock market z_t^a when the news is released at $t = 0$, followed by a bust back to the original steady state. Notice that S_t displays the opposite pattern to z_t^a. Similarly we can generate a nontrivial transition after news about ρ, with similar results. While these patterns are interesting, it is hard to generate much oscillation.

We also considered the case of two monies, as well as money and credit, with similar results, and in particular it is again hard to generate much oscillation.

[19]This makes targeting i look good from the perspective of stabilization, compared to targeting μ, but that is not true in all models (e.g., ones with exogenously sticky prices).

It is less difficult with money and housing, presumably because this model has additional nonlinearity due to the way h_t enters the utility function and not just the budget and liquidity constraints. Figure 15 shows the same experiment, where $i_T = 0.0182$ and $i_t = 0.0082$ for $t \neq T$, announce at $t = 0$. Here the value of housing and the value of money move in opposite directions, and we can generate at least mild oscillations in both, and volatility always increases as we approach the implementation date T. We summarize these findings as follows:

Lesson 7: *Under an interest rate rule, productivity or policy news can induce dynamics in goods and asset prices, news about one country can induce dynamics in both countries, and news about credit conditions can induce dynamics in the value of money and debt limits. It is more difficult to get oscillations under an interest rate rule, but with housing in the model news can induce intricate dynamics in goods and house prices, including oscillations.*

8 Conclusion

This paper studied the dynamic impact of information revelation – i.e., news – in economies where frictions inhibit intertemporal transactions, and hence there is an explicit role for money or other assets, as well as interesting credit arrangements. One motivation was that central bank announcements seem to affect markets, something taken for granted when contemplating forward guidance. In addition to policy, we considered news about productivity and credit conditions. We discussed some evidence, presented a model, and analyzed numerical experiments illustrating key economics ideas catalogued as a series of *lessons*. News affected goods, equity, foreign exchange, housing and credit markets. For each application we characterized the transition after a news shock, and found it could be complex, with cycles, booms and busts, even while imposing the same stationary equilibrium as initial and terminal conditions, and even if the actual policy is neutral in the usual sense. An implication is that market reactions to Fed announcements do not constitute compelling evidence that they control anything of fundamental importance – a currency injection, e.g., can have no real effects, but news about it can still lead to big and complicated responses.

Announcements here accentuated rather than attenuated volatility, providing counterexamples to the notion that transparency engenders stability. This is different from, but also related to, Andolfatto et al. (2014) and Dang et al. (2014). At the risk of oversimplifying those contributions, consider an asset that is randomly good or bad. Suppose someone, maybe a banker, knows the realization. It can be that he should not reveal the information, since when it is bad the asset serves less well as a payment instrument. Of course, when it is good the asset makes a better payment instrument, but the upside gain can be small compared to the downside loss. In fact, opacity is not a Pareto improvement ex post, because it hurts those who trade for the asset when it is bad. Similarly, not telling people about a coming rise in inflation or fall in dividends here hurts those who accept money or assets ex post, but opacity can be good ex ante. We also have examples where annoucing bad news increases welfare precisely because it generates volatility, which relaxes liquidity constraints during some phases of the transition, although the results are sensitive to timing and parameters

Perhaps policy announcements different than those considered here reduce volatility, consistent with conventional wisdom, and suggesting that policy makers should announce their intentions.[20] One candidate for this might be providing information that reduces heterogeneity in beliefs, but we only considered ho-

[20]From the Fed's webpage https://www.federalreserve.gov/faqs/money_12848.htm "In pursuing these objectives [listed as maximum employment, stable prices, and moderate long-term interest rates], the FOMC seeks to explain its monetary policy decisions to the public as clearly as possible. Clarity in policy communications facilitates well-informed decisionmaking by households and businesses, reduces economic and financial uncertainty, increases the effectiveness of monetary policy, and enhances transparency and accountability, which are essential in a democratic society... Communicating this inflation goal clearly helps keep longer-term inflation expectations firmly anchored, thereby fostering price stability and moderate long-term interest rates and enhancing the FOMC's ability to promote maximum employment." Like motherhood, apple pie and the American Way, it is hard to denounce this mission in the abstract, but our examples show precisely how communication can increase volatility and decrease welfare.

mogeneous beliefs. Nevertheless, the rersults show that transparency does not necessarily ameliorate instability. While this was initially surprising, in retrospect it is not at all pathological. It consistent with the idea that releasing information allows agents to trade against it or use it in other ways that make endogenous variables react (e.g., Andolfatto and Martin 2013). It is consistent with the broad position that policy might induce rather than reduce instability in financial markets (e.g., Lacker 2014). It is also related to theories where discrimination can emerge in equilibrium more easily if we assign more labels to people, and to theories of currency unification where 1 money is better than 2 because 2 monies allow extraneous fluctuations in acceptability or exchange rates, while if all the notes look the same they must be equally acceptable and trade at par. All these examples are can be characterized as "too much information."

As a final thought we compare the implications of the New Monetarist approach with an Old Monetarist idea. Friedman (1960) was famously concerned about the efficacy of monetary policy due to *long and variable lags* between implementation and the effects ultimately taking hold (see Williamson for 2015 a recent discussion). This paper was might be said to be concerned instead with *long and variable leads* between implementation and announcements, but of course the two position are not inconsistent.

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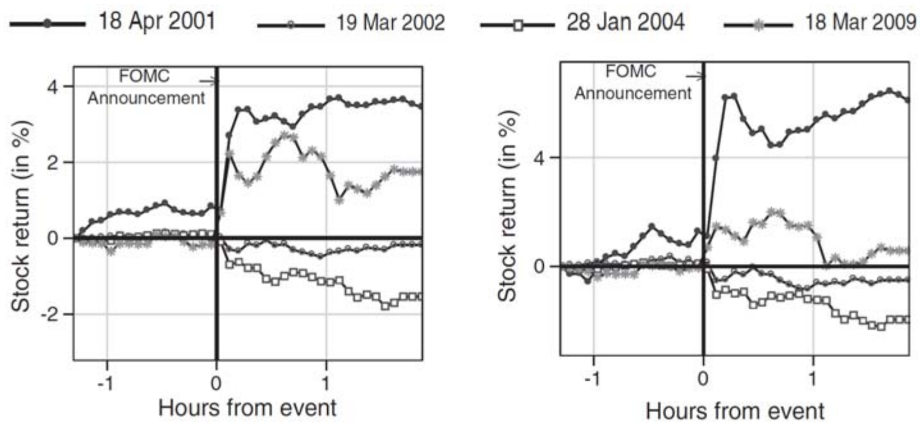
Appendix A – Parameters for Experiments

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

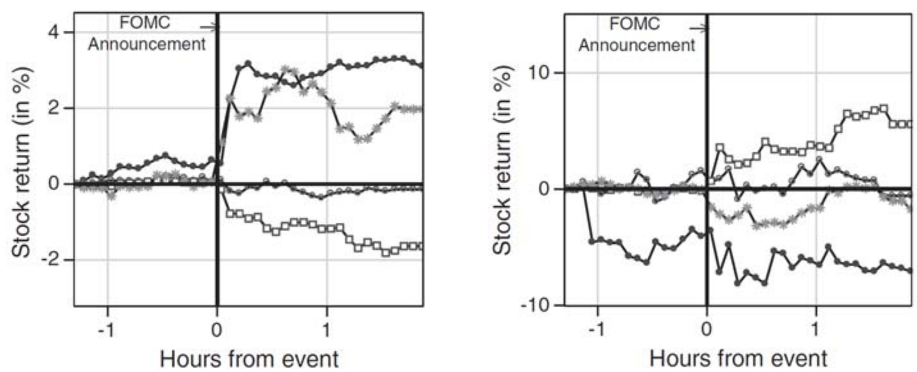
Table 1: Parameters for Experiments under Money Growth Rate Target

Common Values for Figures 4-6(L) and 7: $\alpha = 0.5$, $A = 1$, $b = 0.1$, $\gamma = 0.5, 4, 8$.	
Figure 4	$\mu = 0.0041$, $\mu' = 0.0141$ (L), 0.0049 (R).
Figure 5	$\mu = 0.0041$, $\mu' = 0.0046$ (L), 0.00411 (R).
Figure 6	(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 7	$\mu = 0.0041$, $\mu_{T_1} = 0.0141$, $\mu_{T_2} = -0.0059$, $T_2 = 12$, $T_1 = 0$ (L), 6 (R).
Figure 8	(L) $t_1 = 0$, $t_2 = 4$, $T_1 = 8$, $T_2 = 12$, $\mu = 0.0041$, $\mu' = 0.0191$, $\mu'' = 0.0091$,
	(R) $\Pr(\mu_t = 0.00615) = \Pr(\mu_t = 0.00205) = 0.5$. $\Pr(\mu_T = 0.00615) = 1$
Common Values for Figures 9-10: $A = 0.25$, $b = 0.45$, $\gamma = 3, 6, 9$.	
Figure 9	$\alpha_m = 0.01, 0.001, 1 \times 10^{-4}$, $\alpha_b = 0.5$, $\chi_a = 1$. $\mu = 0.0041$, $\rho = 2 \times 10^{-4}$, $\mu' = 0.0141$.
Figure 10	$\alpha_1 = 0.01, 0.001$, 1×10^{-4}, $\alpha_2 = 0.1\alpha_1$, $\alpha_{12} = 0.5$, $\mu^1 = \mu^2 = 0.0041$, $\mu^{1\prime} = 0.0141$.
Figure 11	$A = 0.25$, $b = 0.45$, $\delta = 0.4$, $\gamma = 3$, 6, 9, $\chi_h = 0.5$, $h = 0.001$, $\alpha_m = 0.01$, $0.001, 1 \times 10^{-4}$, $\alpha_b = 0.5$, $\mu = 0.0041$, $\mu' = 0.0141$.
Figure 12	$\alpha = 0.5$, $A = 1$, $b = 0.1$, $\sigma = 0.2, 0.5, 0.8$, $\gamma = 0$, $\lambda = 0.1$, $\pi = 0.99$, $\rho = 0.9$, $\pi' = 0.98$, $\rho' = 0.89$.
Figure 13	$\alpha = 0.5$, $A = 0.1$, $b = 0.15$, $\gamma = 2, 4$ or 6, $\lambda = 1$, $\pi = 2 \times 10^{-4}$, 2×10^{-5} or 2×10^{-6}, $\mu = 0.0041$, $\mu' = 0.0141$.
Figure 14	$i = 0.0082$, $i' = 0.0182$, the rest follow Figure 9.
Figure 15	$A = 0.25$, $b = 0.05$, $\delta = 0.4$, $\gamma = 6, 9$ 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 – Figures



Dow Jones Industrial Average NASDAQ-100



Standard&Poor's 500 CBOE Market Volatility Index

Figure 1: Stock Indices Reactions to Fed Monetary Policy (from Rosa 2011)

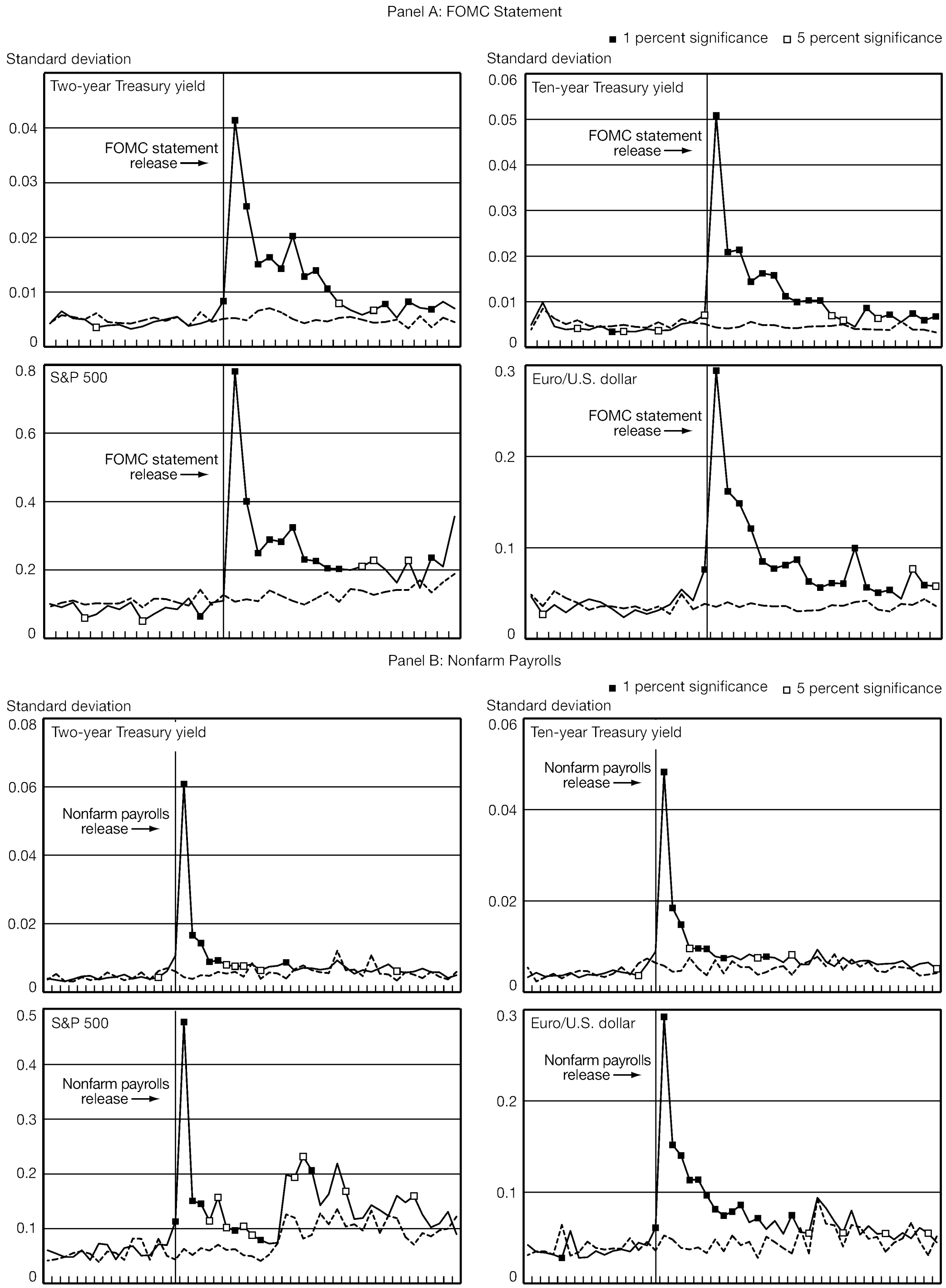


Figure 2: Impact of News on Asset Market volatility (from Rosa 2013)

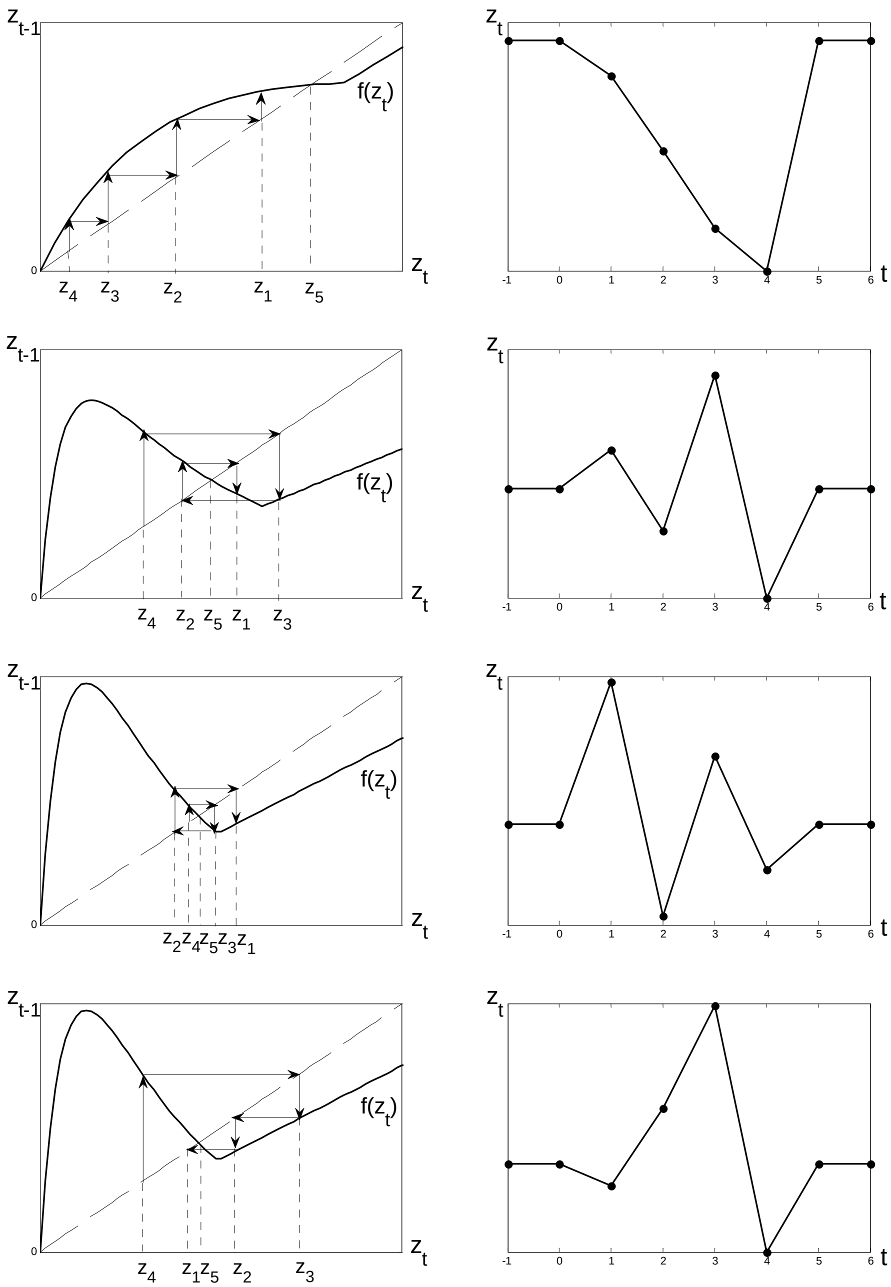


Figure 3: Phase Dynamics and Transition Paths

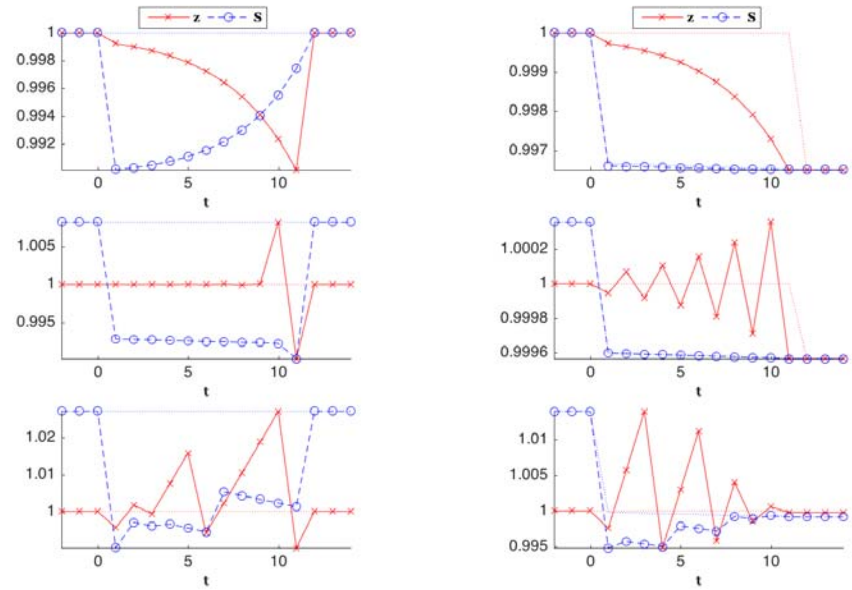


Figure 4: Temporary (left) and Permanent (right) Increase in μ

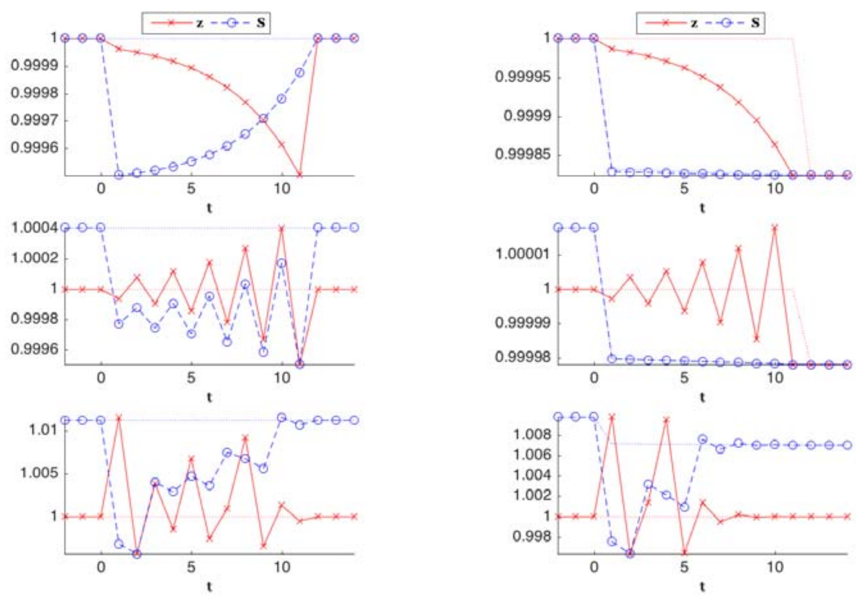


Figure 5: Temporary (left) and Permanent (right) Small Increase in μ

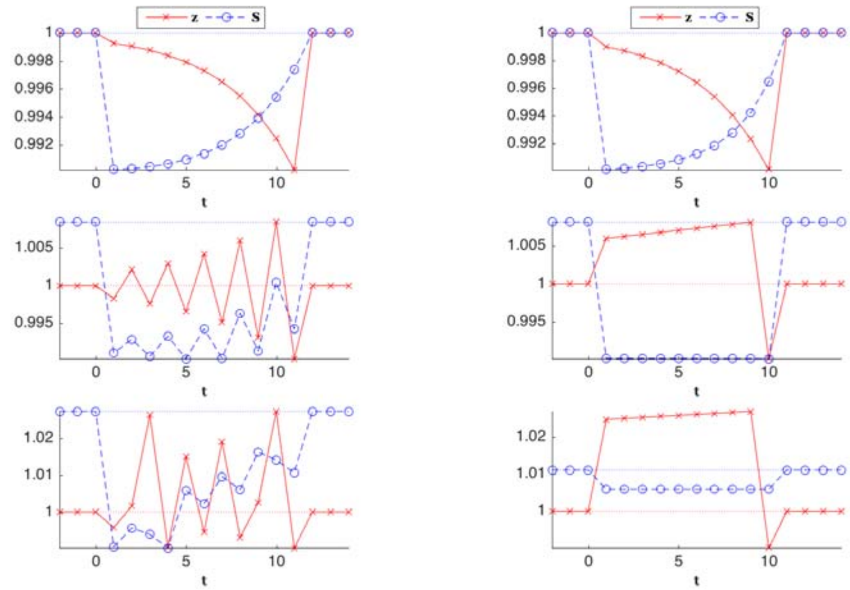


Figure 6: Temporary Increase in μ, Quarterly (left) and Daily (right)

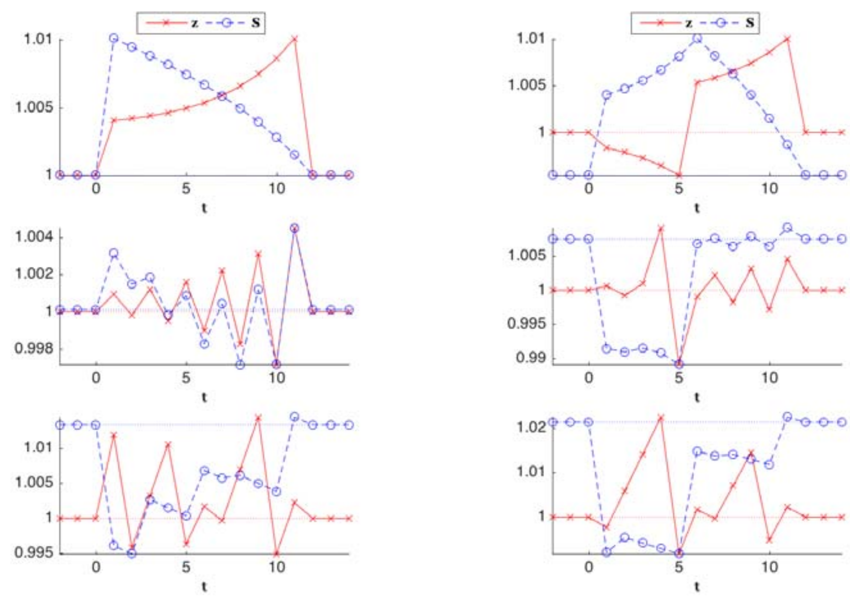


Figure 7: Quantitative Easing with $T_1 = 0$ (left) and $T_1 > 0$ (right)

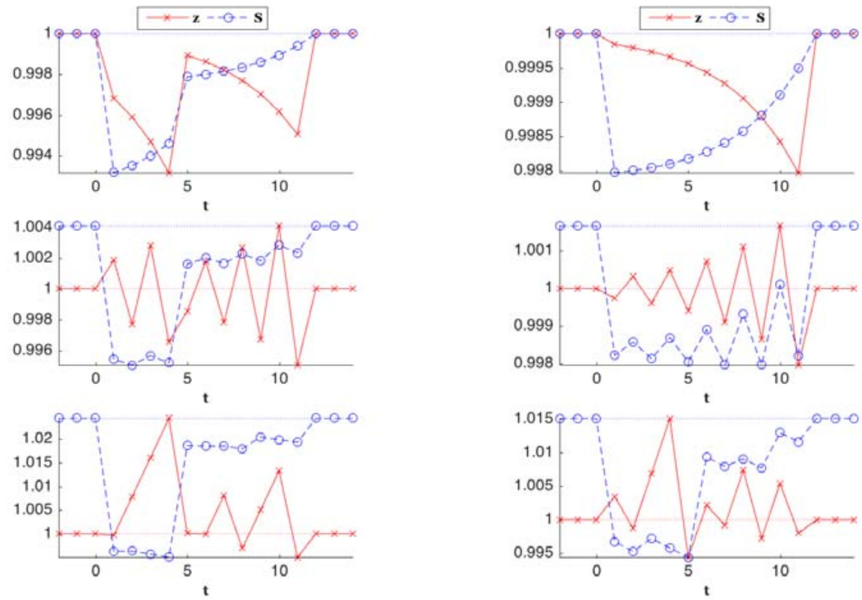


Figure 8: Staggered News (left) and Random News (right)

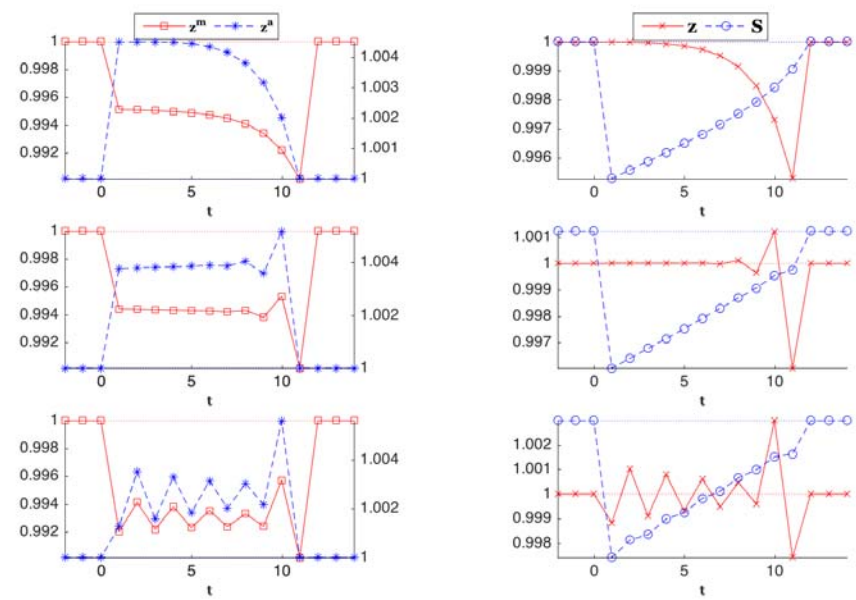


Figure 9: Money-and-Asset Economy, Temporary Increase in μ

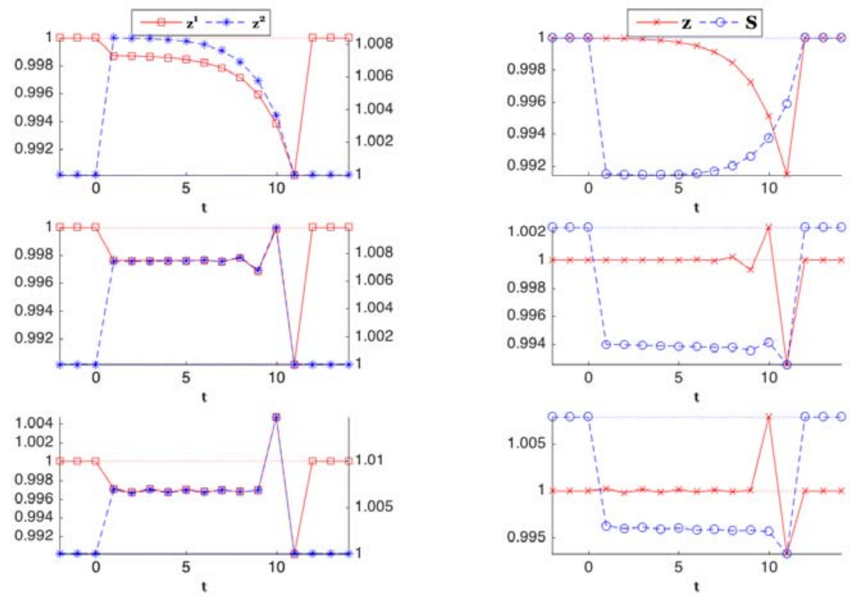


Figure 10: Two-Money Economy, Temporary Increase in μ^1

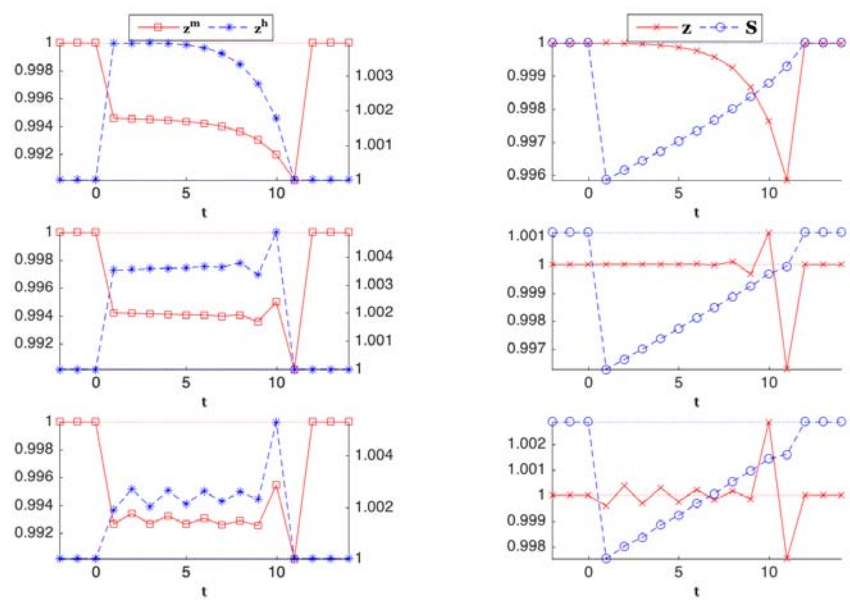


Figure 11: Housing-and-Money Economy, Temporary Increase in μ

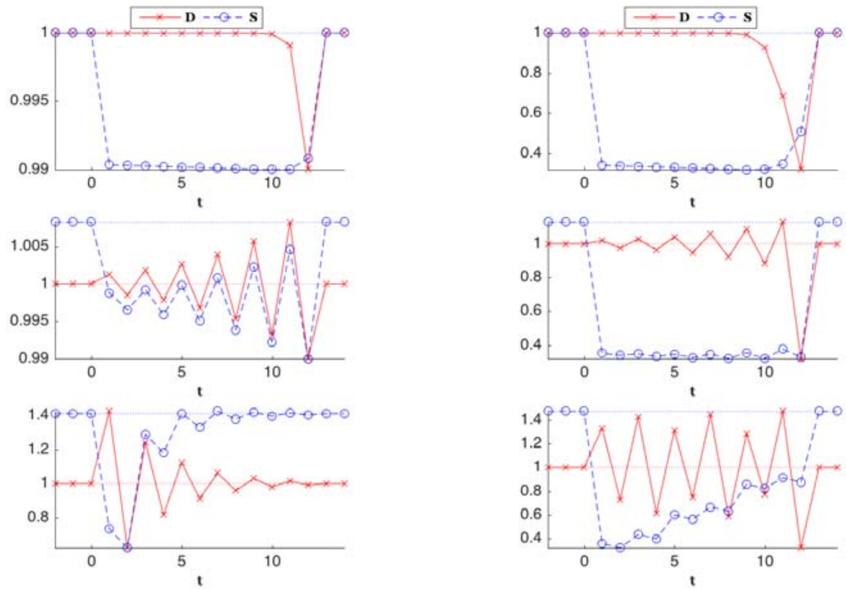


Figure 12: Credit Economy, Temporary Decrease in π (left) and ρ (right)

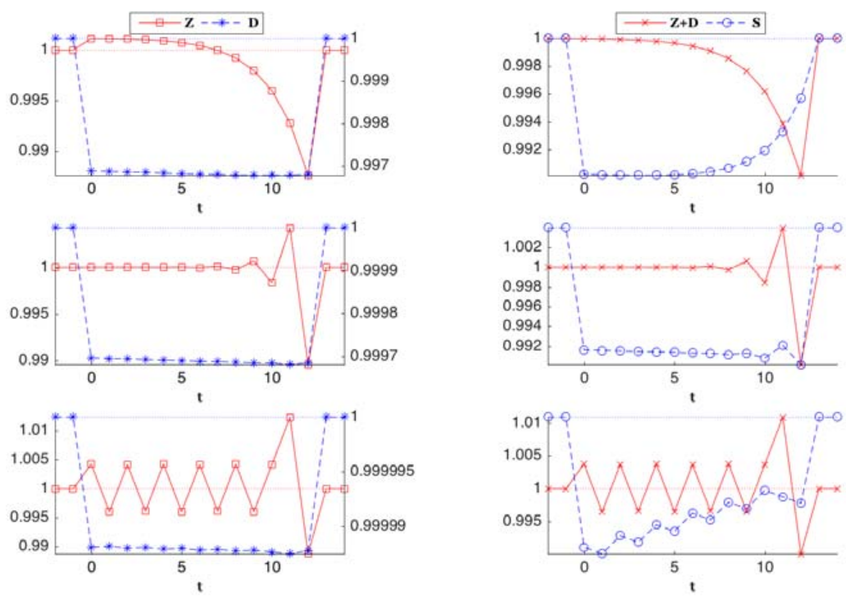


Figure 13: Money-and-Credit Economy, Temporary Increase in μ

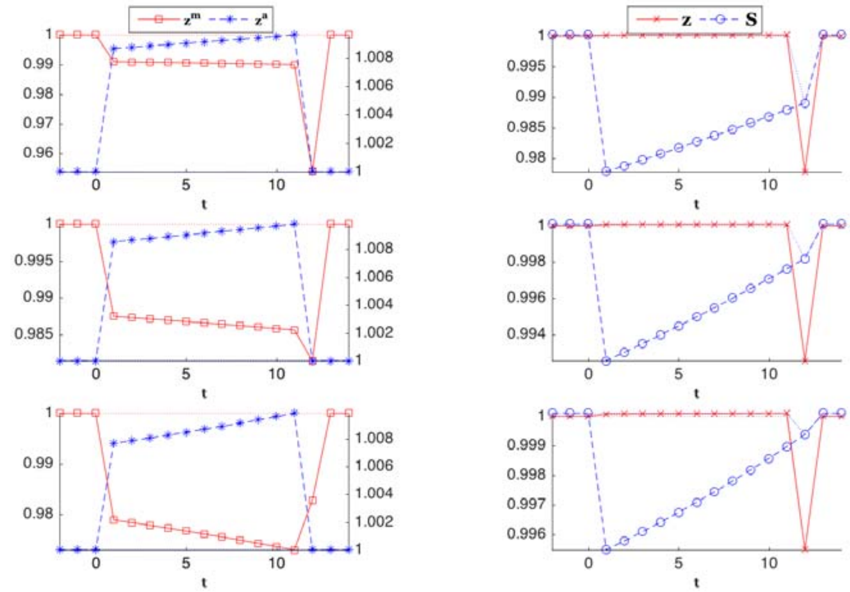


Figure 14: Money-and-Asset Economy, Interest Target, Increase in i

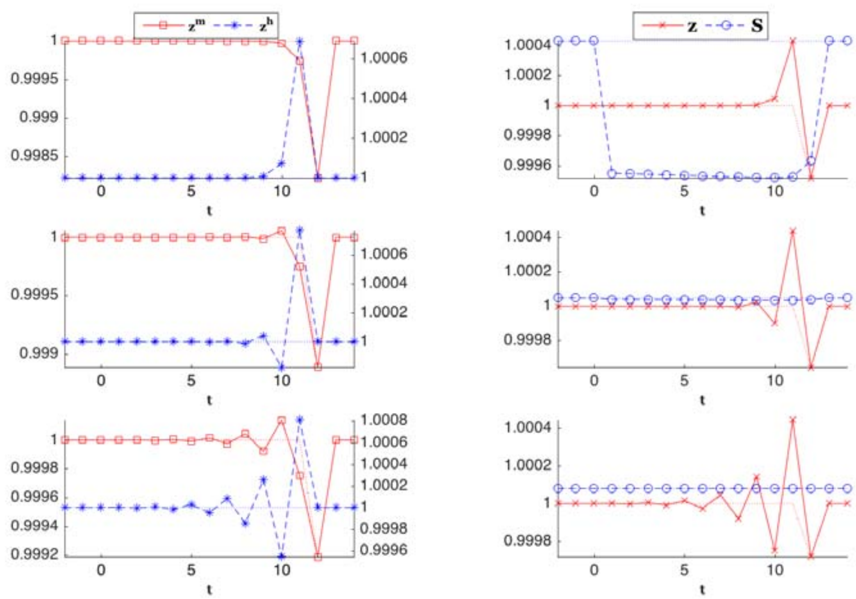


Figure 15: Housing-and-Money Economy, Interest Target, Increase in i