But low discount rates can evaporate quickly, especially when government debt is largely short term and frequently rolled over. A change in discount rate provokes exactly the same sort of unexpected inflation as a change in fiscal surpluses. And like such a change, there is nothing a central bank can do about it.

Concretely, if in the next moment of economic trouble, when our governments try to borrow another several percent of GDP to bail out troubled financial institutions, or fight a war or a recession, or all at the same time, while simultaneously rolling over a large stock of debt, bond market investors may decide our governments are not serious about long-run fiscal solvency. Investors will demand higher real interest rates to hold government debt, putting more strain on budgets. Investors may abandon government debt, driving up inflation. Such an event feels like a "speculative attack," a "bubble," or a "run" to central bankers.

Inflation's resurgence can happen without Phillips curve tightness. It can surprise central bankers of the 2020s just as it did in the 1970s—just as the decline in inflation surprised them in the 1980s, and just as its stability surprised them in the 2010s.

SECTION TWO

Comments on the Zero Lower Bound

Martin Eichenbaum

This essay focuses on two distinct but related points. The first is a critique of John Cochrane's claim that the Great Recession is a Michelson-Morley moment for New Keynesian (NK) models. Since this argument is based on Cochrane (2017), I will reference that paper throughout my comments. The second point builds on the empirical argument made in my first point that the private sector and policy makers systematically underestimated the gravity and duration of the zero lower bound (ZLB) episode and the Great Recession. At a minimum, this fact suggests that economists and policy makers should not depend on analyses that rely critically on a strong form of rational expectations. This view has particular force when we are dealing with rare events like the financial crisis, the Great Recession, or the so-called "quiet ZLB." We should take seriously only model implications that are robust to at least small deviations from rational expectations. I illustrate the usefulness of this "robustness principal" by applying it to three properties of the standard NK model.

DID WE SEE A MICHELSON-MORLEY MOMENT?

A central claim in Cochrane (2017) and the preceding chapter builds on the observation that the federal funds rate was constant for a long period after early 2009. According to John, we can think of that experience as an interest-rate peg. The standard NK model predicts that under a peg, the rational expectations equilibrium is indeterminate and gives rise to the possibility of sunspot volatility. Since inflation has actually been smooth, John infers that we've experienced a Michelson-Morley moment. In his view that moment has invalidated the standard NK model. Since monetarism has also been discredited, we need a new standard model. That model, according to John, is the fiscal theory of the price level coupled with nominal rigidities.

I agree with John about monetarism. The monetarists have been precisely wrong about everything that's happened since the financial crisis ("A tsunami of inflation is coming!"). For this we should thank them. Being exactly wrong exactly all of the time is socially useful because of the guidance it gives to the rest of us. So thanks to the "MV = PQ, V is kind of constant" crowd.

That said, I fundamentally disagree with the premise of John's argument about the NK model and the so-called quiet ZLB. The Fed was not in any sense on an interest-rate peg. What matters for determinacy in the NK model is agents' expectations about the length of the ZLB. In reality no one expected the ZLB to last very long. So determinacy wasn't an issue in the NK model given realistic assumptions about what people were expecting. The experiment that John appeals to just didn't happen. Claiming that we had a Michelson-Morley moment is a clever analogy to the physical sciences. But it doesn't mean that we actually had such a moment.

To substantiate my claims about agents' expectations, consider the evidence in Swanson and Williams (2014). These authors estimate the time-varying sensitivity of the yields on intermediate and long-term bonds to macro announcements using high-frequency data taken from the period when the ZLB was binding. They compare that sensitivity to a benchmark period in which the ZLB wasn't an issue. The idea is that if a given yield is about as sensitive to news in the benchmark period, then the ZLB wasn't a binding constraint on the relevant yield. When a yield responds very little to news, they infer that policy was largely constrained by the ZLB. Based on their analysis, they conclude that until August 2011, market participants expected the ZLB to constrain policy for only a few quarters.

Next consider evidence from the federal funds futures market. The dotted lines in Figure 3.2.1 show what risk-neutral market participants would have thought, at different points in time, the federal funds rate was going to be in the future. The solid line in Figure 3.2.2 shows what the actual federal funds rate was at various points in time. Note that the market consistently overestimated how quickly the federal funds rate would return to normal levels. That's a serially correlated error if I ever saw one. Granted, one could appeal to the last refuge of scoundrels, unobserved time-varying risk premiums. But trying to correct for risk premiums, as

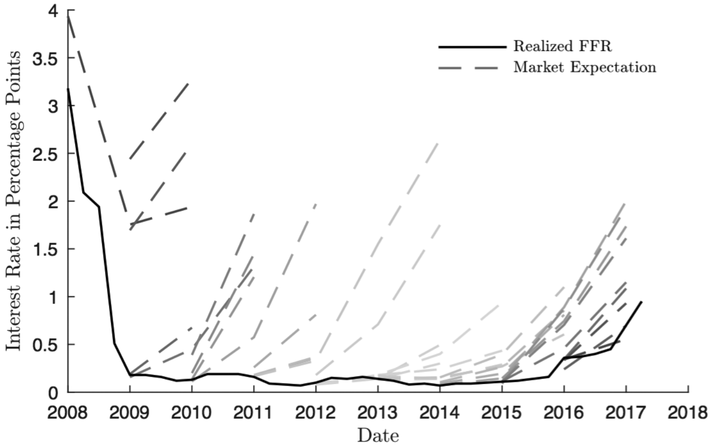

FIGURE 3.2.1. Federal funds rate: level and futures market rate. Source: Federal Reserve Economic Data, Bloomberg.

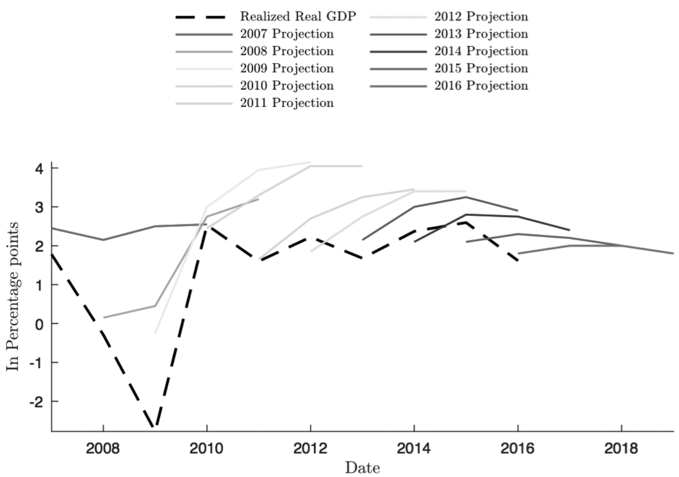

FIGURE 3.2.2. Growth rate of real GDP: level and Board of Governors' forecast. Source: Federal Reserve Economic Data, Board of Governors of the Federal Reserve System.

in Kim and Wright (2005), does little to change your mind: market participants were overly optimistic for a very long time.

What about policy makers? Unfortunately the Green Book forecasts for the federal funds rate aren't available over the relevant sample period. But the Board of Governors' real GDP forecasts are available. The various lines in Figure 3.2.2 display the annualized projections of the Board of Governors, made at various points in time, for future annualized growth rates of real GDP. The dashed line depicts the actual annualized growth rate of real GDP over time. Notice that the board systematically overestimated the growth rate of real GDP. Again the evidence of serially correlated errors is painfully clear.

Figures 3.2.1 and 3.2.2 provide clear evidence that policy makers and market participants thought the economy would recover much more quickly from the financial crisis and the Great Recession than it did. They certainly didn't expect a long-lasting interest-rate peg. Critically, in NK models, how long agents think the interest will be constant is the key determinant of whether the multiplicity issue that Cochrane emphasizes will arise. Given the empirical evidence about agents' expectations, I conclude that the experiment John describes didn't happen. So any conclusions stemming from the alleged episode are unwarranted.

What about John's broader claim that NK models can't explain the postcrisis behavior of inflation? It's true that toy NK models can't do the job. But non-toy NK models do reasonably well at this task. Christiano, Eichenbaum, and Trabandt (2015) show that once you allow for the fact that the growth rate of total factor productivity fell during the Great Recession and the cost of working capital went up, a full-scale NK model does a reasonably good job of accounting for the observed rate of inflation. It's true that the Christiano et al. model isn't simple, but it has the virtue of being able to account for the facts in a plausible way.

THE ROBUSTNESS PRINCIPLE

Figures 3.2.1 and 3.2.2 make clear that people didn't understand in real time the causes of the Great Recession or how long it would last. This evidence motivates what I call the robustness principle. By this I mean that we shouldn't trust model implications that rely on a strict version of rational expectations, certainly not for rare episodes like the Great Recession.

This raises a question: What are the robust implications of the NK model? It is well known that the NK model has multiple equilibriums. But is multiplicity a substantive issue? By this I mean, can we appeal to an interesting selection criterion to rule out alternative equilibriums as empirically uninteresting? The stakes involved in the answer to this question are high. If the answer is no, then the NK model doesn't have any robust properties, and it should be dismissed as pretty much useless for either normative or positive purposes.

Whether you can rule out various equilibriums in the NK model depends on why you think the rational expectations model is an interesting hypothesis to begin with. So let's go back to the distant past, before this model ossified into a religion. At the dawn of creation, it was widely understood by the creators that you should take rational expectations seriously *only* if they were the outcome of some plausible learning process.

Consider the following quote from Lucas (1978): "The model described above 'assumes' that agents know a great deal about the structure of the economy, and perform some non-routine computations. It is in order to ask, then: will an economy with agents armed with 'sensible' rules of thumb, revising these rules from time to time . . . tend as time passes to behave as described in the rational expectations equilibrium?" Lucas took this view so seriously that he devoted an entire section of the paper to a derivation of the rational expectations equilibrium as the limiting outcome of a learning equilibrium.

Now fast-forward to a time when modelers were becoming more familiar with the properties of rational expectations models. Lucas (1986) suggests using stability-under-learning as an equilibrium selection criterion. He writes, “Recent theoretical work is making it increasingly clear that multiplicity . . . can arise in a wide variety of situations involving sequential trading, in competitive as well as finite-agent games. All but a few of these equilibriums are, I believe, behaviorally uninteresting: They do not describe behavior that collections of adoptively behaving people would ever hit on. I think an appropriate stability theory can be useful in weeding out these uninteresting equilibriums.”

Multiple Equilibriums in Benhabib, Schmitt-Grohé, and Uribe (2001)

Let’s take Lucas at his word. Suppose that agents make a small error in forming expectations about a set of variables relative to their values in a particular rational expectations equilibrium. Would the economy converge back to the rational expectations equilibrium under some plausible learning rule? If the answer is yes, we call the equilibrium stable or learnable. If the answer is no, we say the equilibrium isn’t stable or learnable. Like Lucas, I take the view that if an equilibrium isn’t learnable, it’s uninteresting, and we should just disregard it as a theoretical curiosum. If the equilibrium is learnable, it is empirically interesting. It’s even more interesting if we can construct explicit, behaviorally sensible near alternatives to the rational expectations model with unique equilibriums that look like the learnable one.

Consider the classic analysis of multiplicity by Benhabib, Schmitt-Grohé, and Uribe (2001) that is often cited by proponents of the so-called neo-Fisherian view of monetary policy. The basic model is an endowment economy populated by a large number of identical infinitely lived households with additively separable preferences defined over consumption and real balances. The representative household receives a constant endowment of the consumption good and faces the budget constraint

$$C(t) + \tau(t) + B(t)/P(t) + M(t)/P(t) \leq \\ (1 + R(t-1))(B(t-1)/P(t)) + Y + M(t-1)/P(t). \quad (1)$$

Here $P(t)$, $C(t)$, $\tau(t)$, and Y denote the price level, consumption, lump-sum taxes, and endowment at time t. The variables $B(t)$ and $M(t)$ denote the end of time t holdings of one-period nominal bonds and money, respectively. The variable $R(t-1)$ is the nominal interest rate on a bond held at the end of time $t-1$. Monetary policy is given by a Taylor rule, subject to a ZLB constraint on the nominal interest rate:

$$R(t) = \max\{1, \pi^*/\beta + \alpha(\pi(t) - \pi^*)\}. \quad (2)$$

Here π^* is the monetary authority's target rate of inflation, which we suppose is 1. We assume $\alpha > 1$ so that the Taylor principle is satisfied. The presence of the max operator reflects the ZLB constraint.

In this model there are two steady-state equilibriums. Optimality and market clearing imply the Fisher equation

$$1 = \beta R(t)/\pi(t+1). \quad (3)$$

In Figure 3.2.3 the lower line depicts the Taylor rule, while the upper line depicts the Fisher equation. Equations (2) and (3) summarize the equations whose solutions characterize the equilibriums of the model. The first steady-state equilibrium of the model

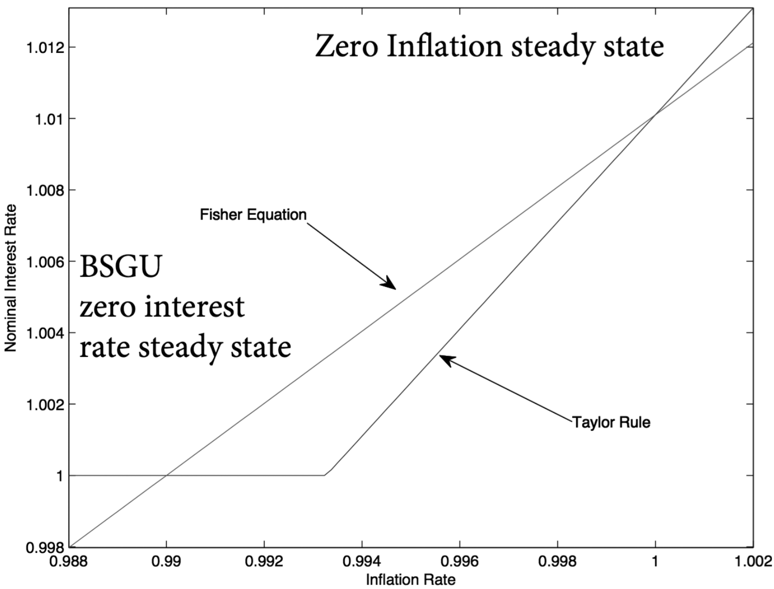

FIGURE 3.2.3. Multiple steady states in a flexible price-level model

economy is deflationary, that is, the steady-state rate of inflation is negative. The other "normal" steady-state equilibrium has the property that inflation is zero (recall π^* is equal to 1).

Is there some reason to take one of the steady states more seriously than the other? Suppose we begin from a particular steady state. Under rational expectations, agents would know what rate of inflation to expect in the future. But suppose that agents made an arbitrarily small mistake about expected inflation. Next period agents would realize that they had made a mistake. Suppose they have some rule for changing their expectations. For simplicity, assume that they set their new expectation as a linear combination of current data and past expectations, that is, they use a constant gain filter. In my experiment agents don't need to know that monetary policy is determined by a Taylor rule (never mind the parameters of that rule). They just revise expectations according to the constant gain filter. So the identification issues stressed by Cochrane (2011) are irrelevant in our context. It is well known that the economy would always *diverge* from the deflationary steady state. If there's an interior equilibrium, the economy will always converge to the zero-inflation steady-state equilibrium (see Christiano, Eichenbaum, and Johansen 2016 and the references therein).

So the deflationary steady-state equilibrium isn't learnable, and the zero-inflation steady-state equilibrium is learnable. Why would you ever want to use the nonlearnable deflationary steady state as a description of the data? The so-called neo-Fisherians sometimes talk about Japan as being caught in a low-deflation steady state. It's certainly true that Japan has low interest rates and low inflation. And I'm not entirely sure I understand why. But the idea that the cause is a nonlearnable rational expectations equilibrium where for twenty years no one has ever made the tiniest expectation error is wildly implausible.

Applying the Robustness Principal to the NK Model

Christiano, Eichenbaum, and Johansen (2016) analyze the nonlinear version of the standard NK model, both with Rotemberg-style and Calvo-style nominal price rigidities. They find that the model has a unique, learnable minimum-state rational expectations equilibrium.[1] The properties of that equilibrium correspond to the standard equilibrium emphasized in the literature. On that basis they infer that multiplicity is not a substantive problem in the NK model. But learnability isn't the same as robustness in the sense that I am using that term. To illustrate this distinction, I now apply the robustness principle to assess some implications of the NK model.

1. We are currently extending the analysis to consider non-minimum state variable equilibriums.

The Response of Inflation and the Nominal Interest Rate to a Monetary Policy Shock

Here I consider the response of inflation and the nominal interest rate to a monetary policy shock in two models: the log-linearized version of the standard NK model and Gabaix's (2017) behavioral NK model, in which agents are partially myopic to unusual events. The Gabaix model is an interesting near alternative to a rational expectations model with strong implications for determinacy issues. For example, the Taylor principle is strongly modified, so that even with an interest-rate peg there's a unique bounded equilibrium. With Gabaix-style behavioralism, the determinacy issue raised by John is a nonissue.

For convenience I assume that the period utility function of the representative consumer is separable over consumption and hours worked, with logarithmic preferences over c_t. The equations defining the log-linearized NK model are given by

$$
\begin{aligned}
-\hat{c}_t &= \hat{R}_t - E_t\hat{c}_{t+1} - E_t\hat{\pi}_{t+1} \\
\hat{\pi}_t &= \frac{(1-\beta\theta)(1-\theta)}{\beta}[(\varphi(1-\eta_g)+1)\hat{c}_t + \varphi\eta_g\hat{g}_t] + \beta E_t\hat{\pi}_{t+1} \\
\hat{R}_t &= \phi_\pi\hat{\pi}_t + \varepsilon_{R,t}.
\end{aligned}
$$

The first equation corresponds to the representative consumer's Euler equation, while the second equation is the NK Phillips curve. The third equation is a Taylor rule for setting the interest rate. A ^ over a variable denotes the percentage deviation of a variable from its steady-state value. In addition ϕ_π is the coefficient on $\hat{\pi}_t$ in the Taylor governing monetary policy, η_g is the proportion of steady-state output that goes to government spending, φ is the inverse Frisch elasticity of labor supply, β is the time discount factor, and θ is the Calvo parameter. We assume that $\varepsilon_{R,t}$ with AR coefficients

ρ_x. I set $\beta = 1$, $\theta = 0.75$, $\varphi = 1$, $\eta_g = 0.2$, $\theta_\pi = 1.5$. Steady-state output is normalized to 1 by setting $\chi = 1.25$.

The Gabaix NK model is defined by the set of equations

$$\begin{aligned} -\hat{c}_t &= \hat{R}_t - ME_t\hat{c}_{t+1} - E_t\hat{\pi}_{t+1} \\ \hat{\pi}_t &= \frac{(1-\beta\theta)(1-\theta)}{\beta}[(\varphi(1-\eta_g)+1)\hat{c}_t + \varphi\eta_g\hat{g}_t] + M^f\beta E_t\hat{\pi}_{t+1} \\ \hat{R}_t &= \phi_\pi\hat{\pi}_t + \varepsilon_{R,t}. \end{aligned} \tag{4}$$

The parameters M and M^f quantify how poorly agents understand future policy and its impact on them. When M and M^f are equal to 1, agents have rational expectations. The closer these parameters are to zero, the more myopic agents are. In what follows we assume that M and M^f are equal to 0.9.

Figure 3.2.4 displays the response of inflation and the nominal interest rate in the learnable equilibrium of the standard NK model

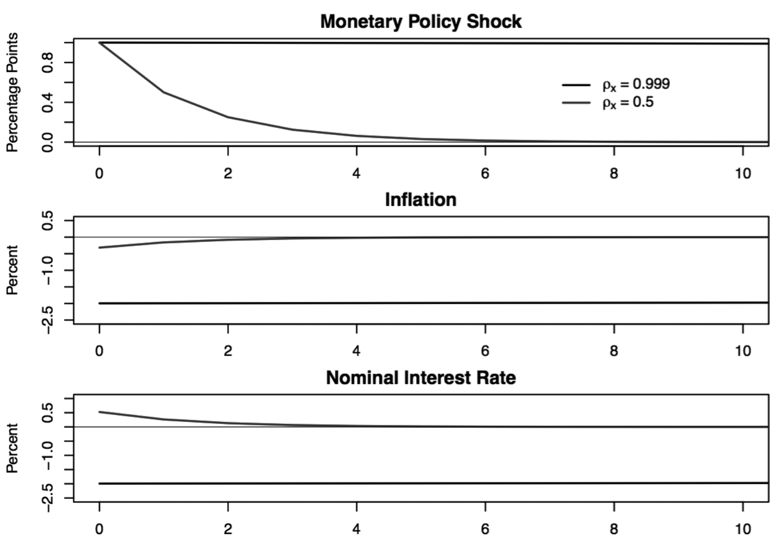

FIGURE 3.2.4. The response of the interest rate and inflation to a monetary policy shock in the NK model

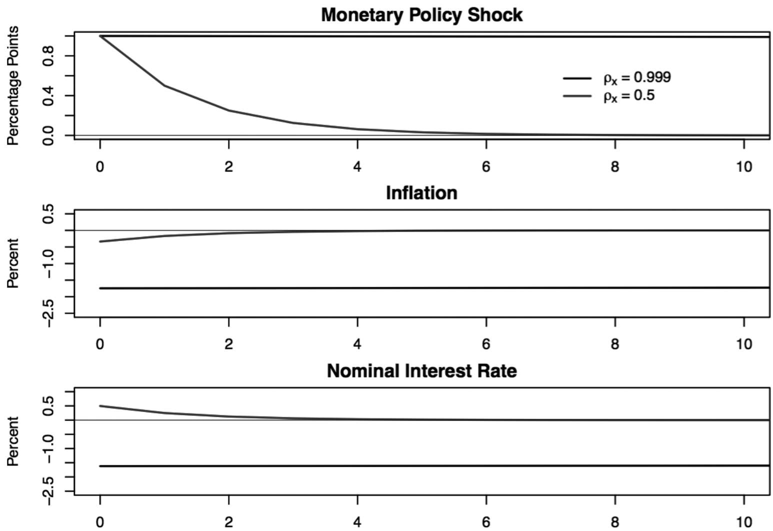

FIGURE 3.2.5. The response of the interest rate and inflation to a monetary policy shock in the Gabaix model

to a monetary policy shock of one hundred basis points when $\rho_x = 0.999$ and when $\rho_x = 0.5$. Figure 3.2.5 presents the corresponding impulse response functions in the Gabaix model.[2] The impulse response functions in Figures 3.2.4 and 3.2.5 are very similar and have what I call a modified-Fisherian property. In particular, a transitory increase in the federal funds rate is associated with a decrease in inflation. But a very persistent decrease in the federal funds rate is associated with a decrease in inflation.

The claims made in Cochrane (2017) that we don't have a model in which transitory increases in the nominal interest rate are robustly associated with decreases in inflation is simply wrong. That pattern is a generic feature of the learnable equilibrium of the standard NK model. It is a virtue of the NK model consistent with the Fisherian view that very persistent increases in the nominal interest

2. The impulse response functions in the Gabaix model don't depend sensitively on the value of M in the area of 0.9.

rate are associated with increases in inflation. No one should be surprised that the model has this property. After all, the limit of a persistent monetary policy shock is a permanent change in π^*, the target rate of inflation in the Taylor rule. In the NK model, a credible change in π^* is associated with a one-to-one change in the nominal interest rate.

Based on the previous results, I conclude that the neo-Fisherian relationship between interest rates and inflation is a robust feature of the standard NK model.

The Fiscal Multiplier When the ZLB Is Binding

We now consider the implications of the standard and Gabaix NK models for the effects of an increase in government purchases when the ZLB is binding. For comparison I also consider a version of the NK model where agents update expectations according to the rule

$$E_t x_{t+1} = x_{t-1}.$$

The timing in this rule reflects the fact that agents don't see the time t aggregate value of variables that their collective decisions determine at time t.[3] Monetary policy is given by (4) subject to the constraint that the net interest rate cannot be negative.

$$R_t = \max\left\{1, \frac{1}{\beta} + \theta_\pi(\pi_t - 1)\right\}.$$

A representative household maximizes

$$E_0 \sum_{t=0}^{\infty} d_t \left[\log(C_t) - \frac{\chi}{2} h_t^2\right],$$

where C_t denotes consumption, h_t denotes hours work, and

3. See Christiano, Eichenbaum, and Johansen (2016) for a more detailed discussion of this point.

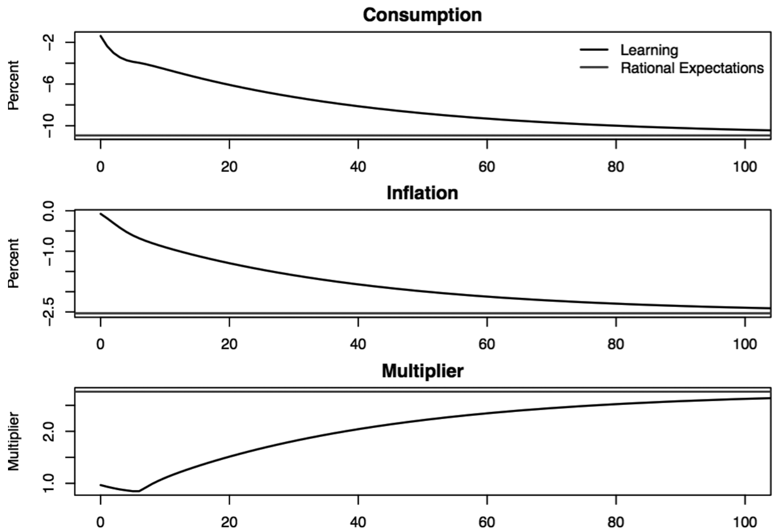

FIGURE 3.2.6. The ZLB fiscal multiplier in the NK model and in a learning model

$$d_t = \prod_{j=0}^{t} \left(\frac{1}{1 + r_{j-1}} \right).$$

The variable r_t can take on two values: r and r^ℓ, where $r^\ell < 0$. The stochastic process for r_t is given by

$$\Pr[r_{t+1} = r^\ell \mid r_t = r^\ell] = p, \Pr[r_{t+1} = r \mid r_t = r^\ell] = 1 - p, \Pr[r_{t+1} = r^\ell \mid r_t = r] = 0,$$

where $r^\ell = -0.02/4$ and $p = 0.775$. I assume that G is equal to 1.05 percent of its steady value for as long as $r = r^l$. Here I work with a log-linearized version of the standard NK model in the ZLB discussed in Christiano, Eichenbaum, and Rebelo (2011).[4]

Figure 3.2.6 displays the value of the constant linear multiplier in the learnable rational expectations equilibrium of the NK model

4. See Christiano, Eichenbaum, and Johansen (2016) for a comparison of the multiplier in the linear and nonlinear learnable equilibriums of the standard NK model.

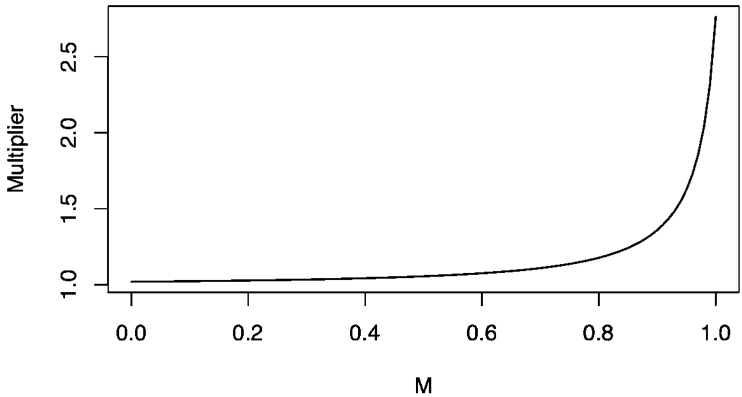

FIGURE 3.2.7. The ZLB fiscal multiplier in the Gabaix model

as well as the multiplier in the learning version of the NK model. Two features are worth noting. First, the multiplier in the standard NK model is very large. Second, while not as large, the multiplier in the learning model soon climbs above 1 and converges to the value in the rational expectations model.

Figure 3.2.7 displays the multiplier in the Gabaix model for different values of the inattention parameter, M. Recall that when M is 1, the model is the same as the standard rational expectations model. As we move to the left, agents are increasingly inattentive. Note that the multiplier substantially exceeds 1 for even substantial deviations of M from 1.

It's worth noting that large fiscal mutipliers emerge even in models that assume the fiscal theory of the price level. Leeper, Traum, and Walker (2017) develop and estimate a full-scale NK model that embeds the fiscal theory of the price level in it. Evaluated at the mean of the posterior distribution of the estimated parameter values, their model implies that, when the ZLB is binding, the fiscal multiplier is approximately equal to 1.5.

Based on the previous results, I infer that the large fiscal multiplier when the ZLB binds is a robust feature of the NK model, even if we embrace John Cochrane's preferred version, namely one that assumes the fiscal theory of the price level.

Forward Guidance

In standard simple NK models, news about shocks to future interest rates are powerful. It turns out that this result is very sensitive to deviations from rational expectations. For example, in Gabaix's NK model, forward guidance is much less powerful because agents discount the future more heavily than in the standard NK model.

A related form of non-robustness pertains to the assumption of complete markets in the standard NK model. McKay, Nakamura, and Steinsson (2016) consider a modified NK model in which agents face uninsurable idiosyncratic income risks and borrowing constraints. Agents' motive for precautionary savings is much stronger than in the standard model, and consumption is much less responsive to news about future interest rates. So forward guidance is much less powerful than in the standard model.

Based on these observations, I infer that the NK model's implication about the efficacy of forward guidance when the ZLB is a binding constraint is not robust. Thus, it shouldn't be taken very seriously.

CONCLUDING REMARKS

In this text I have challenged the central idea in Cochrane (2017). His argument is premised on a counterfactual assumption: we did *not* have a Michelson-Morley moment. That's because private-sector agents and policy makers systematically underestimated how long we would be in a ZLB environment. More generally, I have challenged his claim that multiple equilibriums are an important issue in NK models. In my view, they aren't. Going back to the roots of the rational expectations revolution virtually compels us to insist that equilibriums be learnable as a condition for taking them seriously. Nonlearnable equilibriums are simply (interesting) intellectual curiosa. They should not distract us from the task of using models to understand how the actual economy behaves and giving robust guidance to policy makers.

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