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EXPECTATIONS AND THE NEUTRALITY OF INTEREST RATES

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ABSTRACT

Lucas (1972) is the pathbreaking analysis of the neutrality and temporary non-neutrality of money. But our central banks set interest rate targets, and do not even pretend to control money supplies. How is inflation determined under an interest rate target?

We finally have a complete theory of inflation under interest rate targets, that mirrors the long-run neutrality and frictionless limit of monetary theory: Inflation can be stable and determinate under interest rate targets, including a k percent rule, i. e. a peg. The zero bound era is confirmatory evidence. Uncomfortably, long-run neutrality means that higher interest rates eventually produce higher inflation, other things (and fiscal policy in particular) constant.

With a Phillips curve, we have some non-neutrality as well: Higher nominal interest rates raise real rates and lower output. A good model in which higher interest rates temporarily lower inflation is a harder task. I exhibit one such model. It has the Lucas property that only unexpected interest rate rises can lower inflation. A better model, and empirical understanding, is as crucial to today's agenda as Lucas (1972) was in its day.

Much of this is contentious. The issues are crucial for policy: Can the Fed contain inflation without dramatically raising interest rates? Given the state of knowledge, a bit of humility is in order.

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This paper with updates, slides, and other materials is available at:
https://www.johnhcochrane.com/research-all/inflation-neutrality

1 Introduction

50 years ago, Bob Lucas (1972a) published the watershed "Expectations and the Neutrality of Money." Bob studied expectations and the neutrality—and temporary non-neutrality—of, as the title says, *money*. But our central banks set *interest rates*. The Fed does not even pretend to control money supply, especially inside money. There are no reserve requirements. Super-abundant reserves pay the same or more interest than short-term Treasuries and overnight money markets. The Fed controls interest rates by changing the interest it offers on reserves, not by rationing scarce zero-interest reserves. Other central banks follow similar corridors. The quantity of M2 is whatever people feel like holding in that form.

We need a theory of inflation under *interest rate targets*. The theory should expresses and respect long-run neutrality. The theory should also capture temporary non-neutrality, with robust and clean economics, just as Bob's did.

We do not have such a theory. We have made a lot of progress. We have at last, I think, a satisfactory theory of inflation under interest rate targets, that expresses long-run neutrality. But even that is controversial. The final piece, a satisfactory theory of temporary non-neutrality, the central piece of Bob's paper, is still unfinished. We also lack robust empirical understanding.

Ignorance is great news for researchers. The 1970s were a golden decade for macroeconomic research, as much as they were a miserable decade for the economy. The 2020s are shaping up to repeat both aspects.

The question is also crucial for current policy. The Fed waited a whole year to raise interest rates, and its interest rate increases have been far below the rise of inflation. (Figure 1.) The Fed's reaction is slow even by the standards of the 1970s (Figure 2). The Fed never waited a whole year to do anything, and never let interest rates get 7 percentage points below inflation.

To what extent is the Fed's slow reaction to blame for current inflation? Must the Fed dramatically raise rates, to 10% or more as the Taylor Rule recommends, to keep inflation from spiraling higher? Or is the Fed right that inflation will go away largely on its own without such high nominal interest rates?

(Much of this essay is condensed from prior writing, which also contains detail and extensive references. The most important sources are Cochrane (2023), Ch. 5, 12, 16, 17, 20 and Cochrane (2022).)

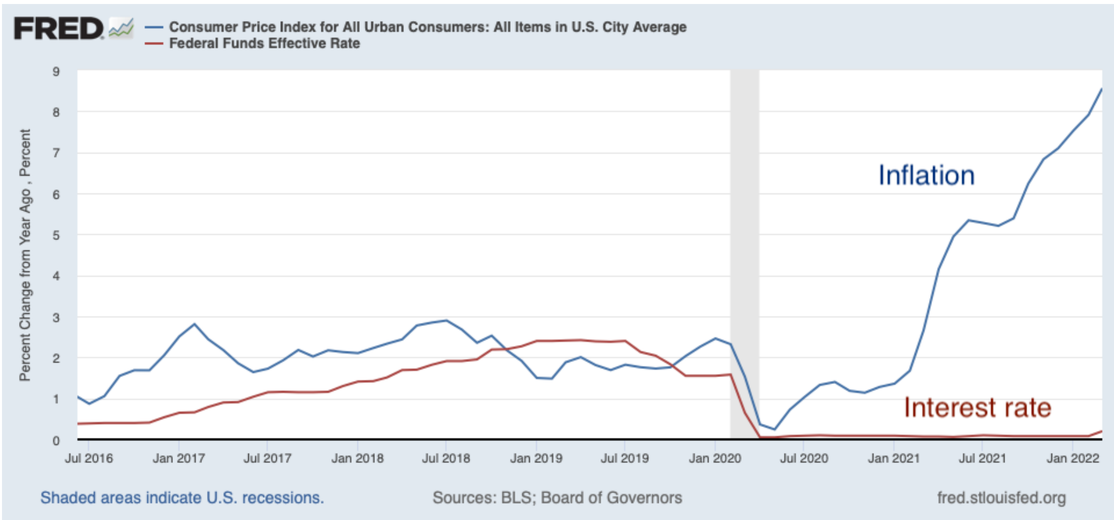

Figure 1: Inflation and Federal Funds Rate

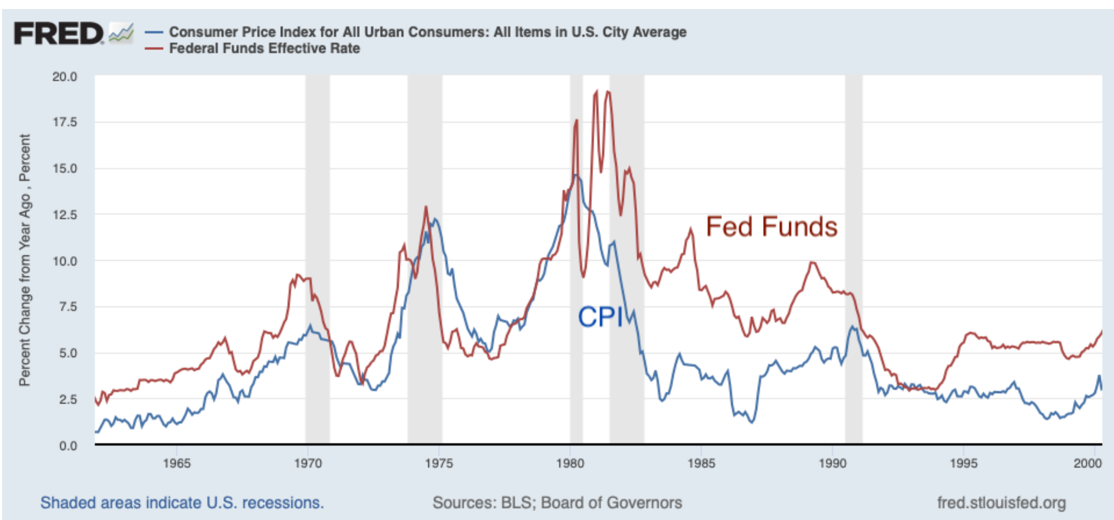

Figure 2: Inflation and Federal Funds Rate in the 1970s

2 Inflation under interest rate targets

What is the dynamic effect of *interest rates*—not money—on inflation? I'll use a very simple standard model to think about this question,

$$x_t = E_t x_{t+1} - \sigma(i_t - \pi_t^e) \tag{1}$$

$$\pi_t = \pi_t^e + \kappa x_t \tag{2}$$

where $x =$ output gap, $\pi =$ inflation, $i =$ interest rate. These are deviations from steady state, in particular leaving out for now a steady state real rate of interest r.

Equation (1) is the first-order condition for consumption. Equation (2) is the Phillips curve. Bob's central innovation was, of course, to specify how expectations enter the Phillips curve so that output variation comes from *unexpected* inflation.

Bob paired that Phillips curve with, essentially, $MV = PY$ and constant V, which determines the price level. In this, Bob already had in hand a theory of price level determination, and one that expresses neutrality to boot. Our challenge is to develop a theory of of price level determination based on interest rates, not money supplies. It should express neutrality as a flexible-price market-clearing launch point, and develop non-neutralities from distortions to that ideal. Unlike Bob, we have to work a bit to get to that launch pad.

I hesitate to write down such a model without preferences, technology, market structure, definition of equilibrium, and recursive statement. But this is well-trod ground and you all know how to fill in those gaps, which are well worked out in the literature.

I simplify further by dropping $E_t x_{t+1}$ on the right hand side of (1), leaving a simple statement that higher real interest rates depress the level of output,

$$x_t = -\sigma(i_t - \pi_t^e).$$

This simplification turns out not to make any difference for the points I want to make, and leaving it out allows me to do everything with transparent algebra. Equation (1) iterates forward to

$$x_t = -\sigma E_t \sum_{j=0}^{\infty}(i_{t+j} - \pi_{t+j+1}),$$

so my static version is the same as the dynamic version when the current real interest rate is a sufficient statistic for that sum. The parameter σ is then larger than the intertemporal elasticity of substitution, as it includes how long the high rates last. Using the static IS curve makes a second point: The troubles I document cannot be fixed just by attenuating the forward-looking part of the IS curve.

Substituting output out of (1)-(2), we obtain the relationship between interest rates and inflation which we are after,

$$\pi_t = (1 + \sigma\kappa)\pi_t^e - \sigma\kappa i_t. \tag{3}$$

The dynamic response of inflation to interest rates now depends on how expectations are formed.

2.1 Expectations, stability, and determinacy

Table 1 summarizes the steady forward march of expectations in the Phillips curve. (Each equation is simplified, of course, to be emblematic of an era. Actual Phillips curves also include error terms.)

Author	Phillips curve	Expectations
Phillips (1958)	$\pi_t = \pi_0 + \kappa x_t$	Absent
Dynamic empirical (1960s)	$\pi_t = \alpha\pi_{t-1} + \kappa x_t,\ \alpha < 1$	(Long run tradeoff)
Friedman (1968); ISLM AS/AD(1970s)	$\pi_t = \pi_{t-1} + \kappa x_t$	Adaptive
Lucas (1972)	$\pi_t = E_{t-1}\pi_t + \kappa x_t$	Rational
Calvo (1983), Rotemberg (1982); NK (1990s)	$\pi_t = E_t\pi_{t+1} + \kappa x_t$	Rational

Table 1: The steady forward march of expectations in the Phillips curve

Phillips, of course, didn't have any expectations or other shifter variables in the Phillips curve, nor did the Keynesian advocates of inflation in the early 1960s such as Samuelson and Solow (1960). (See Nelson (2020) Ch. 13).

Dynamic estimates of the Phillips curve added lags of unemployment or inflation, depending which variable one put on the right-hand side of the regression. These specifications retained a long-run inflation-output tradeoff, $\alpha < 1$ in my case, and when thinking theoretically, adaptive expectations.[1]

[1] Among many others, Lipsey (1960), Gordon (1970). Gordon (1976) p. 192-193 provides a nice summary of the era and its end. Sargent (1971) and Lucas (1972b) also summarize, and foreshadow a main point of the Lucas (1976) critique, that $\alpha < 1$ regression coefficients easily occur in sample even if inflation moves one for one with rationally expected inflation.

Friedman's (1968) address was fundamentally about neutrality. He proclaimed two things that monetary policy *cannot* do. First, he proclaimed that the Phillips curve would shift once people come to expect inflation, so the Fed cannot permanently lower unemployment. But he described explicitly adaptive expectations: "This price expectation effect is slow to develop and also slow to disappear." Phelps (1967) too of course, who writes "a sort of Phillips Curve..that shifts one-for-one with variations in the expected rate of inflation; ...the expected inflation rate adjusts gradually over time to the actual inflation rate."

Second, Friedman proclaimed that the Fed cannot peg the nominal interest rate. We can see this result in our little model. Let expectations be adaptive, $\pi_t^e = \pi_{t-1}$. Then from (3) inflation and interest rates are related by

$$\pi_t = (1+\sigma\kappa)\pi_{t-1} - \sigma\kappa i_t. \tag{4}$$

Inflation is now *unstable* under an interest rate peg, since $(1+\sigma\kappa) > 1$. In Friedman's description, the Fed would needs to print more and more money to keep the interest rate down. The ISLM AS/AD tradition of the 1970s adopted the same adaptive expectations Phillips curve, without money. In that description, a too-low nominal interest rate lowers the real rate, which boosts demand, which boosts inflation, and around we go. The left panel of Figure 3 illustrates instability and the inflation or deflation spirals that break out with a constant interest rate.

Instability under an interest rate target is a deep result. It means that, so far, we do *not* have a satisfactory model of price-level determination under interest rate targets. We can't even get to Lucas' $MV = PY$ launch-pad for non-neutralities.

John Taylor (1993) repaired Friedman's critique of interest rate targets.[2] Let the Fed systematically respond to inflation with higher interest rates, $i_t = \phi\pi_t$ with $\phi > 1$. Substituting for i_t in (4), inflation dynamics become

$$\pi_t = \frac{1+\sigma\kappa}{1+\sigma\kappa\phi}\pi_{t-1}. \tag{5}$$

Now inflation is stable and determinate with an interest rate target. Sensibly, the Fed's interest rate policies act to *stabilize* an inherently unstable economy.

Unstable dynamics are alive and well today, in the widespread opinion that by failing to act, the Fed is making inflation worse, and a sustained dose of high interest rates is the only way to

[2] McCallum (1981) is the first formal statement that the $\phi > 1$ principle resolves problems with interest rate targets. But Taylor is the greatest advocate of the rule which justly bears his name.

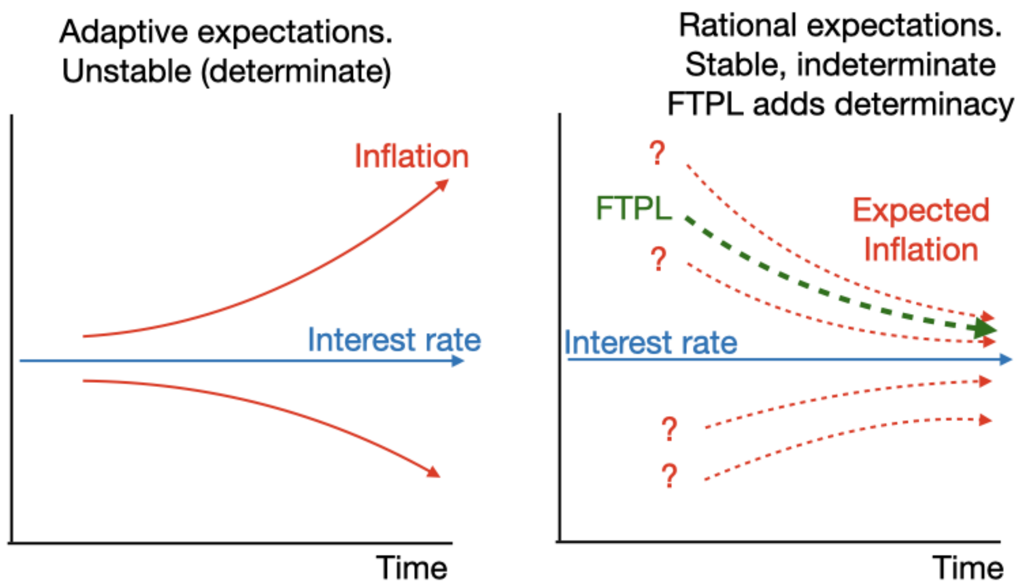

Figure 3: Instability vs. stability with and without indeterminacy

cure inflation. This model captures well most of the verbal analysis by and of the Fed.

But this view does not express monetary *neutrality*. There is no sensible, neutral, flexible-price, frictionless, economic, rational and rational-expectations limit or springboard. Adaptive expectations and the Phillips curve are essential in this view to have any understanding of inflation determination at all. Really, it represents a retreat to the economics of 1971, just before Lucas wrote. Surely we, especially at this event, don't want to sign on to that view, at least without considering the alternatives. Even if expectations are occasionally imperfect, this is the sort of contingent assumption that belongs in a once-in-a-while friction, not an always-and-everywhere description of the basic mechanics of monetary policy.

New-Keynesian models use rational expectations, market clearing, and play by the Lucas rules of how to write and solve models, which are perhaps the most enduring legacy of Lucas (1972). With sticky prices, they base the Phillips curve on inflation relative to rationally expected future inflation, $\pi_t^e = E_t \pi_{t+1}$ (Calvo (1983), Rotemberg (1982). Contemporary new-Keynesian economics is moving a bit back, adding some lagged terms motivated by learning models and indexation, to better match estimates, but that is not central to my story.)

Now from (3) the dynamic response of inflation to interest rates is

$$E_t\pi_{t+1} = \frac{1}{1+\sigma\kappa}\pi_t + \frac{\sigma\kappa}{1+\sigma\kappa}i_t. \tag{6}$$

Inflation is *stable* since $1/(1+\sigma\kappa) < 1$. But the model only ties down expected inflation. Unexpected inflation $\pi_{t+1} - E_t\pi_{t+1}$ can be anything, or wander up and down following sunspots. Sargent and Wallace (1975) modified Friedman's doctrine for rational expectations: Inflation is *indeterminate* under an interest rate peg. Again, we don't have even a starting point, a model of inflation or price-level determination with interest rate targets.

Friedman's unstable (and determinate) is different from Sargent and Wallace's stable and indeterminate. They are frequently confused. Both suggest volatile inflation. But spiraling away on a determinate path is different from batting up and down unpredictably around the peg. Rational vs. adaptive expectations fundamentally change the stability and determinacy properties of the model. The right hand panel of Figure 3 illustrates, with the question mark indicating all the many equilibria that could break out at that point.

New-Keyensian modelers circumvent this problem with an application of the Taylor principle. In this case, if we add $i_t = \phi\pi_t$, inflation dynamics (6) become

$$E_t\pi_{t+1} = \frac{1+\sigma\kappa\phi}{1+\sigma\kappa}\pi_t. \tag{7}$$

Now the Fed takes a *stable* economy and deliberately makes it *unstable*. But we are not back to Friedman's critique, because inflation is still indeterminate. Inflation is now a jump variable. The model only restricts $E_t\pi_{t+1}$, and thus also $E_{t-1}\pi_t$. Inflation π_t itself can therefore jump to the unique value (zero, here) that forestalls an explosion. Adding a rule against such explosions, new-Keynesian modelers produce a determinate inflation, if not quite a price level. The dynamics are still unstable, but the dynamics of the observed equilibrium are stable. (With a jump variable and a rule against explosive solutions, we can solve an unstable difference equation forward, as we solve prices to equal the discounted value of future cashflows.)

The central bank is imagined in this vision to deliberately *destabilize* an economy which is already stable on its own. The central bank threatens hyperinflation or hyperdeflation in order to select, or "coordinate expectations" on the equilibrium it likes. The Fed simply announces its inflation target, announces this threat, and inflation jumps to whatever value the Fed desires. The Taylor Principle is an *equilibrium-selection* policy not an *stabilization* policy.

To see this statement, write the policy $i_t = E_t\pi_t^* + \phi(\pi_t - \pi_t^*)$, where $\{\pi_t^*\}$ is the Fed's stochastic inflation target. By this policy $\pi_t = \pi_t^*$ is the unique bounded equilibrium. If π_t^* is i.i.d. in this example, interest rates never move; the Fed simply announces each period what inflation it would like to see, and that inflation occurs.

But central banks do not have "equilibrium selection" policies. They do not threaten hyperinflation or deflation if inflation comes out against their desires. Such threats being contrary to their objectives, nobody would believe them if they tried. Central banks do not intentionally de-stabilize economies that are stable enough on their own. Ask them. They will respond that they *stabilize* economies; no matter what inflation does, they will act to bring it back.

As I rejected the beautiful $MV = PY$ because central banks do not limit money supply, and money pays the same interest as bonds, we must also reject this elegant solution, because our monetary institutions simply do not remotely behave this way.

The fiscal theory of the price level adds an equation, or rather recognizes one that has been left out so far. In addition to (6), we have

$$\pi_{t+1} - E_t\pi_{t+1} = -(E_{t+1} - E_t)\sum_{j=0}^{\infty}\rho^j \tilde{s}_{t+1+j} \tag{8}$$

Unexpected inflation equals the revision in the present value of future primary surpluses, scaled by the value of debt $\tilde{s_t}$.[3] I call it the "government debt valuation equation." It derives from the consumer's intertemporal budget constraint and equilibrium. It simply recognizes that unexpected deflation raises the real value of government debt, which must correspond to greater real primary surpluses to repay that greater value, and vice versa. If governments refuse fiscal austerity in response to deflation, deflation can't happen.

With the combination (6) and (8), inflation is stable *and determinate* at an interest rate peg. The fiscal theory of the price level resolves Sargent and Wallace's indeterminacy. How volatile

[3] Actually, the equation is

$$\pi_{t+1} - E_t\pi_{t+1} = -(E_{t+1} - E_t)\sum_{j=0}^{\infty}\rho^j \tilde{s}_{t+1+j} + (E_{t+1} - E_t)\sum_{j=0}^{\infty}\rho^j (i_{t+j} - \pi_{t+j+1}).$$

The second term is a discount rate term, or represents interest costs of the debt. We can make it go away by assuming that surpluses respond to pay additional interest costs on the debt. Even without that assumption, inflation remains stable and determinate, but the calculation involvers a bit more algebra, since we have to find the whole inflation path which solves the model including this equation. The latter term is important, and indeed in continuous time the left hand side is zero and this term is the entire mechanism for selecting inflation, as explained in the Appendix. I simplify in the text to make the point, we now have *an* equation that removes multiple equilibria.

inflation is depends on how much fiscal shock or quiet there is. But economics picks one value. We can unite (6) and (8) to write inflation dynamics, now as a function of both monetary and fiscal shocks, as

$$\pi_{t+1} = \frac{1}{1+\sigma\kappa}\pi_t + \frac{\sigma\kappa}{1+\sigma\kappa}i_t - (E_{t+1} - E_t)\sum_{j=0}^{\infty}\rho^j \tilde{s}_{t+1+j} \tag{9}$$

The right hand panel of Figure 3 illustrates this option as well. Fiscal policy determines one of the possible equilibria. In this case, there has been a fiscal shock, producing a period of inflation. That is, roughly, where we are now, in my view, and we are asking monetary policy to offset this fiscal inflation by adding monetary disinflation via interest rates.

The flexible price version of the rational expectations model ($\kappa = \infty$) reduces simply to

$$E_t\pi_{t+1} = i_t - r. \tag{10}$$

(Here I include the steady state real rate r, previously suppressed, for clarity.) This is an extreme version of "stable." Inflation goes instantly to its long run value rather than gently converge. In this version you can see most easily Sargent and Wallace's indeterminacy point: An interest rate target, including a peg, determines expected inflation, but unexpected inflation can be anything. And you can also see how the fiscal theory (8) maintains stability but restores determinacy. Overall inflation dynamics are now

$$\pi_{t+1} = i_t - r - (E_{t+1} - E_t)\sum_{j=0}^{\infty}\rho^j \tilde{s}_{t+1+j}. \tag{11}$$

In this frictionless model, we have two ingredients that determine the price level, the interest rate and fiscal shocks. As with $MV = PY$, the Phillips curve adds non-neutrality and dynamics, but it is not essential for inflation determination or stability. Unlike the adaptive expectations case, sticky prices naturally generalize a well-behaved frictionless benchmark.

With fiscal theory picking unexpected inflation, the Taylor rule is not needed for either stability or determinacy. A Taylor-style rule in which interest rates respond aggressively to inflation is still useful to reduce inflation *volatility*, which may have been its purpose all along. I discuss this below in the context of a slightly more complex model, where the proposition holds.

2.2 Lucas

Lucas (1972a) first made expectations rational, and forward looking, relating output to unexpected inflation only, and moving forward the time subscript in the Phillips curve, $\pi_t^e = E_{t-1}\pi_t^e$. In the spirit of rational expectations, it makes most sense to pair Lucas' Phillips curve with rational expectations in the bond market and consumption. So let's use Lucas' Phillips curve in an interest-rate model by writing

$$x_t = -\sigma(i_t - E_t\pi_{t+1}) \tag{12}$$

$$\pi_t = E_{t-1}\pi_t + \kappa x_t. \tag{13}$$

Eliminating x_t, inflation dynamics (3) are now

$$E_t\pi_{t+1} = i_t + \frac{1}{\kappa\sigma}(\pi_t - E_{t-1}\pi_t) \tag{14}$$

Iterating forward,

$$E_t\pi_{t+2} = E_t i_{t+1}$$

so you can see that Lucas' specification of the rational expectations Phillips curve, along with our IS curve and passive fiscal policy, is stable and indeterminate, like the new-Keynesian model. Under an interest rate peg, Lucas's Phillips curve gives one period of additional inflation after a shock, which then melts away. Adding fiscal theory to this model we again restore determinacy, and name the additional shock.

3 Neutrality and its consequences

We have, finally, a complete economic theory of inflation determination under interest rate targets, comparable to $MV = PY$. It includes rational expectations and market clearing. It starts from a simple frictionless model, analogous to the case that money leads instantly to inflation, but it also allows sticky-price dynamics.

That inflation is stable and determinate under an interest rate target amounts to a sensible characterization and statement of long-run neutrality. Inflation eventually settles down to the nominal interest rate, just as under $MV = PY$ inflation eventually settles down to follow the money growth rate. Good. Monetary theories should be anchored in a benchmark that expresses long-run neutrality. But the implications of long-run interest-rate neutrality are uncomfortable and counterintuitive—as the implications of long-run monetary neutrality were difficult for our predecessors to swallow.

Neutrality for an interest-rate based model, as I have described it, is a little touchier than neutrality for a monetary model with fixed velocity. From $MV = PY$ it follows quickly that more M means more PY and neutrality means it eventually has to be P not Y. Likewise, $i_t = r_t + E_t\pi_{t+1}$ mans that in just about any sensible model, when real and nominal effects decouple, there are steady states with higher i and higher π. But neutrality as I have described it also includes stability—that π will eventually move to follow i, that the steady states are stable. We don't traditionally worry about stability as much with $MV = PY$, the possibility that there are steady states with higher M and higher P, but the economy is unstable so that raising M would send P off on a downward spiral. When money demand is sensitive to interest rates—it is—that proposition is actually not so obvious either. Such models have multiple unstable equilibria. But this theoretical issue is usually ignored, where it is more contentious in today's debates about interest rate targets.

3.1 Interest rate pegs

If inflation is stable and determinate – neutral – then it will be stable and determinate under an interest rate peg. This statement reverses classic contrary doctrines:

- Friedman, ISLM, adaptive expectations models: An interest rate peg is *unstable*. (And determinate).
- Sargent and Wallace, Lucas, flexible-price or New-Keyensian sticky-price, rational expectations (passive-fiscal) models: An interest rate peg is *stable*, but *indeterminate*. It produces multiple equilibria and sunspot volatility.
- Fiscal theory, added to the rational expectations models: An interest rate peg is *stable and determinate*. Inflation *volatility* under a peg depends on fiscal and discount rate volatility.

The preceding doctrines aren't wrong. They just make different assumptions. Friedman and his followers with ISLM spirals assumed adaptive expectations. They, Sargent and Wallace, and their followers assumed passive fiscal policy.

3.2 History

Well, what about the facts? We have just seen something close to an interest rate peg: The long quiet lower bound. Interest rates could not move much in the downward direction, they did not move in the upward direction, and central bankers issued a great deal of forward guidance that interest rates would not move, at least not promptly and more than one for one with observed inflation.

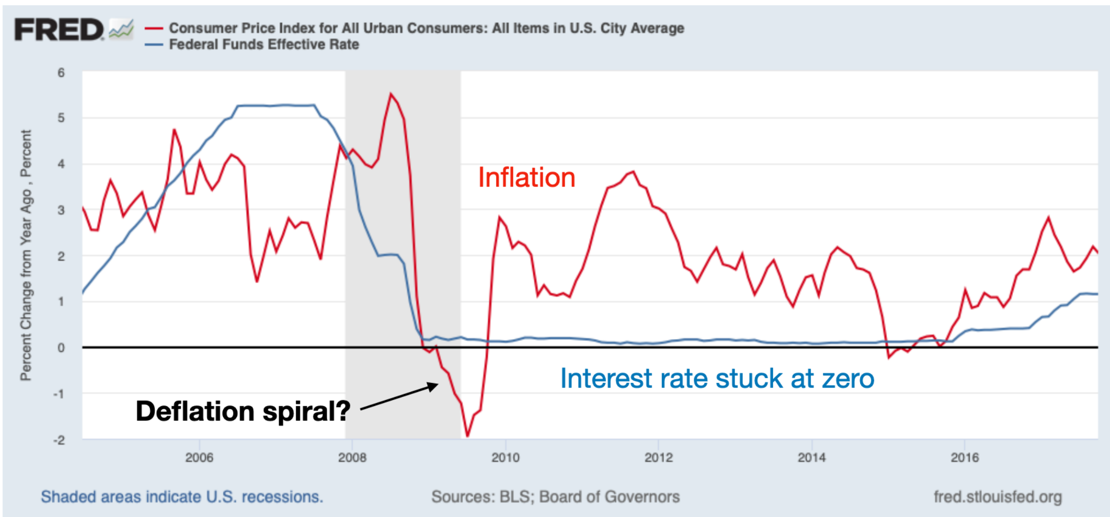

Figure 4: The zero bound in the US

Figure 4 reminds us of this history in the US. In a situation similar to the current one, but with opposite sign, inflation turned to deflation in 2008-2009. The Fed in this case initially and quickly lowered interest rates, but then interest rates were stuck at zero starting in 2008. The experiment lasted longer in Europe and Japan, shown in Figure 5.

The adaptive-expectations model clearly predicted a deflation spiral. Central bankers, oped writers, international institutions, and commenters took this position, correctly given that still-popular view. But the deflation spiral did not happen.

The passive-fiscal new-Keynesian model clearly predicted multiple equilibrium sunspot volatility. That too simply did not happen. (We can model these events by adding a discount rate shock, replacing i_t with $i_t - r_t$, and modeling the response to a decline in r_t.)

What happens if interest rates are stuck at zero for many years? *Nothing* in this case. Inflation quietly batted around. Inflation was if anything *less* volatile at the zero bound than when central banks could move interest rates in their efforts to control inflation.

Score one for rational expectations with fiscal-monetary coordination. A conference celebrating Lucas (1972) should hardly be surprised to cheer the ingredients, though the prediction and result are novel and perhaps uncomfortable.

What about many historical pegs that did seem to lead to spiraling inflation? These were central to Friedman's (1968) argument that pegs are unstable. Well, stability, determinacy and quiet also require no fiscal news in (8). Most governments with interest rate pegs and spiraling inflation are using the peg to hold down interest costs of the debt while they print money and other debt to finance out of control deficits. If you pick episodes ex-post that had large inflation, you also are likely to pick episodes with multiple fiscal shocks. In the zero bound era, for whatever reason, people were rushing to buy government debt at negative real rates. Very low interest costs on the debt act like surpluses. Long run fiscal policy was not in great shape, but there wasn't much news on that score.

3.3 k percent rules

If an interest rate peg at zero is stable and determinate, it follows that a peg at a positive interest rate peg is stable and determinate.

- The central bank may follow a k-percent interest rate rule.

Inflation will simply bat around a higher interest rate, plus or minus the underlying real rate, as it batted around during the long quiet zero bound. K percent may not be the *optimal* rule. But it is *possible*. And the quiet of the zero bound era suggests that maybe central banks' active "stabilization" might not have been doing all that much good. Milton Friedman did not argue for a 4% money growth rule because it solves the optimal control problem of a specific dynamic model, but for its robustness in the fog of reality. The central bank won't fiddle with the hot and cold water producing a scalding or freezing shower.

3.4 Current events

In the present moment, neutrality means that if the Fed does nothing, or only gently raises rates, never exceeding inflation ($\phi < 1$), it is not contributing to greater inflation, and inflation will

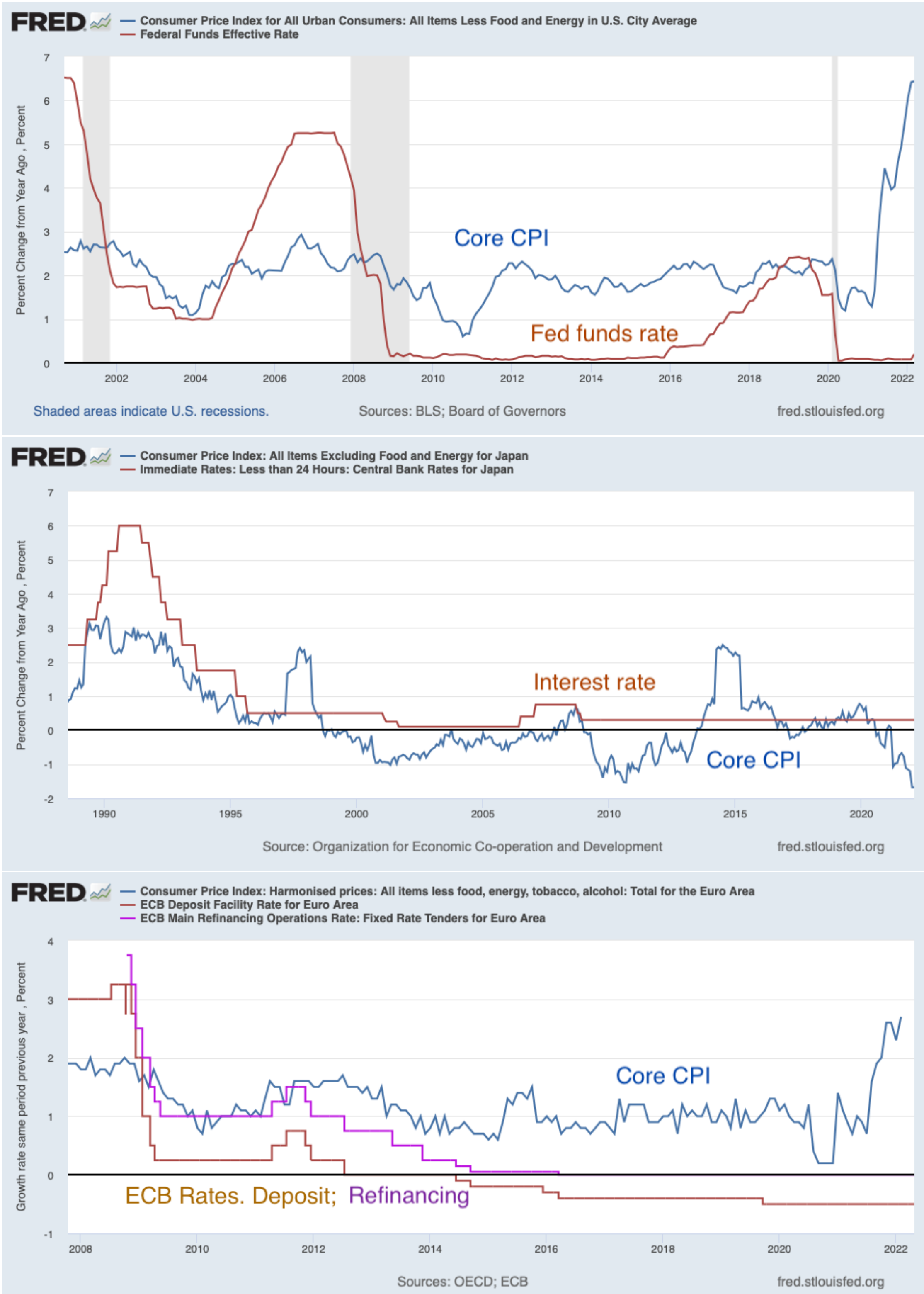

Figure 5: Core CPI and Fed Funds Rate in the Zero Bound Era. US, Japan, Europe

not spiral out of control. Inflation may surge for a while, following other shocks, and as the natural momentum of somewhat sticky prices proceeds. In the fiscal view, it takes a period of low ex-post real interest rates to devalue nominal debt in response to the 2021 fiscal shock. But inflation will eventually come back on its own, so long as fiscal policy or other shocks do not create more inflation. The same modeling that worries about an inflation spiral today worried about a deflation spiral last time.

3.5 Long-run Fisherism

If a k-percent peg is stable and determinate, then raising the peg from k to k+1 percent must move the economy to a new equilibrium with 1 percent higher stable and determinate inflation. *Raising interest rates will raise inflation* at least in the long run.

Long-run Fisherism is an inescapable logical conclusion of stability, determinacy and neutrality. All of the rational expectations models I have written have this prediction.

3.6 Intuition of long-run neutrality

The equations are transparent, but the implications are hard to believe. The frictionless model captures the problem most simply. $i_t = E_t \pi_{t+1} + r$, so peg i_t at a higher level, and once the real rate r settles down, expected inflation $E_t \pi_{t+1}$ must rise as well. If the real rate declines, as in a discount rate shock, and the Fed does not or cannot lower nominal rates, inflation should appear endogenously. Really? How?

An individual takes the price level path as given. Before prices change, a higher nominal interest rate i_t is a higher real rate, and induces the individual to demand less today x_t and more tomorrow x_{t+1}. That change in demand pushes down the price level today p_t and pushes up the expected price level tomorrow p_{t+1}. (I have in mind here the full consumer first-order condition $x_t = E_t x_{t+1} - \sigma(i_t - E_t \pi_{t+1} - r)$.) That force continues until $E_t \pi_{t+1} = i_t - r$. But which is it, lower p_t or higher p_{t+1}? The consumer first-order condition, the intertemporal substitution effect, cannot tell us. As before, that condition alone leaves an indeterminacy, unexpected inflation, in this case $p_t - E_{t-1} p_t$ or $\pi_t - E_{t-1} \pi_t$. Unexpected inflation is determined by the consumer's budget constraint, a wealth effect, which is the mirror of the government debt valuation equation. If we pair the higher interest rate with no change in surpluses, and thus no wealth effect, then the initial price level p_t does not change and the entire effect of higher interest rates is a rise in p_{t+1}.

Whether reflected in an unexpectedly lower price level p_t or higher price level p_{t+1}, however, the proposition is that higher nominal interest rates raise higher expected *future* expected inflation $E_t(p_{t+1} - p_t) = E_t\pi_{t+1}$, and that is a natural outcome of the consumer's intertemporal optimization.

A common intuition says that higher interest rates should lower current demand, and thus lower inflation. That intuition confuses unexpected inflation $\pi_t - E_{t-1}\pi_t$ with the change in expected inflation $E_t\pi_{t+1}$. It adds a wealth effect of higher future fiscal surpluses to the intertemporal substitution effect.

We solve rational expectations models from the future to the present. Look at the Phillips curve $\pi_t = E_t\pi_{t+1} + \kappa x_t$. If people, including ourselves, expected inflation to spiral away in the future $E_t\pi_{t+1}$, then inflation would have already risen π_t. If you think of inflation today causing inflation to spiral up in the future, then you're not thinking as we do in a rational expectations context.

4 Short run non-neutrality; Can higher interest rates temporarily lower inflation?

We have inflation determination, rational expectations, long-run neutrality, and a consequent prediction that higher interest rates raise inflation eventually. We should stop and smile. Pretty much everything that you used to do with money growth starting with $MV = PY$ and stable velocity you can now do with an interest rate in the place of money growth.

However, extensive experience suggests that higher interest rates can at least *temporarily* lower inflation, at least under some conditions. And there is nothing in what we have done so far that rules out a *temporary* negative sign.

If that were true, then the Fed could do some good by raising rates, and at least temporarily offset the underlying causes (fiscal, I think) of inflation. We could then also understand central bankers' and policy commentators' belief in a uniformly negative effect, as well as the absence of a well-documented long-run positive effect in econometric estimates. Outside the zero bound era, central banks never left rates alone long enough (with a background of stable fiscal policy and no other shocks) to see the positive long-run effect. Until the lower bound provided the experiment, I would add, but one episode might be excused with epicycles.

We are, in short, where Bob started. We have, finally, a full theory of inflation determination with long-run neutrality. But Bob's central contribution was to describe the short-run *non-neutrality* of money.

4.1 A failure in simple sticky price models

Figure 6 plots the response of my simplied models to an interest rate rise. Inflation rises in the rational expectations models, even in the short run. Despite sticky prices, these models only draw out the positive response of inflation to interest rates.

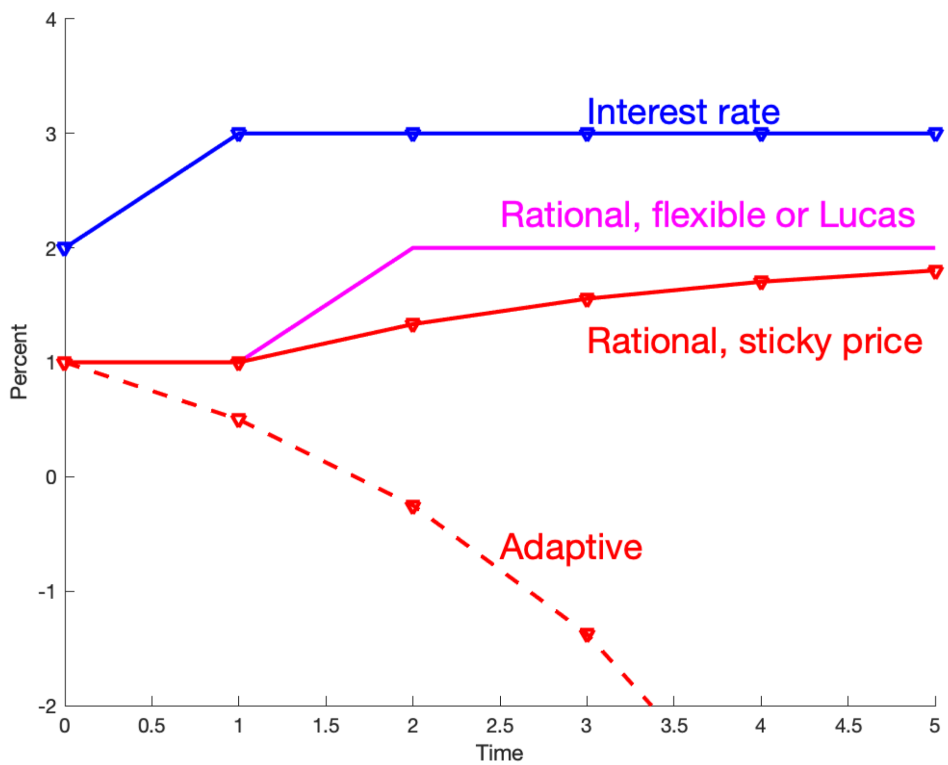

Figure 6: Inflation response to 1% rise in the interest rate. Values after time 1 are expected values as of that date, $E_1\pi_t$. "Adaptive" plots (4), $\pi_t = (1+\sigma\kappa)\pi_{t-1} - \sigma\kappa(i_t - r)$. "Rational, sticky price" plots (6), $E_t\pi_{t+1} = \frac{1}{1+\sigma\kappa}\pi_t + \frac{\sigma\kappa}{1+\sigma\kappa}(i_t - r)$. "Rational, flexible or Lucas" plots (10) $E_t\pi_{t+1} = i_t - r$ and (14), $E_t\pi_{t+1} = i_t - r + \frac{1}{\kappa\sigma}(\pi_t - E_{t-1}\pi_t)$. Parameters are $\sigma\kappa = 0.5$, $r = 1$.

We still have short-run non-neutrality. Sticky prices have done their job! The higher nominal interest rate produces a higher real interest rate, since inflation rises more slowly than the higher nominal rate. The higher real interest rate lowers output and employment, not shown. So if your objective is only to produce a model in which the Fed can cool economic activity in the short run with interest rate rises, you have it. You might stop here and say, we have indeed redone Lucas (1972) with interest rate targets, since his purpose was to understand how money growth affects the real economy. But we want to go one step further, and produce a model in which the Fed can also cool *inflation* with interest rate rises, and we don't have that yet.

The adaptive expectations model produces standard intuition, that higher interest rates lower inflation, by setting off a classic spiral. In reality, of course, the Fed gives in and drops the nominal interest rate to stop the spiral.

You can also see a negative sign of inflation on interest rates in adaptive-expectations dynamics (4), and a positive sign in the rational-expectations counterparts including the new-Keynesian, (6), sticky price with fiscal theory (9), flexible price (10) (11) and Lucas Phillips curve (14) cases.

To our quest, the adaptive expectations model goes too far: To produce a short-run negative effect, it induces a long-run negative effect; to produce a short-run non-neutrality, it abandons long-run neutrality. If fundamentally change the stability and determinacy properties of the economy. It does not have a neutral limit. It fundamentally and immutably separates monetary policy from standard optimizing and market clearing economics.

New-Keynesian models produce response functions with temporarily lower inflation. However, they implicitly pair the interest-rate rise with a contractionary fiscal shock. New-Keynesian models have the same dynamics as (9),

$$\pi_{t+1} = \frac{1}{1+\sigma\kappa}\pi_t + \frac{\sigma\kappa}{1+\sigma\kappa}i_t - (E_{t+1} - E_t)\sum_{j=0}^{\infty}\rho^j \tilde{s}_{t+1+j} \tag{15}$$

with $\kappa \rightarrow \infty$ as the frictionless limit. They assume that the Fed chooses $(E_{t+1} - E_t)\pi_{t+1}$ by equilibrium-selection policy, and then fiscal policy follows with the required taxes. If one specifies the monetary policy process to give the same interest rate path but not induce a fiscal contraction, inflation does not go down.

Part of my rules of the game is that we are looking for a model in which higher interest rates cause lower inflation without contemporary fiscal policy changes. Our goal is to see if there is a mechanism by which the Fed can lower inflation on its own, as budget-neutral open market operations can lower inflation under $MV = PY$.

We do not have to rehash the active fiscal vs. active money controversies in this investigation, however. An observational equivalence theorem unites the new-Keynesian and sticky-price fiscal-theory approaches: You can't see off-equilibrium actions from time series drawn from an equilibrium. It is enough to ask new-Keynesians to display the implied fiscal policies, the lump-sum taxes that are often alluded to in footnotes to satisfy the government debt valuation equation ex-post. Plot fiscal surpluses along with inflation, output, employment, and other model predictions. If a new-Keynesian disinflation requires a strong response of lump-sum taxes to pay interest costs on the debt and a windfall to bondholders, one should compare that prediction to data, and make clear it is part of the policy experiment. The fiscal theory approach gives the same response to a contemporaneous fiscal and monetary policy shock. If one doubts that our fiscal authorities will respond to disinflation and recession with austerity, rather than largesse, then one can change the monetary policy shock process to produce the same path of equilibrium interest rates, but no fiscal response. One can arrive at my figures by this process (Cochrane (2023) Section 17.4.2).

4.2 An imperfect model that produces a negative effect

Figure 7 is the best concrete example I know of a transparent model in which there is such a short-run negative effect.

The model is

$$
\begin{aligned}
x_t &= E_t x_{t+1} - 0.5(i_t - E_t \pi_{t+1}) \\
\pi_t &= E_t \pi_{t+1} + 0.5 x_t \\
i_t &= i_{t-1} + \varepsilon_{i,t} \\
\rho v_{t+1} &= v_t + r^n_{t+1} - \pi_{t+1} - \tilde{s}_{t+1} \\
E_t r^n_{t+1} &= i_t \\
r^n_{t+1} &= 0.9 q_{t+1} - q_t
\end{aligned}
$$

The maturity structure of government debt is geometric, with decay parameter 0.9. Here I use the full model, i.e. including the $E_t x_{t+1}$ term in the consumption equation. I raise interest rates, but I leave fiscal surpluses unchanged.

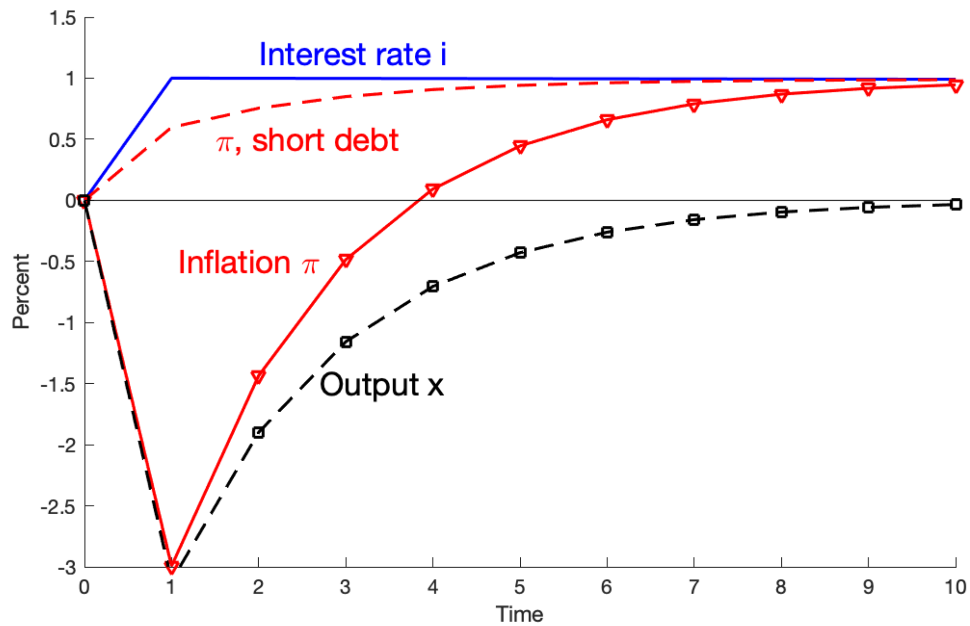

Figure 7: Response of inflation to an interest rate shock, and no change in fiscal policy, with long term debt. In the base case, debt has a geometric maturity structure, decaying at rate 0.9^t with $t =$ maturity. The short-term debt case is one-period debt only.

Long-term debt is the crucial innovation relative to the simple models of Figure 6, and its inclusion produces the negative sign. With long-term debt, but no ability to change surpluses, the central bank can lower inflation now, but by raising inflation later. Raising interest rates, and thus inflation in the long run, devalues long-run debt, and thus raises the value of short-term debt.

Sims (2011) calls the pattern of Figure 7 "stepping on a rake" and offered it as a parable of the 1970s inflation cycles, in which higher rates temporarily lowered inflation, but inflation came back larger. The pattern also represents a form of unpleasant interest-rate arithmetic, a successor to Sargent and Wallace (1981) unpleasant monetarist arithmetic. (Sargent and Wallace focus on seignorage in a model with money and real debt. In this model, there is no seignorage or money. Instead, inflation devalues nominal debt. Higher real interest payments on the debt also cause inflation.) Unpleasant interest-rate arithmetic is here a negative sum, or inequality proposition: The Fed gets more long-run inflation than it saves in short-run inflation.

A Taylor-type rule, in which the interest rate reacts to inflation, adds this sort of response to the inflationary effect of fiscal or other shocks. In this way, a Taylor rule spreads the inflation of a such shocks forward, reducing their immediate impact. With the forward-looking Phillips curve, random walk inflation has no output effect, so by smoothing inflation forward the Taylor rule reduces output volatility. In this model, the Taylor-rule coefficient must be slightly less than one, so the rule but not the greater-than-one principle is important.

Taylor emphasizes that his rule works well in a variety of models, and that robustness rather than strict optimality in a particular model is its virtue. It reduces volatility by eliminating instability of the adaptive expectations model; it reduces volatility by eliminating indeterminacy of the rational expectations model; and it reduces volatility by spreading a short sharp inflation out over time to a small persistent inflation in the rational-expectations fiscal-theory model.

This response is the sort of result we are looking for. As it was with monetary neutrality in 1968, or 1972, the logic and experience driving us to long-run interest-rate neutrality is compelling. So if there is a negative effect, it must be temporary. And we should have an economic model that expresses both the temporary negative sign and long-run neutrality in a positive sign.

The negative effect is limited however. The point of a model is to isolate when effects such as this do and don't work.

This negative effect only holds for *unexpected* interest rate rises. Lower inflation breaks out when the higher interest rate is announced, not when it happens. Thus, we have a lovely continuation of our list by which interest rates inherit many Lucas (1972) properties of money growth. For fitting the data, however, this may be a virtue or a limitation. Maybe expected interest rate rises can also lower inflation. If so, we need a different model.

The negative sign in this model relies on devaluing long-term debt by the expectation of higher interest rates to come, in order to raise the value of short-term debt. The effect thus vanishes when governments borrow short term, as illustrated by the "π, short debt" line of Figure 7 which plots the result with only short term debt. More generally, the size of the effect depends on the maturity structure of debt. It is not obvious in experience that the negative sign is closely tied to the maturity structure of government debt.

More deeply, this is a completely novel intuition for the negative effect of interest rates on inflation. It will be a long time before we write opeds, Fed chairs explain, and we teach to undergraduates that the central mechanism by which the Fed can temporarily lower inflation is to rearrange the real payoffs to different maturities of nominal government debt. Maybe that's true, but maybe we want models that express other intuitions as well.

The negative effect only kicks in for long-lasting interest rate increases, that raise long-term interest rates. Like maturity structure, it is not obvious that higher interest rates only lower inflation when they are persistent, and when they propagate to the long-term yield curve.

Price stickiness *reduces* the strength of the effect, though drawing out its dynamics. With sticky prices, the higher real interest rates add interest costs of the debt, an inflationary force. The effect holds, and is strongest, in the flexible price case.

Clearly, this is not at all an always and everywhere, mechanical connection between higher rates and lower inflation, Lucas holy water sprinkled on IS-LM thinking. It does not produce something like the adaptive-expectations dynamics in the short run, which then turn around and become stable when some suitable friction or information problem is resolved.

These features are not counterfactual. They are just unknown: This model is new, and nobody has looked to see if the negative effect only occurs with these preconditions. I suspect not, however, which leads me to a search for a better model that produces the same sort of result with a different and more plausible mechanism. Unless empirical work verifies its preconditions, I offer it as a good start down an important theoretical and empirical path rather than a reincarnation of Lucas (1972) in interest rate clothes.

4.3 Expected declines?

Both my little model and the standard new-Keynesian model (which adds a fiscal shock) produce lower inflation after an interest rate rise by inducing a shock to unexpected inflation. They produce one period of negative $\pi_{t+1} - E_t\pi_{t+1}$, which then drags out by sticky price dynamics. In the flexible price limit, the price level declines and inflation starts immediately.

One intuition wants higher interest rates to produce lower *expected* inflation, directly, and not just the after effects of an instant unexpected inflation decline. We do not see sharp declines in inflation that melt away, we seem to see inflation or disinflation that build after a shock.

That sort of negative response will be doubly difficult to achieve. From $i_t = r_t + E_t\pi_{t+1}$, a higher nominal rate i_t can only lower expected inflation $E_t\pi_{t+1}$ if real rates go down *more* than one for one as nominal rates go up. It is not enough for sticky prices to simply slow down adjustment, to allow *some* of a nominal interest rate rise to be real as in Figure 6.

We may never get there, and only build models in which the disinflation is the result of the shock. Lucas (1972) translated to interest rate targets may be right. If so, that suggests a powerful limit on common intuition about how interest rates actually lower inflation.

4.4 Estimates

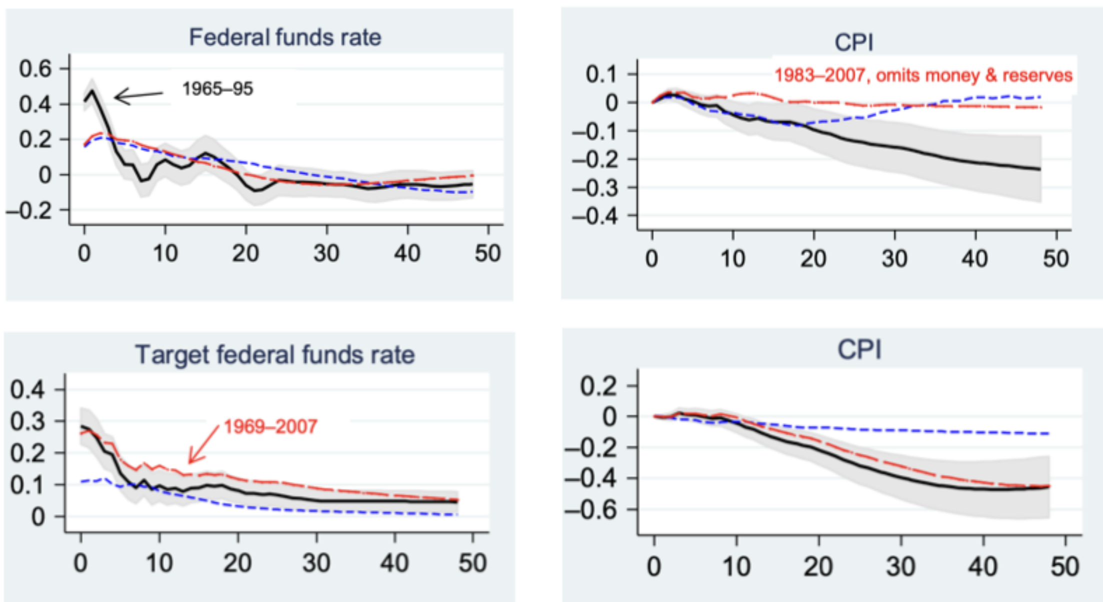

Figure 8: Two estimates of the effect of monetary policy shocks. Top: Christiano et al. (1999) identification. 1965m1–1995m6 full specification: solid black lines; 1983m1–2007m12 full specification: short dashed blue lines; 1983m1–2007m12, omits money and reserves: long-dashed red lines. Light gray bands are 90% confidence bands. Bottom: Romer and Romer monetary shock. Coibion VAR 1969m3–1996m12: solid black lines; 1983m1–2007m12: short dashed blue lines; 1969m3–2007m12: long- dashed red lines. Source: Ramey (2016).

The empirical estimates we have, when they indicate that higher interest rates reduce inflation at all, show no immediate effect, and then a slow downward drift of the price level.

Figure 8 presents two estimates of the effect of higher interest rates that have the desired sign, from Valerie Ramey's (2016) comprehensive review. (The plots show the *price level* not the inflation rate.) The top estimate implements the classic Christiano, Eichenbaum, and Evans (1999) VAR. The lower estimate is based on the Romer and Romer (2004) narrative identification.

Here and more generally monetary VARs find that higher nominal interest rates raise real interest rates and reduce *output*, but they have slow, small, and uncertain effects on *inflation*.

Given that the US currently hopes that higher interest rates will swiftly reduce the current inflation, these plots are sobering.

By starting with a big unexpected inflation, the response of Figure 7 comes much more quickly than these estimates. Sims (2011) produces a hump-shaped output response by adding habit persistence in consumption, but still does not produce the slow-starting long but small price level decline of the VARs.

On the other hand, one may feel that the VARs completely miss the important effect of an intervention such as 1980. They isolate transitory idiosyncratic movements in the federal funds rate, not long-lasting movements. Most of all, by design, they find idiosyncratic deviations from a rule, not changes in rule or "regime" that may durably change expectations. If the art of reducing inflation is to convince people that something has changed so they should lower inflation expectations, then the response to a monetary policy "shock" orthogonal to a stable "rule" completely misses the successful policy.

No current VAR attempts to find monetary policy shocks orthogonal to fiscal shocks, so we must read them with that additional grain of salt relative to the conceptual experiment we wish to learn about. The estimated federal funds responses die out quickly, so the VARs do not tell us anything about long-run neutrality or the model's prediction that a persistent interest rate rise would have a larger and instant negative effect on inflation. Evaluating this model of Figure 7 remains low-hanging fruit.

5 Paths to follow

So, despite 50 years of modern macro since Lucas (1972) started us off, we still don't have a solid well-agreed on theoretical or empirical answer to the basic question: If higher interest rates temporarily lower inflation, by what economic mechanism do they do so?

If you want to return to adaptive expectations, or add complex learning and expectation formation schemes (Gabaix (2020), García-Schmidt and Woodford (2019), Bianchi-Vimercati, Eichenbaum, and Guerreiro (2022)) to produce a negative sign by reversing stability, then you have to face the failure of that approach during the zero bound era—as well as adaptive expectations' failures in stagflation, in the relatively rapid end of inflation in 1982, and in the success of inflation targets and ends of hyperinflations in which inflation fell with no monetary stringency or output consequence. Yes, expectations might sometimes seem adaptive. But as Bob also taught us in Lucas (1973) and Lucas (1976), apparently adaptive expectations are ephemeral too. The Calvo fairy visits every day in Argentina, and every hour in Venezuela. Rational expectations produces adaptive-looking decision rules, because decision rules must react to current observables. The point of rational expectations is that those rules change when exploited, not that they don't hold in sample.

More deeply, this approach produces the desired sign by changing the stability and determinacy properties of the flexible-price rational economy. Stability and determinacy are basic and robust dynamic properties, and the lessons of the zero bound era are powerful. Forward-looking expectations appear robustly stable, and adaptive robustly unstable: Driving a car looking at the road through the windshield, drivers tend to stay on the road. Driving looking at the rear-view mirror, they tend to veer off. Just how much stability and determinacy reflect this one ingredient in general models is, however, a good question.

To change stability and determinacy, you have to move an eigenvalue across one. Small changes in model structure or parameterization are not going to work, as they change eigenvalues by small amounts. (One needs an unusual model for the eigenvalue to change discontinuously with a parameter.) That means that this approach needs to make a large deviation from rationality, and rational or flexible price limits eventually cross back across one to ruin the result. (See Cochrane (2016) for a concrete example.)

Founding the most basic prediction of monetary economics on the idea that people are permanently, exploitably, immutably and substantially irrational, to the point that reverses the stability and determinacy of the underlying frictionless economy, at least makes our branch of economics ephemeral. In the absence of $MV = PY$, explaining to the public, central bankers, and undergraduates how monetary policy works will require that we say it only works because people are predictably and immutably dumb. If they only woke up, the Fed would be powerless. Fortunately those hotshots at the Fed can exploit their dumbness—despite the Fed's own rather dubious inflation-forecasting skills.

A model of temporary, limited or contingently adaptive expectations, that then turn around to become rational in a suitable long run is a possibility. Some verbal commentary distinguishes times that people are paying attention to national attention and quieter times when they mind their own business. Following Lucas, however, we need to describe the transition between the neutral and the non-neutral behavior. I am not aware of such a model.

You may wish to put money back in the model. Raising interest rates means printing less money, which lowers PY and eventually P. (Alvarez, Atkeson, and Edmond (2009) is a good example.) But it's not so easy as a matter of theory, and as in the first paragraph, money supply control simply does not describe our world.

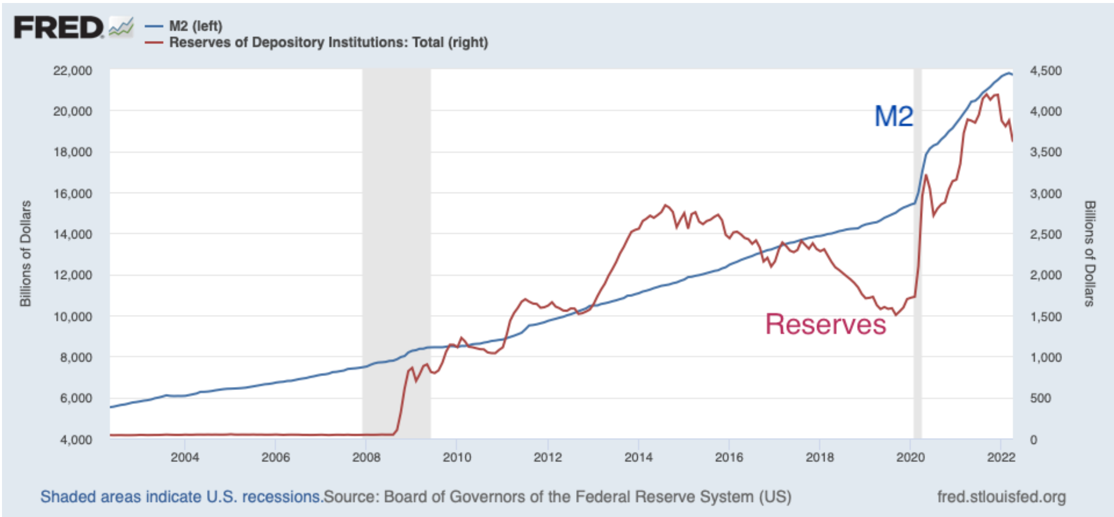

Figure 9: Reserves and M2

Returning to monetarism is not a great empirical success either, and requires us to acknowledge its failures. Figure 9 plots reserves and M2. Yes, M2 rose ahead of the recent inflation along with reserves. But M2 and reserves have no connection in the three great QEs. Monetary predictions of hyperinflation in the QE era were also wrong. Moreover, the recent spike in M2 did not come from the Fed lowering interest rates and working down a money demand curve; it did not come from a loosening of reserve requirements; and it did not come from a deficit-neutral open market operation, relieving the private sector of treasury debt in exchange for reserves. It came from the largest fiscal helicopter drop in living memory, in which the Fed and Treasury got together to print $3 trillion of new reserves and borrow $2 trillion more and send people checks, mechanically raising M2. Surely that is not a coincidental fact.

You might say that the Fed *should* go back to controlling the money supply, and start cracking down on inside liquid money substitutes. But we need some advice for central banks in the meantime, and at least we should understand how our current interest rate based system works, or doesn't. Inflation is something while banks control interest rates, and we need a theory of what that something is.

One is drawn to add model ingredients. Surely in the DSGE soup there are enough ingredients to come up with a temporary negative sign. That is, I think, exactly the right answer. My point is, it has not yet been done–and especially, it has not been done with the kind of clarity, simplicity, economic rigor, transparency and tractability that Bob brought to the non-neutrality of money.

One easily jumps to financial frictions, price and wage-setting frictions, strategic complementarities or other model complications. But the negative response of inflation to interest rates should be a more universal and deeply rooted phenomenon, one that will not vanish if, for example, the US changes the downpayment rules on mortgages. In his Nobel Lecture, Lucas (1996), Bob cites David Hume for understanding the neutrality and non-neutrality of money in 1752. Velde (2009) documents a beautiful non-neutrality episode in 1724 France, with a monetary and financial system utterly unlike our own.

It may be relatively straightforward to find *sufficient* conditions to deliver the negative sign, with enough model complications. Our goal though is the minimum *necessary* conditions, that apply most broadly.

Again, Lucas (1972) is a great example. In his economy, the flexible version leads to superneutrality: An increase in money just raises the price level. Bob put in *one* "friction," imperfect information about aggregates, leading to a confusion between relative and aggregate price movements. But it is limited: if the information problem is absent, the non-neutrality goes away.

This brings us back to the Phillips curve. In my little models, the Phillips curve is the central source of inflation dynamics. (The Appendix makes this point clear in a continuous time model.) Yet the Phillips curve has not achieved great theoretical and empirical clarity, despite decades of dedicated work by top macroeconomists. It may make sense that firms sell more when output prices are high, or that worker work harder when wages are high. But these are relative prices, where the Phillips curve states that somehow output and employment increase when all prices and wages rise together. So, it needs some confusion or correlation of relative prices with the overall price level. (On the other hand, public discourse utterly confuses relative prices with the price level, so perhaps that's not so unrealistic an assumption!)

So, in addition to wondering what ingredients to put in, perhaps this is one we should take out. Perhaps we can start to study the dynamic relationship between inflation and nominal interest rates apart from the Phillips curve.

Our goal is to understand $\pi_t = a(L)i_t$, the dynamic relationship between interest rates and inflation. The Phillips curve came from thinking about output and employment *effects* of inflation. That's what Lucas (1972a) was all about. The Phillips curve wasn't designed to be the central mechanism for *nominal* dynamics. Why should the Phillips curve, and not, say, supply chain network pricing dynamics, be at the center of our study of the economics connecting nominal interest rates to nominal prices? We will of course still want to understand how inflation affects output and employment, and surely that understanding will feed back on inflation dynamics, but in the spirit of adding ingredients and frictions one at a time, perhaps the price dynamics should come before the Phillips curve.

There is, of course, another possibility: It might not be true. A persistent nominal interest rate rise, with no change in fiscal policy, may not lower inflation even in the short run. The VAR literature is tenuous despite enormous effort. The "price puzzle" that higher interest rates seem to raise inflation without delicate orthogonalization may have been trying to tell us something. Most interest-rate rises in the past that have seemed to lower inflation may have come with fiscal tightenings, or pro-growth fiscal and microeconomic policy that raise revenue. Fiscal authorities respond to the same economic and political situations that drive monetary authorities to tighten.

6 Conclusion

What is the dynamic effect of *interest rates* on inflation, $\pi_t = a(L)i_t$, in our world of abundant liquid assets, in which central banks set nominal interest rates, do not control money supplies, do not make equilibrium-selection threats, and cannot directly change fiscal policy? And, of course, after that, how do interest rates then affect output, employment, and other variables?

I have followed one line of thought on these questions to its logically inevitable conclusion: Rational expectations and fiscal underpinnings of monetary policy imply that inflation is stable and determinate in the long run. That implies neutrality, that higher interest rates (without fiscal shocks) eventually raise inflation, and a k percent rule is possible. I think there may well be a short-run negative effect of interest rates on inflation, and I show one suggestive model, but we need better models of that effect.

Thus, as I see it, we have made a lot of progress. We're finally at the launch pad, and we have some promising ideas, but we're still waiting for a new Lucas – and then, perhaps Sims on the empirical side – to finish the project.

If this path succeeds, however, we will be left with a view that central banks are a lot less powerful than we thought. First, fiscal policy remains a central determinant of inflation. When a fiscal shock occurs, when the government borrows or prints and spends and people do not expect the debt to be repaid, and absent explicit default, inflation must rise to devalue the debt, sooner or later. The central bank can choose when and how abruptly, but inflation is no longer always and everywhere just a monetary phenomenon. Second, the central bank's ability to lower inflation by higher interest rates, provoking a little bit of recession, remains contingent on the frictions of the model that produces a temporary negative effect, just as the central bank's ability to affect output by changing the money supply is contingent in Lucas (1972). The central bank still fully controls the long-run price level, however, by its ability to drag expected inflation to wherever it sets the nominal interest rate.

All this is controversial. Much of the point of this essay is to proclaim and explain the neutral benchmark, which is otherwise a bit implicit in the equations of fiscal theory models, as yet a niche pursuit. Most academic literature still uses new-Keynesian equilibrium-selection threats, and the long-run neutrality of even that model is not widely recognized. Most of the policy world uses a muddle with somewhat adaptive expectations, or expectations as an independent force. Thus, across economics today, basic questions are still up for grabs. In the long run, is inflation stable or unstable, determinate or indeterminate under a peg? If the Fed raises rates persistently, and there is no fiscal news or other shocks, does inflation rise or decline in the long run? If not this, what is the neutral, frictionless benchmark on which we build a theory of inflation under interest rate targets?

The short run non-neutral and disinflationary effects of higher interest rates have more consensus of opinion behind them, but even less well-accepted theory behind that opinion. If the Fed raises interest rates, does inflation temporarily decline? If so, by what mechanism, and under what preconditions? And even though most economists seem to believe in the sign of the effect, the all important magnitude is still contentious. Must the Fed raise interest rates by more than the current rate of inflation, following the Taylor Principle, in order to lower inflation at all? Or will the substantially lower interest rate rises the Fed has followed and envisions be sufficient for inflation to fade away, at least until the next big shock?

How is it that we've been playing with interest-rate based models for at least 40 years, yet such basic questions are still unanswered? I think another important Bob Lucas lesson applies. I recall attending a seminar in which Bob was presenting an early draft of Lucas (2009). Bob had been working on it over a year. In response to question after question why Bob had not included some ingredient, he answered to the effect of "I tried that, but it didn't make an important difference," and then explained why. Bob does not so much build models as he sculpts them, removing unneccessary piece after unneccessary piece.

As I look at monetary models based on interest rate targets, I think we have been guilty of playing with too-complex models when we don't really understand basics, such as stability, determinacy, and the frictionless limit. But this is always the way in economics, as it is in the sciences. Ideas start complex and simplicity only emerges after much hard work.

This is all great news for young researchers. These are the good old days. Low-hanging fruit abounds. We're really at the beginning stages where simple models need exploration, not, as it appears, in a mature stage where essentials are settled and all there is to do is to add to the immense stock of complicated epicycles.

Given the state of actual agreed-on knowledge, central banks' proclamations of detailed technocratic ability to manipulate delicate frictions is laughable. Figure 10 shows in chart form the Rube-Goldberg list of mechanisms the ECB thinks it understands and can manipulate. Central bankers who think they have any idea how all these boxes and arrows work, and how to manipulate them, should reread Bob's unsung classic "on a report to the OECD" Lucas (1979) once a week. A little humility would do us all good.

The chart below provides a schematic illustration of the main transmission channels of monetary policy decisions.

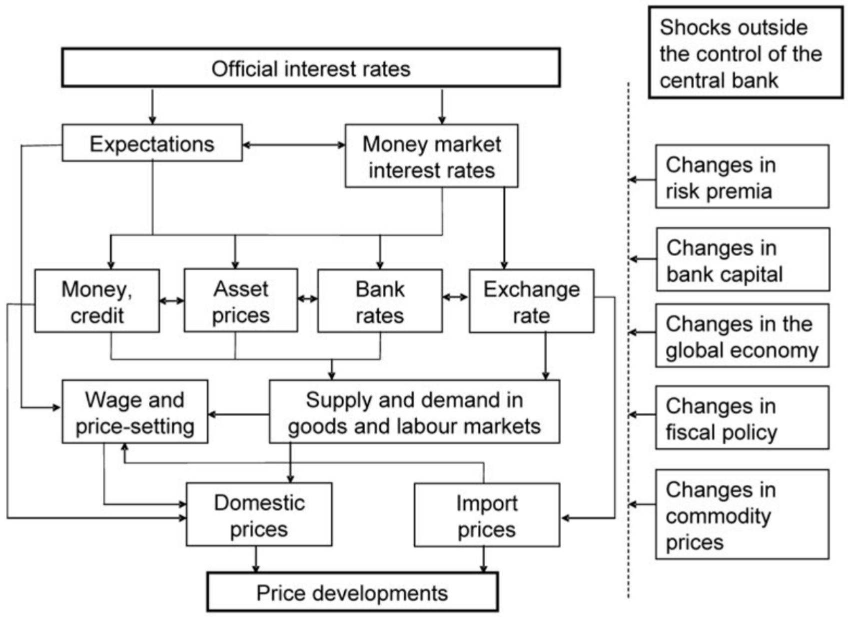

Figure 10: The ECB's view of monetary policy. Source: https://www.ecb.europa.eu/mopo/intro/transmission/html/index.en.html

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Appendix. Continuous Time.

Here I develop the simple models in continuous time. This is a clearer though less familiar way to see the main points. In particular, we can see here that the central question is really the sign of output in the Phillips curve—Is output high when inflation is *increasing* or *decreasing*? In continuous time, some of the timing conventions that obscure the analysis vanish. In particular, we see that rational expectations in the IS curve are not an issue, which suggest that various attempts to modify the IS curve, such as adding hand to mouth consumers, may not change the fundamental sign and stability properties of the model. Continuous time with sticky prices points to a fundamentally different reinterpretation of the model: The government debt valuation equation does not adjust via price-level jumps on the date of a shock, but by choosing a whole path of inflation that adjusts the discount rate applied to future surpluses.

Write the standard model

$$E_t(x_{t+\Delta} - x_t) = \sigma(i_t - E_t\pi_{t+\Delta})\Delta \quad (16)$$

$$E_t(\pi_{t+\Delta} - \pi_t) = -\kappa x_t \Delta \quad (17)$$

The standard model in continuous time is thus

$$E_t dx_t = \sigma(i_t - \pi_t)dt \quad (18)$$

$$E_t d\pi_t = -\kappa x_t dt. \quad (19)$$

Normally a term $-\rho\pi_t dt$ appears on the right of (17) and (19). As I simplified the discrete time Phillips curve from $\pi_t = \beta E_t\pi_{t+1} + \kappa k_t$ with $\beta = 1$, I simplify here with $\rho = 0$; the Phillips curve is centered on expected future inflation.

The price level is differentiable, and cannot jump or diffuse. In an instant dt only a fraction λdt of producers may change prices. The inflation rate may have jumps or diffusions. But $E_t\pi_{t+\Delta} - \pi_t$ is still of order Δ, so the relevant inflation in the consumer's first order condition (16) is $\pi_t\Delta$ and $\pi_t dt$ in (18). The issue whether inflation in that condition should be rationally anticipated or adaptive disappears. This is a central clarification of continuous time.

Equations (17) and (19) express the standard rational-expectations Phillips curve. The adaptive-expectations analogue is

$$\pi_t - \pi_{t-\Delta} = \kappa x_t \Delta \quad (20)$$

$$d\pi_t = \kappa x_t dt. \tag{21}$$

Thus, adaptive and rational expectations differ by whether higher output corresponds to increasing (21) or decreasing (19) inflation; by inflation greater than future or past inflation. Essentially, they differ by the sign of κ. Adaptive expectations also produce a differentiable inflation, with neither jumps nor diffusion terms.

Again I simplify the model so we can see the main points without algebra, by using a static version of the consumption equation.

$$x_t = -\sigma(i_t - \pi_t) \tag{22}$$

Integrating forward the actual relation (18)

$$x = -\sigma E_t \int_{\tau=0}^{\infty} (i_{t+\tau} - \pi_{t+\tau}) d\tau. \tag{23}$$

Therefore, the coefficient σ in (22) is no longer the intertemporal substitution elasticity. It includes an assumption that the real interest rate will last for a while, and a measure of how long that while is.

In sum, with rational expectations our simple model is

$$\begin{aligned} x_t &= -\sigma(i_t - \pi_t) \\ E_t d\pi_t &= -\kappa x_t dt \end{aligned}$$

and with adaptive expectations it is

$$\begin{aligned} x_t &= -\sigma(i_t - \pi_t) \\ d\pi_t &= \kappa x_t dt. \end{aligned}$$

Eliminating output, we have the relation between interest rates and inflation. With rational expectations

$$E_t d\pi_t = -\sigma\kappa\pi_t dt + \sigma\kappa i_t dt \tag{24}$$

while with adaptive expectations

$$d\pi_t = \sigma\kappa\pi_t dt - \sigma\kappa i_t dt. \tag{25}$$

The models differ only on whether one takes the derivative of inflation forward or backward.

We have immediately the results of the discrete-time model. With passive fiscal policy, and with the usual sign restrictions $\kappa > 0$, $\sigma > 0$, inflation is stable but indeterminate under rational expectations; while inflation is unstable but determinate under adaptive expectations.

"Stable" means that the coefficient in front of π_t on the right hand side is negative. "Indeterminate" means that we do not fully determine inflation. We can write (24)

$$d\pi_t = -\sigma\kappa\pi_t dt + \sigma\kappa i_t dt + d\delta_t \tag{26}$$

where

$$d\delta_t = d\pi_t - E_t d\pi_t$$

is an arbitrary random variable (compensated jump or diffusion) with $E_t d\delta_t = 0$.

For rational expectations the solutions of (26) are

$$\pi_t = \sigma\kappa \int_{\tau=0}^{t} e^{-\sigma\kappa\tau} i_{t-\tau} d\tau + e^{-\sigma\kappa t}\pi_0 + \int_{\tau=0}^{t} e^{-\sigma\kappa\tau} d\delta_{t-\tau}. \tag{27}$$

"Stability" means that the influence of past interest rates disappears over time, while "indeterminacy" means that the expectational errors $d\delta_t$ appear.

For adaptive expectations, the solutions of (25) are

$$\pi_t = \sigma\kappa \int_{\tau=0}^{t} e^{\sigma\kappa\tau} i_{t-\tau} d\tau + e^{\sigma\kappa t}\pi_0.$$

Despite the $\sigma\kappa\pi_t dt$ on the right hand side of (25), we solve the model backward, because there is no jump or diffusion in inflation. If we try to solve forward,

$$\pi_t = \sigma\kappa \int_{\tau=0}^{\infty} e^{-\sigma\kappa\tau} i_{t+\tau} d\tau,$$

the right hand side can require a jump or diffusion that the model rules out. Inflation is predetermined. "Instability" means that for all but one special π_0, inflation or deflation spirals. But π_0 is just as predetermined as at other dates, and in particular cannot react to the future realizations of the interest rate.

In the case of a peg, $i_t = i$, for rational expectations,

$$\pi_t = (1 - e^{-\sigma\kappa t})i + e^{-\sigma\kappa t}\pi_0 + \int_{\tau=0}^{t} e^{-\sigma\kappa\tau} d\delta_{t-\tau}.$$

"Stability" means that the influence of past interest rates disappears over time, while "indeterminacy" means that the expectational errors $d\delta_t$ appear.

For adaptive expectations, a peg leads to

$$\pi_t = (1 - e^{\sigma\kappa t})i + e^{\sigma\kappa t}\pi_0 = i + e^{\sigma\kappa t}(\pi_0 - i).$$

There are steady states with higher interest and higher inflation, but they are unstable.

As in discrete time, a Taylor rule stabilizes the unstable adaptive expectations model. Adding

$$i_t = \phi\pi_t + u_{i,t}$$

the adaptive-expectations dynamics (25) become

$$\frac{d\pi_t}{dt} = \sigma\kappa(1 - \phi)\pi_t - \sigma\kappa u_{i,t}$$

With $\phi > 1$, dynamics are now stable and determinate; a monetary policy shock $u_{i,t}$ raises the interest rate and lowers inflation.

Rational-expectations dynamics (25) become

$$E_t d\pi_t = \sigma\kappa(\phi - 1)\pi_t dt - \sigma\kappa u_{i,t} dt$$

Now $\phi > 1$ induces instability. A monetary policy shock lowers expected inflation, but it also lowers interest rates, so the model is Fisherian. To overcome that, one must induce a contemporaneous negative expectational error $d\delta_t$.

This time instability means we can solve the integral forward, and with a rule against nominal explosions recover determinacy,

$$\pi_t = -\sigma\kappa E_t \int_{\tau=0}^{\infty} e^{-\sigma\kappa(\phi-1)\tau} u_{i,t+\tau} d\tau.$$

Define an inflation target π_t^* and define i_t^* by

$$E_t d\pi_t^* = -\sigma\kappa\pi_t^* dt + \sigma\kappa i_t^* dt$$

In words, i_t^* is the interest rate target that implements π^* as an equilibrium. Now write the policy rule as

$$i_t = i_t^* + \phi(\pi_t - \pi_t^*)$$

With this notation, we can write rational-expectations dynamics as

$$E_t d(\pi_t - \pi_t^*) = \sigma\kappa[-(\pi_t - \pi_t^*) + (i_t - i_t^*)]dt$$

$$E_t d(\pi_t - \pi_t^*) = \sigma\kappa(\phi - 1)(\pi_t - \pi_t^*)dt.$$

Here we see that monetary policy has two parts, an interest rate policy i_t^* which generates the desired path of expected inflation, and an equilibrium-selection policy $\phi(\pi_t - \pi_t^*)$ which generates explosions unless $d\pi_t - E_t d\pi_t = d\pi_t^* - E_t d\pi_t^*$.

Fiscal theory offers an alternative route to determinacy in the rational expectations model. Add to the model the linearized evolution of real government debt, with instantaneous debt and differentiable prices

$$dv_t = (rv_t + i_t - \pi_t - \tilde{s}_t)dt$$

where $\tilde{s}_t$ is the real primary surplus scaled by the steady-state value of the debt. Integrating forward, taking expectations, and imposing the transversality condition,

$$v_t = E_t \int_{\tau=0}^{\infty} e^{-r\tau}[\tilde{s}_{t+\tau} - (i_{t+\tau} - \pi_{t+\tau})]d\tau \tag{28}$$

To use this equation in the rational-expectations dynamics (26), let $\Delta_t v_t \equiv v_t - E_t v_t$ isolate the compensated jump or diffusion component of a process. In this case, and unlike discrete time, $\Delta_t v_t = 0$. Short-term nominal debt is predetermined, and since prices cannot jump or diffuse, the value of debt cannot jump or diffuse. Rather than shock the initial value of debt at all, of the multiple equilibria, we pick the inflation *path* in which the discount rate/interest cost effect, the second term, exactly balances any change in surplus, the first term. In the absence of a surplus change, such as a pure monetary policy shock, we pick the inflation path so that the integral of the discount rate term is zero.

For example, consider an impulse-response function. Now there is a shock at time 0, and all variables represent how their expected values respond to that shock. The response of inflation to the shock (27),

$$\pi_t = \kappa\sigma \int_{\tau=0}^{t} e^{-\sigma\kappa\tau} i_{t-\tau} d\tau + e^{-\sigma\kappa t}\pi_0 \tag{29}$$

gives us a family of inflation paths indexed by π_0. Only one of these paths satisfies (28),

$$0 = \int_{t=0}^{\infty} e^{-rt}[\tilde{s}_t - (i_t - \pi_t)]dt. \tag{30}$$

For example, if the interest rate rises from 0 to a new value i, and with no change to surpluses $\tilde{s}_t = 0$, then we have the family of solutions,

$$\pi_t = (1 - e^{-\sigma\kappa t})i + e^{-\sigma\kappa t}\pi_0. \tag{31}$$

Plugging this into the valuation equation (30),

$$0 = \int_{t=0}^{\infty} e^{-rt}\pi_t dt - \frac{i}{r} \tag{32}$$

$$0 = \int_{t=0}^{\infty} e^{-rt}[(1 - e^{-\sigma\kappa t})i + e^{-\sigma\kappa t}\pi_0]dt - \frac{i}{r} \tag{33}$$

$$0 = \int_{t=0}^{\infty} e^{-rt}(-e^{-\sigma\kappa t}i + e^{-\sigma\kappa t}\pi_0)dt \tag{34}$$

$$\pi_0 = i. \tag{35}$$

In this simple case, we pick the super-Fisherian solution.