The Federal Reserve's Current Framework for Monetary Policy: A Review and Assessment*

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The Federal Reserve's current monetary policy framework combines conventional policy that sets the level of the federal funds rate with policies that operate through the slope of the term structure, including forward guidance and large-scale asset purchases. These slope policies are particularly important when the federal funds rate is at the zero lower bound. We assess the performance of counterfactual monetary policies since the Great Recession using a structural vector autoregression, identified using high-frequency jumps in asset prices around FOMC meetings as external instruments. We find that slope policies played an important role in supporting the recovery, but only partially circumvented the zero lower bound. In our simulations, earlier and more aggressive use of slope policies supports a faster recovery. The recovery would also have been faster, with the unemployment gap closing seven quarters earlier, if the Fed had inherited a higher level of inflation and nominal interest rates consistent with a 3 percent inflation target coming into the financial crisis recession.

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1. Introduction and Summary

The Humphrey–Hawkins Act of 1978 instructs the Federal Reserve Board (the Fed) to "promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates." The methods by which this dual mandate of maximum employment and price stability is to be achieved are left to the Fed. Those methods have evolved over time as the Fed and economists learned more about the theory and practice of monetary policy (Fuhrer et al. 2018).

The current framework for monetary policy, formally adopted in 2012, consists of a symmetric 2 percent inflation target, a commitment to support maximum employment, and a suite of policy actions that Federal Reserve officials can take to achieve those goals. Those policy actions affect current and expected future interest rates and communicate the Federal Open Market Committee's (FOMC's) intentions about monetary policy. A key element of this suite, setting the current level of the federal funds rate from one FOMC meeting to the next, has been central to Fed policy for decades. The current monetary policy framework, however, also includes newer elements developed during this century to influence term premiums and/or expectations of future Fed policy. One such element is forward guidance through measures such as statements accompanying FOMC meeting announcements, the Summary of Economic Projections, and speeches by Fed officials. Another such element is direct purchases of long-term assets (large-scale asset purchases, or LSAPs), which both directly affect the prices of long-term assets and convey information about future Fed policy.

In our empirical framework, discussed in more detail below, we identify two dimensions of monetary policy shocks using high-frequency data around FOMC announcements. The first are federal funds shocks—unexpected changes in the level of the federal funds rate. This is the classic concept of a monetary policy shock. The second shock is identified as the component of the change in the slope of the term structure around FOMC announcements that is orthogonal to the federal funds rate surprise. Shocks to the federal funds rate will affect the slope of the yield curve, but this second shock represents changes to the slope that are *not* driven by the normal response to changes in the target funds rate. Such changes in the slope could be caused by any of the newer elements of monetary policy—forward guidance, LSAPs, or maturity extensions. However, because we are identifying them from high-frequency changes in the slope of the term structure, we refer to them collectively as *slope* shocks, to differentiate them from traditional policy that sets the current level of the federal funds rate. These new tools of slope policy are particularly relevant when conventional policy—that is, the current level of the federal funds rate—is constrained by the floor on nominal interest rates, generally referred to as the zero lower bound.

This paper reviews and assesses the current monetary policy framework in the context of the experience of the expansion that began in the second quarter of 2009.[1] Our assessment draws on the large literature examining the functioning and consequences of these policies, on a review of macroeconomic performance over the expansion, and on counterfactual simulations of alternative policies using the historical record. These alternative policies draw on the elements of the current framework but implement them in a way that allows us to consider alternative policy paths. We conduct these counterfactuals using an empirical model that combines the response of the unemployment gap to monetary policy shocks with a New Keynesian Phillips curve. Although this model is newly developed for this paper, and we are basing our analysis on this particular model, we also compare our results with others in the literature. We find that the dynamics in our model are generally consistent with those obtained using other, sometimes quite different, approaches.

Examining hypothetical counterfactuals overlaid on the actual experience of the expansion, as we do, has the advantage of making concrete the plusses and minuses of these counterfactuals, including possible unintended consequences. A disadvantage of this overlay is that it could be interpreted as second-guessing the Fed: It is not. Many of the counterfactuals we consider were not available in real time, at least in part because we are able to evaluate their effects with the benefit of hindsight, and also because of data revisions. By using this evaluative method, our aim is to inform future options as the Fed evaluates its current monetary policy framework.

[1] Because our focus is on the current long-term monetary policy framework, we do not consider the special measures and facilities that provided liquidity during the financial crisis.

Our analysis leads us to five main conclusions.

First, the current monetary policy framework—in particular, its new suite of slope policies—played an important role in supporting the recovery. Absent slope policy, the recovery of the labor market would have been slower, and the rate of inflation lower, than it was. The magnitude of the effect is substantial: absent slope policy, we estimate that the unemployment rate would have crossed the Congressional Budget Office's (CBO's) estimate of the natural rate more than one year later than it did, and the rate of inflation would have been approximately 0.2 percentage point lower than it was during the latter part of the recovery.

Second, despite the efficacy of slope policy, the zero lower bound significantly restricted the scope of monetary policy during the recovery. Absent the zero lower bound, we (and others) estimate that normal Fed policy would have led to a federal funds rate of approximately –5 percent. Our estimates suggest that Fed slope policies were able to offset perhaps 1 percentage point of the zero lower bound constraint. Multiple authors have pointed to a high probability of hitting the zero lower bound again during future downturns, and our simulations suggest that, when this happens, it meaningfully limits the efficacy of Fed policy.

Third, small changes in policy would have produced small changes in realized outcomes. For example, speeding up or delaying liftoff of the federal funds rate by one year would have changed the unemployment gap, relative to actual, by a few tenths of a percentage point, and would have had a negligible effect on the inflation rate.

Fourth, of the counterfactuals we consider, the policies with the largest effect are ones with early and aggressive slope policy, undertaken roughly when the federal funds rate hits the zero lower bound. We estimate that "stronger sooner" slope policies have a relatively rapid effect on the economy, so early aggressive action to flatten the term structure could substantially speed the recovery in the labor market and support reflation. This said, more aggressive use of slope policy comes with a number of concerns and potential channels that we do not model. These include risks that driving down longer-term interest rates could lead to "reach for yield" behavior, that the Fed could end up buying such a large share of Treasury or agency mortgage-backed securities as to disrupt these markets, or that the Fed could face an extended period of reduced or zero remittances to Treasury (Carpenter et al. 2015). That might in turn undermine political support for central bank independence. These concerns could constrain the Fed's ability to implement aggressive slope policies in practice.

Fifth, the current suite of policies would have led to a substantially faster recovery and a rate of inflation closer to target had the Fed inherited higher nominal interest rates and inflation rates consistent with a higher inflation target. For example, we estimate that inheriting interest rates, inflation rates, and an inflation target 1 percentage point higher than actual, combined with the slope policies actually used over the expansion, would have resulted in the unemployment rate falling below the CBO natural rate of unemployment seven quarters earlier than it did. With inherited nominal rates, inflation, and an inflation target 2 percentage points higher than actual, we estimate that the unemployment rate would have crossed the CBO natural rate 10 quarters earlier than it did, allowing liftoff to occur in 2014.

Our analysis of real outcomes focuses on the labor market, specifically the unemployment rate. The recovery post-2009 was associated with historically slow growth of gross domestic product (GDP). As discussed in Fernald et. al. (2017) and in Eberly, Stock, and Wright (2019), the main forces behind this slow growth of GDP are trends that predate the recession. These include the slowing of the growth of the labor force because of the retirement of the baby boom and the plateau of women entering paid work, and the productivity slowdown that started in the early or mid-2000s. These trends and other factors, such as fiscal drag from 2012 to 2016, are outside the reach of monetary policy. To the extent that monetary policy could have sped up the recovery of the labor market, GDP growth would have been modestly faster, but even so, the demographic and other headwinds would have produced a growth rate of GDP below that of the 2001–07 expansion, and well below that of the expansions of the 1980s and 1990s.

Our results also have implications for fiscal policy. Even though adjustments to the long-run framework, including "stronger sooner" policies and a higher inflation target, could enhance the Fed's efforts to stabilize the economy in a future recession, as we discuss, there are limits to the Fed's use of forward guidance and LSAPs. Moreover, the federal funds rate is at historic lows for this late stage of the business cycle. These observations underscore the importance of complementary countercyclical fiscal policies, especially automatic stabilizers, in future recessions.

The remainder of the paper is organized as follows. We begin in section 2 with a brief overview of the current monetary policy framework. There is now a large literature that has examined the effect of asset purchases and forward guidance on long-term interest rates and on economic outcomes, and we review that literature in section 3. Section 4 briefly reviews the observed decline in the equilibrium real rate of interest (r^*). Section 5 presents our simulation model, section 6 presents the counterfactuals, and section 7 provides caveats and conclusions.

2. The Current Framework for Monetary Policy

The current monetary policy framework was put in place in January 2012 and, while subsequently refined operationally, remains largely unchanged. This framework is summarized on the Fed's website, including timelines of the evolution and implementation of the framework.[2]

The framework has two objectives: keeping the rate of price inflation, as measured by the personal consumption expenditure (PCE) price index, close to 2 percent, and keeping the unemployment rate close to the long-run full-employment rate, sometimes called the natural rate of unemployment or the non-accelerating inflation rate of unemployment (NAIRU). In two subsequent meetings, in 2014 and 2016, respectively, FOMC statements clarified that inflation outcomes above and below the 2 percent goal were equally costly, then explicitly referred to the inflation objective as a "symmetric inflation goal." Although there is an explicit numerical objective for inflation, there is no corresponding numerical objective for unemployment. This is because the natural rate is seen as time varying, not directly measurable, and driven by nonmonetary factors. Also, for

[2]See "Timelines of Policy Actions and Communications" at https://www.federalreserve.gov/monetarypolicy/review-of-monetary-policy-strategy-tools-and-communications-fed-listens-timelines.htm.

the unemployment rate, the FOMC has not explicitly characterized its operating policy as being symmetric around NAIRU.[3]

The historical path to the current framework reflects a trend toward greater transparency in central banking, as well as greater resolution about the use of new tools over time. As part of the trend toward greater transparency, the January 2012 monetary policy framework integrated and expanded the Summary of Economic Projections (SEP), which had been in place since October 2007. From the start, the SEP numbers were released quarterly, and they covered real GDP growth, the unemployment rate, PCE, and core PCE inflation at horizons out to three years. In 2009, projections were expanded to include long-run real GDP growth, the unemployment rate, and headline inflation. The January 2012 monetary policy framework made additional changes. It included numerical forecasts of the future path of the federal funds rate at year-end and in the longer run by individual FOMC participants, the so-called dot plots. This change is notable for publishing numerical forecasts of future policy, not only economic conditions.

In addition to the overarching framework describing monetary policy objectives, the FOMC has provided guidance about the implementation of monetary policy, or its operating policy. These operating policies govern the use of the tools to achieve the objectives. The current monetary policy framework uses short-term interest rates as the primary tool for influencing aggregate demand, but can also use forward guidance, long-term asset purchases, and other measures that affect the maturity composition of the Fed's balance sheet. As documented by Fuhrer et al. (2018), Fed operating policies have changed historically, and the FOMC has used several approaches over the past 10 years.[4]

The Fed's use of forward guidance evolved from 2007 through 2018.[5] When the FOMC lowered its target for the federal funds rate

[3]This approach allows for uncertainty in the observation of labor market conditions, as well as conditioning the response to labor market conditions on other economic conditions and shocks.

[4]We take a longer perspective for this section, as the FOMC has these tools available to it, even if not currently in use, and they are relevant for the counterfactual analysis in section 6.

[5] Forward guidance predates the financial crisis recession. FOMC statements in 2003–05 contained early forms of forward guidance. For example, at several

to a range of 0 to $\frac{1}{4}$ percent in December 2008, it communicated that conditions were likely to warrant exceptionally low levels of the rate "for some time." In addition to moving the current federal funds rate, this forward guidance potentially affects expectations of future interest rates, and hence longer horizon interest rates. In March 2009, the language "for some time" was replaced with "for an extended period." In August 2011, this qualitative language was replaced with a calendar threshold of "at least through mid-2013," which was then extended to 2014 and 2015 in January and September of 2012, respectively. The calendar-based guidance was replaced by outcome-based thresholds starting in December 2012, stating that the low range would be maintained "at least as long as the unemployment rate remains above $6\frac{1}{2}$ percent, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2 percent longer-run goal, and longer-term inflation expectations continue to be well-anchored." Threshold-based guidance continued until the unemployment rate reached $6\frac{1}{2}$ percent in 2014. These three periods represent three approaches to operating policy: qualitative guidance, calendar-based guidance, and outcome- or threshold-based guidance.

The Fed's balance sheet policies have also evolved since 2007. Starting in November 2008, the Federal Reserve's balance sheet programs were announced with both quantitative amounts of asset purchases and a time horizon for the transactions. As the programs were completed, the FOMC clarified reinvestment policies and its commitment to use policy tools to meet its economic objectives, for example in September 2010, "to provide additional accommodation if needed to support the economic recovery and to return inflation, over time, to levels consistent with its mandate." This commitment was renewed throughout the LSAP and maturity extension program implementation periods. While no explicit outcome-based

meetings in 2003, the FOMC statement said that "policy accommodation can be maintained for a considerable period." Gürkaynak, Sack, and Swanson (2005) document that even before the crisis, much of the news from FOMC announcements came in the form of news about the path of future policy rather than news about the target level of the federal funds rate. However, forward guidance assumed a much greater role after the financial crisis.

thresholds were introduced, the policy was conditional on economic outcomes.[6]

The statement of a possible calendar time for slowing purchases was first broached in 2013 and announced in December 2013. A formal policy statement governing balance sheet normalization was published in September 2014. This statement was refined in the interim, and an addendum was issued in June 2017 with quantitative steps to govern balance sheet normalization. In addition to guidance for principal reinvestment, this addendum included the statement that the Committee would be prepared to resume reinvestment of principal payments if there were a "material deterioration in the economic outlook" that would warrant a sizable reduction in the target federal funds rate. The Committee affirmed that it was prepared to use "its full range of tools," including the size and composition of the balance sheet, "if future economic conditions were to warrant a more accommodative monetary policy than can be achieved solely by reducing the federal funds rate." The Federal Reserve thus retains economic conditionality for future balance sheet policies.

The Summary of Economic Projections added median forecasts starting in September 2015 and included fan charts in the expanded version of the projections that is published with the minutes, starting in March 2017. The Federal Reserve Chairman gives a press conference after every meeting, starting in 2012, and after all meetings, starting in 2019.

3. Effects of LSAPs and Forward Guidance on Yields and the Macroeconomy

The existing monetary policy framework treats short-term interest rates as the primary tool of monetary policy, but also uses forward guidance and LSAPs and related maturity policies, such as the maturity extension program and reinvestment of principal policy at the zero lower bound (ZLB). Kuttner (2018) gives a recent review of the experience of unconventional monetary policy after the financial

[6]See, for example, the FOMC statements of September 2012, March 2013, and May 2013.

crisis recession. In this section, we review evidence on their effects on yields and on macroeconomic outcomes.

3.1 Asset Purchases

Much of the evidence for the efficacy of LSAPs comes from event-study evidence, which was particularly apparent in the first round of purchases, QE1, because these announcements came as complete surprises and were immediately followed by sharp drops in yields. Gagnon et al. (2011) and Krishnamurthy and Vissing-Jorgensen (2011) find that QE1 announcements were followed by immediate drops in Treasury yields that added up to around a percentage point.

The event-study approach only measures the short-run effect of the announcement. Bond yields rose during the asset purchase implementation phases, as opposed to the announcements, of QE1, QE2, and QE3 (Greenlaw et al. 2018). This is consistent with the effects of the announcements wearing off over time, though it is hard to establish causality, as many other shocks hit the economy over the implementation phases of LSAPs. There have been studies on trying to estimate the persistence of the effects (Wright 2012, Swanson 2017, Greenlaw et al. 2018), but confidence intervals are very wide, and results are sensitive to the inclusion of the March 2009 FOMC announcement. This announcement came as a complete surprise that caused a sharp drop in yields that was, however, reversed over the next couple of months. Greenlaw et al. (2018) suggest that this may be because market participants initially interpreted the announcement as a sign of further measures that did not then come in the subsequent months. Another question about the effects of LSAP purchases on Treasury yields is the potential for Treasury to offset the effect by issuing more of the securities that the Federal Reserve is going to buy, leaving the net supply to the market unchanged. The Treasury did indeed substantially lengthen the maturity of its issuance during the LSAP period. We will study the dynamic effects not of LSAPs specifically, but of slope shocks more generally, in section 5. Federal Reserve purchases of Treasury securities reduce the effective supply of these assets to market participants. Several authors have studied the effects of overall Treasury supply on yields, including Hamilton and Wu (2012), Krishnamurthy and Vissing-Jorgensen (2012), and Greenwood and Vayanos (2014). These papers all frame the question slightly differently, but nonetheless end up with consistent results—changes in the supply of Treasuries have a small but significant effect on yields. Belton et al. (2018), reviewing the existing literature, conclude that adding to 1 percent of GDP (or around $200 billion today) to the supply of 10-year equivalent Treasuries raises the term premium by about 6 basis points. A rule of thumb like this is market conventional wisdom, and close to what was found by Hamilton and Wu (2012). Li and Wei (2013) estimate supply effects in an affine term structure model and get a somewhat larger estimate in which a 1 percent of GDP increase in the supply of Treasuries raises the term premium by about 10 basis points. They conclude that the total effect of QE1, QE2, and Operation Twist was to lower 10-year yields by about a percentage point. Note that these estimates relate yields to the stock of asset purchases, not the flow of asset purchases. Some of the QE1 announcements had announcement effects that were bigger than can readily be explained by changes in the stock of Treasuries. In particular, the March 2009 announcement of $300 billion in Treasury purchases lowered 10-year yields by 40 to 70 basis points, depending on the time window used for the event study. This is a far bigger effect than would be predicted by any of the conventional elasticities, but it happened at a time of severe market disruption when arbitrage was disrupted.

There is also evidence of LSAP effects on credit markets, which is crucial since affecting Treasury yields is not an end in itself. Di Maggio, Kermani, and Palmer (2016) document that mortgage-backed securities (MBS) purchases increased mortgage refinancing activity, at least among households that were not underwater and thus were eligible to refinance. This also underscores a limitation of MBS purchases: many homeowners were simply unable to refinance, because they were underwater or for other reasons, and so they could not benefit from the reduction in mortgage rates. Foley-Fisher, Ramcharan, and Yu (2016) and Rodnyansky and Darmouni (2017) use differences-in-differences approaches to argue that asset purchases increased bank lending.

LSAPs had an effect on bond markets, but it is less clear through what channels they worked. There are broadly two possibilities. One is that they worked by reducing term premiums on longer-term bonds as investors have demand for specific long-duration assets, as in the preferred-habitat model of Vayanos and Vila (2009). The other is that they signal that the Federal Reserve will keep policy rates low for longer (Bauer and Rudebusch 2014). There can be elements of both. But the view that LSAPs worked only through expectations and left term premiums unchanged should imply that near-term yields fell, but long-term yields should be little changed[7] unless one views the commitment to lower policy rates to last beyond a few years, which does not seem credible given FOMC turnover. However, the announcements of LSAPs lowered 10-year yields by substantially more than 2-year yields (Gagnon et al. 2011). Moreover, the announcements of asset purchases had the greatest effect on the specific securities being purchased relative to others with similar maturity that were not being purchased (D'Amico et al. 2012, D'Amico and King 2013), which also points to the importance of preferred-habitat or local supply mechanisms. A similar indicator that asset purchases operated significantly through the impact of asset supply is the fact that announcements of MBS purchases had large effects on MBS rates, but announcements of Treasury purchases alone had much more muted effects on MBS rates (Krishnamurthy and Vissing-Jorgensen 2011).

3.2 Forward Guidance

As noted in section 2, from March 2009 until June 2011 the post-meeting FOMC statements declared that exceptionally low levels of rates would be warranted for "an extended period." Surprisingly, over this period, the market appeared to continually believe that liftoff was just around the corner, as evidenced from the Survey of Professional Forecasters (SPF) and also from the fact that two-year Treasury yields remained quite sensitive to macroeconomic news (Swanson and Williams 2014). Swanson and Williams conclude from the sensitivity of Treasury yields to macroeconomic news surprises that the more explicit date-based forward guidance that came in August 2011, coupled with the introduction of the dot plot the following January, was effective in pushing the expected time of liftoff back to around two years from then. Femia, Friedman, and Sack (2013) reach a similar conclusion using survey evidence.

[7]Indeed long-term interest rates should, if anything, increase with higher inflation expectations.

The theoretical concept of forward guidance is a commitment to allow an inflationary boom in the future (Eggertsson and Woodford 2003). This is very powerful in standard dynamic stochastic general equilibrium (DSGE) models, arguably implausibly so (Del Negro, Giannoni, and Patterson 2012). Campbell et al. (2012) refer to this as Odyssean forward guidance. However, neither the Federal Reserve nor any other central bank has given this kind of forward guidance, and indeed Kohn (2009) stated that this was not the intention of FOMC forward guidance. A planned overshoot of inflation as in Eggertsson and Woodford (2003) is not envisioned in the current monetary policy framework.

3.3 Summary of Economic Projections

One of the transparency initiatives of the FOMC over the past decade or so has been the introduction of the Summary of Economic Projections and its expansion to include forecasts of interest rates in 2012. The hope was that market expectations would move in line with the SEP and give them more of a hold on longer-term interest rates.

The SEP interest rate projections, viewed as the Committee's forecasts, have turned out to be quite poor, perhaps in part because they represent up to 19 different views, many of which are quite distinct. Federal Reserve Chairs have noted that the dot plot is not a consensus forecast of the FOMC and that the statement is the mechanism that the Committee uses to express its collective judgment about the likely future path of rates. Nonetheless, the dot plot gets a lot of attention and is, not surprisingly, viewed by markets and the press as a Committee forecast, notwithstanding insistence to the contrary. This is especially true since the statement does not normally include much explicit guidance about future interest rates. Eberly, Stock, and Wright (2019) used event-study evidence to argue that a 1 percentage point higher-than-expected SEP interest rate expectation raises Eurodollar rates at that same horizon by about 18 basis points.

Faust (2016) argues that the dot plot conveys the diversity of views on the Committee but fails to represent how the Committee is likely to aggregate those views into a consensus. Consequently, he argues the dot plot gives the illusion of transparency but adds to public confusion. He cites a political science literature that maximal apparent transparency can actually be counterproductive (Stasavage 2007, Sunstein 2016).

3.4 Macroeconomic Effects

By the standards of time-series macroeconometrics, the data span available for studying the macroeconomic effects of slope shocks is relatively short, so it is perhaps not surprising that the literature has obtained a wide range of results. Using a Bayesian VAR identified via sign and zero restrictions, Weale and Wieladek (2016) found that asset purchases of 1 percent of GDP, in the United States, led to a peak increase in both real GDP and CPI (consumer price index) of 0.6 percentage point. These are very large estimated effects—the size of the Fed balance sheet increased by nearly 20 percentage points of GDP. Hesse, Hofmann, and Weber (2018) use a similar Bayesian VAR methodology but get somewhat smaller, though still very positive, effects on both economic activity and inflation. In subsample analysis, they find that the effects of asset purchases were stronger in the early stages, right after the crisis, than later on.

Nakamura and Steinsson (2018a) identify a policy news shock as the first principle component of the jump in five short-term interest rates around FOMC announcements and find that surprise *tightening* of policy is associated with an *increase* in growth expectations. This exercise does not attempt to separate shocks to the level of funds rate from shocks to the slope of the yield curve. They interpret this as being due to the possibility that tighter monetary policy reveals Federal Reserve information about the state of the economy, along the lines also indicated by Campbell et al. (2012, 2017).

Several authors have identified forward guidance, or path surprises, in structural VARs using high-frequency financial variables around announcements as instruments, with mixed results. These papers interpret shocks to the slope of the yield curve as forward-guidance surprises, but they may also include elements of LSAPs, especially since the two kinds of announcements often came out concurrently. Bundick and Smith (2018) find that forward guidance shocks that lower the path of expected policy rates lead to moderate increases in output and inflation, but Kim (2017) and

Lakdawala (2019) find that these forward guidance shocks are contractionary, which they see as supporting the information signaling view of Nakamura and Steinsson (2018a).

A number of authors use either DSGE or the FRB/US models to simulate the effects of LSAPs and forward guidance. These papers have found that LSAPs and forward guidance have modest but beneficial effects on both economic activity and inflation. We return to these papers in section 6.

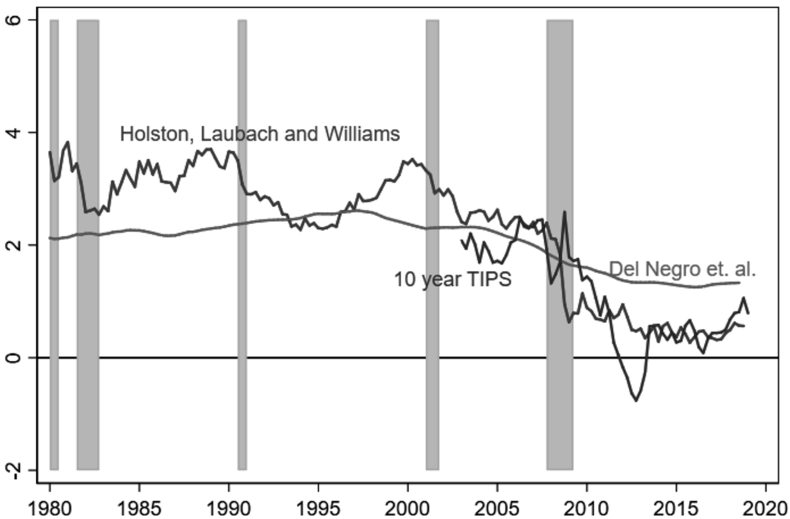
4. The Decline in r^*

Over the past 15 years, nominal interest rates have fallen by more than the rate of inflation, suggesting that the long-run equilibrium real rate of interest has declined. All else being equal, a lower equilibrium real rate implies a lower equilibrium nominal rate, which (holding constant the inflation target) implies a higher probability of hitting and staying at the zero lower bound as a result of countercyclical monetary policy.[8]

Figure 1 shows the yield on 10-year Treasury inflation-protected securities (TIPS), along with two estimates of the equilibrium rate of interest, which are updated estimates based on Del Negro et al. (2017) and on Holston, Laubach, and Williams (2017). Although the numerical values differ, all three series point to a decline both in the real rate, as measured by the return on TIPS, and on the underlying long-run equilibrium real rate, which is unobserved. The estimated equilibrium rate using the Holston, Laubach, and Williams (2017) method is approximately 50 basis points over 2017–18. The current Summary of Economic Projections has a long-run projection for the federal funds rate of 2.8 percent, implying an equilibrium real interest rate of 80 basis points. Chung et al. (2019, figure 1) plot the range of seven different estimates of r^*. While there is disagreement about the precise value of r^* currently, there is broad agreement that it has declined by 1 percentage point, or perhaps more, since the early 2000s. This decline is an international phenomenon, shared by all developed economies (Obstfeld 2019, Rachel and Summers 2019).

[8]For example, Kiley and Roberts (2017) estimate that the zero lower bound will bind about one-third of the time in the future.

Figure 1. Two Estimates of the Long-Term Equilibrium Real Rate of Interest (r^*) and the Yield on 10-Year TIPS



Source: Holston, Laubach, and Williams (2017), updated, and Del Negro et al. (2017), updated. TIPS: Federal Reserve Economic Database (FRED).
Note: Shading denotes NBER-dated recessions.

Economists have suggested multiple explanations for the decline in r^*, including the aging of the population (increasing the demand for savings), an increasing premium for safety and liquidity (perhaps due to greater global demand for safe assets), and a lower trend rate of growth of productivity; see Andrade et al. (2019) and Rachel and Summers (2019) for a discussion of these forces and relevant references. Most of these forces represent low-frequency trends that are not affected by monetary policy and can reasonably be expected to persist for an extended period of time.

5. Simulation Model

Our assessment of the performance of Fed policy over the expansion uses a model of monetary policy, interest rates, the unemployment rate, and price inflation. Section 5.1 provides an overview of the model, and sections 5.2 and 5.3 provide econometric details.

5.1 Overview of the Simulation Model

The simulation model groups monetary policy actions into two categories: traditional monetary policy circa 2000, in which the FOMC sets a range for the federal funds rate, and slope shocks, which explicitly aim to affect the slope of the Treasury yield curve.

Slope shocks comprise the multiple additional tools or actions of the current monetary policy framework, including forward guidance, releases of the SEP, LSAPs, and maturity management. The common feature of these tools is that they affect the slope of the safe-asset term structure, either by providing information about future policy and, thus, changing expectations of future short rates, or by directly affecting the value of current long rates. As discussed in section 2, these policies are nuanced, interact, and have evolved over time. Instead of trying to estimate their effects separately, we quantify the collective effect of this new suite of policies through their combined effect on the slope of the term structure, which in our base model is measured by the spread between the yield on 10-year Treasuries and the federal funds rate.

The simulation model quantifies the response of the unemployment gap and the rate of inflation over time to federal funds and/or slope monetary policy shocks. The simulation model merges two separate models, one of the CBO unemployment gap and another of core PCE inflation.

For the unemployment gap, we use a monthly structural vector autoregression (SVAR) to estimate the separate effects of federal funds and slope shocks. These effects are identified using an instrumental-variables strategy that exploits Kuttner's (2001) insight that, in a tight window around an FOMC announcement, the predominant reason for a change in interest rates or Treasury bond prices is the information about policy revealed by the announcement. From these announcement-window changes we construct two instrumental variables, one for the federal funds shock and one for the slope shock, which we use in conjunction with a vector autoregression to estimate the separate effects of federal funds and slope shocks on the unemployment rate over time.

These announcement-window changes in interest rates are directly attributable to policy shifts that are at least partially unexpected and comprise part of the overall monthly change in interest rates. We use this policy-related exogenous variation in rates to identify the effect of policy changes on relevant macroeconomic variables. With this effect in hand, we trace out the dynamic effect of the federal funds or slope shocks on the unemployment gap using a vector autoregression, using the structural vector autoregression-instrumental variables (SVAR-IV) method, as used with a single shock by Gertler and Karadi (2015).

The simulation model merges this response of the unemployment gap to federal funds and slope monetary policy with a hybrid New Keynesian Phillips curve, which relates the rate of inflation to past inflation, expected future inflation, and inflationary pressure exerted by the unemployment gap. In the combined model, a contractionary federal funds policy—that is, a tightening of monetary policy through a higher federal funds rate, holding constant the 10-year federal funds spread—implies a contractionary path of the unemployment gap. The increase in the expected discounted value of the unemployment gap then exerts negative pressure on inflation, which falls somewhat at first, then more as the inertial effects of the initial inflation rate wear off. Similarly, a contractionary slope shock—an increase in the 10-year federal funds spread, holding constant the federal funds rate—leads to an expected deterioration of macroeconomic conditions which also results in a decline in current and future rates of inflation. Thus, the simulation model can be used to compute counterfactual paths for the rates of unemployment and inflation under policies that differ from those actually implemented.

There are other useful frameworks that are widely used for evaluating monetary policy counterfactuals. The Fed's main macro model, FRB/US, is routinely used for this purpose—see Bernanke, Kiley, and Roberts (2019) and Chung et al. (2019) for recent examples. Another approach is to use a DSGE model, such as the one recently used for related simulations by Debortoli, Galí, and Gambetti (2019) and Sims and Wu (2019). An advantage of our approach is its transparency and simplicity. We view these approaches as complementary, and in section 6 we compare our results with those obtained by other researchers using other methods.

5.2 Identification and Estimation of the Effects of Federal Funds and Slope Shocks on the Unemployment Rate

We use the SVAR-IV method to estimate the dynamic effect of a federal funds shock and a slope shock on the unemployment gap.[9] Gertler and Karadi (2015) use announcement-window changes and the SVAR-IV method to identify the dynamic effect of a federal funds shock, and our model of the unemployment gap can be seen as an extension of their approach to include both a federal funds and a slope shock.[10]

In our base model, the vector autoregression consists of five monthly variables: the unemployment gap, the federal funds rate, the spread between the yield on 10-year Treasury bonds and the federal funds rate, the Gilchrist and Zakrajšek (2012) excess bond premium (EBP), and the inflation rate as measured by core PCE. The two instruments are drawn from a panel of changes in interest rates of maturities from overnight (the federal funds rate) through 10 years around FOMC monetary policy announcements. The full balanced panel of these announcement-window changes runs from 1994:M2 to 2019:M2.[11]

[9] The SVAR-IV method (Stock 2008, Stock and Watson 2012, Mertens and Ravn 2013) consists of two steps. In the first, a reduced-form VAR is estimated, yielding the VAR innovations (residuals). In the second, instrumental-variables regression is used to estimate the causal effect of a shock by regressing the other VAR innovations (e.g., the unemployment gap innovation) on the causal variable of interest (e.g., the federal funds rate) using instrumental-variables regression. The resulting IV coefficients estimate the impact effect of a monetary policy shock, which is traced out dynamically using the VAR. See Stock and Watson (2018) for an overview and a discussion of the relation between SVAR-IV and local projections-IV (LP-IV).

[10] Kim (2017) and Lakdawala (2019) both use a two-instrument/two-shock identification approach with announcement-window changes; however, they focus on forward guidance shocks and shorter ends of the term structure.

[11] The data are from Gürkaynak, Sack, and Swanson (2005), as updated by Federal Reserve staff. The data are announcement-window changes, computed using two-hour windows, in the following interest rates: the first six federal funds futures contracts, the front eight Eurodollar futures contracts, on-the-run three- and six-month bill yields and on-the-run 2-, 5-, 10-, and 30-year Treasury coupon yields. The data also include announcement-window changes in S&P 500 futures contracts. In months with no announcement, the value of the announcement-window change is zero. In months with multiple announcements, the announcement-window changes were summed over that month for the total

For the federal funds shock, the instrument is the difference between the target decision and the expectation implied by current-month (and potentially next-month) federal funds futures contracts, constructed as described by Kuttner (2001). The effect of a federal funds shock is then estimated by instrumental-variables regression of the VAR variables on the federal funds rate.

For the slope shock, the instrument identifies policy-induced changes in the slope of the interbank/Treasury term structure, holding constant changes in the federal funds rate. To this end, the slope instrument is the residuals from a regression of announcement-window changes in the 10-year on-the-run Treasury yield onto the Kuttner shock. This residual is similar in spirit to the path surprise of Gürkaynak, Sack, and Swanson (2005), but using a much longer maturity concept of the slope. The impact effect of the slope shock is then estimated by instrumental-variables regression of the VAR variables on the 10-year federal funds spread, using the slope instrument.

The SVAR-IV method permits different estimation samples to be used for the VAR and the instrumental-variables regressions. The (reduced-form) monthly vector autoregression is estimated with four lags[12] over the period 1990:M1–2019:M2, a period that omits the Great Inflation and its immediate aftermath. The IV regression that estimates the impact effect of the federal funds shock is estimated over the period 1994:M2–2007:M12, which avoids the zero lower bound period during which there were no federal funds policy changes. The IV regression that estimates the effect of the slope shock is estimated over 2008:M1–2019:M2, the period during which the instruments of slope policy were refined and implemented.[13]

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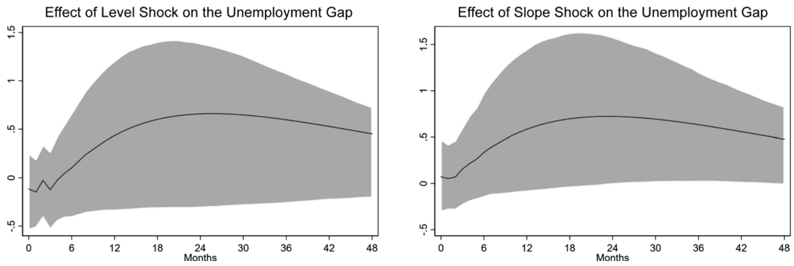
monthly announcement-window change. Otherwise, the monthly observation is the single announcement-window change in that month.

[12]The Akiake information criterion (AIC) selects four lags and the Bayesian information criterion (BIC) selects two lags, and the unemployment gap impulse response functions (IRFs) are insensitive to using either the AIC or BIC choice.

[13]As noted in section 2, the first use of slope policy in the modern era was the appearance of forward guidance in 2003; the SEP, LSAPs, and maturity policy were not developed until the crisis. Thus the period prior to 2003, and arguably prior to 2007, was one in which there was little or no reliance on slope policy. Because our instruments start in 1994:M2, this provides a period for a placebo test of our scheme for identifying the effect of slope shocks prior to 2007. Our method should not detect slope policy during that early period, and as is reported in the

Figure 2. Estimated Response of the Unemployment Gap to Unit Federal Funds and Slope Monetary Policy Shocks



Notes: The federal funds shock increases the federal funds rate by 1 percentage point. The slope shock increases the 10-year Treasury–federal funds spread by 1 percentage point. The instrument for the federal funds monetary policy shock is the difference between the pre-announcement level of the federal futures rate and the announced target (the Kuttner shock). The instrument for the slope monetary policy shock is the residual from regressing the announcement-window change in the 10-year on-the-run Treasury yield on the Kuttner shock. Estimation samples are 1990:M1–2019:M2 for the VAR, 1994:M2–2007:M12 for the federal funds shock IV regression, and 2008:M1–2019:M2 for the slope shock IV regression. Shaded area denotes one-standard-error bands, computed by parametric bootstrap.

The estimated impulse response functions are shown in figure 2. First consider the federal funds shock. The instruments are strong, with a heteroskedasticity-robust first-stage F statistic of 17.0. A 1 percentage point monetary policy increase in the federal funds rate, holding the slope of the term structure constant, is estimated to increase the unemployment rate by approximately 0.6 percentage point after 18 months; however, this effect is imprecisely estimated.[14]

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supplement, indeed it does not. (The supplement is available from the authors upon request.)

[14] Many monetary SVARs use quarterly data and/or a flow activity variable, such as industrial production, instead of the unemployment rate, complicating a direct comparison. Two papers that consider monthly monetary VARs with the response of the unemployment rate to a federal funds shock are Coibion (2012) and Ramey (2016). Ramey's figure 2(c) proxy VAR (SVAR-IV) estimate of the unemployment rate impulse response function is very close to ours, including the initial dip and a maximum value of approximately 0.4 percentage point attained after approximately two years, despite important differences (different sample period and she uses the Romer and Romer 2004 monetary policy shock

For the slope shock, the instrument is weaker than for the federal funds shock (first-stage $F = 5.8$). A 1 percentage point slope shock—that is, a shock that increases the 10-year federal funds spread by 1 percentage point—increases the unemployment rate by a peak of about 0.7 percentage point, attained after 18 to 28 months.

An issue that affects the interpretation of the slope shock impulse response function is the extent to which the elements of slope policy revealed during an announcement convey Fed inside information about the economy, as opposed to information about the future path of policy (see, for example, Campbell et al. 2012; Kim 2017; Nakamura and Steinsson 2018a, 2018b; and Lakdawala 2019). If movements in the slope of the term structure around announcement windows reflect news about the economy, rather than a reaction to policy actions and intentions, the impulse response function will be a biased estimate of the dynamic causal effect of the slope shock. We do not provide a complete analysis of this issue, but we do offer three observations. First, the sign of the news channel is the opposite of that in figure 2: to the extent that an announcement of, for example, prolonging a zero federal funds rate also conveys bad news about the economy, then the announcement-window decline in the 10-year federal funds spread would be associated with a lower future unemployment gap than expected, the opposite of what we estimate. Second, similar reasoning implies that an announcement that conveys bad economic news would increase the excess bond premium, but our estimated response of the EBP to the slope shock has the opposite sign, with moderate persistence (see section A.1 of the appendix). Third, if the announcement conveys news, then one would expect bad news (a reduced spread) to be associated with a decline in the stock market. Because our data set contains the announcement-window change in the S&P 500, we can examine this implication

as an instrument, not announcement-window changes). Coibion (2012) treats the Romer and Romer (2004) monetary policy shocks as shocks, not as instruments, which in the SVAR-IV framework is the reduced-form response to the instrument. Despite this and other important differences, Coibion's (2012, figure 7 and table 2) estimates of the peak response of the unemployment rate bracket our estimates. Using a DSGE model, Sims and Wu (2019) find that the peak response of output is about 0.5 percentage point, which translates into a quarter percentage point on unemployment with the conventional Okun coefficient, and that is in turn a bit smaller than most SVAR estimates.

empirically, and it does not hold up in the data: the announcement-window change in the S&P 500 is negatively correlated with our slope instrument, and indeed is negatively correlated with the residuals from regressions of announcement-window changes against the Kuttner shock at horizons of three or more months over the period 2008:M1–2019:M2.[15] While these observations do not rule out some potential bias from announcements having an economic news component, together they suggest that the impulse responses reported here primarily reflect the slope policy channel. To the extent that there is some potential for an information channel, the impulse responses that we report are maximal effects that assume no news effect is operative.

Section A.1 of the appendix shows estimates of these IRFs obtained using local projections with instrumental variables, which (for these instruments) does not require the SVAR assumption of invertibility. Robustness checks of the IRFs in figure 2 to various modeling assumptions are reported in the supplement.[16]

5.3 The Phillips Curve

The second part of the model quantifies the relation between the unemployment gap and inflation, which is quantified using the hybrid Phillips curve,

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f \pi^e_{t+1} + \kappa Ugap_t + e_t, \tag{1}$$

where π_t is quarter-over-quarter core PCE inflation (at an annualized rate), $Ugap_t$ is the unemployment gap, π^e_{t+1} is expected inflation as measured from the Michigan survey, and e_t is the error term.[17]

[15]The 18 correlations between the S&P 500 change and the various orthogonalized interest rate futures or yield changes (excluding the current- and next-month federal funds futures rates) range from −0.06 to –0.33, with only four being significant at the 5 percent level.

[16]The supplement is available from the authors upon request.

[17]Because the inflation rate is included in the VAR, one option would be to estimate the effect of the two monetary policy shocks on inflation by SVAR-IV, as we do for the unemployment rate. Doing so, however, has two disadvantages. First, as McLeay and Tenreyro (2019) emphasize, monetary policy has successfully stabilized the inflation rate in a range that is narrow by historical standards, but from an econometric perspective this successful management of inflation confounds the reduced-form relation estimated using a VAR or a conventional Phillips curve that

Because the unemployment gap responds to supply shocks that also affect the rate of inflation (and thus are contained in the error term e_t), the unemployment gap is endogenous and the parameters of equation (1) cannot reliably be estimated by ordinary least squares. We therefore estimate equation (1) by generalized method of moments. For instruments, we draw inspiration from Debortoli, Galí and Gambetti (2019) and, more closely, Barnichon and Mesters (2019a). Barnichon and Mesters (2019a) point out that monetary policy shocks, were they observable, would provide valid instruments because they would be uncorrelated with the supply shocks comprising e_t. Although monetary policy shocks are not observed, observable instruments for those shocks can be used instead. Because monetary policy shocks enter with a lag, a distributed lag of those instruments should be used if they are to be relevant.

Accordingly, we construct instruments from the panel of announcement-day changes described in footnote 11. Specifically, from the 20 announcement-day interest rate changes (the Kuttner shock and the 19 announcement-day changes with various maturities) we construct the first three principal components. From these, we construct two sets of instruments. The first set consists of exponentially weighted moving averages (EWMAs) of each principal component, with EWMA coefficients of 0.9 and 0.7, for a total of six instruments. The second set of instruments adopts Barnichon and Mesters' (2019a) approach and uses polynomial distributed lags, here with degree 2 and maximum lag length 12.

The estimation results are summarized in table 1. The estimates using the two instrument sets show similar coefficients. The first set

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does not take into account the endogeneity of monetary policy. This is the classic problem that when a variable is controlled, the historical relationship used for that control breaks down (Kareken and Solow 1963, Goldfeld and Blinder 1972). McLeay and Tenreryo (2019) show that this can manifest as a Phillips curve that appears flat when in reality it is not. The VAR simply estimates a dynamic version of this Phillips curve and thus inherits this endogeneity problem. Second, because the Phillips curve is estimated implicitly in the VAR, it is difficult to use SVAR-IV methods to conduct sensitivity checks to changes in the Phillips curve and/or its lead-lag dynamics. Third, the VAR leaves the role of expectations implicit, but it is useful to know explicitly how important they are in the simulations. Fourth, the VAR covers a long period in which the slope of the Phillips curve is thought to have been flattening, and estimating the Phillips curve separately allows us to do so using more recent data.

Table 1. Estimated Phillips-Curve Coefficients

Instrument Set (# IVs)	$Ugap_t$	π_{t+1}	π^e_{t+1}	$\kappa/(1-\gamma_b-\gamma_f)$	First-Stage F-effective	J-statistic (p-value)
A (6)	−0.094	0.099	0.400	−0.187	43.65	4.89
	(0.024)	(0.049)	(0.092)	(0.054)		(0.43)
B (9)	−0.122	0.055	0.354	−0.206	6.94	5.18
	(0.024)	(0.044)	(0.066)	(0.043)		(0.74)

Notes: The unemployment gap is from the Congressional Budget Office. Data are quarterly. Standard errors are strong-instrument Newey-West (eight lags). All regressions include an intercept. The first-stage F statistic is the Montiel Olea and Pflueger (2013) effective F. Instrument set B: polynomial distributed lags of degree 2 of first three principal components of announcement-window changes in the panel of interest rates (including federal funds), 1994:Q2–2018:Q4 (maximum lag = 12). Instrument set B: EWMA of first three principal components using weight coefficients 0.90 and 0.70.

(the EWMA instruments) is stronger, and we use those estimates for our base model.[18] The estimates in table 1 are in the range of those in the literature; see, for example, the estimates in Crump et al. (2019) and McLeay and Tenreyro (2019, table 2). These estimates imply fairly flat Phillips curves. One measure of the implied Phillips-curve slope is the long-run effect of a sustained unit increase in the unemployment gap, which, in terms of the coefficients in equation (1), is given by $\kappa/(1-\gamma_b-\gamma_f)$. This value is reported in table 1 and is similar, approximately -0.2, for the two estimates.

5.4 Combined Simulation Model and Simulation Method

The unemployment rate impulse responses from section 5.2 are monthly, which takes advantage of the monthly data on announcement-window changes, while the Phillips-curve estimation is quarterly, the frequency of observation of the Michigan inflation expectations survey. To combine the two models, the impulse responses of the unemployment gap to the two monetary shocks were temporally aggregated by averaging the unemployment rate responses for the months within the quarter. Given these two quarterly impulse responses, the hybrid Phillips curve is solved forward.[19] Doing so yields two mutually consistent pairs of impulse responses of the inflation rate and the unemployment gap first to the federal funds shock and second to the slope shock.

The model for the federal funds shock is completed by augmenting the unemployment gap and inflation rate impulse responses by the dynamic response of the federal funds rate to the federal funds shock. Given this trio of impulse response functions, we follow Sims

[18] Results for alternative specifications, including different sample periods, using core CPI inflation and the Survey of Professional Forecasters expectations method, and different estimators are reported in the supplement.

[19] The forward solution of equation (1) involves a variant of the Blanchard and Kahn (1980) method. Assume that $\gamma_f > 0$, $\gamma_b > 0$, and $\gamma_f + \gamma_b \leq 1$. Define $z_t = \pi_t - \theta\pi_{t-1}$ and guess that $z_t = \zeta E_t z_{t+1} + \varphi Ugap_t$ for unknown parameters θ, ζ, and φ. We verify that this guess satisfies equation (1) if $\zeta = \gamma_f/\lambda$, $\varphi = \kappa/\lambda$, and $\lambda\theta = \gamma_b$, where $\lambda = 1 - \theta\gamma_f$. Solving the third of these equations gives $\theta = \left(1 - \sqrt{1-4\gamma_b\gamma_f}\right)/2\gamma_f$. Then solve forward to write $z_t = (\kappa/\lambda)\sum_{j=0}^{\infty}(\gamma_f/\lambda)^j E_t Ugap_{t+j}$ and hence $\pi_t = \theta\pi_{t-1} + (\kappa/\lambda)\sum_{j=0}^{\infty}(\gamma_f/\lambda)^j E_t Ugap_{t+j}$.

(1986) and compute the sequence of federal funds shocks that would deliver a specified path of the federal funds rate, and then compute the effect of that sequence of federal funds shocks on the unemployment gap and the rate of inflation. Similarly, by augmenting the slope shock pair of impulse responses by the dynamic response of the 10-year federal funds spread to a unit slope shock, we can compute the sequence of slope shocks to obtain a stipulated path of this spread and thus their effect on the unemployment gap and the rate of inflation.

Both trios of impulse response functions imply a dynamic reduced-form Phillips relation, that is, the cumulative change in the rate of inflation divided by the cumulative change in the rate of unemployment. Because the two shocks have different dynamics, these two ratios differ for the two shocks; however, they turn out to be numerically close. For our base model after 24 months, this Phillips slope is −0.188 for the federal funds shock and –0.185 for the slope shock. The 24-month Phillips multiplier is approximately $\kappa/(1-\gamma_b-\gamma_f)$, which is reported in table 1. The estimates of McLeay and Tenreyro (2019), using pooled ordinary least squares estimation with metro area data (their table 3) imply an estimate of $\kappa/(1-\gamma_b-\gamma_f)$ of −0.308. Barnichon and Mesters (2019b), using high-frequency instruments, get a post-1990 Phillips multiplier of about −0.15 at three to four years, but they estimate a steeper Phillips curve using Romer and Romer (2004) shocks as instruments. Section A.2 of the appendix and the supplement explore the sensitivity of our counterfactual estimates to using a more responsive Phillips curve.

6. Performance Under Counterfactuals

We use this simulation model to assess how the U.S. economy would have performed under alternative monetary policies implemented using the tools of the current monetary policy framework. We start by compiling the assumptions underlying this analysis. First and most importantly, our analysis takes full advantage of the benefits of hindsight and, as such, care must be taken in interpreting the results. For example, several of our counterfactuals are infeasible hypothetical cases, and all our simulations rely on ex post data that were unavailable to Fed decisionmakers in real time. Thus, finding that macroeconomic performance is better under a given counterfactual does not imply that the Fed should or could have made different decisions in real time. Rather, such a finding, based on what we know now, can inform future Fed policy as it navigates the next recession and recovery. Second, our conclusions depend on a particular estimated structural VAR model, except that the mapping from unemployment gap to inflation impulse responses is instead described by a hybrid Phillips curve, identified by instrumental variables. We do, however, compare our results to those of other papers and find that they are broadly consistent with many other estimates in the literature. Third, we assume that we have correctly identified two shocks—a federal funds shock and a slope shock—and that these are predominantly policy surprises, not the revelation of private information by the Fed. And finally, we are assuming that counterfactual policies can be represented as a sequence of unanticipated federal funds and slope shocks. We are therefore omitting any effects that these policies might have by changing expectations. As a consequence, our framework is not suited to assessing how commitment, or even imperfect commitment, might also work through altering agents' expectations.

We begin by describing the counterfactuals, then turn to the results.

6.1 Counterfactuals

No ZLB. Our first counterfactual supposes that there is no zero lower bound on interest rates and that the Fed had followed a Taylor rule for the federal funds rate, with no LSAPS. Here and subsequently, the Taylor rule we use is $FF_t = 2 + \pi^{(12)}_{t-1} + 0.5\left(\pi^{(12)}_{t-1} - 2\right) - 2 * Ugap_{t-1}$, where FF, $\pi^{(12)}$, and $Ugap$ are, respectively, the federal funds rate, the 12-month rate of core PCE inflation, and the unemployment gap. This is based on the Taylor (1999) rule, which uses the output gap as the slack measure, with a coefficient of 1. Yellen (2012) uses this version of the Taylor rule and refers to it as the "balanced approach" rule, and this output gap coefficient of 1 is also used by Chung et al. (2019). We translate the coefficient on the output gap into a coefficient of –2 on the unemployment gap, using an Okun's law coefficient of 2.[20] This counterfactual does not, of course, simulate a feasible policy path; like Christiano, Eichenbaum, and Trabant (2015) and Gust et al. (2017), we use it to calibrate the macroeconomic cost of the zero lower bound on interest rates.[21]

[20] Our Taylor rule has no interest rate inertia, as we want to focus on how the FOMC responds to inflation and the unemployment gap. Historically, the FOMC has moved quickly to cut rates in downturns.

[21] Alternative policy scenarios are implemented as a sequence of unanticipated federal funds and slope monetary policy shocks to provide a specified path for observable variables. We provide details here for the "No ZLB" scenario; the calculations for the other scenarios are similar. For the "No ZLB" scenario, the Taylor rule determines the value of the federal funds rate in the next period and thus the value of the federal funds shock, which in turn affects the realized values of inflation and unemployment and, via the Taylor rule, the subsequent value of the federal funds rate. Solving forward recursively yields the paths of the observable variables. The "No LSAP" hypothetical is implemented by calculating the sequence of slope shocks that remove the historical effect of LSAPs on the 10-year federal funds spread. To assess the effects of LSAPs, we take the change in System Open Market Account (SOMA) 10-year equivalents as a share of nominal GDP, relative to December 2008, and multiply this by an assumed elasticity of 10-year yields of 6 basis points per percentage point of GDP (Belton et al. 2018). This assumes that LSAPs work through the stock of purchases, rather than the flow. There likely were transitory flow effects, especially in disrupted financial markets in 2009, but we omit these for the purposes of our working calibration. Our no-LSAP scenario adds slope shocks to steepen the yield curve by the required amount. Because this negation of historical slope policy is calibrated by a no-LSAPs scenario, it does not necessarily remove the effects of forward guidance. The effect of the sequence of federal funds shocks on interest rates, the unemployment gap, and inflation are computed using the IRFs for those series with respect to the levels shock, and, similarly, the slope shock IRFs are used for the sequence of slope shocks. The combined effect on all variables (interest rates, unemployment, and inflation) is the sum of the level and slope effects for each variable. For scenarios below that specify "historical slope policy," no changes are made to historical slope shocks, so the counterfactual paths for interest rates, inflation, and the unemployment gap arise solely from the federal funds shock and the federal funds shock IRFs. Slope shocks are allowed to affect the level of the funds rate after liftoff in December 2015, but not during or before December 2015 when the economy was stuck at the ZLB. Finally, for plotting purposes, results are reported in terms of the unemployment rate by adding the CBO natural rate of unemployment to the simulated path of the (CBO) unemployment gap, under the assumption that the monetary policy counterfactuals do not affect the natural rate of unemployment.

Follow Taylor (1999) Rule (Constrained by ZLB) with No LSAPs. This counterfactual is like the "no ZLB" counterfactual, except that the ZLB is imposed and there are no LSAPs, as discussed in footnote 21.

Earlier/Later Liftoff. These counterfactuals imagine that the observed path of increases in the federal funds rate started, alternatively, one year earlier or one year later. For these counterfactuals, slope policy is unchanged, that is, the realized historical slope shocks are used.

Alternative 10-Year Federal Funds Slope Policies. We consider several counterfactuals in which federal funds policy is the same as it was historically but slope policy differs. Specifically, we consider four such counterfactuals that focus on the 10-year federal funds spread: no LSAPs (computed as described in footnote 21); a slope policy that flattened the 10-year federal funds slope by 1 percentage point for two years; an earlier and stronger slope policy that flattened the slope by 2 percentage points for 18 months beginning December 2008; and a slope policy that fixed the 10-year federal funds spread at 2 percentage points for five years starting in December 2008.

Historical $\pi* = 3\%$ or 4%. This hypothetical supposes, counterfactually, that entering the recession, the Fed had inherited nominal interest rates, rates of inflation, and an inflation target either 1 or 2 percentage points higher than actual. For example, for the 10 years through 2000, core PCE inflation averaged 2.1 percent, essentially at the 2 percent target. Under the $\pi* = 3\%$ counterfactual, inflation hypothetically would have averaged 3.1 percent, essentially at a 3 percent target. More generally, we quantify the concept of inheriting an inflation target that is x percentage points higher by increasing the values of all nominal variables (interest rates and inflation) by x percentage points at an annual rate, while leaving real variables unchanged. These higher nominal rates are then combined with various policy rules or targets to provide counterfactuals. For example, one such counterfactual is inherited nominal rates 1 percentage point higher and an inherited 3 percent inflation target, historical federal funds policy (still driving the federal funds rate to the ZLB), and historical slope policy (historical slope shocks). Another counterfactual specifies a 3 percent inflation target coupled with no slope policy, which is implemented as an absence of LSAPs as described in footnote 21.[22]

Temporary Price-Level Targeting. Temporary price-level targeting involves the Fed committing to make up shortfalls in inflation when at the zero lower bound. The simplest form of temporary price-level targeting would commit the Fed to remain very accommodative until cumulative average inflation since hitting the zero lower bound reaches the target. Conventional inflation targeting (which references only the rate of inflation, not the price level) would resume once away from the ZLB. In unreported results, we simulated this version of temporary price-level targeting; however, the magnitude of disinflation in the recession was such that it would take quite extreme policies to hit the temporary price-level target by 2019, and inflation would have to go considerably above 2 percent. This finding is broadly consistent with findings in Bernanke, Kiley, and Roberts (2019), so we examine instead their proposal for temporary

[22]A mechanical alternative interpretation of the higher-inflation steady-state counterfactual is that the Fed could drive nominal rates below zero by the difference between 2 percent and the hypothesized rate. We do not endorse this interpretation, however, because such a policy would go sufficiently beyond the scope of historical experience that we would not consider our simulation model to be reliable were nominal rates to be reduced below zero by more than a small amount. Moreover, the literature that has studied negative rates concludes that when rates are negative, further cuts are less stimulative than in normal times and may even be contractionary. Negative interest rates have been in Europe and in Japan. No country has set a policy rate below –75 basis points, and only Switzerland has gone this low. The European Central Bank (ECB) has set its deposit facility rate at –40 basis points. However, deposit rates have generally been bounded at zero, and bank profits may be hurt by negative rates. Brunnermeier and Koby (2018) considered the idea of a reversal interest rate at which further cuts would hurt bank profitability and might be contractionary. Consistent with this, whereas event-study evidence has typically found that monetary policy raises bank equity returns, Ampudia and Van den Heuvel (2018) find that surprise monetary policy easing lowers bank equity prices at negative interest rates. Eggertsson et al. (2019) document that in Swedish data, for negative policy rate, cuts in policy rates have no effect on bank deposit rates and, if anything, increase bank lending rates. Eggertsson et al. (2019) and Ulate Campos (2018) both study the effects of negative interest rates on economic activity in DSGE models. Ulate Campos finds that interest rate cuts are less stimulative than when rates are positive; Eggertsson et al., who do not incorporate bank monopoly power, find that they are outright contractionary. Burke et al. (2010) concluded that, in the United States, a rate below about −35 basis points might lead banks to switch reserves into physical currency.

price-level targeting with a one-year lookback, which is equivalent to average inflation targeting where the average is computed over the prior 12 months. This policy would commit the Fed to maintain very accommodative policy until inflation over the previous year averages 2 percent. We consider two forms of temporary price-level targeting with this one-year lookback period. One promises federal funds shocks to keep the funds rate at zero until the target is reached; the other instead promises slope shocks to achieve the same effect.

Makeup Rule. Reifschneider and Williams (2000) propose that if the federal funds rate hits the zero lower bound, the Fed would keep the rate at the zero lower bound for an additional period after the Taylor-rule rate rises above zero, where the additional time is enough to make up for the excursion of the Taylor-rule rate below zero. (This makeup rule is the third rule listed on page 37 of the February 2019 Monetary Policy Report).

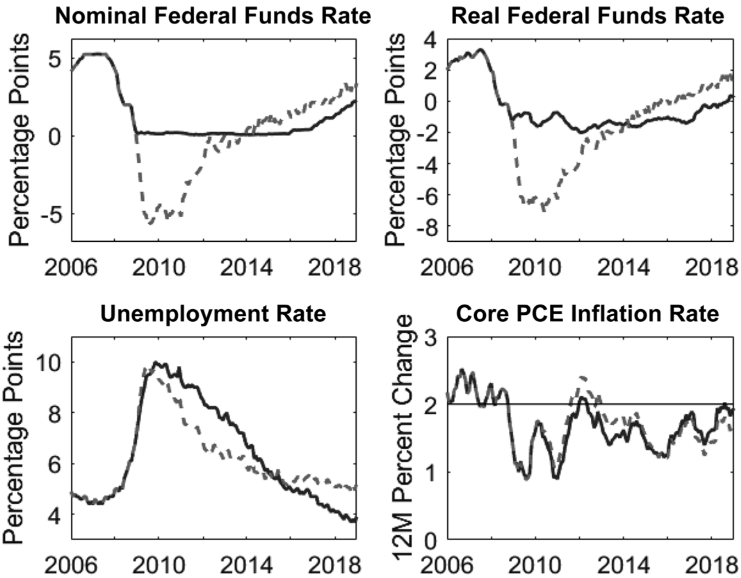
6.2 Results

The results of each counterfactual are summarized in four-panel figures, which depict the actual and counterfactual paths of the nominal federal funds rate or 10-year federal funds spread (upper left), the real federal funds rate (upper right), the unemployment rate (lower left), and the 12-month rate of core PCE inflation (lower right).

Figure 3 shows the results for the Taylor (1999) rule with no-ZLB counterfactual. Absent the ZLB, the Taylor rule would have prescribed a nominal funds rate of −5.5 percent in 2009 and 2010, resulting in a much faster decline of the unemployment rate.[23] However, the funds rate would have returned to being positive in 2012, which would have slowed the pace of progress on unemployment during the second half of the recovery, and the unemployment rate would have stabilized approximately at the CBO NAIRU. These results are very similar to the findings of Gust et al. (2017), who consider a DSGE model where the federal funds rate is the only instrument

[23]The original Taylor (1993) rule has a coefficient of 0.5 on the output gap, which translates into −1 on the unemployment gap, with the conventional Okun's coefficient. This would prescribe a funds rate of −2 percent in 2009 with a slower recovery than we obtain with the Taylor (1999) rule. We show this counterfactual in the supplement.

Figure 3. Counterfactual with Unconstrained Taylor (1999) Rule

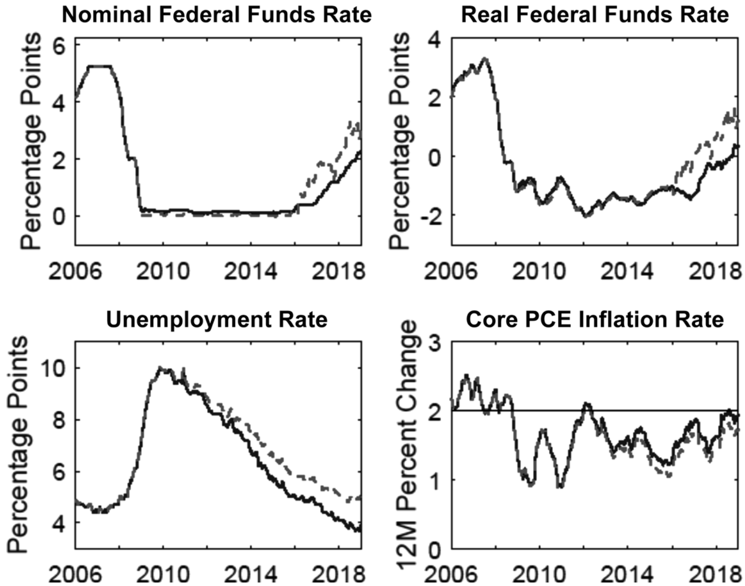


Note: Actual is solid line; counterfactual is dashed line.

of monetary policy (no forward guidance, LSAP, or other slope policy). Their monetary policy reaction function calls for a nominal funds rate falling to −5.5 percent. In their model, the inability to drive the funds rate below zero accounts for 30 percent of the fall in output in 2009 and most of the subsequent slow recovery.

Figure 4 shows the results for the Taylor rule incorporating the ZLB and undoing the effects of LSAPs, as discussed in footnote 21. The federal funds rate would have been at the ZLB until liftoff in late 2015. Progress on the unemployment rate would have been slower than was actually observed, especially later in the recovery, initially as a result of the steeper yield curve in the absence of LSAPs, then compounded by a steeper pace of tightening after liftoff. The unemployment rate would remain over 5 percent in early 2019, and the slow progress on unemployment would have further reduced the inflation rate, relative to what was actually observed.

Figure 4. Counterfactual with Taylor (1999) Rule Incorporating ZLB and No LSAPs



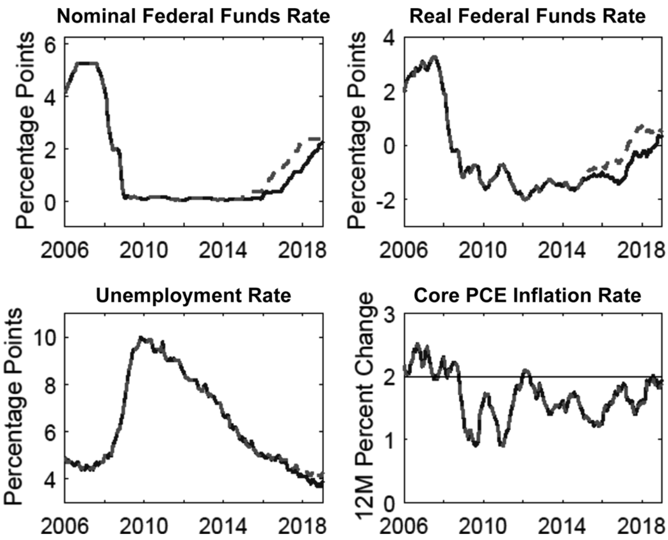
Note: Actual is solid line; counterfactual is dashed line.

Figure 5 and figure 6 envision a liftoff from the ZLB that is, respectively, one year earlier and one year later than actual, with no change in slope policy (same slope shocks as historical). Specifically, in the early liftoff simulation, we use federal funds shocks to get the funds rate starting in December 2014 to where it actually was one year later, and likewise for late liftoff. An earlier liftoff slightly slows progress on unemployment, but it has virtually no effect on inflation. Later liftoff would lower the unemployment rate at the end very slightly, but because of the lags the effect is negligible as of the end of the sample in February 2019.

Figures 7–11 simulate various alternative slope policies, combined with the actual historical federal funds policy. These counterfactuals are organized as a progression with increasingly aggressive slope policy.

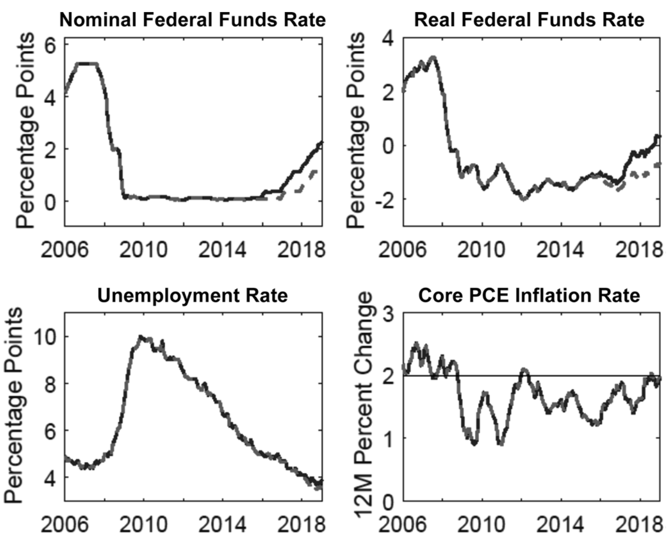
The first of these, in figure 7, contemplates a less aggressive slope policy than actual, calibrated to correspond to an absence of LSAPs.

Figure 5. Early Liftoff



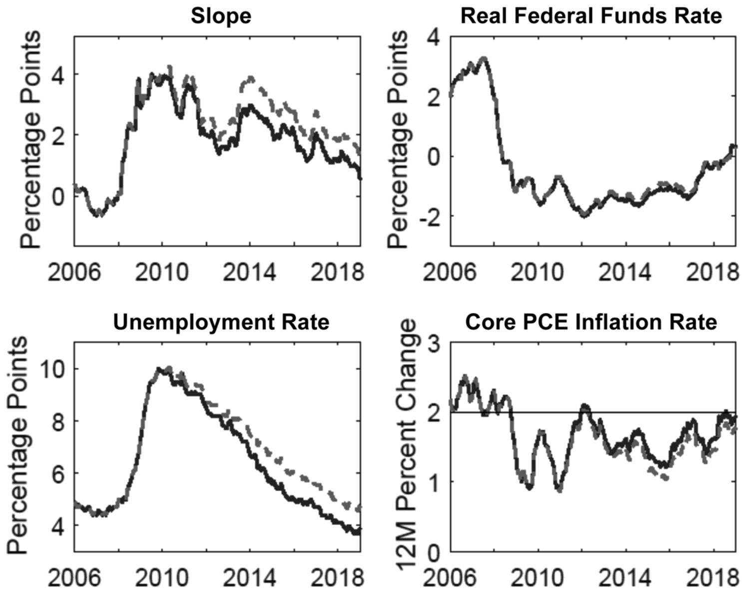
Note: Actual is solid line; counterfactual is dashed line.

Figure 6. Late Liftoff



Note: Actual is solid line; counterfactual is dashed line.

Figure 7. No LSAPs



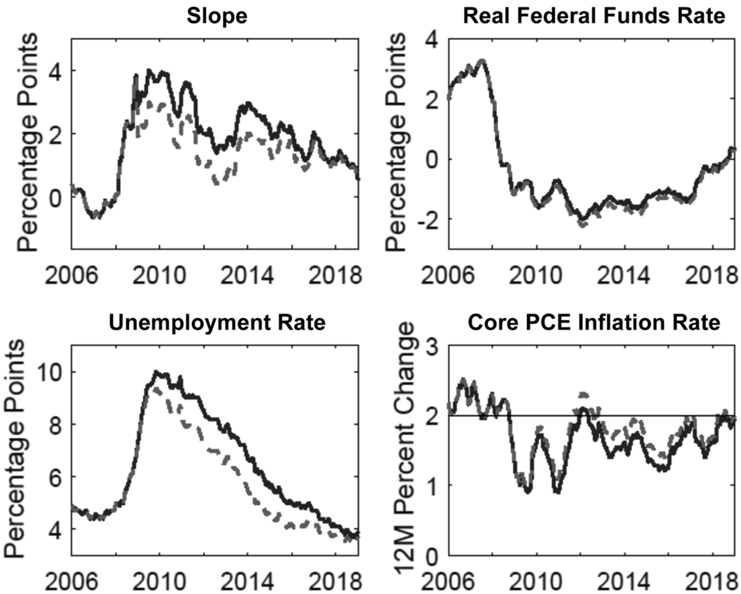
Note: Actual is solid line; counterfactual is dashed line.

This counterfactual has a steeper yield curve, especially after 2012.[24] The steeper yield curve would have slowed the improvement in the unemployment rate by more than a year, keeping the unemployment rate around 5 percent at the end of the sample, and the rate of inflation would have been even lower than it actually was.

Figures 8–11 consider more aggressive counterfactual slope policies. The first of these, in figure 8, counterfactually supposes a slope policy that flattens the yield curve by an additional 1 percentage point for five years, relative to the actual historical outcomes, starting in December 2008. Assuming an elasticity of 6 basis points per

[24]The reason why the effect on slope is largest after 2012 is that we assume that the effect of LSAPs is proportional to the stock of 10-year Treasury equivalents in the SOMA portfolio, as a share of nominal GDP, which peaked in 2014. To the extent that LSAPs might have had transitory flow effects, which might have been particularly large when financial markets were disrupted in 2009, this assumption could understate their effects in 2009 and overstate their effects later in the sample.

Figure 8. Counterfactual of Five Years of Additional Flattening



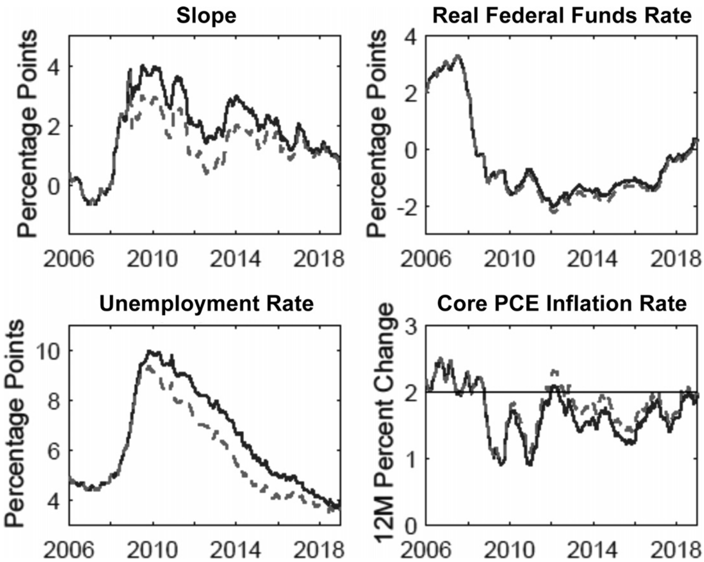
Note: Actual is solid line; counterfactual is dashed line.

percentage point of GDP 10-year equivalents, this corresponds to additional LSAPs of about $2.5 trillion over and above the LSAPs that were actually implemented, although the slope shock could also be implemented in part by forward guidance. This slope shock would have closed the unemployment gap two years earlier and raised inflation a bit.

Figure 9 considers a threshold (state-dependent) version of the previous calendar (time-dependent) policy, in which the yield curve is flattened by 1 percentage point until either the unemployment gap falls to 1 percent or inflation exceeds 2.5 percentage points. The outcome is very similar to the simulation in figure 8, as the slope shocks get turned off after about five years.

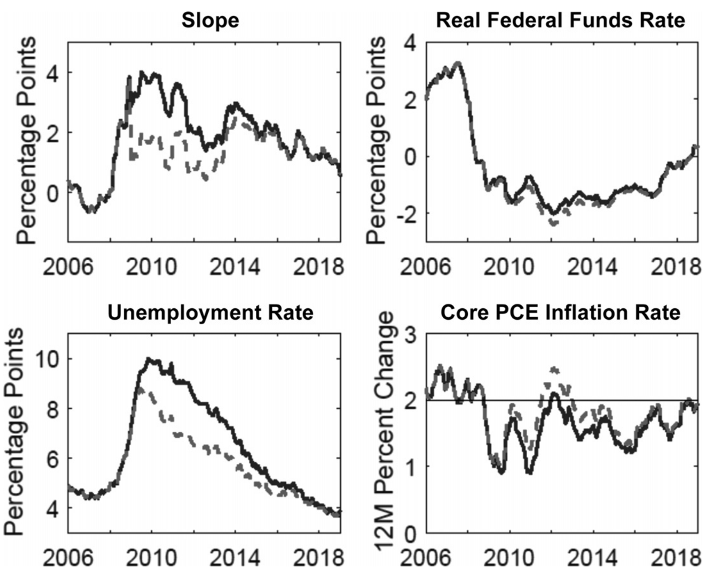
Figure 10 considers a "stronger sooner" front-loaded version of slope policy, in which slope policy flattens the yield curve by 2 percentage points but only for 18 months starting in December 2008, relative to the actual historical outcomes. It is particularly hard

Figure 9. Counterfactual of Additional Flattening until Threshold Achieved



Note: Actual is solid line; counterfactual is dashed line.

Figure 10. Front-Loaded Additional LSAPs: Yield Curve Flattened by an Additional 2 Percentage Points for 18 Months



Note: Actual is solid line; counterfactual is dashed line.

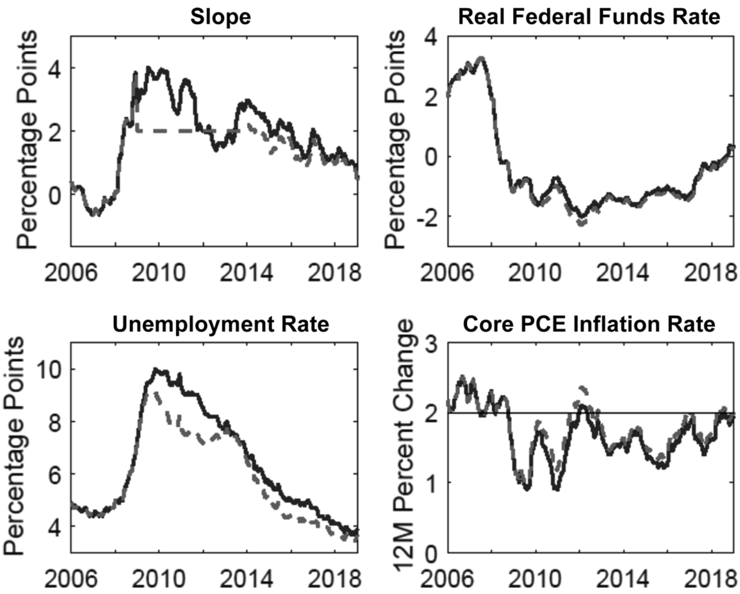
to know what kind of asset purchases would have been needed to achieve this outcome. Our working assumption from footnote 21 of the effects of the stock of asset purchases on 10-year yields would indicate that about $5 trillion of additional LSAPs would have been needed. In the disrupted financial markets of 2009 and 2010, however, it might have been possible to achieve such a flattening of the yield curve with smaller asset purchases. Additional forward guidance might also play a role in reducing the requisite volume of LSAPs. In our simulation, this early aggressive slope policy would have shaved slightly more than 1 percentage point off the cyclical peak of the unemployment rate, would have reduced the unemployment gap by an average of 1.7 percentage points over the first four years of the recovery, and inflation would have been materially higher, though still below the 2 percent target on average over the last decade.

Figure 11 considers an alternative version of front-loaded policy, which pins the slope to 2 percentage points for five years. With the funds rate at the ZLB, this is equivalent to pinning the 10-year yield to 2 percent.[25] With our illustrative assumption of the effects of the stock of asset purchases on 10-year yields, this would have required very large purchases. As pointed out by Bernanke (2016b), such a policy might not need such large purchases if it were fully credible, although it is hard to see long-term commitments as being fully credible, if only because of FOMC turnover. In our simulations, this slope shock would again have brought the unemployment rate down much faster early in the recovery.

Figures 12–15 consider counterfactuals in which the Fed had, prior to the recession, inherited a higher inflation target and, with it, initial higher rates of inflation and nominal rates of interest, without changing initial values of all real variables including real rates. These counterfactuals postulate that inflation and all nominal interest rates came into the financial crisis recession shifted up by either 1 or 2 percentage points. These are not simulations of transitioning

[25]There are precedents for policies of this sort. The Federal Reserve enforced a ceiling of 2-1/2 percent on long-term Treasury yields during and immediately after World War II (Hetzel and Leach 2001). The Swiss National Bank has long targeted three-month interest rates as a tool of policy, which goes slightly out the term structure. And the Bank of Japan is currently using a "yield-curve control" policy that simultaneously targets short- and long-term interest rates.

Figure 11. Yield-Curve Slope Set to 2 Percentage Points for Five Years

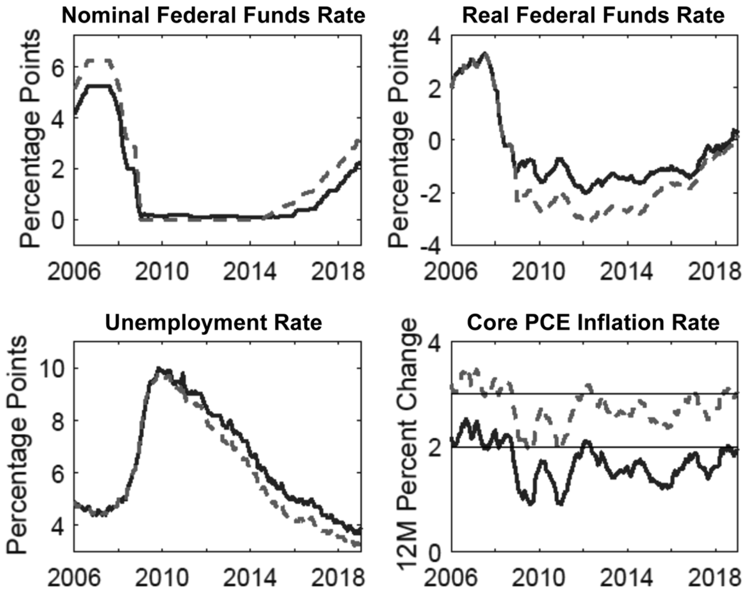


Note: Actual is solid line; counterfactual is dashed line.

from a lower to a higher inflation target during the recession or recovery.

The first of these exercises, shown in figure 12, considers inheriting a 3 percent inflation target, combined with policy that (like actual policy) goes to the ZLB after December 2008. Under this counterfactual, Fed funds policy lifts off when either of two conditions are met: the unemployment gap falls to 1 percent or the inflation rate exceeds target by 0.5 percentage point. The historical slope shocks are preserved, so implicitly the Fed conducts the same LSAPs and forward-guidance policy as it did historically. In this simulation, the inherited extra percentage point of headroom allows the real funds rate to fall by a further percentage point. In this counterfactual, liftoff comes when the unemployment gap falls to 1 percent, which happens in 2014. The unemployment gap closes seven quarters earlier than in the actual data, and inflation averages

Figure 12. 3 Percent Inherited Inflation Target with Historical Slope Shocks Counterfactual

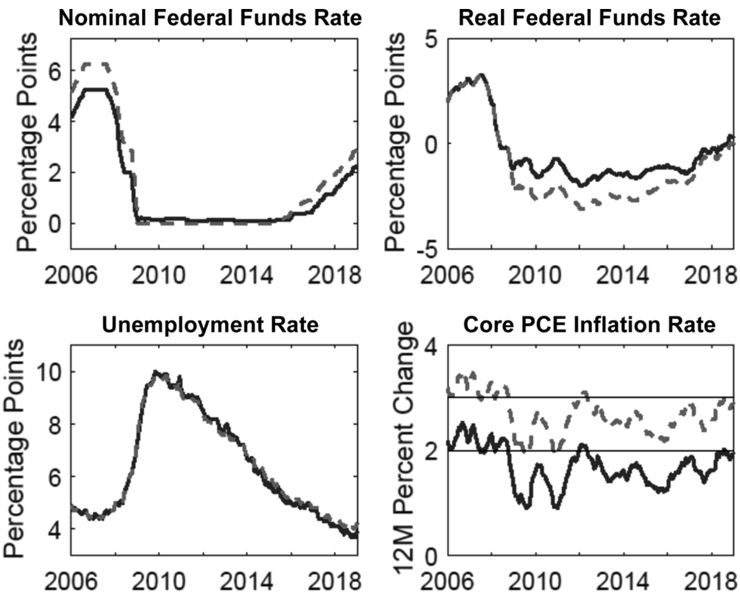


Notes: Actual is solid line; counterfactual is dashed line. In the bottom-right panel, horizontal lines denote 2 percent and 3 percent inflation levels.

1.1 percentage points higher—the 1 percent assumed nominal starting point plus a small boost from the stronger economy. Inflation still falls just short of the 3 percent hypothetical inflation target.

Figure 13 repeats the hypothetical of a 3 percent inflation target but removes historical LSAPs. Specifically, federal funds policy drops the federal funds rate to the ZLB in December 2008, where it stays until the unemployment gap falls to 1 percent or inflation exceeds the target by 0.5 percentage point. However, this simulation adds in slope shocks to reverse the effects of LSAPs. The real funds rate is reduced, but the outcome for the unemployment rate is almost identical to that actually observed in the data. The path of inflation is also almost identical to that observed in the data, except that it is shifted up by a percentage point. This simulation implies that the LSAPs that were actually conducted have about the same ability to stimulate the economy as an additional percentage-point

Figure 13. 3 Percent Inherited Inflation Target with No LSAPs

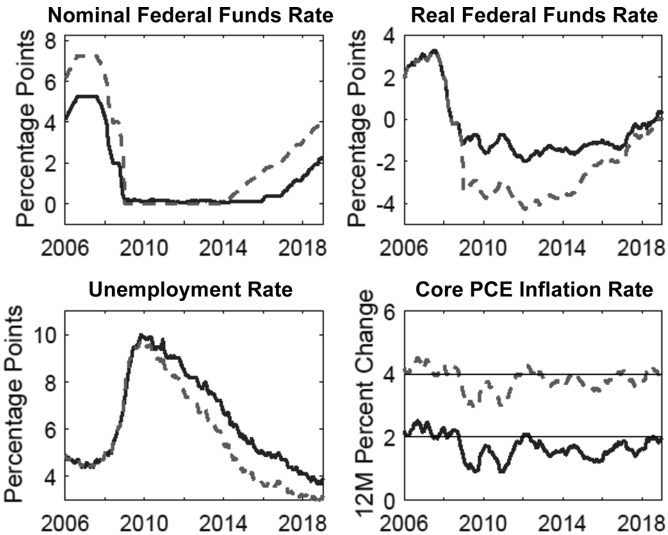


Notes: Actual is solid line; counterfactual is dashed line. In the bottom-right panel, horizontal lines denote 2 percent and 3 percent inflation levels.

cut in the real funds rate. Alternatively, had the Fed inherited a 3 percent inflation target, it could achieved the same outcomes as were actually observed without any LSAPs.

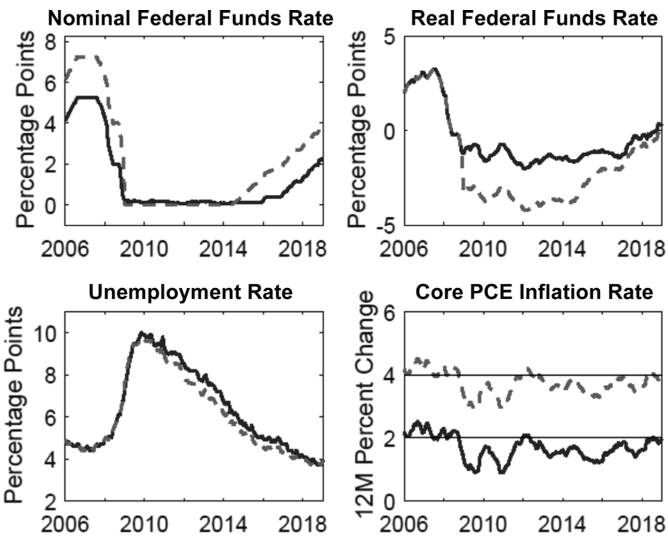
Figures 14 and 15 repeat the previous two counterfactuals, but now with an inherited 4 percent inflation target. Figure 14 keeps the historical slope shocks, while figure 15 reverses the slope shocks from LSAPs. Inheriting a 4 percent inflation target in combination with historical slope shocks would have given a much faster recovery, with liftoff arriving in early 2014 and the unemployment gap closing in the third quarter of 2014. But, because of the historically flat Phillips curve, even this would not have been enough to quite hit the 4 percent target, on average, over the last decade. A 4 percent target with no LSAPs (figure 15) would have given a slightly faster recovery than was actually observed.

Figure 14. 4 Percent Inherited Inflation Target with Historical Slope Shocks



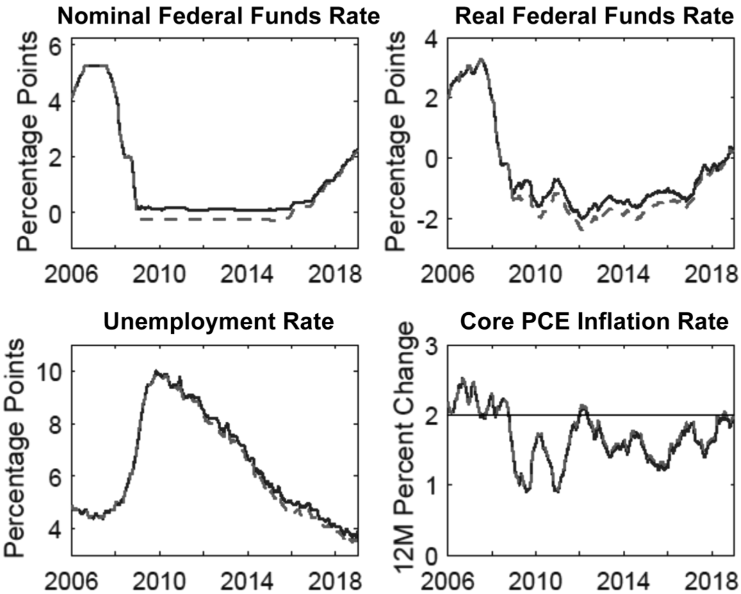
Notes: Actual is solid line; counterfactual is dashed line. In the bottom-right panel, horizontal lines denote 2 percent and 4 percent inflation levels.

Figure 15. 4 Percent Inherited Inflation Target with No LSAPs



Notes: Actual is solid line; counterfactual is dashed line. In the bottom-right panel, horizontal lines denote 2 percent and 4 percent inflation levels.

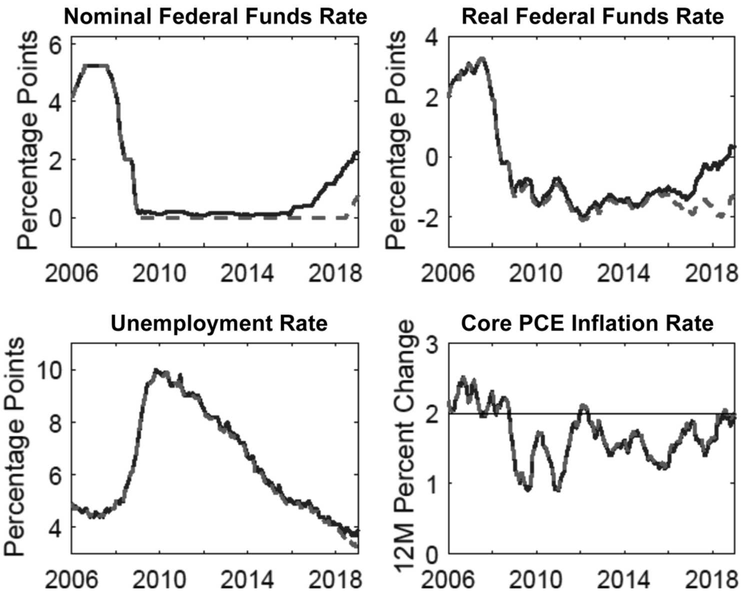
Figure 16. Federal Funds Rate of −25 Basis Points



Note: Actual is solid line; counterfactual is dashed line.

In theory, another possibility for achieving a lower real federal funds rate is to push the federal funds rate below zero, as has been done for short rates by the ECB and by the Swiss National Bank without changing the inflation target. Figure 16 considers the counterfactual of setting the federal funds rate to –25 basis points during the period that it was, in fact, at the ZLB. This would amount to more than 35 basis points of additional accommodation, as the effective funds rate was never quite at zero. We estimate the macroeconomic effect of this policy to be small, lowering the unemployment rate by at most two-tenths of a percentage point and having virtually no effect on inflation. Moreover, this counterfactual is done in the context of a linear model in which an easing of policy has, by assumption, the same incremental effect when rates are positive or negative. Easing, however, is arguably less effective when rates are negative, because of the effect on the banking system (see footnote 22). Thus, even the small effects that we find arguably overstate the benefits of cutting the federal funds rate to −25 basis points.

Figure 17. Temporary Price-Level Targeting via Federal Funds Shocks

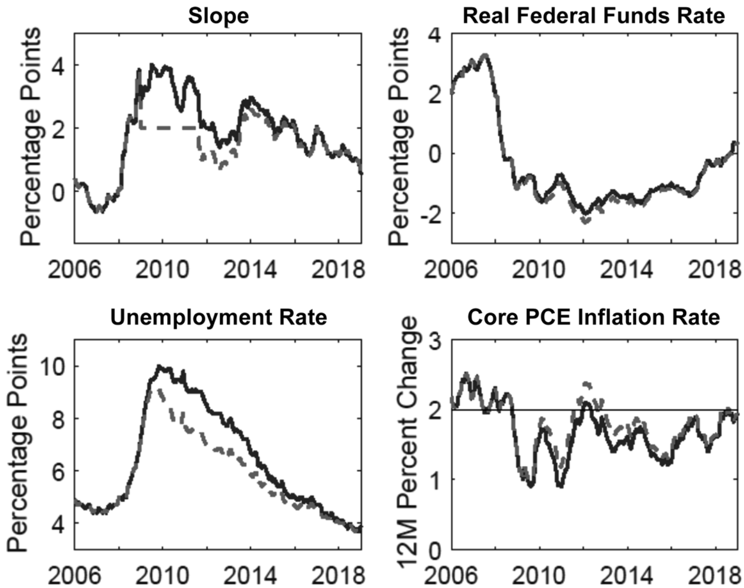


Note: Actual is solid line; counterfactual is dashed line.

The next two figures examine a form of temporary price-level targeting. Figure 17 adopts a rule of adding federal funds shocks to keep the funds rate at zero from December 2008 until the temporary price-level target with a 2 percent inflation rate and a one-year lookback period has been reached. This ends up implying a liftoff from the zero lower bound that does not come until 2018. Inflation is slightly higher at the end, and the unemployment rate falls a bit faster, but the difference is small. The disinflationary forces from the recession were too big to be easily addressed by federal funds shocks alone, even with temporary price-level targeting. Figure 18 adopts a rule of adding slope shocks to keep the slope of the yield curve at 2 percent from December 2008 until the same temporary price-level target has been reached. This enables a faster recovery, and the target is reached in 2012.

We conclude this section with two simulations that examine the Reifschneider and Williams (2000) makeup rule, where the federal

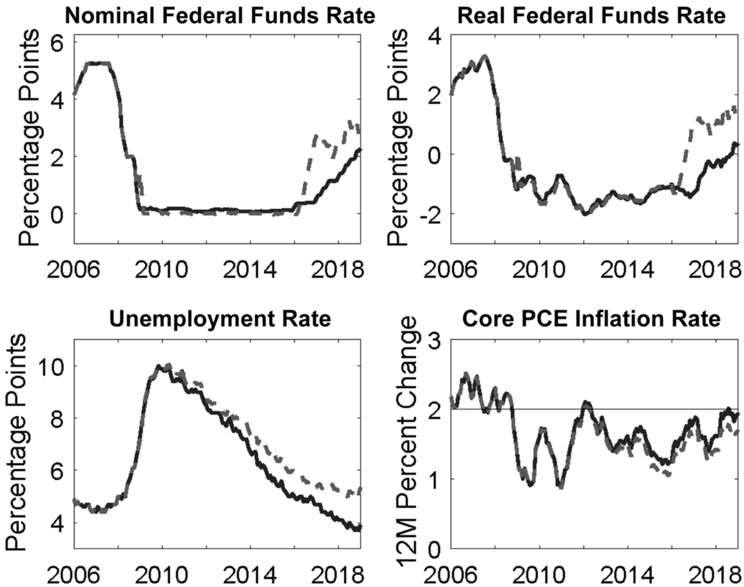
Figure 18. Temporary Price-Level Targeting via Slope Shocks



Note: Actual is solid line; counterfactual is dashed line.

funds rate remains at zero long enough to make up for the cumulative miss of the funds rate from the Taylor (1993) rule rate created because of the zero lower bound. We consider two cases: in figure 19, with r* = 2%, and in figure 20, modifying the Taylor (1993) rule to have r* take on the Holston-Laubach-Williams (2017) value. Both cases are illustrated for the case of no LSAPs, so that the makeup rule is the only adjustment the Fed makes to policy as a result of the zero lower bound. Comparing the two figures, the liftoff date depends heavily on the value of r^* used to implement the makeup rule, with the 2 percent value leading to higher federal funds rates after 2015 than actual, and the Holston-Laubach-Williams (2017) r^* leading to staying at the zero lower bound longer than actual. The main feature of both of these simulations, however, is that the policy does not compensate for the effect of shutting down LSAPs; that is, the makeup policy alone prolongs the recession, and suppresses inflation, relative to actual historical policy.

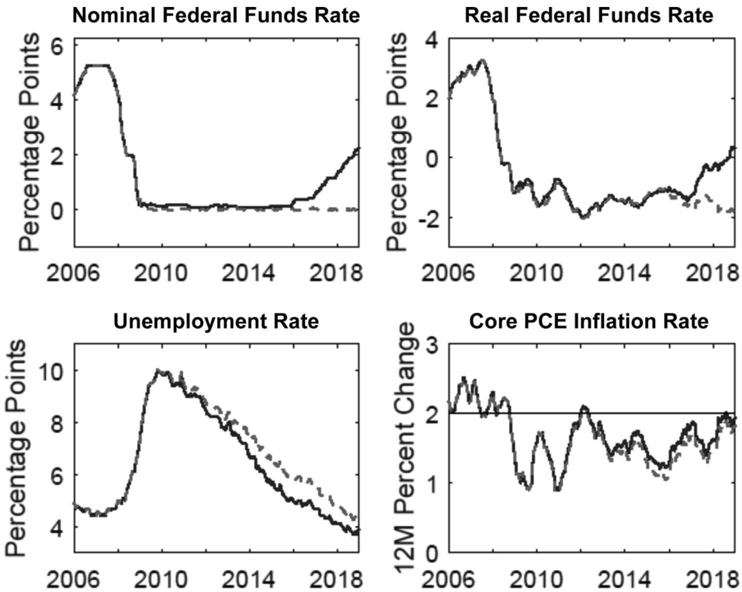
Figure 19. Makeup Rule, with $r^* = 2\%$



Note: Actual is solid line; counterfactual is dashed line.

Expectations and a Caveat. In principle, much of the potential advantage of average inflation targeting and makeup rules arises because the rule changes agents' expectations of future Fed policy, which is then reflected in lower medium- and long-term interest rates. In addition, these policies have the potential to affect inflation expectations directly. Because we implement these policies through a sequence of unanticipated federal funds shocks, these channels are shut down in our SVAR counterfactuals. As a result, our estimates could understate the effects of temporary price-level targets. This said, those expectational channels require the Fed to have a credible ability to commit to future policy and for that commitment to be well understood by markets and, in the case of price expectations, price setters. Because of these commitment and informational challenges, expectational mechanisms that are powerful in theory may be less so in reality.

Figure 20. Makeup Rule, with Holston, Laubach, and Williams (2017) Value of r*



Note: Actual is solid line; counterfactual is dashed line.

6.3 Comparison to Other Simulations

A number of authors have considered the effects of asset purchases in the FRB/US model. Engen, Laubach, and Reifschneider (2015) simulate the effects of all the quantitative easing programs from the financial crisis until the end of 2014.[26] Their results come from an entirely different methodology, and yet are quite close to ours. They find that the peak effect of asset purchases on the unemployment rate is to lower it by $1\frac{1}{4}$ percentage points, while the peak effect on inflation is to raise it by $\frac{1}{2}$ a percentage point. We get almost exactly the same effect on unemployment, but our effect on inflation is only $\frac{1}{4}$ percentage point, because of our flat Phillips curve. Our estimated effect of a slope shock on the unemployment rate comes faster than in the FRB/US simulations, perhaps because of sluggish adjustment

[26]Earlier FRB/US analyses of LSAPs include Chung et al. (2012) and Durdu et al. (2013).

of real variables in FRB/US. This comes notwithstanding the fact that we are modeling policies by a sequence of unanticipated shocks which shut down expectational mechanisms in FRB/US which allow term premium effects to be frontloaded.

Sims and Wu (2019) find that quantitative easing of 4 percent of GDP would raise output by about half a percentage point at the peak in a DSGE model. This is difficult to compare precisely with our estimates, but with our assumed elasticity of 10-year yields to asset purchases and the conventional Okun coefficient, it ends up being roughly comparable to our estimate that a 1 percentage point slope shock should raise the unemployment rate by 0.7 percentage point.

Chung et al. (2019) consider balance sheet and other policies in FRB/US in a hypothetical future zero lower bound scenario, and Chen, Cúrdia, and Ferrero (2012) simulate the effects of the QE2 program specifically in a DSGE model. Our counterfactuals are not directly comparable to the specific counterfactuals considered in these two papers. However, our conclusions are qualitatively consistent with theirs. Shocks that flatten the yield curve move unemployment and inflation in the right direction, but even very large balance sheet actions have quite limited macroeconomic effect. For example, Chung et al. (2019) consider an expansion of the balance sheet to 33 percent of GDP in a future fairly severe downturn and find that this balance sheet policy would close the output gap just four quarters earlier and raise inflation by half a percentage point. Our estimated responses to slope policy are comparable in magnitude to those in FRB/US but take effect more quickly.

Our counterfactual simulations also relate to the question of the relevance or irrelevance of the ZLB over the period since the financial crisis. Different authors have posed this question somewhat differently. Gust et al. (2017) compare scenarios with an unconstrained federal funds rate with that incorporating the ZLB, but where there are no policy alternatives like forward guidance or LSAPs. They find that macroeconomic conditions would have improved more rapidly with the ability to drive rates below zero, and we find something very similar in figure 3. Swanson (2018) argues that the Fed always had room to drive intermediate-term interest rates lower by additional forward guidance and asset purchases, and in this sense argues that the Fed never really hit the limits of unconventional monetary policy. This too is consistent with our simulations, especially in figure 10, in which a "stronger sooner" slope policy would have fostered a quicker recovery. Debortoli, Galí, and Gambetti (2019) provide evidence that the ZLB did not change the time-series properties of key economic variables, which theory suggests should change if the ZLB was a substantial constraint on monetary policy. We interpret this finding as consistent with the evidence in figure 13, which indicates that actual slope policy provided roughly the equivalent of 1 percentage point of easing of the ZLB. While the Fed, through its new tools of slope policy, was able to offset partially the effect of the ZLB, the presence of the ZLB did constrain the macroeconomic outcomes the Fed was able to achieve.

7. Caveats and Discussion

The results presented in section 6 are subject to important caveats. First, the proper interpretation of the counterfactuals in section 6 is not as second-guessing the decisions of the Fed, but rather informing Fed decisionmaking going forward about the efficacy of its monetary policy tools in a low-inflation environment, calibrated to the experience of the current recovery. Indeed, the counterfactual simulations in section 6 are conducted with the benefit of hindsight, and many of the scenarios would not or might not have been feasible in real time. For example, some of the scenarios consider more aggressive slope policy than was actually taken. But the macroeconomic effects of those policies were not known at the time and are still quite uncertain. Some observers of monetary policy as well as some members of the FOMC expressed concerns that the expansion of the balance sheet was setting the stage for a surge in inflation. That this surge never transpired is only known with the benefit of hindsight. Another potential concern was that the size of the balance sheet would make it difficult for the Fed to control short-term interest rates. In hindsight, this fear was also not realized, although the Fed did make some minor adjustments to the spread between interest on excess reserves and the federal funds target.

Second, because the model is estimated on historical data, there is uncertainty about the responses of both the unemployment gap and inflation to monetary policy interventions. The dynamic response of the unemployment gap to a federal funds shock has been well studied, and our estimate is consistent with other estimates in the literature. The history available to study slope shocks is shorter. Our estimated effect of a slope shock is consistent with that in FRB/US, although our estimates suggest shorter lags than in FRB/US. Perhaps the greatest source of uncertainty in our estimates concerns the response of inflation to changes in slack. Our Phillips curve is consistent with others estimated using time-series data, and this flat Phillips curve is consistent with the small fluctuations in the rate of inflation that have been observed over the past 20 years despite large fluctuations in slack. Against this aggregate evidence, regional evidence on price inflation, as well as national evidence on wage inflation, suggests that the Phillips curve could be steeper than estimated using aggregate time-series price data. The simulations in section A.2 of the appendix consider a Phillips curve estimated from regional data, with a long-run response of inflation to a change in the unemployment gap twice as large as in our base model. With this steeper Phillips curve, the more expansionary policies considered in section 6 result in higher rates of inflation, but even so, those rates generally remain at or below the Fed's inflation target.

Third, in our model, expectations of future policy affect the inflation process through their effect on expected future unemployment gaps. We do not, however, consider mechanisms whereby expectations change about the target rate of inflation. Bernanke (2019) and Bernanke, Kiley, and Roberts (2019) point out that imperfect credibility of the Fed can constrain the sorts of policies it undertakes and in particular motivates temporary price-level targeting with a short and rolling lookback period, which is the version of temporary price-level targeting we consider here.

Fourth, several of our counterfactuals posit using slope policy more aggressively. Doing so, however, comes with potential risks that are not in our model. As discussed in Carpenter et al. (2015), if the Federal Reserve has a portfolio of long-duration assets, then its remittances to the Treasury will decline as short-term interest rates increase; the larger the balance sheet, the bigger is this effect. While a period of zero remittances is operationally possible, it could pose other institutional challenges. Unconventional monetary policy also had international spillover effects.[27] Announcements of easing of monetary policy by the United States led to sharp drops in foreign yields but also depreciation of the dollar relative to foreign currencies. They also led to portfolio inflows into emerging markets where interest rates remained well away from the zero lower bound. These international spillovers are relevant because international financial markets can in turn affect U.S. economic conditions. Another concern associated with very low interest rates (both short and long) is that financial institutions will be led to take on more risk. To some degree, more risk-taking is the intended consequence of monetary policy easing (e.g., Chodorow-Reich 2014). But very low rates could lead institutions to invest in riskier assets than is socially optimal in order to achieve a target promised return.[28]

A central finding of our analysis is that, despite the efficacy of slope policy, the zero lower bound significantly restricted the scope of monetary policy during the recovery. Absent the ZLB, we (and others) estimate that normal federal funds policy would have led to a federal funds rate of approximately –5 percent. Our estimates suggest that the suite of Fed slope policies was able to offset perhaps 1 percentage point of the ZLB constraint. Although we do not undertake any probability estimates ourselves, simulation evidence in the literature suggests a high probability of hitting the ZLB in future recessions.[29] In short, the ZLB imposes

[27]See, for example, Ait-Sahalia et al. (2012), Rogers, Scotti, and Wright (2014), Bowman, Londono and Sapriza (2015), Bhattarai and Neely (2016), Fratzscher, Lo Duca, and Straub (2017), and Dell'Ariccia, Rabanal, and Sandri (2018).

[28]Some evidence for this "reach for yield" behavior was found by Becker and Ivashina (2015) for insurance companies and Di Maggio and Kacperczyk (2017) for money market mutual funds. Chodorow-Reich (2014) also found evidence for some "reach for yield" behavior for money market mutual funds and private defined-benefit pension funds, but argued that it was modest and short-lived.

[29]Kiley and Roberts (2017) conclude that with a 1 percent neutral real rate and 2 percent inflation target, FRB/US would imply that the effective lower bound will bind 30 percent of the time. Bernanke, Kiley, and Roberts (2019) find that it binds between 15 and 40 percent of the time, depending on the monetary policy reaction function, with temporary price-level targeting being effective at keeping the economy away from the ZLB. Chung et al. (2019) find a probability between 20 and 50 percent of the ZLB binding at some point within the next decade. The model of Mertens and Williams (2018) has a probability of being at the ZLB of at least 30 percent.

significant constraints on the efficacy of Fed policy, and our estimates suggest that those constraints are only partially offset by the new slope policies. The costs imposed by the ZLB underpin our finding that the current suite of policies would have led to a substantially faster recovery had the Fed inherited higher nominal interest rates and inflation consistent with a higher inflation target.

Although there might be benefits to a higher inflation target, there are potential costs as well. With staggered price setting, higher trend inflation causes greater resource misallocation. It could be that inflation does not enter into the decisionmaking of households and firms at very low levels, but there might be a threshold level beyond which this changes. Higher trend inflation will have distributional effects, and poorer households especially may be less able to protect their savings against inflation (Bernanke 2016a). And a higher inflation target might be seen as inconsistent with the Fed's congressional mandate of price stability.

Our framework is not suited to address the question of an optimal inflation target. Coibion, Gorodnichenko, and Wieland (2012) consider an optimal inflation target with a constant equilibrium real interest rate in a DSGE microfounded DSGE model and find that it is low—less than 2 percent. Andrade et al. (2019) study the effect of a reduction in r^* on optimal inflation and find that, calibrating the model to current U.S. or euro-area conditions, it results in an increase in the inflation rate that is slightly less than one-for-one. Given the widespread view that r^* has fallen, that would call for a higher inflation target, although it does not tell us what the right level is.

Our conclusion that the tools in the current monetary policy framework would have been more effective over the past decade had the Fed inherited a higher inflation target raises the question of how the Fed might reach a higher inflation target, should it choose to do so. We do not model such a transition process, but we do offer some thoughts based on historical experience. The decline in inflation from 1985 through 2005 was gradual, with the rate of core PCE inflation falling from an average of 3.6 percent in the second half of the 1980s to 1.7 percent in the first half of the 2000s. This decline was largely a result of policy of opportunistic disinflation (Orphanides and Wilcox 2002), in which the Fed did not actively use monetary policy to lower inflation but at the same time did not seek to reverse declines in inflation when they occurred. During this period of opportunistic disinflation, inflation expectations of both professionals and the public also fell gradually, tracking the slow decline in inflation: from the first half of the 1990s through the first half of the 2000s, the Survey of Professional Forecasters expected 10-year rate of CPI inflation gradually declined from 3.6 percent to 2.5 percent, and the Michigan survey measure of inflation expectations fell from 3.2 percent to 2.6 percent. This period of slowly falling rates of inflation and inflation expectations was accompanied by historically low inflation volatility. Moreover, from 1990 to 2005, inflation expectations also exhibited low volatility, with quarterly standard deviations of 0.2 percentage point and 0.4 percentage point for the long-term SPF and Michigan survey measures, respectively, around their slowly declining trend.

In the same way, the Fed might now accept opportunistic reflation (Brainard 2019), where it does not seek to reverse increases in inflation coming from, for example, a tight labor market or supply-side price shocks. A policy of opportunistic reflation could have challenges. Given the flat Phillips curve that has been observed over the past two decades and which is the source of the sluggish response of inflation to slack in our simulations, sustained unemployment rates below current estimates of the natural rate could, by themselves, have modest and slow effects in raising the inflation rate to a higher target: like the disinflation, the reflation would likely be slow. The policy would need to be clearly communicated so that inflation expectations could adjust accordingly, as they did during the period of opportunistic disinflation. Sustained low interest rates could raise other potential concerns such as asset bubbles (Brainard 2017). These and other potential challenges warrant additional study.

Appendix. Additional Results

A.1 Additional Impulse Response Functions

Figures A.1 and A.2 provide additional results related to the SVAR-IV estimates of the unemployment rate impulse responses to the federal funds and slope shock.

Figure A.1. Unemployment Gap Response to the Federal Funds Shock (left) and Slope Shock (right), Estimated by LP-IV

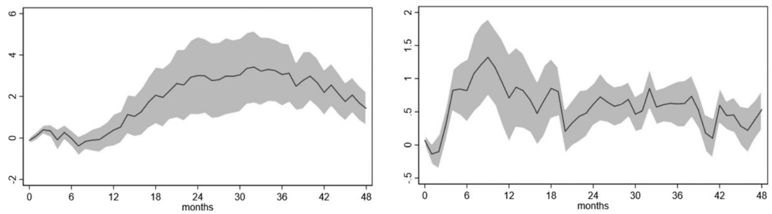


Figure A.1 shows the local projections-instrumental variables (LP-IV) estimates of the IRFs. Note that these are estimated only over the sample period of the IV regression (1994:M2–2007:M12 for the federal funds shock, 2008:M1–2019:M2 for the slope shock), not the full VAR period used for the SVAR-IV. The LP-IV IRFs are generally similar in shape to the SVAR-IV IRFs. For the federal funds shock, the LP-IV estimates indicate a greater effect of the shocks than the SVAR-IV estimates. For the slope shock, the LP-IV estimates are similar in magnitude, but the LP-IV predicts the effect on the unemployment rate to occur somewhat more quickly than does the SVAR-IV.

Figure A.2 presents the SVAR-IV estimates of the effect of the two shocks on the Gilchrist-Zakrajšek (2012) excess bond premium. The SVAR-IV predicts that both contractionary shocks increase financial market risk premiums, as measured by an increase in the EBP, with an effect that decays within a year. LP-IV estimates (reported in the supplement) are generally similar to the SVAR-IV estimates.

The supplement reports multiple checks of the robustness of the unemployment rate IRFs to changes in specification, estimation date, and control variables.

A.2 Counterfactual Simulation Results Using a Steeper Phillips Curve

For these counterfactuals, the Phillips curve in the first line of table 1 is replaced by a Phillips curve with a greater long-run slope, estimated using MSA-level data. Specifically, we take the

Figure A.2. Response of the Gilchrist-Zakrajšek Excess Bond Premium to a Federal Funds Shock (left) and a Slope Shock (right), Estimated by SVAR-IV

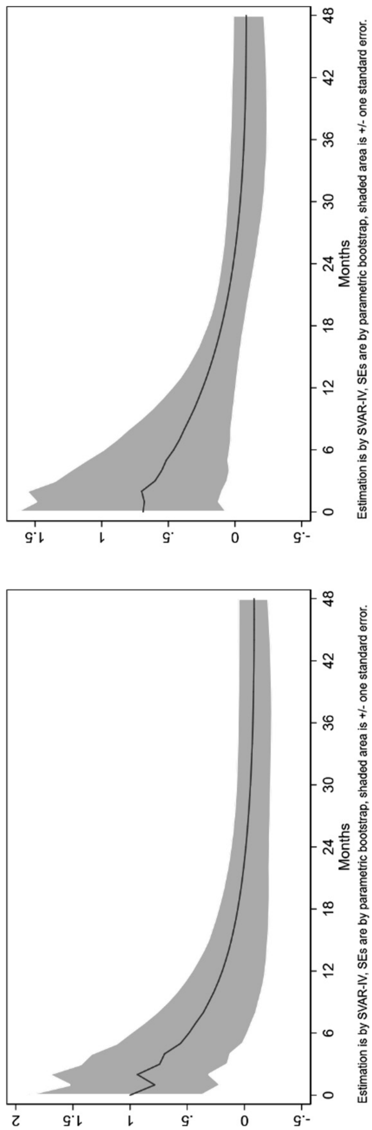
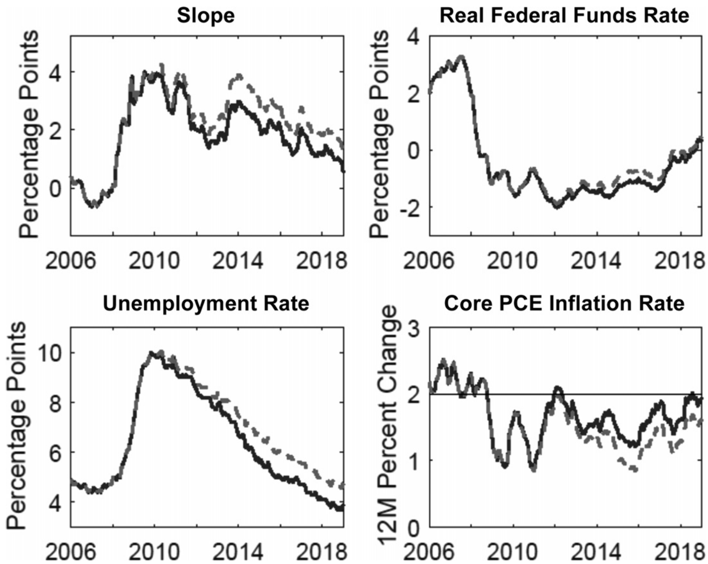


Figure A.3. No LSAP Counterfactual: Steeper Phillips Curve



estimated coefficients from column 4, table 3 in MacLeay and Tenreyro (2019), which has the hybrid Phillips-curve coefficients $\kappa = -0.367, \gamma_f = -0.067$, and $\gamma_b = 0.073$, which have a long-run slope of $\kappa/(1 - \gamma_{f-}\gamma_b) = -0.369$, approximately twice that of the time-series estimate used for the simulations in the paper. Results for selected counterfactuals are shown in figures A.3–A.5; a complete set of results for all the counterfactuals is given in the supplement.

Figure A.3 shows the "no LSAP" counterfactual (compare with figure 7). Compared with the base model with the flatter Phillips curve, the PCE core inflation rate is estimated to be substantially lower, that is, farther from the 2 percent target.

Figure A.4 shows the "stronger sooner" policy counterfactual of figure 10. With the aggressive early flattening and declining unemployment rate in this scenario, inflation overshoots its target but then returns to 2 percent. The lack of persistence of shocks to inflation is a consequence of the small dynamic coefficients in the McLeay-Tenreyro MSA-based estimate.

Figure A.5 shows the counterfactual in figure 12, in which the Fed inherits a 3 percent inflation target and additionally uses the

Figure A.4. Front-Loaded Additional LSAPs: Yield Curve Flattened by an Additional 2 Percentage Points for 18 Months, Steeper Phillips Curve

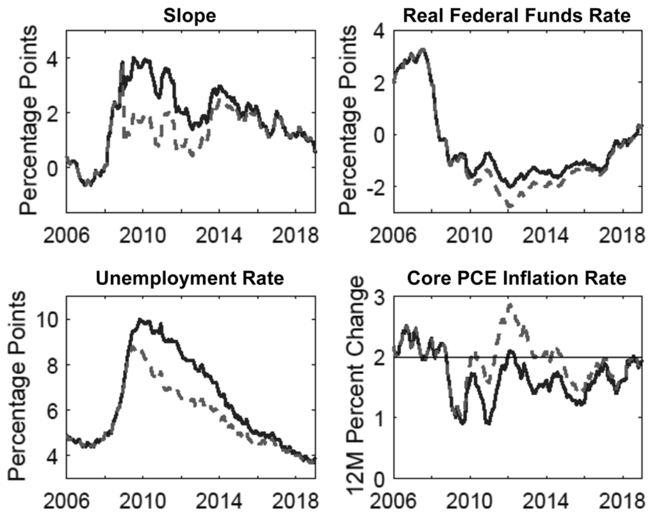
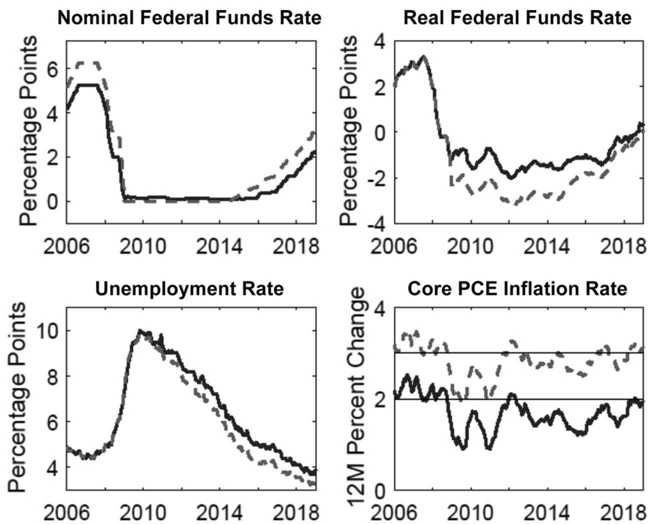


Figure A.5. 3 Percent Inherited Inflation Target with Historical Slope Shocks Counterfactual: Steeper Phillips Curve



slope policies it actually did use. With the steeper Phillips curve, the rate of inflation returns to its 3 percent target in the middle of the expansion, then fluctuates around that target.

References

Ait-Sahalia, Y., J. Andritzky, A. Jobst, S. Nowak, and N. Tamirisa. 2012. "Market Response to Policy Initiatives during the Global Financial Crisis." *Journal of International Economics* 87 (1): 162–77.

Ampudia, M., and S. Van den Heuvel. 2018. "Monetary Policy and Bank Equity Values in a Time of Low Interest Rates." Working Paper.

Andrade, P., J. Galí, H. Le Bihan, and J. Matheron. 2019. "The Optimal Inflation Target and the Natural Rate of Interest." Forthcoming in *Brookings Papers on Economic Activity.*

Barnichon, R., and G. Mesters. 2019a. "Identifying the Phillips Curve from Shifts in Demand." Working Paper.

———. 2019b. "The Phillips Multiplier." Working Paper.

Bauer, M. D., and G. D. Rudebusch. 2014. "The Signaling Channel for Federal Reserve Bond Purchases." *International Journal of Central Banking* 10 (3, September): 233–89.

Becker, B., and V. Ivashina. 2015. "Reaching for Yield in the Bond Market." *Journal of Finance* 70 (5): 1863–1902.

Belton, T., K. Dawsey, D. Greenlaw, H. Li, S. Ramaswamy, and B. Sack. 2018. "Optimizing the Maturity Structure of U.S. Treasury Debt: A Model-Based Framework." Working Paper No. 46, Hutchins Center, Brookings Institution.

Bernanke, B. S. 2016a. "Modifying the Fed's Policy Framework: Does a Higher Inflation Target Beat Negative Interest Rates?" Brookings Institution (September 13). https://www.brookings.edu/blog/ben-bernanke/2016/09/13/modifying-the-feds-policy-framework-does-a-higher-inflation-target-beat-negative-interest-rates/.

———.2016b. "What Tools Does the Fed Have Left? Part 2: Targeting Longer-Term Interest Rates." Brookings Institution (March 24). https://www.brookings.edu/blog/ben-bernanke/2016/03/24/what-tools-does-the-fed-have-left-part-2-targeting-longer-term-interest-rates/.

———. 2019. “Evaluating Longer-for-Lower Policies: Temporary Price-Level Targeting.” Brookings Institution (February 21). https://www.brookings.edu/blog/ben-bernanke/2019/02/21/evaluating-lower-for-longer-policies-temporary-price-level-targeting/.

Bernanke, B. S., M. T. Kiley, and J. M. Roberts. 2019. “Monetary Policy Strategies for a Low-Rate Environment.” Finance and Economics Discussion Series No. 2019-09.

Bhattarai, S., and C. J. Neely. 2016. “An Analysis of the Literature on International Unconventional Monetary Policy.” Working Paper No. 2016-21, Federal Reserve Bank of St. Louis.

Blanchard, O. J., and C. M. Kahn. 1980. “The Solution of Linear Difference Models under Rational Expectations.” *Econometrica* 48 (5): 1305–11.

Bowman, D., J. M. Londono, and H. Sapriza. 2015. “U.S. Unconventional Monetary Policy and Transmission to Emerging Market Economies.” *Journal of International Money and Finance* 55 (July): 27–59.

Brainard, L. 2017. “Rethinking Monetary Policy in a New Normal.” Speech at the Panel on Monetary Policy “Rethinking Macroeconomic Policy,” a conference sponsored by the Peterson Institute for International Economics, Washington, D.C., October 12.

———. 2019. “The Disconnect between Inflation and Employment in the New Normal.” Speech given at the National Tax Association 49th Annual Spring Symposium, Washington, D.C., May 16.

Brunnermeier, M. K., and Y. Koby. 2018. “The Reversal Interest Rate.” NBER Working Paper No. 25406.

Bundick, B., and A. L. Smith. 2018. “The Dynamic Effects of Forward Guidance Shocks.” Working Paper.

Burke, C., S. Hilton, R. Judson, K. Lewis, and D. Skeie. 2010. “Reducing the IOER Rate: An Analysis of Options.” Memorandum, Federal Reserve.

Campbell, J. R., C. L. Evans, J. D. M. Fisher, and A. Justiniano. 2012. “Macroeconomic Effects of Federal Reserve Forward Guidance.” *Brookings Papers on Economic Activity* 43 (1, Spring): 1–80.

Campbell, J. R., J. D. M. Fisher, A. Justiniano, and L. Melosi. 2017. “Forward Guidance and Macroeconomic Outcomes Since the Financial Crisis.” *NBER Macroeconomics Annual,* Vol. 31, ed. M. Eichenbaum and J. A. Parker, 283–357 (chapter 4). University of Chicago Press.

Carpenter, S. B., J. E. Ihrig, E. C. Klee, D. W. Quinn, and A. H. Boot. 2015. "The Federal Reserve's Balance Sheet and Earnings: A Primer and Projection." *International Journal of Central Banking* 11 (2, March): 237–84.

Chen, H., V. Cúrdia, and A. Ferrero. 2012. "The Macroeconomic Effects of Large-Scale Asset Purchase Programmes." *Economic Journal* 122 (564): F289–F315.

Chodorow-Reich, G. 2014. "Effects of Unconventional Monetary Policy on Financial Institutions." *Brookings Papers on Economic Activity* 45 (1, Spring): 155–227.

Christiano, L. J., M. S. Eichenbaum, and M. Trabandt. 2015. "Understanding the Great Recession." *American Economic Journal: Macroeconomics* 7 (1): 110–67.

Chung, H., E. Gagnon, T. Nakata, M. Paustian, B. Schlusche, J. Trevino, D. Vilán, and W. Zheng. 2019. "Monetary Policy Options at the Effective Lower Bound: Assessing the Federal Reserve's Current Policy Toolkit." Finance and Economics Discussion Series No. 2019-003.

Chung, H., J.-P. Laforte, D. Reifschneider, and J. C. Williams. 2012. "Have We Underestimated the Likelihood and Severity of Zero Lower Bound Events?" *Journal of Money, Credit and Banking* 44 (s1): 47–82.

Coibion, O. 2012. "Are the Effects of Monetary Policy Shocks Big or Small?" *American Economic Journal: Macroeconomics* 4 (2): 1–32.

Coibion, O., Y. Gorodnichenko, and J. Wieland. 2012. "The Optimal Inflation Rate in New Keynesian Models: Should Central Banks Raise Their Inflation Targets in Light of the Zero Lower Bound?" *Review of Economic Studies* 79 (4): 1371–1406.

Crump, R. K., S. Eusepi, M. Giannoni, and A. Sahin. 2019. "A Unified Approach to Measuring u*." Forthcoming in *Brookings Papers on Economic Activity.*

D'Amico, S., W. English, D. López-Salido, and E. Nelson. 2012. "The Federal Reserve's Large-Scale Asset Purchase Programmes: Rationale and Effects." *Economic Journal* 122 (564): F415–F446.

D'Amico, S., and T. B. King. 2013. "Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply." *Journal of Financial Economics* 108 (2): 425–48.

Debortoli, D., J. Galí, and L. Gambetti. 2019. "On the Empirical (Ir) Relevance of the Zero Lower Bound Constraint." Forthcoming in *NBER Macroeconomics Annual*, Vol. 34, ed. M. S. Eichenbaum, E. Hurst, and J. A. Parker. University of Chicago Press.

Del Negro, M., D. Giannone, M. P. Giannoni, and A. Tambalotti. 2017. "Safety, Liquidity, and the Natural Rate of Interest." *Brookings Papers on Economic Activity* 48 (1, Spring): 235–316.

Del Negro, M., M. P. Giannoni, and C. Patterson. 2012. "The Forward Guidance Puzzle." Staff Report No. 574, Federal Reserve Bank of New York.

Dell'Ariccia, G., P. Rabanal, and D. Sandri. 2018. "Unconventional Monetary Policies in the Euro Area, Japan, and the United Kingdom." *Journal of Economic Perspectives* 32 (4): 147–72.

Di Maggio, M., and M. Kacperczyk. 2017. "The Unintended Consequences of the Zero Lower Bound Policy." *Journal of Financial Economics* 123 (1): 59–80.

Di Maggio, M., A. Kermani, and C. Palmer. 2016. "How Quantitative Easing Works: Evidence on the Refinancing Channel." NBER Working Paper No. 22638.

Durdu, B., T. Laubach, D. Lebow, J. Millar, and M. Palumbo. 2013. "Evaluating the Efficacy of the Federal Reserve's Large Scale Asset Purchases." Memorandum.

Eberly, J. C., J. H. Stock, and J. H. Wright. 2019. "The Federal Reserve's Current Framework for Monetary Policy: A Review and Assessment." NBER Working Paper No. 26002.

Eggertsson, G. B., and M. Woodford. 2003. "The Zero Bound on Interest Rates and Optimal Monetary Policy." *Brookings Papers on Economic Activity* 34 (1): 139–235.

Eggertsson, G. B., R. E. Juelsrud, L. H. Summers, and E. Getz Wold. 2019. "Negative Nominal Interest Rates and the Bank Lending Channel." NBER Working Paper No. 25416.

Engen, E. M., T. Laubach, and D. Reifschneider. 2015. "The Macroeconomic Effects of the Federal Reserve's Unconventional Monetary Policies." Finance and Economics Discussion Series No. 2015-005.

Faust, J. W. 2016. "Oh What a Tangled Web We Weave: Monetary Policy Transparency in Divisive Times." Working Paper No. 25, Hutchins Center, Brookings Institution.

Femia, K., S. Friedman, and B. P. Sack. 2013. "The Effects of Policy Guidance on Perceptions of the Fed's Reaction Function." Staff Report No. 652, Federal Reserve Bank of New York.

Fernald, J. G., R. E. Hall, J. H. Stock, and M. W. Watson. 2017. "The Disappointing Recovery of Output after 2009." *Brookings Papers on Economic Activity* 48 (1, Spring): 1–81.

Foley-Fisher, N., R. Ramcharan, and E. Yu. 2016. "The Impact of Unconventional Monetary Policy on Firm Financing Constraints: Evidence from the Maturity Extension Program." *Journal of Financial Economics* 122 (2): 409–29.

Fratzscher, M., M. Lo Duca, and R. Straub. 2018. "On the International Spillovers of US Quantitative Easing." *Economic Journal* 128 (608): 330–77.

Fuhrer, J. C., G. P. Olivei, E. S. Rosengren, and G. M. B. Tootell. 2018. "Should the Fed Regularly Evaluate Its Monetary Policy Framework?" *Brookings Papers on Economic Activity* 49 (2, Fall): 443–517.

Gagnon, J., M. Raskin, J. Remache, and B. Sack. 2011. "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases." *International Journal of Central Banking* 7 (1, March): 3–43.

Gertler, M., and P. Karadi. 2015. "Monetary Policy Surprises, Credit Costs, and Economic Activity." *American Economic Journal: Macroeconomics* 7 (1): 44–76.

Gilchrist, S., and E. Zakrajšek. 2012. "Credit Spreads and Business Cycle Fluctuations." *American Economic Review* 102 (4): 1692–1720.

Goldfeld, S. M., and A. S. Blinder. 1972. "Some Implications of Endogenous Stabilization Policy." *Brookings Papers on Economic Activity* 3 (3): 585–644.

Greenlaw, D., J. D. Hamilton, E. Harris, and K. D. West. 2018. "A Skeptical View of the Impact of the Fed's Balance Sheet." NBER Working Paper No. 24687.

Greenwood, R., and D. Vayanos. 2014. "Bond Supply and Excess Bond Returns." *Review of Financial Studies* 27 (3): 663–713.

Gürkaynak, R. S., B. P. Sack, and E. T. Swanson. 2005. "Do Actions Speak Louder than Words? The Response of Asset Prices to Monetary Policy Actions and Statements." *International Journal of Central Banking* 1 (1, May): 55–93.

Gust, C., E. Herbst, D. López-Salido, and M. E. Smith. 2017. "The Empirical Implications of the Interest-Rate Lower Bound." *American Economic Review* 107 (7): 1971–2006.

Hamilton, J. D., and J. C. Wu. 2012. "The Effectiveness of Alternative Monetary Policy Tools in a Zero Lower Bound Environment." *Journal of Money, Credit and Banking* 44 (s1): 3–46.

Hesse, H., B. Hofmann, and J. Weber. 2018. "The Macroeconomic Effects of Asset Purchases Revisited." *Journal of Macroeconomics* 58 (December): 115–38.

Hetzel, R. L., and R. F. Leach. 2001. "The Treasury-Fed Accord: A New Narrative Account." *Economic Quarterly* (Federal Reserve Bank of Richmond) 87 (1, Winter): 7–22.

Holston, K., T. Laubach, and J. C. Williams. 2017. "Measuring the Natural Rate of Interest: International Trends and Determinants." *Journal of International Economics* 108 (Supplement 1): S59–S75.

Kareken, J., and R. M. Solow. 1963. "Lags in Monetary Policy." In *Stabilization Policies*, ed. E. C. Brown et al., 14–96. Prepared for the Commission on Money and Credit.

Kiley, M. T., and J. M. Roberts. 2017. "Monetary Policy in a Low Interest Rate World." *Brookings Papers on Economic Activity* 48 (1, Spring): 317–96.

Kim, K. 2017. "Identification of Monetary Policy Shocks with External Instrument SVAR." Finance and Economics Discussion Series No. 2017-113.

Kohn, D. L. 2009. "Monetary Policy Research and the Financial Crisis: Strengths and Shortcomings." Speech at the Federal Reserve Conference on Key Developments in Monetary Policy, Washington, D.C., October 9.

Krishnamurthy, A., and A. Vissing-Jorgensen. 2011. "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy." *Brookings Papers on Economic Activity* 42 (2, Fall): 215–87.

———. 2012. "The Aggregate Demand for Treasury Debt." *Journal of Political Economy* 120 (2): 233–67.

Kuttner, K. N. 2001. "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market." *Journal of Monetary Economics* 47 (3): 523–44.

———. 2018. "Outside the Box: Unconventional Monetary Policy in the Great Recession and Beyond." *Journal of Economic Perspectives* 32 (4): 121–46.

Lakdawala, A. 2019. "Decomposing the Effects of Monetary Policy Using an External Instruments SVAR." Forthcoming in *Journal of Applied Econometrics*.

Li, C., and M. Wei. 2013. "Term Structure Modeling with Supply Factors and the Federal Reserve's Large-Scale Asset Purchase Programs." *International Journal of Central Banking* 9 (1, March): 3–39.

McLeay, M., and S. Tenreyro. 2019. "Optimal Inflation and the Identification of the Phillips Curve."

Mertens, K., and M. O. Ravn. 2013. "The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States." *American Economic Review* 103 (4): 1212–47.

Mertens, T. M., and J. C. Williams. 2018. "What to Expect from the Lower Bound on Interest Rates: Evidence from Derivatives Prices." Staff Report No. 865, Federal Reserve Bank of New York.

Montiel Olea, J. L., and C. Pflueger. 2013. "A Robust Test for Weak Instruments." *Journal of Business and Economic Statistics* 31 (3): 358–69.

Nakamura, E., and J. Steinsson. 2018a. "High-frequency Identification of Monetary Non-neutrality: The Information Effect." *Quarterly Journal of Economics* 133 (3): 1283–1330.

———. 2018b. "Identification in Macroeconomics." *Journal of Economic Perspectives* 32 (3): 59–86.

Obstfeld, M. 2019. "Global Dimensions of Monetary Policy." Manuscript.

Orphanides, A., and D. W. Wilcox. 2002. "The Opportunistic Approach to Disinflation." *International Finance* 5 (1): 47–71.

Rachel, L., and L. H. Summers. 2019. "On Falling Neutral Real Rates, Fiscal Policy, and the Risk of Secular Stagnation." Forthcoming in *Brookings Papers on Economic Activity*.

Ramey, V. A. 2016. "Macroeconomic Shocks and Their Propagation." *Handbook of Macroeconomics,* Vol. 2, ed. J. B. Taylor and H. Uhlig, 71–162 (chapter 2). Elsevier.

Reifschneider, D., and J. C. Williams. 2000. "Three Lessons for Monetary Policy in a Low-Inflation Era." *Journal of Money, Credit and Banking* 32 (November): 936–66.

Rodnyansky, A., and O. M. Darmouni. 2017. "The Effects of Quantitative Easing on Bank Lending Behavior." *Review of Financial Studies* 30 (11): 3858–87.

Rogers, J. H., C. Scotti, and J. H. Wright. 2014. "Evaluating Asset-Market Effects of Unconventional Monetary Policy: A Multi-country Review." *Economic Policy* 29 (80): 749–99.

Romer, C. D., and D. H. Romer. 2004. "A New Measure of Monetary Shocks: Derivation and Implications." *American Economic Review* 94 (4): 1055–84.

Sims, C. A. 1986. "Are Forecasting Models Usable for Policy Analysis?" *Quarterly Review* (Federal Reserve Bank of Minneapolis) 10 (1): 2–16.

Sims, E. R., and J. C. Wu. 2019. "Evaluating Central Banks' Tool Kit: Past, Present, and Future." NBER Working Paper No. 26040.

Stasavage, D. 2007. "Polarization and Publicity: Rethinking the Benefits of Deliberative Democracy." *Journal of Politics* 69 (1): 59–72.

Stock, J. H. 2008. "What's New in Econometrics: Time Series." Lecture 7. Short course lectures, NBER Summer Institute. http://www.nber.org/minicourse_2008.html.

Stock, J. H., and M. W. Watson. 2012. "Disentangling the Channels of the 2007–09 Recession." *Brookings Papers on Economic Activity* 43 (1, Spring): 81–156.

———. 2018. "Identification and Estimation of Dynamic Causal Effects in Macroeconomics Using External Instruments." *Economic Journal* 128 (610): 917–48.

Sunstein, C. 2016. "Output Transparency vs. Input Transparency." Working Paper.

Swanson, E. T. 2017. "Measuring the Effects of Federal Reserve Forward Guidance and Asset Purchases on Financial Markets." NBER Working Paper No. 23311.

———. 2018. "The Federal Reserve Is Not Very Constrained by the Lower Bound on Nominal Interest Rates." NBER Working Paper No. 25123.

Swanson, E. T., and J. C. Williams. 2014. "Measuring the Effect of the Zero Lower Bound on Medium- and Longer-Term Interest Rates." *American Economic Review* 104 (10): 3154–85.

Taylor, J. B. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39 (1): 195–214.

———. 1999. "The Robustness and Efficiency of Monetary Policy Rules as Guidelines for Interest Rate Setting by the European Central Bank." *Journal of Monetary Economics* 43 (3): 655–79.

Ulate Campos, M. 2018. "Going Negative at the Zero Lower Bound: The Effects of Negative Rates on Bank Profitability." Working Paper.

Vayanos, D., and J.-L. Vila. 2009. "A Preferred-Habitat Model of the Term Structure of Interest Rates." NBER Working Paper No. 15487.

Weale, M, and T. Wieladek. 2016. "What Are the Macroeconomic Effects of Asset Purchases?" *Journal of Monetary Economics* 79 (May): 81–93.

Wright, J. H. 2012. "What Does Monetary Policy Do to Long-Term Interest Rates at the Zero Lower Bound?" *Economic Journal* 122 (564): F447–F466.

Yellen, J. 2012. "The Economic Outlook and Monetary Policy." Speech given at the Money Marketeers of New York University, New York, New York, April 11.