The New Tools of Monetary Policy

American Economic Association Presidential Address

Ben S. Bernanke*

January 4, 2020

**Brookings Institution, 1775 Massachusetts Ave. NW, Washington DC 20036.* *I thank Sage Belz, Michael Ng, and Finn Schuele for outstanding research assistance and many colleagues for useful comments. This lecture is dedicated to the memory of Paul Volcker.*

In the last decades of the twentieth century, U.S. monetary policy wrestled with the problem of high and erratic inflation. That fight, led by Federal Reserve chairs Paul Volcker and Alan Greenspan, succeeded. The result—low inflation and well-anchored inflation expectations—provided critical support for economic stability and growth in the 1980s and 1990s, in part by giving monetary policymakers more scope to respond to short-term fluctuations in employment and output without having to worry about stoking high inflation.

However, with the advent of the new century, it became clear that low inflation was not an unalloyed good. In combination with historically low real interest rates—the result of demographic, technological, and other forces that raised desired global saving relative to desired investment—low inflation (actual and expected) has translated into persistently low nominal interest rates, at both the long and short ends of the yield curve. Chronically low interest rates pose a challenge for the traditional approach to monetary policymaking, based on the management of a short-term policy interest rate. In the presence of an effective lower bound on nominal interest rates—due to, among other reasons, the existence of cash, which provides investors the option of earning a zero nominal return—persistently low nominal rates constrain the amount of "space" available for traditional monetary policies. Moreover, as the experience of Japan in recent decades has demonstrated, low inflation can become a self-perpetuating trap, in which low inflation and low nominal interest rates make monetary policy less effective, which in turn allows low inflation or deflation to persist.

In the United States and other advanced economies, the critical turning point was the global financial crisis of 2007-09. The shock of the panic, and the subsequent sovereign debt crisis in Europe, drove the U.S. and global economies into deep recession, well beyond what could be managed by traditional monetary policies. After cutting short-term rates to zero (or nearly so), the Federal Reserve and other central banks turned to alternative policy tools to provide stimulus, including large-scale purchases of financial assets ("quantitative easing"), increasingly explicit communication about the central bank's outlook and policy plans ("forward guidance"), and, outside the United States, some other tools as well.

We are now more than a decade from the crisis, and the U.S. and global economies are in much better shape. But, looking forward, the Fed and other central banks are grappling with how best to manage monetary policy in a twenty-first century context of low inflation and low nominal interest rates. On one point we can be certain: The old methods won't do. For example, simulations of the Fed's main macroeconometric model suggest that the use of policy rules developed before the crisis would result in short-term rates being constrained by zero as much as one-third of the time, with severe consequences for economic performance (Kiley and Roberts, 2017). If monetary policy is to remain relevant, policymakers will have to adopt new tools, tactics, and frameworks.

The subject of this lecture is the new tools of monetary policy, particularly those used in recent years by the Federal Reserve and other advanced-economy central banks.[1] I focus on quantitative easing and forward guidance, the principal new tools used by the Fed, although I briefly discuss some other tools, such as funding-for-lending programs, yield curve control, and negative interest rates. Based on a review of a large and growing literature, I argue that the new tools have proven quite effective, providing substantial additional scope for monetary policy despite the lower bound on short-term interest rates.[2] In particular, although there are dissenting views, most research finds that central bank asset purchases meaningfully ease financial conditions, even when financial markets are not unusually stressed. Forward guidance has become increasingly valuable over time in helping the public understand how policy will respond to economic conditions and in facilitating commitments by monetary policymakers to so-called lower-for-longer rate policies, which can add stimulus even when short rates are at the lower bound. And, for the most part, in retrospect it has become evident that the costs and risks

[1] These tools are often referred to as "unconventional" or "nonstandard" policies. Since I will argue that these tools should become part of the standard toolkit, I will refer to them here as "new" or "alternative" monetary tools.
[2] My review is necessarily selective. Useful surveys of so-called unconventional policies and their effects include Gagnon (2016), Kuttner (2018), Dell'Ariccia, Rabanal, and Sandri (2018), Bhattarai and Neely (2018), and Committee on the Global Financial System (2019). For detailed chronologies of actions by major central banks, see Fawley and Neely (2013) and Neely and Karson (2018).

attributed to the new tools, when first deployed, were overstated. The case for adding the new tools to the standard central bank toolkit thus seems clear.

But how much can the new tools help? To estimate the policy space provided by the new tools, I turn to simulations of the Fed's FRB/US model. Assuming, importantly, that the (nominal) neutral rate of interest, defined more fully below, is in the range of 2 to 3 percent—consistent with most current estimates for the U.S. economy—then the simulations suggest that a combination of asset purchases and forward guidance can add roughly 3 percentage points of policy space. That is, when the new tools are used, monetary policy can achieve outcomes similar to what traditional policies alone could attain if the neutral interest rate were three percentage points higher, in the range of 5-6 percent—which, it turns out, is close to what is needed to negate the adverse effects of the effective lower bound in most circumstances. In particular, as I will argue, in this scenario the use of the new tools to increase policy space seems preferable to the alternative strategy of raising the central bank's inflation target.

An important caveat to these conclusions, as already indicated, is that they apply fully only when the neutral interest rate is in the range of 2-3 percent or above. If the neutral rate is below 2 percent or so, the new tools still add valuable policy space but are unlikely to compensate entirely for the constraint imposed by the lower bound. The costs associated with a very low neutral rate, measured in terms of deeper and longer recessions and inflation persistently below target, underscore the importance for central banks of keeping inflation and inflation expectations close to target. A neutral rate below 2 percent or so also increases the relative attractiveness of alternative strategies for increasing policy space, such as raising the inflation target or relying more heavily on fiscal policy to fight recessions and to keep inflation and interest rates from falling too low.

I. Assessing the New Tools of Monetary Policy

When the short-term policy interest rate reaches the effective lower bound, monetary policymakers can no longer provide stimulus through traditional means.[3] However, it is still possible in those circumstances to add stimulus by operating on longer-term interest rates and other asset prices and yields. Two tools for doing that, both actively used in recent years, are (i)

[3] The term *effective lower bound* embraces the possibility of negative short-term rates. In the United States, thus far the effective lower bound has been zero. I will use the term "lower bound" for short.

central bank purchases of longer-term financial assets (popularly known as quantitative easing, or QE), and (ii) communication from monetary policymakers about their economic outlooks and policy plans (forward guidance).[4] I'll discuss QE first, returning later to forward guidance, as well as to some other new tools used primarily outside the United States.

I focus throughout this lecture on monetary tools aimed at achieving employment and inflation objectives, excluding policies aimed primarily at stabilizing dysfunctional financial markets, such as the Federal Reserve's emergency credit facilities and currency swaps and the European Central Bank's (ECB) Securities Markets Program, under which the ECB made targeted purchases to help restore confidence in sovereign debt markets.[5] The stabilization of financial markets improves economic outcomes, of course, but lender-of-last-resort programs are not useful outside of a crisis and thus should not be viewed as part of normal monetary policy.

A. Central Bank Asset Purchases (QE)

The Fed announced its first program of large-scale asset purchases in November 2008, when it made public its plans to buy mortgage-backed securities (MBS) and debt issued by the government-sponsored enterprises (GSEs), Fannie Mae and Freddie Mac. In March 2009, in an action that would become known as QE1, the Federal Open Market Committee (FOMC) authorized both increased purchases of MBS and, for the first time, large-scale purchases of U.S. Treasury securities. Asset purchases under QE1 totaled about $1.725 trillion. Three other major programs would follow: (1) QE2, announced in November 2010, in which the Fed committed to $600 billion in additional Treasuries purchases; (2) the Maturity Extension Program, announced in September 2011 and extended in June 2012, under which the Fed lengthened the average maturity of its portfolio by selling off short-term Treasuries and buying longer-term government debt; and (3) QE3, announced in September 2012, an open-ended program that committed the

[4] The popular use of the term "QE" blurs a useful distinction: QE as practiced by the Fed was importantly different from the QE undertaken by the Bank of Japan before the crisis. The former emphasized the effects of buying longer-term assets on longer-term interest rates, the latter the effects of purchase on bank reserves and the monetary base. In general, increases in reserves *per se* should have limited benefit in a liquidity trap, being only a swap of one set of short-term liquid securities for another. However, Christensen and Krogstrup (2016) argue that changes in reserves, by affecting bank investment decisions, can induce portfolio balance effects and thus affect yields.
[5] The ECB in particular maintained a strong distinction between financial stabilization programs and monetary policy, for example, by sterilizing the effects of bond purchases under its Securities Markets Program to avoid net changes in the money supply (Hartmann and Smets, 2018). The Fed created a wide variety of emergency lending programs but largely phased them out by early 2010.

Fed to buying both Treasury securities and MBS until the outlook for the labor market had improved “substantially.” In 2013, hints that asset purchases might begin to slow led to a “taper tantrum” in bond markets, with the 10-year yield rising by nearly a percentage point over several months. The Fed’s purchases did not end however until October 2014. Total net asset purchases by that point were about $3.8 trillion, approximately 22 percent of 2014 GDP. Most purchases were of longer-term securities; between 2007 and late 2014 the average duration of the Fed’s portfolio increased from 1.6 years to 6.9 years (Engen, Laubach, and Reifschneider, 2015).

The Fed was by no means the only central bank to employ asset purchases as a monetary policy tool. The first to confront the lower bound, the Bank of Japan, adopted an asset purchase program in March 2001, but its focus was increasing the monetary base rather than reducing longer-term rates by buying longer-term assets. The BOJ began aggressive purchases of longer-term securities in 2013 with the advent of “Abenomics,” the set of policies advocated by Prime Minister Shinzo Abe. The Bank of England adopted QE more or less in parallel with the Federal Reserve, announcing its first major program in March 2009, a few days ahead of the Fed’s QE1 announcement. The BOE then periodically increased targets for its total purchases in response to economic developments. The European Central Bank faced political and legal opposition to asset purchases and undertook its first large QE program in pursuit of monetary policy objectives only in January 2015. Variants of QE have been employed by smaller economies, including Sweden and Switzerland.

The types of assets purchased varied considerably by central bank. Facing tighter legal constraints than most of its peers, the Fed was able to purchase only Treasury securities and securities issued by the GSEs, which by late 2008 were fully backed by the federal government. Other central banks had wider authorities, and to varying degrees bought not only government debt but also corporate bonds, covered bonds issued by banks, and even equities.

In the immediate aftermath of the financial crisis, the relative lack of experience with QE created substantial uncertainty about how effective asset purchases would be in easing financial conditions, if they would help at all. Indeed, some benchmark models predict that asset purchases will have no or at best transient effects on asset prices (Eggertsson and Woodford, 2003). The positive case for QE rested on two arguments. First, if investors have “preferred habitats” because of specialized expertise, transaction costs, regulations, liquidity preference, or other factors, then changing the net supplies of different securities or classes of securities should affect their relative prices. This *portfolio balance effect* was modeled formally by Vayanos and Vila (2009), who showed that, generally, the effect will not be undone by the efforts of arbitrageurs. U.S. policymakers saw QE as working in part by removing duration risk from the Treasury market, pushing investors to bid up the values of both remaining longer-term Treasuries and close substitutes, such as mortgages and corporate bonds. In addition, MBS purchases were expected to reduce the spread between Treasury yields and mortgage rates.

Second, QE may have a *signaling effect* if it serves as a commitment mechanism, or perhaps as a signal of seriousness, leading investors to believe that policymakers intend to keep short-term policy rates low for an extended period. Although several channels have been proposed for how this might work, in practice much of the signaling effect appears tied to investors' beliefs about the likely sequencing of policies. With encouragement from policymakers, market participants are typically confident that central banks will not raise short-term interest rates so long as asset purchases are continuing. Since QE announcements typically include information about the likely duration of purchases, which may be measured in quarters or years, and since QE programs are rarely terminated prematurely (because of the likely costs to policymakers' credibility), the initiation or extension of a QE program often pushes out the expected date of the first short-term rate increase. Observing this signal that short rates will be kept low, investors bid down longer-term rates as well.

Longer-term yields can be conceptually divided into (1) the average expected short rate over the life of the security, and (2) the difference between the total yield and the average expected short rate, known as the term premium. To a first approximation, portfolio balance effects work by affecting the term premium, while the signaling effect works by influencing expectations of future short rates. Using that approximation to distinguish the portfolio balance and signaling channels is not straightforward, however, because term premiums and expected future short rates are not directly observable. There are also indirect effects to account for: For example, changes in term premiums arising from the portfolio balance channel, if they influence the economic outlook, will also affect expectations of future short rates.

If QE successfully reduces longer-term interest rates, through either portfolio balance or signaling channels, then the presumption is that the economy will respond much in the same way that it does to conventional monetary easing, as a lower cost of capital, higher wealth, a weaker currency, and stronger balance sheets increase spending on domestic goods and services.[6]

QE event studies: some initial evidence

Did post-crisis QE work, in the sense of meaningfully affecting broad financial conditions? Early QE announcements, at least, appeared to have substantial market impacts across a wide range of financial assets. This fact is well-documented by event studies, which look at asset price changes in narrow time windows around QE announcements.

An illustrative event study for the Fed's QE1 program is shown in Table 1, which reports the changes in key asset prices and yields summed over five days, identified by Gagnon et al. (2011), on which important information bearing on QE1 became public.[7] Evidently, QE1 had powerful announcement effects, including a full percentage point decline in the yield on 10-year Treasuries and more than a percentage point decline in the yields on mortgage-backed securities. Qualitatively, these results hold up well for different choices of event days or for shorter or longer event windows. Similar event-study results are obtained for the introduction of QE, at about the same time, by the Bank of England (Joyce et al, 2011).

Table 1. Responses of asset prices and yields to QE1 announcements

2-year Treasuries	-57
10-year Treasuries	-100
30-year Treasuries	-58
Mortgage-backed securities	-129
AAA corporate bonds	-89
SP500 index	2.32

[6] Kiley (2014) presents a model in which, because some households have limited ability to substitute between short-term and long-term debt instruments, both short-term and long-term rates affect aggregate demand. An implication is that changes in longer-term interest rates arising from changes in term premiums may have weaker aggregate demand effects than other changes in longer-term rates. On the other hand, QE may also stimulate aggregate demand through channels other than the cost of borrowing, for example, by increasing confidence and promoting bank lending. See Krishnamurthy and Vissing-Jorgensen (2011) for a discussion of the channels of QE.
[7] Gagnon et al. (2011) also considered a larger set of eight announcement days. Using the larger set leaves the results of Table 1 essentially unchanged.

Note: One-day responses, summed over five announcement dates identified by Gagnon et al. (2011). Yield changes are in basis points, stock price changes are in percentage points.
Source: Author's calculations.

The strong market reactions to the initial rounds of QE encouraged policymakers at the time, and they should refute strong claims that central bank asset purchases are neutral. However, critics have made two rejoinders to the event-study evidence.[8] First, in contrast to the results shown in Table 1 for QE1, event studies of later rounds of quantitative easing have tended to find much less dramatic effects. For example, Krishnamurthy and Vissing-Jorgenson (2011) looked at the market reactions associated with the introduction of QE2, the second round of U.S. quantitative easing. Using two identified announcement days and one-day event windows, they found the total decline in the 10-year Treasury yield associated with QE2 was a relatively moderate 18 basis points, well less than the QE1 effect even with some adjustment for the different sizes of the two programs. Analogous results have been found in event studies of other later-round QE programs, in both the United States and in other countries. A possible interpretation is that the initial rounds of QE were particularly effective because they were introduced, and provided critical liquidity, in a period of exceptional dysfunction in financial markets. However, if QE only works in such extraordinary circumstances, it is of limited use for monetary policymakers during calmer times.

The second point raised by critics is that event studies, by their nature, capture asset market reactions over only a short period. It may be that these studies reveal only short-term liquidity effects, analogous (although much larger) to the within-day price effects of an unexpectedly large purchase or sale of a stock. Such effects would be expected to dissipate quickly and would not provide much monetary accommodation, since private spending decisions presumably respond only to persistent changes in financial conditions. A variant of this objection, which takes a slightly longer-term perspective, begins by pointing out that longer-term Treasury yields did not consistently decline during periods in which asset purchases were being carried out. For example, the 10-year yield at the termination of QE1 purchases was actually higher than it was before QE1 was announced. Perhaps investors came to appreciate over time that asset-purchase programs would not be effective? Using time series methods, Wright (2011) argues that the effects of post-crisis policy announcements died off fairly quickly.

[8] See, e.g., Greenlaw et al (2018). The reply to their paper by Gagnon (2018) anticipates some points I make here.

Additional evidence on the effects of QE

These two critiques of the event-study evidence raise important issues. However, other evidence on the effects of QE provides counterpoints. I take each of the critiques in turn.

First, although the weaker effects on asset prices found in event studies of later rounds of QE could be the result of the calmer market conditions, those findings could also reflect that later rounds of QE were better anticipated by investors, who by then had been educated about the tool and the willingness of central banks to use it. If later QE rounds were largely anticipated, then their effects would have been incorporated into asset prices in advance of formal announcements, accounting for the event-study results (Gagnon, 2018).

Surveys of market participants and media reports suggest that later rounds of QE in the United States and elsewhere were in fact widely anticipated. For example, according to the New York Fed's survey of primary dealers, prior to the announcement of QE2 in November 2010, dealers placed an 88 percent probability that the Fed would undertake another round of asset purchases. The primary dealers also expected the program to be significantly larger and more extended than what was subsequently announced (Cahill et al., 2013, Appendix A). It's not surprising then that the market reaction on the date of the QE2 announcement was small; in fact, 10-year Treasury yields rose slightly on the day, presumably reflecting investor disappointment about the program's scale.

For event-study researchers, a possible way to address this problem is to include more event days, to capture more announcements, data releases, and other events bearing on the probability of new asset purchases (Greenlaw et al. 2018). However, adding event days also adds noise from non-monetary news affecting asset prices. A more direct solution to this identification problem is to try to control for the policy expectations of market participants, then to observe the effects on asset prices of the *unexpected* component of QE announcements.

For traditional monetary policy, based on management of the short-term interest rate, fed funds and Eurodollar futures markets provide useful estimates of policy expectations (Kuttner, 2001), but no analogous markets exist for asset purchases and other nontraditional policies. As an alternative, several researchers have used surveys and media reports to try to quantify those expectations. For example, in the European context, De Santis (2019) attempted to estimate the financial market effects of the ECB's Asset Purchase Program, its first foray into large-scale QE, announced in January 2015. ECB policymakers and media commentary had strongly foreshadowed the program, so its actual announcement—like the announcement of later rounds of QE in the United States—had only modest market effects, with the average (GDP-weighted) 10-year sovereign debt yield in the euro area declining by about 10 basis points. To try to control for market expectations of ECB actions, De Santis counted the number of news stories on Bloomberg that contained various key words. From these, he created an index of media and market attention to QE in Europe. Controlling both for this measure and for macroeconomic and country-specific factors, De Santis found that the ECB's initial QE program reduced average 10-year sovereign debt yields by 63 basis points over the period from September 2014 to October 2015. This reduction is economically significant and, when adjusted for the size of the program, comparable to estimates from event studies of early QE programs in the United States and the United Kingdom, even though in early 2015 European financial markets were functioning normally.

A related empirical strategy for measuring the effects of QE relies on the fact that, even when the size of a QE program was well anticipated, market participants may have been unsure about the specific assets to be purchased. If the portfolio balance effect is operating, then news that an unexpectedly large share of the central bank's planned purchases will be devoted to a particular asset should raise the price of that asset relative to others. An impressive literature has been built on this insight.[9] For example, in a careful study, Cahill et al. (2013) used data on within-day prices on all outstanding U.S. Treasury securities (excluding inflation-indexed bonds) for the period 2008 to 2012. Their goal was to study, over time frames as short as 30 minutes, not just how QE announcements affected overall yields but how they affected the relative yields of individual securities. That led them to focus on announcements about which securities would be targeted for purchase. To measure unexpected shifts in purchase plans, the authors used the Primary Dealer Survey and other sources.

To illustrate their approach: On November 3, 2010, at 2:15 pm, the FOMC announced QE2, a plan to purchase $600 billion of Treasury securities. As already discussed, the program was largely anticipated, and the announcement accordingly had little effect on Treasury yields overall. However, at the same time as the FOMC announcement, the New York Fed released

[9] D'Amico and King (2012) pioneered this approach, but that paper considered only QE1. For more U.S. results, see also Meaning and Zhu (2011) and D'Amico et al. (2012).

information about how it planned to allocate purchases across Treasury securities of different maturities. This document revealed that, in a change unexpected by the primary dealers, bonds between 10 and 30 years maturity would make up only about 6 percent of planned purchases, compared to 15 percent in earlier rounds. If the portfolio balance channel is operating, that news should have led to a decline in the prices and a rise in the yields of the longer-maturity bonds, relative to those with shorter maturity. That was indeed what the authors found.

Cahill et al. (2013) performed similar analyses of QE1, the Fed's decision in August 2010 to keep its asset holdings constant by reinvesting the proceeds of maturing securities, the Maturity Extension Program, and the extension of the MEP that preceded QE3. (Their study was completed before the announcement of QE3.) They found in each case that unanticipated changes in implementation plans had significant cross-sectional effects on bond prices and yields. Their estimated effects are both economically large and, importantly, show no tendency to decline over time or as the size of the central bank's balance sheet increases. These results, which have been replicated in a number of studies, including for the United Kingdom, once again do not support the view that QE is only effective when markets are dysfunctional.[10]

Cahill et al. (2013), like most studies in this literature, look at the differential impact of asset purchase programs on Treasury debt of varying maturity. But the Fed's purchase programs also differed in how they treated Treasuries versus mortgage-backed securities, with QE1 including substantial MBS purchases for example, but QE2 involving only purchases of Treasuries. If portfolio balance effects are at work, then unanticipated changes in the Treasury-MBS mix should affect the relative yields of those asset classes. That too seems to have been the case, as illustrated for example by Krishnamurthy and Vissing-Jorgenson (2011) in their comparison of the effects of QE1 and QE2. Relatedly, a paper by Di Maggio, Kermani, and Palmer (2016) considered the effects of the Fed's QE programs on the relative returns to MBS issued by the GSEs, which were eligible for purchase by the Fed, and MBS backed by larger ("jumbo") mortgages, which by law cannot be guaranteed by the GSEs and thus were not eligible for Fed purchase. These authors found that QE1, which included large quantities of MBS

[10]An interesting example of a British study is Banerjee, Latto, and McLaren (2014). These authors consider three "natural experiments," dates on which the Bank of England announced changes to the maturity distribution of its asset purchases, for reasons unrelated to monetary policy plans or objectives. They find strong local supply effects (higher prices for assets favored by the changes in plans) which do not fade over time. Studies finding similar results for the UK include Joyce and Tong (2012) and Meaning and Zhu (2011).

purchases, depressed mortgage rates in general by more than 100 basis points but reduced the rates on jumbo mortgages by only about half as much, consistent with the portfolio balance effect. In contrast, they found that QE2 and the Maturity Extension Program, neither of which included MBS purchases, did not differentially affect rates on GSE-eligible mortgages and jumbo mortgages.

Note that studies of the cross-sectional asset-price impacts of QE announcements should reflect only portfolio balance effects. Studies have also found evidence of signaling effects, that is, QE announcements tend to be associated with changes in the expected path of short-term interest rates (Bauer and Rudebusch, 2014). In the "taper tantrum" episode of 2013, market participants were surprised by my comments in a congressional testimony and a press conference that asset purchases might soon be slowed; the significant increases in longer-term yields and expected short-term rates that followed show that signaling effects can be powerful and were not restricted to the earliest QE announcements. I will return to the role of policy communications.

The evidence described so far suggests that, once we control for the fact that market participants substantially anticipated later rounds of QE, the impact of asset purchases did not significantly diminish over time, as financial conditions calmed, or as the stock of assets held by the central bank grew. That still leaves the second broad objection to the event-study evidence, that those studies prove only that announcements of assets purchases have short-run effects on asset prices and yields. If the effects of announcements are quickly reversed, then QE programs would likely be ineffective in stimulating the economy.

The claim that the effects of QE announcements were mostly transitory, due for example to pure liquidity effects, is not particularly persuasive on its face. The normal presumption is that the effects on asset prices identified by event studies should be largely persistent, even if the event window is relatively short. If that were not the case—if the effects of asset purchase announcements were predictably temporary—then smart investors could profit by betting on reversals. Indeed, in a response to Wright (2011), Neely (2016) showed that time series models that imply reversals of the effects of QE announcements do not predict asset prices as well out of sample as the simple assumption that asset prices tomorrow will be the same as today. In other words, predicting reversals of the effects of asset purchase programs is not a money-making strategy, as we should expect. Moreover, Neely (2010), Gagnon et al. (2011), and many others found that the prices of assets not subject to Fed purchases—including corporate bonds, equities, the dollar, and a variety of foreign assets—moved substantially following announcements of asset purchase programs, and in much the same way as following conventional policy announcements. QE also appeared to stimulate the global issuance of corporate bonds (Lo Duca, Nicoletti, and Martinez, 2016) and to reduce the cost of insuring against corporate credit risk via credit default swaps (Gilchrist and Zakrajsek, 2013). The cross-asset impacts seem inconsistent with the view that the event-study findings reflect only asset-specific liquidity effects.[11]

As noted earlier, proponents of the view that QE had only transient effects sometimes point out that longer-term yields did not reliably decline during periods in which the Fed was executing its announced asset purchases. In part, this pattern can be explained by the confounding influences on yields of other factors, including fiscal policy, global conditions, and changes in sentiment. For example, the rise in yields in the latter part of 2009, during the implementation of QE1, was seen at the Fed not as a policy failure but rather as an indication that its aggressive monetary policies, together with other factors such as the Obama administration's fiscal program and the successful stress tests of major banks, were increasing public confidence in the economic outlook. Indeed, judging from the returns to inflation-protected securities, much of the increases in 10-year yields during the implementation phases of QE1 and QE2 reflected higher inflation expectations, a desired outcome of the programs.

A deeper response to this argument turns on the distinction between two views of how QE works, the so-called stock and flow views. The standard portfolio balance channel of QE, recall, holds that policymakers can affect longer-term yields by changing the relative supplies—that is, the stocks outstanding—of various financial assets. In this *stock view* of QE, the effect of asset purchases on yields at each point in time depends on the accumulated stock of central bank purchases and (because asset markets are forward-looking) on expected stocks of central bank holdings at all future dates. The alternative *flow view* holds that the current pace of purchases is the critical determinant of asset prices and yields. This view implicitly underlies the argument that the effectiveness of QE can be evaluated by looking at the behavior of longer-term yields during periods of active central-bank purchases. The flow view would be correct if QE affected asset prices and yields primarily through short-run liquidity effects.

[11] Professional forecasters also seem to believe that QE announcements have persistent effects. For example, using survey data, Altavilla and Giannone (2015) found that, following such announcements, forecasters saw significant declines in Treasury and corporate bond yields lasting at least one year.

However, the stock view conforms better to the underlying theory and has better empirical support (D'Amico and King, 2013). Substantial research has tried to quantify the dynamic relationship between yields and the relative supplies of securities under the stock view. In an important article, Ihrig et al. (2018) estimated an arbitrage-free model of the term structure of Treasury yields, in which current and expected holdings of securities by the Fed are allowed to influence yields.[12] They carefully modeled the evolution of the Fed's balance sheet, given its purchases and the maturing of existing securities, and they developed reasonable measures of market expectations of future purchases. They also incorporated estimates of new Treasury debt issuance, which partially offset the effects of the Fed's purchases on the net supply of government debt (Greenwood et al., 2014).

Putting these elements together, Ihrig et al. (2018) found significant effects of the Fed's asset purchase programs on Treasury yields. For example, their estimates suggest that, at inception, QE1 reduced the 10-year term premium by 34 basis points, the Maturity Extension Program reduced term premiums by an additional 28 basis points, and QE3 reduced term premiums yet more, by 31 basis points on announcement and more over time. This finding is consistent with other papers that show no reduction in the effectiveness of later programs relative to the earliest ones. Their results also imply substantial persistence: Although the effect of any given QE program decayed over time, as securities matured and ran off the Fed's balance sheet, Ihrig et al. (2018) estimated that the cumulative effect of the purchases on the 10-year yield exceeded 120 basis points when net purchases ended in October 2014 and was still about 100 basis points as of the end of 2015. In related work, Wu (2014) found quite similar results, crediting Fed asset purchases with more than half of the 217 basis point decline in 10-year Treasury yields between the Lehman failure and the taper tantrum. Altavilla, Carboni, and Motto (2015) and Eser et al. (2019) estimated related models for the euro area, likewise finding that ECB purchases had sizeable and persistent impacts on asset prices—notwithstanding, once again, that the ECB's program was announced at a time of low financial distress.

[12] For a summary of this approach and its findings, see Bonis, Ihrig, and Wei (2017). This work builds on Li and Wei (2013) and Hamilton and Wu (2012), the latter of whom find somewhat weaker effects of asset purchases. A number of papers use regression methods to assess the effects of bond supply on term premiums, e.g., Gagnon et al. (2011); the line of research typified by Ihrig et al. (2018) can be seen as an attempt to impose greater structure (including the no-arbitrage condition) on this approach. See also Greenwood and Vayanos (2014).

In sum, while there is room for disagreement about the effects of QE on longer-term yields, most evidence supports the view that they were both economically significant and persistent. In particular, the research rejects the notion that QE is only effective during periods of financial disruption. Instead, once market participants' expectations are accounted for, the impact of new purchase programs seems to have been more or less constant over time, independent of market functioning, the level of rates, or the size of the central bank balance sheet.

B. Forward Guidance

The second new tool used by almost all major central banks in recent years, other than asset purchases, is forward guidance. Forward guidance—or "open mouth operations" (Guthrie and Wright, 2000)—is communication about how monetary policymakers expect the economy and policy to evolve. Forward guidance takes many forms (such as the specification of policy targets, economic and policy projections) and occurs in many venues (speeches and testimonies, monetary policy reports). The Fed took several steps to enhance its communications during the post-crisis period, including introducing press conferences by the chair, setting a formal inflation target, and releasing more detailed economic projections by FOMC participants, including policy rate projections. I focus here though on formal guidance by the policy committee about the future paths of key policy instruments, especially policy rates and asset purchases.[13]

Forward guidance, at least in a broad sense, was not new to the post-crisis period. The Fed used variants of forward guidance in the Greenspan era, for example, in the promises of the FOMC in 2003-04 to keep rates low "for a considerable period" or to remove accommodation "at a pace that is likely to be measured." Ample evidence suggests that these and other pre-crisis communications by the FOMC affected market expectations of policy rates and thus asset prices and yields generally. For example, Gürkaynak, Sack, and Swanson (2005), using a high-frequency event study, showed that the effects of monetary policy announcements on asset prices can be decomposed into two factors: one associated with unexpected changes in the current setting of the federal funds rate and the other with news about the expected future path of the funds rate, which the authors associated with the (implicit or explicit) forward guidance in the policy statement. Both factors are important, with the forward guidance factor being particularly

[13] Feroli et al. (2017) provide a detailed review and analysis of the past two decades of Fed communications.

influential in determining longer-term yields. Other central banks had also used communication as a policy tool before the crisis, an early example being the Bank of Japan, whose zero-interest-rate policy included a promise not to raise the policy rate from zero until certain conditions had been met.

Campbell et al (2012) introduced the useful distinction is between Delphic and Odyssean forward guidance. *Delphic* guidance (after the oracles at the Temple of Apollo at Delphi) is intended only to be informative, to help the public and market participants understand policymakers' economic outlook and policy plans. In contrast, *Odyssean* guidance goes beyond simple economic or policy forecasts by incorporating a promise or commitment by policymakers to conduct policy in a specified, possibly state-contingent way in the future (as when Odysseus bound himself to the mast to avoid the temptations of the Sirens).

Both Delphic and Odyssean guidance have potentially important roles when policymakers confront the lower bound on rates. Delphic guidance that helps the public better understand the central bank's reaction function may be valuable at the lower bound since—given the "history dependence" of optimal monetary policy (Woodford, 2013)—the responses of monetary policymakers to a given configuration of inflation and employment after a period at the lower bound may be quite different than during more-normal times. Odyssean guidance is useful at the lower bound because optimal monetary policy in those circumstances may be at least somewhat time-inconsistent, in the sense of Kydland and Prescott (1977)—that is, at the lower bound, monetary policymakers may want to commit to interest-rate paths or to other actions from which they will have incentives to deviate in the future.

For example, when short-term rates cannot be reduced further, policymakers may want to put downward pressure on longer-term rates by persuading market participants that they intend to keep the policy rate at the lower bound for an extended period—a so-called *lower-for-longer policy*—even if that involves a possible (time-inconsistent) overshoot of their inflation target. As I will discuss, lower-for-longer policies are in turn closely related to so-called makeup strategies, in which policymakers promise to compensate for protracted undershoots of their inflation or employment goals by a period of overshoot (Yellen, 2018). Odyssean guidance can make such commitments clear and create a reputational stake for the central bank to follow through.

In the immediate aftermath of the financial crisis most examples of forward guidance were qualitative, using language similar to Greenspan's "considerable period" rather than precisely specifying the future path of rates or the conditions under which rates would be raised. Some research has criticized the Fed's guidance during this time. Woodford (2012) argued that the guidance in the FOMC's policy statements lacked sufficient commitment to be effective—that is, the language was Delphic when it should have Odyssean. Engen, Laubach, and Reifschneider (2015) noted that, in 2009-2010, private (Blue Chip) forecasters continued to believe that the Fed intended to begin raising rates relatively soon, notwithstanding (qualitative) guidance to the contrary; according to these authors, the forecasters' beliefs evidently reflected both a misunderstanding of the Fed's reaction function and excessive optimism about the likely speed of the recovery. Campbell et al. (2017) concluded that Fed forward guidance only became Odyssean (that is, effectively committing to lower for longer) in 2011, at which point it began to lead to better macroeconomic outcomes. Gust et al. (2017) similarly found, in the context of an estimated dynamic stochastic general equilibrium (DSGE) model, that market participants only gradually understood the FOMC's lower-for-longer message. Supporting the critics' view is that, despite the Fed's efforts to talk down rates, the two-year Treasury yield—an indicator of near-term monetary policy expectations—remained near 1 percent through the spring of 2010, declining only gradually after that.

Over time, the FOMC pushed back against the excessively hawkish expectations of market participants with more precise and aggressive forward guidance. In August 2011, the FOMC for the first time explicitly tied its guidance to a date, indicating that it would keep the fed funds rate near zero "at least through mid-2013." In January 2012 it extended that commitment "at least through late 2014," and in September 2012 it extended the commitment yet again to "at least through mid-2015." In December 2012, the FOMC switched from guidance specifying a date for policy action (calendar guidance) to a description of the conditions that would have to be met for rates to be raised (state-contingent guidance). Specifically, policymakers promised not even to consider raising the policy rate until unemployment had fallen at least to 6.5 percent, as long as inflation and inflation expectations remained moderate. A year later, this statement was strengthened further, with the FOMC indicating that no rate increase would occur until "well past the time" that unemployment declined below 6.5 percent. In principle, state-contingent guidance, which ties future policy rates to economic conditions, is preferable to calendar guidance because it permits the market's rate expectations to adjust endogenously to incoming information bearing on the outlook (Feroli et al., 2017). However, calendar guidance has the not-inconsiderable advantages of simplicity and directness, and it can be adjusted if needed (Williams, 2016).

The increasingly explicit guidance by the FOMC ultimately had the desired effect of shifting market rate expectations in a dovish direction: Two-year Treasury yields declined to about 0.25 percent in the second half of 2011, where they remained for several years. Table 2, using the event study methodology described earlier, shows the sum of one-day responses of several key asset prices to the first two calendar guidance announcements, in August 2011 and January 2012.[14] The table shows that the Fed's announcements appear to have moved interest rates down significantly, increasing stimulus. The two announcements were also associated with a decline in the dollar (not shown) and a rise in equity prices.

Table 2. Responses of asset prices and yields to two Fed forward guidance announcements

2-year Treasuries	-10
10-year Treasuries	-27
30-year Treasuries	-14
Mortgage-backed securities	-17
AAA corporate bonds	-16
SP500 index	5.61

Note: Sums of one-day responses to announcements of August 9, 2011, and January 25, 2012. Yield changes are in basis points, stock price changes are in percentage points.
Source: Author's calculations.

Other evidence suggests that these announcements worked as intended: Femia, Friedman, and Sack (2015) showed that, during this period, professional forecasters reacted to FOMC guidance by repeatedly marking down the unemployment rate they expected to prevail when the Committee lifted the funds rate from zero, implying a perceived change in the Fed's reaction function in the lower-for-longer direction. Using information drawn from interest rate options, Raskin (2013) came to a similar conclusion. Carvalho, Hsu, and Nechio (2016), counting particular words in magazine and newspaper articles to measure policy expectations, found that

[14] Like the first QE announcements, the first calendar guidances were probably largely unanticipated. Besides being better anticipated, the subsequent changes to guidance occurred at the same meetings as important changes to the Fed's asset purchase programs. Since it would be difficult to separate their effects from the announcements of asset purchases, they are excluded from the table.

unanticipated communications by the Fed influenced longer-term interest rates, while Del Negro, Giannoni, and Patterson (2012) concluded that forward guidance positively affected inflation and growth expectations.

I have been discussing QE and forward guidance separately, but in practice the two tools are closely intertwined. As noted earlier, QE works in part by implicitly signaling the likely path of policy rates; increasingly, central banks (notably the ECB) have made this connection explicit, for example, by promising no rate increases until well after the conclusion of asset purchase programs. Policymakers can also offer guidance about future asset purchases (Greenwood, Hanson, and Vayanos, 2015) or even tie the trajectory of asset holdings to the level of rates, as when the FOMC indicated that it would begin to pare down its balance sheet only after the policy rate had moved sufficiently above zero. And both asset purchases and forward guidance affect asset prices in complicated ways, making it difficult to separate the effects of the two tools (Eberly, Stock, and Wright, 2019). An interesting attempt at making that decomposition is the work of Swanson (2017), who extended the event-study methods of Gürkaynak, Sack, and Swanson (2005) to the post-crisis period. He showed that, during 2009-2015, movements in asset yields and prices during 30-minute windows around FOMC announcements were dominated by two factors: (1) changes in the expected path of the federal funds rate, which Swanson identified with forward guidance, and (2) changes in the level of long-term interest rates, which he identified with QE. With these identifying assumptions, he found that both forward guidance and QE significantly and persistently affected a range of asset prices, in a manner comparable to pre-crisis policies.

The Fed's experience during the post-crisis era illustrates the more general point that central banks, collectively, have been learning how to make better use of forward guidance. Like the Fed, the Bank of England moved from qualitative guidance to explicit, state-contingent guidance. The Bank of Japan has used increasingly aggressive guidance, both state-contingent and calendar. The ECB has employed statements and press conferences effectively to guide expectations about how it will deploy its complex mix of policy tools. Charbonneau and Rennison (2015) provide a chronology and a review of the evidence on post-crisis forward guidance. Altavilla et al (2019) used a statistical analysis similar to that of Gürkaynak, Sack, and Swanson (2005) and Swanson (2017) to identify the key dimensions of ECB communication.

Hubert and Labondance (2018) found that the ECB's forward guidance persistently lowered rates over the entire term structure.

Overall, the evolving evidence suggests that forward guidance can be a powerful policy tool, with the potential to shift the public's expectations in a way that increases the degree of accommodation at the lower bound. Communication can also reduce perceived uncertainty and, through this channel, lower risk premiums on bonds and other assets (Bundick, Herriford, and Smith, 2017). And, like Draghi's famous "whatever it takes" statement in July 2012, timely communication can reduce perceived tail risks, promoting confidence (Hattori, Schrimpf, and Sushko 2016).

The limits to forward guidance depend on what the public understands, and what it believes. In normal times, the general public does not pay much attention to central bank statements, so robust policies should be designed to be effective even if they are followed closely only by financial market participants. Even sophisticated players can misunderstand, as in the taper tantrum, which means that policymakers must communicate consistently and intelligibly.

Ensuring the credibility of forward guidance is also essential. The personal reputations and skills of policymakers matter for credibility, but since policymakers can bind neither themselves nor their successors, institutional reputation is important as well. Policymakers have an incentive to follow through on earlier promises because they want to be able to make credible promises in the future (Nakata, 2015). The success of frameworks like inflation targeting—which grant policymakers only "constrained discretion" (Bernanke and Mishkin, 1997)—shows that these reputational forces can be quite effective. On the other hand, failure to achieve stated targets over a long period can damage institutional credibility, as shown by the difficulty that the Bank of Japan has had in raising inflation expectations (Gertler, 2017).

Forward guidance in the next downturn will be more effective—better understood, better anticipated, and more credible—if it is part of a policy framework clearly articulated in advance. As of this writing, the Federal Reserve is formally reviewing its policy framework and considering alternatives. Many of these frameworks, including variants of price-level targeting and average inflation targeting, involve the lower-for-longer or "makeup" policies described earlier. Bernanke, Kiley, and Roberts (2019), using simulation methods, found that several of the frameworks under consideration offer substantial promise to improve economic outcomes when encounters with the lower bound are frequent. Importantly, many of the alternatives they considered are only mildly time-inconsistent, involving only modest overshoots of the inflation target. Moreover, as Bernanke, Kiley, and Roberts (2019) discussed, several of these frameworks involve only tweaks to the current inflation-targeting framework, which would ease any transition; and their effectiveness is not substantially reduced if they affect the beliefs and behavior of only financial market participants, as opposed to the general public. Improving policy and communications frameworks to incorporate more systematic forward guidance at the lower bound should be a high priority for central banks.

C. Other New Monetary Policy Tools

The Federal Reserve supplemented traditional policy with QE and forward guidance during the post-crisis period, as did other central banks. But major central banks outside the United States also used some other tools, which I will discuss briefly here.[15] As already noted, I will not discuss policy tools aimed primarily at financial (as opposed to macroeconomic) stabilization.

The alternative tools fell into several major categories. First, unlike the Fed, which by law was largely limited to purchasing only government bonds or government-guaranteed MBS, other central banks also purchased a range of private assets, including corporate debt, commercial paper, covered bonds, and (in the case of the Bank of Japan) even equities and shares in real estate investment trusts. These programs likely gave those central banks greater ability to affect private yields, especially credit spreads, although plenty of evidence suggests spillovers from sovereign debt purchases to private yields as well (D'Amico and Kaminska, 2019). Purchasing private assets has disadvantages as well: They involve taking credit risk, as well as the interest-rate risk associated with all QE programs, and they may generate political controversies, if they create the perception that the central bank is favoring some firms or industries.

Second, several foreign central banks subsidized bank lending through cheap long-term funding, usually on the condition that banks increase their lending to approved categories of borrowers. Leading examples include the Bank of England's Funding for Lending Scheme and

[15] For further discussion, see Dell'Ariccia, Rabenal, and Sandri (2018) and Committee on the Global Financial System (2019).

the ECB's Targeted Long-term Refinancing Operations. Unlike crisis-era programs aimed at stemming the financial panic, these lending programs were aimed at broader economic stabilization, by overcoming lending bottlenecks in bank-dominated economies and, more generally, by offering bank-dependent borrowers the same access to credit as borrowers with access to securities markets. Most of the available evidence on these programs suggests that they lowered bank funding costs, promoted lending, and improved monetary policy passthrough to the real economy (Andrade et al., 2019; Churm et al., 2018; Cahn, Matheron, and Sahuc, 2019.) However, the efficacy of these programs seems likely to depend in a complicated way on the health of the banking system: If banks are well-capitalized, then their need for cheap liquidity from the central bank may be limited. Conversely, if banks are short of capital, their lending may be constrained or their incentives to make good loans distorted, notwithstanding the availability of low-cost funding.

Third, the Bank of Japan, the ECB, and the central banks of several smaller European countries adopted negative short-term interest rates, enforced by a charge on bank reserves. The ability of the public to substitute into cash, which pays a zero nominal rate, or to pre-pay nominal liabilities such as taxes, limits how far into negative territory the short rate can fall. Negative rates also raise financial stability concerns. One risk is that bank capital and lending capacity will be impaired by negative rates, because in practice banks cannot easily pass negative rates on to retail depositors. Indeed, a "reversal rate" of interest may exist, below which the adverse effects of the negative rate on bank capital and lending make it economically contractionary on net (Brunnermeier and Koby, 2018). However, central banks can address the reversal rate problem through various devices, such as paying a higher rate to banks on a portion of their reserves ("tiering"), as has been done by the BOJ and the ECB. In addition, when rates decline, banks benefit from the upward revaluation of their assets and from improvements in overall economic conditions, which reduce credit losses.

Within the limited range so far experienced, negative policy rates appear to have been passed through to bank lending rates, money market rates, and longer-term interest rates (Arteta et al., 2018; Hartmann and Smets, 2018). An International Monetary Fund (2017) review summed up by saying, "Experience is limited, but so far [negative interest rate policies] appear to have had positive, albeit likely small, effects on domestic monetary conditions, with no major internal side effects on bank profits, payment systems, or market functioning." The evidently moderate costs and benefits of negative rates seem disproportionate to the rhetorical heat they stimulate in some quarters. Money illusion can be powerful.

Finally, the Bank of Japan in September 2016 initiated a program of "yield curve control," a framework which includes a peg for the short-term interest rate (as in traditional policymaking) but also a target range for the yield on 10-year Japanese government bonds (JGBs), enforced by purchases of those bonds. Yield curve control allows the BOJ to provide stimulus by lowering interest rates throughout the term structure. Yield curve control may be thought of as a form of QE that targets the price of bonds and leaves the quantity of bonds purchased by the central bank to be determined endogenously, rather than the reverse as in standard QE programs. Because the program is credible and because many private holders of JGBs appear not to be very price-sensitive, it seems that the BOJ can maintain low long-term rates with a slower rate of asset purchases than in the prior (quantity-based QE) regime, reducing concerns about whether there are enough JGBs available for the BOJ to buy. Yield curve control, besides providing the ability to target financial condition more precisely, thereby also appears—in the Japanese context, at least—to be more sustainable.

Clearly, novel monetary policy options extend beyond QE and forward guidance. Will the Federal Reserve ever adopt any of these supplementary tools? Other than GSE-backed mortgages, the Fed does not have the authority to buy private assets, except under limited emergency conditions, and—in light of the political risks and philosophical objections by some FOMC participants—seems unlikely to request the authority. A program targeting bank lending, such as the Bank of England's Funding-for-Lending Scheme or the ECB's targeted refinancing operations, is conceivable and was indeed discussed at the Fed during the post-crisis period. At the time, though, FOMC participants did not feel that bank liquidity was constraining lending, and there were some reservations about the quasi-fiscal and credit allocation aspects of subsidizing bank loans. Freeing up bank lending is also macroeconomically more consequential in jurisdictions like the euro area and Japan where the bulk of credit flows through banks, as opposed to securities markets. Still, one can imagine circumstances—for example, if constraints on bank lending are interfering with the transmission of monetary policy—in which this option might resurface in the United States.

Federal Reserve officials believe that they have the authority to impose negative short-term rates (by charging a fee on bank reserves) but have shown little appetite for negative rates thus far because of the practical limits on how negative rates can go and because of possible financial side effects. That said, categorically ruling out negative rates is probably unwise, as future situations in which the extra policy space provided by negative rates could be useful are certainly possible. Moreover, theory and empirical evidence suggest that ruling out negative short-term rates reduces the ability of the central bank to influence longer-term rates near the lower bound, through QE or other means (Grisse, Krogstrup, and Schumacher, 2017). Maintaining at least some constructive ambiguity about the possibility of negative policy rates thus seems desirable.

Yield curve control in the Japanese style—that is, pegging or capping very long-term yields—is probably not feasible, or at least not advisable, in the United States, given the depth and liquidity of U.S. government securities markets. If long-term yields were pegged, and market participants came to believe that the future path of policy rates was likely higher than the targeted yield, the Fed might need to buy a large share of the outstanding bonds to try to enforce the peg. Those purchases in turn would flood the banking system with reserves and expose the central bank to large capital losses.[16] However, pegging Treasury yields at a shorter horizon, say two years, would likely be feasible and might prove a powerful method for reinforcing forward rate guidance. Board staff analyzed this possibility in 2010 (Bowman, Erceg, and Leahy, 2010) and it has been recently raised by Brainard (2019).

D. Costs and Risks of the New Policy Tools

The appropriate use of new policy tools depends not only on their benefits but on their potential costs and risks. I briefly discuss here the potential costs and risks of these policies, especially QE, that most concerned U.S. policymakers in real time. My principal sources are FOMC minutes and transcripts, and a survey of FOMC participants about the costs and risks of asset purchases that they discussed at their December 2013 meeting. In retrospect, most of the

[16] The Fed capped longer-term rates during and after World War II (1942-51). However, the bond market was much smaller and less liquid then, and short-term rates were pegged, evidently credibly, at a rate well below the cap on longer-term rates. See Chaurushiya and Kuttner (2003).

costs and risks that concerned policymakers and outside observers have not proved significant.[17] The possible exception is the risk of financial instability, which I leave to last.

Impairment of market functioning. Central banks using QE have tried to ensure that securities markets continue to function well, for example, by putting limits on the fraction of individual issues eligible for asset-purchase programs. The JGB market in Japan has at times had very low activity outside of central bank purchases. In the other major economies however there has been only limited evidence of poor market functioning, absence of two-way trade, or loss of price discovery. Asset purchases likely improved market functioning during the global financial crisis and during the European sovereign debt crisis, by adding liquidity, promoting confidence, and strengthening the balance sheets of financial institutions.

High inflation. FOMC participants were appropriately skeptical of the crude monetarism sometimes espoused in the early days of QE, which held that the large increases in the monetary base associated with asset purchases—which are financed by crediting banks' reserve accounts at the central bank—would lead to runaway inflation. Fed policymakers and staff understood that, with short-term interest rates near zero, the demand for bank reserves would be highly elastic and the velocity of base money could be expected to fall sharply.[18] However, some FOMC participants did express concern about the possibility that the combination of extraordinary monetary measures and large fiscal deficits could un-anchor inflationary expectations, the determinants of which are poorly understood. This was a minority view and, of course, inflation and inflation expectations remained low—often frustratingly so—in all major jurisdictions despite the use of QE and other new tools.

Managing exit. FOMC participants worried about whether the expansion of the Fed's balance sheet could ultimately be reversed without disrupting markets, and about how (in a mechanical sense) short-term interest rates could be raised when the time came to do so if banks remained inundated with reserves. The taper tantrum of 2013 would show that the communication around ending or reversing growth in the central bank balance sheet can indeed be delicate. To bolster confidence both inside and outside the Fed, Board staff and FOMC

[17] Beyond the costs and risks discussed here, policymakers feared Knightian uncertainty—the possibility that using relatively untested tools would have unanticipated side effects. In the December 2013 survey, five participants assessed "unanticipated/unknown" costs of QE as being of moderate concern, and one designated them as being of high concern.

[18] The velocity of base money can be decomposed into the money multiplier (inside money, such as M1, divided by base money) and the velocity of inside money. Both fell significantly as reserves rose.

participants worked to develop methods for raising the policy rate at the appropriate time—including the payment of interest on bank reserves, which would ultimately become the key tool. These efforts largely succeeded, as the Fed's balance sheet has neared its new steady-state level and rates were raised from zero with only occasional and relatively minor disruptions thus far.

Distributional considerations. FOMC participants did not often discuss distributional considerations—mainly, the effects of low interest rates on savers and the purported tendency of the new monetary tools to increase inequality—nor were these concerns included in the internal 2013 FOMC survey about potential costs. However, these issues were (and remain) prominent in the political debate in the United States and several other countries. Most policymakers believe that monetary policies that promote economic recovery have broadly felt benefits, including higher employment, wages, profits, capital investment, and tax revenues; lower borrowing costs; and reduced risk of unwanted disinflation or even a deflationary trap. Given these benefits, it would be unwise to avoid accommodative monetary policies even if they did have some adverse distributional implications. In any case, the research literature is close to unanimous in its finding that the distributional effects of expansionary monetary policies are small, once all channels are considered, and may even work in a progressive direction, for example by promoting a "hot" labor market.[19] Inequality is primarily structural and slowly evolving rather than cyclical, and as such should be addressed by the fiscal authorities and other policymakers, not central banks.

Capital losses. The large, unhedged holdings of longer-term securities associated with asset purchase programs risked substantial capital losses if interest rates had risen unexpectedly, losses which in turn could have ultimately reduced the Federal Reserve's remittances of profits to the Treasury.[20] The social costs of any such losses would probably have been small: They would not have affected the ability of the Fed to operate normally, and—even ignoring offsetting gains to investors—government revenue gains from a stronger economy would have more than

---

[19] On the distributional effects of monetary policy, see for example Bivens (2015) for the United States, Ampudia et al. (2018) for the euro area, and Pugh, Bunn, and Yeates (2018) for the United Kingdom. Aaronson et al. (2019) document the benefits to lower-wage workers of a "hot" labor market. The argument that easy money increases wealth inequality is slightly more plausible than that it increases income inequality, because of its effects on asset prices. Note though that the benefits to asset holders of higher asset prices are partially offset by the lower returns they can earn on their wealth.

[20] Assuming that securities are held to maturity, the effect on remittances would be indirect, arising only at the point that the short-term rate paid by the Fed on reserves rises sufficiently relative to the returns on its portfolio. See Bonis, Fiesthumel, and Noonan (2018). Cavallo et al (2018) discuss the fiscal implications of the Fed's balance sheet under various scenarios.

compensated for reduced remittances. Nevertheless, FOMC participants worried about the political fallout and threats to Fed independence that large losses could have produced.[21]

Several factors mitigated but did not eliminate this risk. First, a significant portion of the Fed's liabilities—namely currency—pays no interest, providing some cushion to the Fed's ability to make payments to the Treasury. Additional cushion is provided by securities owned by the Fed prior to the introduction of QE, which enjoyed capital gains when yields fell. Second, since the Fed earns the long-term interest rate on its holdings of bonds but pays the short-term interest rate on bank reserves, it earns a net positive return when the yield curve has its normal upward slope. Third, the taxpayer is hedged against Fed capital losses in the sense that a rise in longer-term yields is more likely to occur when the economy is strengthening, which increases tax revenues. (However, some FOMC participants worried about a sudden, spontaneous rise in long rates—the bursting of the "bond bubble.") In fact, the Fed's asset purchase programs proved hugely profitable, with net profits resulting in remittances to the Treasury totaling about $800 billion between 2009 and 2018, about triple pre-crisis rates. Such an outcome, though likely, was not guaranteed, and the risk of capital losses is likely to remain a concern for policymakers involved in large asset-purchase programs.[22]

Financial instability. FOMC participants worried that post-crisis monetary policies raised risks of financial instability—a natural concern, given the recentness and largely unpredicted nature of the global financial crisis. Many mechanisms linking monetary policy to stability risks were suggested, including but not limited to the creation of asset bubbles; incentivizing "reach for yield" and excessive risk-taking by investors; the promotion of excessive leverage or maturity transformation; and the destabilization of the business models of insurance companies and pension funds, which rely on receiving adequate long-run returns, and of banks, whose profits depend in part on their ability to earn positive net interest margins. U.S. central bankers also heard frequently from their foreign counterparts, especially in emerging markets, about the "spillover effects" of Fed policies on financial conditions abroad (Rey, 2013).

[21] In the United Kingdom, the central bank was backstopped by the Treasury, but there were no such arrangements in the United States or, to my knowledge, in other major economies. Such arrangements avoid direct capital losses on the central bank's balance sheet but have the downside of possibly compromising the independence of monetary policy. Also, a Treasury backstop does not necessarily avoid adverse political consequences since the taxpayer still bears the ultimate costs if losses occur.

[22] The fiscal gains from asset purchases has occasionally led to the opposite critique, that by buying government debt and remitting profits, central banks are "enabling" irresponsible fiscal policymakers. The Fed's view—which I believe is appropriate—is that it is not the central bank's job to dictate fiscal choices to elected legislators.

We are far from a full understanding of the links between monetary policy and financial stability. A good bit of evidence suggests that monetary easing works in part by encouraging private actors to take risks—the so-called risk-taking channel (Borio and Zhu, 2012). Easy money increases risk-taking through several mechanisms: It improves the overall economic outlook and reduces downside risks; it strengthens bank and borrower balance sheets, which increases the willingness of lenders to extend credit; and it reduces the cost of liquidity, which complements risk-taking by banks (Drechsler, Savov, and Schnabl, 2018). Increased risk-taking is by no means always a bad thing, of course: Encouraging banks, borrowers, and investors to take reasonable risks, rather than hoarding cash and hunkering down, is a desirable goal for policies aimed at ending a recession or crisis and restoring normal growth. However, risk-taking may become excessive if investors and lenders are less than perfectly rational about trading off risk and return, if institutional arrangements distort incentives for risk-taking, or if there are externalities associated with increased leverage or illiquidity (Stein, 2013). So these concerns can hardly be dismissed; indeed, given the economic damage that a financial crisis can cause, we must be humble about our understanding and remain vigilant for building risks.

There is a lively debate, which I will not try to resolve here, about the extent to which monetary policymakers should take financial stability considerations into account when setting interest rates (Svensson, 2016; Gourio, Kashyap, and Sim, 2017; Adrian and Liang, 2018). Most participants in that debate agree that that the first line of defense against financial instability risks should be targeted regulatory and macroprudential policies, and that monetary policy should be brought to bear only if 1) those targeted policies are insufficient and 2) the benefits of using monetary policy to reduce crisis risks exceed the costs of undershooting near-term inflation and employment objectives. The main source of disagreement is the great uncertainty associated with trying to measure those costs and benefits. In this context it is worth noting that the United States seriously lags many other countries in the development of macroprudential tools; for example, the United Kingdom, Canada, and several Asian countries are well ahead in their ability to address dangerous credit booms, particularly real estate credit booms.

A narrower but still important question is whether the new monetary tools pose greater stability risks than traditional policies or, for that matter, than the generally low rate environment expected to persist even when monetary policies are at a neutral setting. There is not much evidence that they do. For example, QE is arguably *less* risky than other expansionary policies, because it flattens the yield curve and thus reduces the incentive for maturity transformation (Woodford, 2016; Greenwood, Hanson, and Stein, 2016). As often noted, the portfolio balance effect of QE involves pushing some investors out of longer-term Treasuries into other, possibly riskier assets; but in general equilibrium, by removing duration risk from the system, QE reduces the riskiness of private-sector portfolios in aggregate, increases the supply of safe and liquid assets, and helps compensate for reduced private risk-bearing capacity during periods of high uncertainty (Caballero and Kamber, 2019). The spillover effects of the new monetary tools on foreign economies do not appear markedly different from spillovers from traditional policies (Curcuru et al., 2018). And as already mentioned, the new tools are most likely to be used when the economy is depressed and increased risk-taking is desirable. For example, Chodorow-Reich (2014) found that, in the post-crisis period, monetary easing had beneficial effects on banks and life insurance companies without inducing excessive risk-taking.

II. Macroeconomic Effects of the New Monetary Tools

So far, I have argued that the new monetary tools, including QE and forward guidance, can materially affect financial conditions, in much the same way traditional monetary policies do when rates are away from the lower bound. The more important question, of course, is whether using these new tools near the lower bound can lead to significantly better economic outcomes, similar to what traditional policies can deliver away from the lower bound. That question occupies the remainder of this lecture.

A. The New Monetary Tools and the Great Recession

Our only historical experience involving extensive application of the new monetary tools is the recovery from the Great Recession. As I've discussed, the Federal Reserve and other major central banks, including the Bank of England, the ECB, and the Bank of Japan, all made use of the new tools at various times. In each of these jurisdictions, the recessions were nevertheless severe and the recoveries slow, showing the limits of monetary policy. But, on the other hand, even away from the lower bound, monetary policy has never proved able to reverse large shocks, only to mitigate them and speed recovery. Moreover, the post-crisis period featured some unusual headwinds, including—in the United States—the after-effects of the financial crisis and the housing bust and a transition from fiscal expansion to austerity. And the recovery, though not rapid, was unusually sustained, in 2019 becoming the longest documented expansion in U.S. history. Did the limits imposed by the lower bound make the Great Recession significantly worse, or the recovery slower? How much did the new tools help?

The literature does not provide a consensus on these questions. Some work suggests that the new tools substantially overcame the limitations imposed by the lower bound. For example, Fernald, Hall, Stock, and Watson (2017), using growth accounting methods, attributed the slow pace of the U.S. recovery from the Great Recession primarily to subdued productivity growth and demographically-induced declines in labor force participation, both trends in place before the financial crisis. They noted that indicators of resource utilization like the unemployment rate—which are more subject to the influence of monetary policy than is potential growth—behaved relatively normally during the recovery.[23] If the recovery from the Great Recession was relatively normal, given the size of the shock and the economy's underlying growth potential, then presumably the lower bound could not have been a major constraint on policy.

An interesting alternative approach to measuring the effectiveness of post-crisis monetary policy is through the construction of "shadow" short-term interest rates. Following an insight of Black (1995), Wu and Xia (2016) used an affine term structure model to make inferences from the full yield curve about what the short-term interest rate would have been had it not been constrained by the lower bound. During normal times, the so-called shadow rate they estimated generally equals the actual policy rate, while during lower-bound periods the shadow rate is usually negative. Wu and Xia interpreted the shadow rate as a summary measure of the stance of monetary policy, including nontraditional measures, finding that its relationships with asset prices and macro variables look much like those of the actual federal funds rate before the crisis. Based on this measure, these authors found that the new tools provided only limited stimulus early in the recovery, but that, ultimately, these tools provided about 3 percentage points of additional accommodation (that is, the shadow rate fell, by 2015, to about -3 percent). They estimated that this easing resulted in a slightly greater reduction in the unemployment rate than

[23] The average quarterly peak-to-trough change in the unemployment gap (the unemployment rate minus the Congressional Budget Office estimate of the natural rate) between 2009 and 2019 was -0.14 percentage points, about the same as in previous postwar recessions. The quarterly peak-to-trough change in the prime-age employment-to-population ratio, 0.12, was noticeably lower than in the recoveries from the deep 1973-75 and 1981-82 recessions but similar to other recoveries, including those following the recessions of 1990-91 and 2001.

in a counterfactual with traditional policies and no lower bound. Krippner (2015) provided an alternative shadow rate series, which he argued is more robust to alternative estimation assumptions and sample periods. His measure also implies that the new policy tools delivered significant stimulus—the equivalent of setting the short-run policy rate more than 5 percentage points below zero by 2013—but, like Wu and Xia (2016), Krippner found that monetary stimulus was more limited in the earliest stages of the recovery.

A small literature has cited indirect evidence to argue that the lower bound did not much constrain post-crisis monetary policy in the United States (see Swanson, 2018, for further discussion). For example, Swanson and Williams (2014) showed that market interest rates reacted to economic news in about the same way after the crisis as before, suggesting that the proximity of the lower bound had limited effect on market expectations of the monetary policy response to changes in the outlook. Debortoli, Gali, and Gambetti (2019) found that the cyclical behaviors of key macroeconomic and financial variables during the Great Recession were not atypical, as they should have been if monetary policy had been constrained by the lower bound.

However, in contrast to the research cited above, other work finds that the constraint imposed by the lower bound led to materially worse outcomes after the crisis, despite the new policy tools. In a 2015 paper, Engen, Laubach, and Reifschneider used simulations of FRB/US, a model of the U.S. economy used extensively by Federal Reserve Board staff in forecasting and policy analysis, to perform a retroactive assessment of the macroeconomic effects of the Fed's policies. They found that, taken together, QE and forward guidance helped to ease financial conditions after the lower bound was reached, but that the economy nevertheless enjoyed a meaningful boost beginning only in 2011. The limited benefit of the new tools in 2009-2010, according to their simulations, was the result of the ineffectiveness of the Fed's early forward guidance, as noted earlier; the gradual accumulation of the effects of asset purchases, which peaked only after the introduction of QE3 in 2012; and, importantly, the lagged effects inherent in all monetary policies. In 2011, these authors found, use of the new tools began to speed up the recovery appreciably. That led to an unemployment rate in early 2015 about 1-1/4 percentage points lower and, slightly later, to inflation about ½ percentage point higher, relative to the counterfactual with no use of new tools.

In a similar vein, Eberly, Stock, and Wright (2019) found that post-crisis monetary policies reduced the slope of the yield curve and assisted the recovery. However, they estimated that an unconstrained monetary policy would have set the federal funds rate as much as 5 percentage points below zero, and that the new policies made up only about 1 percentage point. Gust et al. (2017), previously cited, also found that the lower bound significantly constrained monetary policy during and after the crisis. Based on simulations, they calculated that the lower bound accounted for about 30 percent of the sharp contraction in 2009 and also contributed importantly to the slowness of the recovery.

My reading of the post-crisis experience is that, in both the United States and elsewhere, the new policy tools helped ease financial conditions and led ultimately to significantly better economic outcomes than would have otherwise occurred. In particular, model simulations do not fully account for the beneficial effects of the policy interventions on confidence, risk-taking, and credit flows, each of which was badly damaged by the crisis. However, it also seems unlikely that the new tools deployed during the Great Recession entirely compensated for the limits imposed by the lower bound. Particularly in the early post-crisis period, monetary policymakers were uncertain about the economic outlook, concerned about the costs and risks of the new tools, and learning through experience how to implement and communicate about them. Thus, policymakers were more cautious and less effective than they would be later. Notably, in the United States, neither QE nor forward guidance was explicitly tied to economic conditions until the introduction of state-contingent guidance for QE3 in late 2012. And, in retrospect, the economic thresholds set by the FOMC for those policies were insufficiently aggressive. It also took time for financial market participants and others to understand the new tools and the evolving reaction functions of central banks. While these observations imply that the early stage of the recovery from the Great Recession were less strong than it conceivably could have been, they also suggest that, with improved understanding and the benefit of experience, these policies could be significantly more effective the next time they are needed.[24]

B. How Much Policy Space Can the New Monetary Tools Provide?

Looking forward, in a world in which short-term interest rates could hit the lower bound much more frequently, and traditional monetary policies accordingly could be less effective, how

[24] The Federal Reserve's QE was also partially offset by a contemporaneous Treasury policy of lengthening the maturity of its debt issuance, a situation that should be avoided in the future (Greenwood et al., 2014).

much additional policy space can the new monetary tools provide? As noted by Kiley and Roberts (2017) and others, and as I will demonstrate, the answer depends importantly on the prevailing level of the neutral interest rate, defined here as the interest rate associated with full employment and inflation at target in the long-run steady state—and, therefore, with monetary policies that, on average, are neither expansionary nor contractionary. I focus here on the potential only of QE and forward guidance, leaving aside other tools, like funding-for-lending and negative interest rates, that might provide some additional space if necessary.

A small literature has used DSGE models to study this issue. For example, Gertler and Karadi (2013) modeled QE as a means by which the central bank can substitute for the private sector in intermediating credit during periods of financial stress. Incorporating this interpretation into an otherwise standard new Keynesian model, they found in simulations that QE can have powerful effects on output but—not unexpectedly, given their modeling approach—that these effects are largely confined to periods of disruption in private credit flows. Sims and Wu (2019) expanded the Gertler-Karadi framework to include forward guidance (and negative interest rates as well). They found that QE is particularly effective in achieving monetary policy objectives, largely offsetting the lower bound in both a simulation meant to mirror the Great Recession and in simulations aimed at capturing the long-run behavior of the U.S. economy. These studies, and others in the DSGE tradition, improve our understanding of specific mechanisms by which QE and other new tools affect the economy. The tradeoff is that, in their focus on particular mechanisms, these models may omit other key channels. For example, the Gertler-Karadi framework does not include a portfolio balance channel for QE, despite the evidence in its favor.

With the microfoundations of the new tools still under construction, many studies of the potential role for such policies have used FRB/US or other macroeconometric models favored by central banks. These models, though motivated by economic theory, typically contain ad hoc elements. Their advantages are that they are flexible, include substantial sectoral detail, and—having been workhorses of policy analysis for many years—tend to produce quantitatively plausible results in diverse scenarios. Importantly for this purpose, FRB/US and similar models include rich descriptions of the financial sector and the linkages between financial conditions and the real economy. Given estimates of the financial effects of new policy tools, these models can therefore be used to trace out the expected macroeconomic consequences of their use.

For example, Reifschneider (2016) used FRB/US simulations to evaluate the ability of the Fed to respond to a hypothetical severe recession. He found that, assuming a nominal neutral interest rate of 3 percent, a combination of forward guidance and QE could provide enough stimulus to substantially offset the effects of the lower bound. Chung et al. (2019), also using FRB/US simulations and studying a similar scenario, were somewhat more pessimistic, finding that forward guidance and QE would be "modestly effective" in promoting recovery and returning inflation to target but would do little to limit the initial rise in unemployment in a severe recession. The differences in their results appear to be due to more-conservative assumptions by Chung et al. (2019) about the effects of asset purchases on rates, as well as assumptions about initial conditions, the baseline policy rule, and expectations formation that differ from some other papers in this literature. Their finding that the new monetary tools would do little to limit the initial rise in unemployment following a severe recessionary shock seems largely to reflect estimated lags of monetary policy, traditional or nontraditional. The existence of these lags provides an argument for more-proactive policies, and perhaps for policy frameworks that lead financial market participants and others to understand in advance that policymakers will respond aggressively when the short rate hits the lower bound.

An alternative approach to using FRB/US to study a single historical episode or hypothetical scenario is to use the model to simulate the long-run behavior of the U.S. economy under differing policy rules or frameworks, with shocks drawn from the historical distribution of model residuals. Because they allow researchers to study the performance of alternative policies under a realistic mix of shocks, including the possibility that adverse shocks may hit an economy already in recession, so-called stochastic simulations arguably provide more robust assessments of policy alternatives. Studying the long-run behavior of the model, as opposed to simulating the "next recession," is also more useful from the perspective of choosing among policy frameworks or toolkits, which once decided upon are likely to remain in place for an extended period.

Kiley and Roberts (2017) and Bernanke, Kiley, and Roberts (2019) used stochastic simulations in FRB/US to study the performance of alternative monetary policy rules and frameworks near the lower bound. However, neither of these papers considered central bank asset purchases. Kiley (2018) remedied this omission, using FRB/US simulations to study the effects of the systematic use of QE (without forward guidance). He considered Fed balance sheet rules of varying aggressiveness, in which the quantity of assets purchased after the policy rate hits zero is tied to the estimated output gap. For a nominal neutral interest rate of 3 percent, he found that QE programs can overcome a significant portion of the effects of the lower bound. Chung et al. (2019), mentioned above, also conducted stochastic simulations that included asset purchases, incorporating anticipatory effects of future purchases. As noted, their work finds somewhat more modest effects of QE on the economy.

Some new simulation results

In the rest of this lecture, I present new simulation results aimed at assessing how much policy space the new monetary tools could provide prospectively. Like the papers described immediately above, I employ stochastic simulations of FRB/US to compare expected economic performance under alternative monetary policy frameworks, given historically realistic patterns of shocks. So as to consider cases in which the lower bound is an important constraint, I assume that the real and nominal neutral interest rates remain historically low. Specifically, letting r^* be the *real* neutral rate, I consider the cases $r^* = 1$ and $r^* = 0$, which bracket some standard estimates (Williams, 2018). Unless otherwise stated, I will also assume that the central bank's inflation target is 2 percent and that long-run inflation expectations are anchored at that level. If i^* is the *nominal* neutral interest rate, then the two cases considered correspond to $i^* = 3$ and $i^* = 2$. We know from Kiley and Roberts (2017) that $i^* = 3$ is sufficiently low as to lead, under traditional monetary policies, to frequent encounters with the lower bound. However, it is possible of course that the nominal neutral rate is, or will become, lower even than my assumed case of $i^* = 2$. I return to this possibility below.

The alternative policies to be evaluated are listed in the leftmost panels of Tables 3 and 4 below. Briefly, the policies considered are as follows:

Baseline rules. The traditional policy approach, taken here as the baseline, is represented by variants of the standard Taylor (1993) rule. I assume the "balanced approach" version of the rule, which gives greater relative weight to unemployment than Taylor's original formulation (Yellen, 2017). I assume also that the rule is inertial, that is, the policy rate depends in part on the lagged policy rate, with a coefficient of 0.85 in quarterly data. I report results for the central case in which the central bank's inflation target equals 2 percent ($\pi^* = 2$) but also for alternative inflation targets ($\pi^* = 4$ and $\pi^* = 5$). Higher inflation targets are assumed here to result in one-for-one increases in the nominal neutral rate, thereby affording more policy space. Also reported are results for the case, labeled "unconstrained" in the tables, in which $\pi^* = 2$ but the constraint imposed by the zero lower bound on the short-term rate is ignored. Comparing the unconstrained case to other policy rules measures the costs imposed by the lower bound.

Threshold forward guidance. As in Chung et al. (2019) and Bernanke, Kiley, Roberts (2019), I consider variants of forward guidance in which, once the short-term rate is constrained by the lower bound, the central bank promises to hold the policy rate at zero until inflation has reached a specified level.[25] Once that threshold is reached, policy reverts to the baseline Taylor rule. I report results for three alternative inflation thresholds: 1.75, 2.0, and 2.25 percent. I also considered thresholds based on the unemployment rate (not reported), with results that were qualitatively similar to the policies using inflation thresholds.

In some standard models, the implied effects of forward guidance on the economy are implausibly large—the so-called forward guidance puzzle (Del Negro, Giannoni, and Patterson, 2013; McKay, Nakamura, and Steinsson, 2016). The puzzle appears to be smaller in FRB/US than in other models (Chung, 2015; Kiley and Roberts, 2017). Nevertheless, to be conservative, I imposed the restriction that agents do not expect forward guidance to be effective for more than 28 quarters. After that, they expect policy to revert to the baseline Taylor rule. Assuming that guidance is credible for as long as 28 quarters seems reasonable, because the guidance is at worst mildly time-inconsistent—the implied overshoots of the inflation target are small and might well be welcome if the FOMC were concerned about reinforcing the credibility of its symmetric inflation target after a period of inflation undershoot. In any case, as will be seen, I do not find forward guidance to be particularly powerful in my simulations, and my overall results do not rely on unrealistic foresight on the part of the public.

Quantitative easing. Following Kiley (2018), I consider four alternative QE policies, ranging from least aggressive (A) to most aggressive (D). In all cases, QE is assumed to be deployed when the output gap has become sufficiently large. For example, under QE(A), the least aggressive policy, QE is assumed to be initiated when the output gap is 5 percent, with purchases continuing at a rate of $25 billion per quarter for every percentage point that the output gap exceeds 5 percent. The QE(D) policy, the most activist, is initiated when the output gap is 2.5 percent, at a pace of $50 billion per quarter for each percentage point that the output gap exceeds 2.5 percent. For each of the QE programs, when the output gap shrinks sufficiently,

[25] Specifically, inflation is defined as the four-quarter percent change in the core PCE price index.

asset purchases are assumed to end, and the central bank's balance sheet begins a gradual wind-down. (See Kiley, 2018, or the online appendix for precise specifications.) The simulations keep track of the size of the central bank's balance sheet, with new QE programs assumed to add to assets already on the balance sheet from any prior programs. Thus, it is possible to observe the long-run distribution of balance sheet sizes associated with any particular strategy.

Following Engen et al. (2015), Reifschneider (2016), and Kiley (2018), and consistent with the empirical evidence (e.g., Ihrig et al., 2018), I assume that $500 billion in asset purchases by the Fed lowers the 10-year Treasury yield by 20 basis points, and the 5-year and 30-year yields by 17 and 7 basis points, respectively.[26] Assuming smaller effects of QE on rates would increase the scale of asset purchases required to achieve any particular economic outcome in my simulations but otherwise not affect the results. I assume that the effects of QE on longer-term rates are linear, exhibiting neither increasing nor decreasing returns. Since the ability of QE to depress term premiums may be limited in practice, I also ran simulations (not reported) in which term premiums are constrained from falling more than 120 basis points below their steady-state, no-QE level, consistent with the maximum effect found by Ihrig et al. (2018) for the Great Recession period. This additional assumption led to no material change in the results.

Combination policies. Finally, I consider policies that combine forward guidance, with an inflation threshold of 2 percent, with QE programs of varying aggressiveness.

For each policy rule to be evaluated, I ran 500 simulations of FRB/US, drawing model residuals from the 1970-2015 period. Each simulation is 200 periods (quarters). Results are reported for the second 100 quarters of each simulation, with the first 100 quarters used to set initial conditions. Except for the 28-quarter limit on the credibility of forward guidance, I assume model-consistent expectations, that is, the agents in the model are assumed to understand the dynamics of the economy, including the form of the policy rule. Since the comparisons here are between steady states, model-consistent expectations seems the right assumption. An alternative assumption is that only participants in financial markets know the model and the policy rule; see Bernanke, Kiley, and Roberts (2019) for a discussion. Simulations using this alternative expectational assumption do not change the broad conclusions of the study; under the alternative

[26] The $500 billion is roughly in 2014 dollars—roughly, because it draws from several empirical sources. Alternatively, the QE effects could have been calibrated to asset purchases relative to GDP or to the outstanding stock of Treasury securities.

assumption, forward guidance becomes somewhat less effective (not surprisingly), but QE becomes slightly more effective. The solution method imposes a lower bound of zero on the current short-term interest rate and on expected future short-term rates. Longer-term interest rates are not prevented from going negative, reflecting negative term premiums; see below for further discussion.

Results are shown for the case *r* = 1* in Table 3, and *r* = 0* in Table 4. The corresponding nominal neutral interest rates, *i**, are in each case assumed to be the sum of the assumed real neutral rate, *r**, and the inflation target, π*. In particular, the nominal neutral rate is 3 percent in Table 3 and 2 percent in Table 4, except for the two policy rules in each table that assume an inflation target higher than 2 percent.

Table 3: Performance of Alternative Policies in Stochastic Simulations

r* = 1

	Mean Loss	Mean Unemploy-ment Gap	Mean Inflation	ELB Frequency	Mean ELB Duration	Mean Stock of Assets($B)	Mean Peak Stock of Assets($B)
Panel A: Baseline Rules							
Taylor, $\pi^* = 2$	9.8	0.7	0.9	31.2	16.3	0	0
Taylor, $\pi^* = 4$	4.3	0.1	3.8	4.6	9.1	0	0
Taylor, $\pi^* = 5$	3.7	0	5.0	1.6	7.0	0	0
Taylor unconstrained, $\pi^* = 2$	3.3	0	2.0	-	-	0	0
Panel B: Threshold-based Forward Guidance, $\pi^* = 2$							
Inflation > 1.75	7.6	0.4	1.4	31.6	16.7	0	0
Inflation > 2	7.0	0.3	1.6	30.1	16.3	0	0
Inflation > 2.25	6.5	0.2	1.7	28.3	16.0	0	0
Panel C: Quantitative Easing, $\pi^* = 2$							
QE (A)	6.1	0.4	1.4	22.7	12.1	269	1,000
QE (B)	5.2	0.3	1.6	18.4	10.9	375	1,507
QE (C)	4.5	0.2	1.7	15.6	9.4	502	1,761
QE (D)	3.7	0	1.9	11.3	7.5	698	2,627
Panel D: Forward Guidance + Quantitative Easing, $\pi^* = 2$							
Inflation > 2 + QE (B)	3.8	0	2.0	20.7	11.8	257	1,103
Inflation > 2 + QE (C)	3.6	-0.1	2.1	18.5	11.5	364	1,348
Inflation > 2 + QE (D)	3.2	-0.2	2.2	15.7	10.5	524	2,059

Note: Mean Loss = $= \frac{1}{N}\frac{1}{T}\sum_{j=1}^{N}\sum_{i=1}^{T}(\mathbf{1}_{\widehat{u_{i,j}}>0} \times \widehat{u_{i,j}}^2) + (\pi_j - \pi^*)^2$ for i, j period-simulations. Results based on 500 simulations of 100 quarters each.
Source: Author's calculations.

Table 4: Performance of Alternative Policies in Stochastic Simulations

r* = 0

	Mean Loss	Mean Unemploy-ment Gap	Mean Inflation	ELB Frequency	Mean ELB Duration	Mean Stock of Assets($B)	Mean Peak Stock of Assets($B)
Panel A: Baseline Rules							
Taylor, $\pi^* = 2$	15.5	1.4	0.1	56.4	24.7	0	0
Taylor, $\pi^* = 4$	6.1	0.3	3.6	12.7	11.6	0	0
Taylor, $\pi^* = 5$	4.3	0.1	4.8	4.6	9.1	0	0
Panel B: Threshold-based Forward Guidance, $\pi^* = 2$							
Inflation > 1.75	13.8	1.1	0.5	58.1	25.2	0	0
Inflation > 2	12.9	1.0	0.7	56.1	24.6	0	0
Inflation > 2.25	11.9	0.9	0.9	53.6	23.4	0	0
Panel C: Quantitative Easing, $\pi^* = 2$							
QE (A)	9.3	0.8	0.8	45.8	17.9	478	1,660
QE (B)	7.3	0.6	1.0	39.3	15.9	660	2,563
QE (C)	6.3	0.5	1.2	34.0	13.8	808	2,584
QE (D)	4.6	0.2	1.6	24.9	10.3	1,050	3,757
Panel D: Forward Guidance + Quantitative Easing, $\pi^* = 2$							
Inflation > 2 + QE (B)	5.7	0.3	1.6	41.6	15.9	525	2,106
Inflation > 2 + QE (C)	5.0	0.1	1.7	37.0	14.2	643	2,194
Inflation > 2 + QE (D)	3.8	-0.1	2.0	28.6	11.9	841	3,176

Note: Mean Loss = $= \frac{1}{N}\frac{1}{T}\sum_{j=1}^{N}\sum_{i=1}^{T}(\mathbf{1}_{\widehat{u_{i,j}}>0} \times \widehat{u_{i,j}}^2) + (\pi_j - \pi^*)^2$ for i, j period-simulations. Results based on 500 simulations of 100 quarters each.
Source: Author's calculations.

For each policy rule, the mean loss across simulations is shown in the first column of the table. The loss for each simulation is defined as the sum of the squared deviations of inflation from target and of the unemployment rate from the natural unemployment rate (the "unemployment gap"), except that no penalty is assigned when unemployment is below the natural rate. Higher losses imply worse average performance. The results are not much affected if positive and negative unemployment gaps are treated symmetrically, as is more conventional, or if the loss is calculated in terms of the output gap instead of the unemployment gap. Mean losses are a useful summary measure that provides a natural way to rank alternative policies, evaluate the marginal benefits of new policy tools, or—by comparing losses of alternative policies to that of the unconstrained baseline Taylor rule—assess how close those policies can come to fully offsetting the effects of the lower bound.

Also shown in Tables 3 and 4, for each policy rule, are the mean unemployment gap across simulations, the mean inflation rate, the percentage of quarters in which the simulated economy is at the effective lower bound (ELB frequency), the mean duration of lower-bound episodes (mean ELB duration), the mean stock of assets held by the central bank as the result of QE programs (in billions of dollars), and the mean *peak* stock of assets attained, all averaged over the 500 simulations of the rule.

There are several takeaways from Tables 3 and 4. First, as previous work has demonstrated, traditional policy rules with a 2 percent inflation target (and with no use of the new policy tools) perform quite poorly when neutral interest rates are low. For example, when $r^* = 1$ and $i^* = 3$ (Table 3), the baseline rule leaves the economy at the lower bound some 31 percent of the time, with mean inflation less than 1 percent, well short of the 2 percent target, and a mean unemployment gap of 0.7 percent. When $r^* = 0$ and $i^* = 2$ (Table 4), the baseline policy rule leaves the economy at the lower bound 56 percent of the time. These results, which are similar to those of Kiley and Roberts (2017), are if anything too favorable to the baseline rules, since they assume that inflation expectations remain at target. If expectations fall in response to persistently below-target inflation, as no doubt they ultimately would, then the nominal neutral interest rate would decline, reducing policy space yet further.

Second, higher inflation targets, which for these simulations I assume to result one-for-one in higher nominal neutral rates, improve the performance of the baseline rules, by increasing policy space and making encounters with the lower bound less frequent. For example, with $r^* = 1$ (Table 3), an inflation target of 5 percent would result (by assumption) in a neutral nominal rate $i^* = 6$. In this case, according to these simulations, the lower bound would bind less than 2 percent of the time, and the mean loss associated with the baseline rule would be close to the fully unconstrained case, illustrating the increased policy space. Importantly, though, the losses calculated here ignore the costs of having a permanently higher inflation rate, as well as the costs of the transition to a higher inflation target, both of which likely would be significant.[27]

[27] An important transition cost would be the uncertainty and volatility associated with having to un-anchor inflation expectations and re-anchor them at a higher level, which could take a long time and damage the Fed’s credibility. Running the economy hot to reach the higher inflation target could have both benefits (including the benefits of a “hot” labor market) and costs (such as financial stability risks).

Moreover, it may be that raising the inflation target would provide less additional space than assumed in these simulations, because at higher inflation rates economic behavior could change in ways that reduce the potency of monetary policy (L'Huillier and Schoenle, 2019).

Third, taken separately, both forward guidance and QE lead to improved performance, relative to the baseline rule with a 2 percent inflation target. However, the economic benefits of forward guidance alone in these simulations are moderate, and less than in much of the literature (e.g., Bernanke, Kiley, and Roberts, 2019). The reduced impact of forward guidance in these simulations appears to be the result of my limitation of credible guidance to 28 quarters in the future, which implies that this policy is relatively ineffective during long episodes at the lower bound. In contrast, QE taken alone appears powerful in these simulations: With $r^* = 1$ and $i^* = 3$ (Table 3), the most aggressive QE program, QE(D), achieves economic outcomes that are about the same as the baseline rule with a 5 percent inflation target (for which $i^* = 6$), and that are also relatively close to the unconstrained baseline rule, consistent with Kiley (2018). With $r^* = 1$, the mean *peak* stock of central bank assets for this policy (over a typical 25-year period) is about $2.6 trillion, a high value but not out of the range of recent experience. However, the QE(D) policy results in the economy spending about 11 percent of the time at the lower bound, compared to 2 percent of the time for the balanced Taylor rule with a 5 percent inflation target. With $r^* = 0$ and $i^* = 2$ (Table 4), the performance of the QE(D) program deteriorates somewhat but remains close to that of the baseline rule with a 5 percent inflation target.

Fourth, importantly, for both $r^* = 1$ (Table 3) and $r^* = 0$ (Table 4), corresponding to nominal neutral rates of 3 percent and 2 percent respectively, combinations of QE and forward guidance can almost fully compensate for the effects of the lower bound. For example, for $r^* = 1$, the combination of a 2 percent inflation threshold for forward guidance and the QE(C) program produces a lower average loss than the baseline policy with a 5 percent inflation target; and the same forward guidance combined with QE(D) implies a lower loss than even the unconstrained baseline policy. For $r^* = 0$, the combination of a 2 percent inflation threshold and the QE(D) policy yields a lower loss than the baseline policy with a 5 percent inflation target, and an only slightly greater loss than that of the (hypothetical) unconstrained baseline policy. None of these combination policies implies unreasonably high average durations of lower-bound episodes or peak asset central-bank accumulations outside historical experience. In contrast to the baseline rules, these policies also produce inflation rates near target, consistent with inflation expectations remaining well anchored.

The finding that, with an inflation target of 2 percent, a plausible combination of new policy tools performs as well as traditional policies with an effective inflation target of 5 percent, yields two implications. First, it suggests that, when the nominal neutral rate is in the range of 2-3 percent, the new monetary tools are capable of adding about 3 percentage points worth of policy space, relative to traditional policies. That is, when the nominal neutral rate is in the range of 2-3 percent, the use of the new tools allows policymakers to achieve economic outcomes similar to those that could be attained by traditional policies if the nominal neutral rate were 3 percentage points higher, which in turn are close to the outcomes traditional policies could achieve in the absence of any constraint on short-term rates. Second, the finding significantly weakens the argument for raising the inflation target to create more policy space. Unless the direct costs of low nominal interest rates, in terms of increased financial stability risks for example, exceed the costs of reaching and maintaining 5 percent inflation, the use of new policy tools is preferable to a higher inflation target.

Obviously, there are qualifications. Tables 3 and 4 include no standard errors, but in reality, the uncertainty surrounding the reported estimates is high. Reasonable people can disagree about the precise effects of asset purchases on financial conditions, the credibility of forward guidance, or the effects of changes in financial conditions on growth and inflation. And whatever its strengths, FRB/US is just one, imperfect model of the U.S. economy. On the other hand, the reported simulations may in some ways understate the potential of new monetary tools. For example, I have ruled out the use of negative short-term rates, funding-for-lending programs, and other tools that might provide additional policy space. I have also excluded MBS purchases, which could reduce the spread between mortgage rates and Treasury yields. A policy framework that made inflation thresholds a condition for raising rates from the lower bound, if it led market participants to expect that policy response even in advance of rates hitting the bound, would be more powerful than the threshold-based guidance in the simulations. And FRB/US does not include all of the new tools' potential channels of effect, such as the possible impacts of asset purchases on bank lending (Rodnyansky and Darmouni, 2017).

The role of the neutral interest rate

An especially important qualification to my results is the uncertainty about the level of the neutral interest rate. As I have discussed, if the nominal neutral rate is in the range of 2-3 percent or higher, the use of the new monetary tools appears able (based on the simulations) largely to overcome the effects of the lower bound on short-term rates, adding about 3 percentage points of policy space. If the assumed nominal neutral rate is much lower than 2 percent or so, simulations of FRB/US (not reported) continue to show substantial benefits from using the new monetary tools, relative to baseline policies that make no use of these tools. However, in this case the losses for all policies are greater than those of the (hypothetical) unconstrained policy, implying that even active use of the new tools cannot compensate for the constraint of the lower bound. Moreover, for very low nominal neutral rates, simulations of all policies—both traditional and those employing the new monetary tools—show the economy spending a large fraction of the time at the lower bound, and with longer-term interest rates frequently in negative territory, reflecting negative term premiums. For any given policy, these adverse outcomes are much less likely in the simulations when the neutral rate is in the 2-3 percent range.[28]

A finding that long-term rates are frequently negative in the simulations is a concern, for several reasons. First, as noted earlier, if bond market participants believe that the lower bound on short-term rates is zero, then they may be unwilling to hold longer-term bonds yielding less than zero (Grisse, Krogstrup, and Schumacher, 2017). Thus, at least for the United States and other jurisdictions that have indicated that they are unlikely to use negative short-term rates, simulations that assume that longer-term rates can be negative may overstate the amount of stimulus that is attainable in practice. Second, interest rates that are zero or negative much of the time raise concerns about financial instability and other risks, as discussed earlier. Thus, although it remains true that the new monetary tools add policy space when the nominal neutral rate is below 2 percent or so, in that range none of the policy approaches considered here can be thought fully satisfactory.

[28] For example, for $r^* = 1$, the simulated 10-year yield is negative 21.0 percent of the time for the baseline rule but only 0.2 percent of the time for the baseline rule with a 5 percent inflation target and 2.2 percent of the time for the inflation > 2 + QE(D) policy. For $r^* = 0$, the corresponding figures are 50.9, 1.2, and 12.4 percent.

What is the best estimate of the nominal neutral rate? Sufficient conditions for the nominal neutral rate to be in the 2-3 percent range assumed here are that inflation expectations be close to the 2 percent target and that the real neutral rate be at least zero. Both conditions are consistent with most estimates for the United States. For example, as of this writing, all 17 FOMC participants reporting in the Fed's Summary of Economic Projections have provided estimates of the long-run nominal policy rate between 2.0 and 3.3 percent (with a median of 2.5 percent), implying a real neutral rate between zero and 1.3 percent (median 0.5 percent). The Federal Reserve Bank of New York, using the methods of Laubach and Williams (2003), reports a current estimate of the real neutral rate above 0.9 percent, implying a nominal neutral rate close to 3.0 percent. Alternatively, using estimates from the term structure model of Adrian, Crump, and Moench (2013), the New York Fed reports a 10-year average expected short rate, a proxy for the nominal neutral rate, of 2.8 percent. Combining macroeconomic and term structure data, Davis, Fuenzalida, and Taylor (2019) obtain estimates close to those of Laubach and Williams (2003). All of these estimates are in the 2-3 percent range in nominal terms.[29]

On the other hand, Kiley (2019) has recently argued that, when global factors are taken into account, the best estimate of the real neutral rate in the United States might be much lower than the current consensus, perhaps as low as -1 percent, implying a nominal neutral rate in the range of 1 percent. Although Kiley's estimate is an outlier, it does underline the uncertainty around all estimates of the neutral rate. One current source of uncertainty is the difficulty in determining whether the sharp reductions in global interest rates in the wake of the financial crisis and the Great Recession imply corresponding permanent—indeed, ongoing—declines in neutral rates. Since the usual arguments hold that r^* is determined primarily by slow-moving forces, like demography and technology, it is possible that the estimates by Kiley and others are taking too much signal from recent developments, which may reflect persistent but ultimately fading after-effects of the crisis as well as of shortfalls in aggregate demand in some major foreign economies. On the other hand, perhaps the overheated financial conditions before the crisis kept rates artificially high, and the recent downward trend in the neutral rate will continue.

[29] As I write, the 10-year Treasury yield is a bit below 2 percent. That is entirely consistent with the nominal neutral rate being in the range of 2-3 percent; it implies only that current policy is slightly accommodative. In simulations with, say, $r^* = 1$ and $i^* = 3$, simulated long-term rates frequently fall below their current real-world level.

If the nominal neutral rate in the United States does ultimately prove to be as low as 1 percent, as Kiley finds, then moving that rate higher—to provide more monetary policy space, and perhaps for other reasons including reducing financial stability risks—will be an important goal of public policy. In that situation, the case for a moderate rise in the inflation target would certainly be stronger, notwithstanding the associated costs. That step seems premature as of this writing. However, a cautious approach could include making plans to increase the countercyclicality of fiscal policy, for example, by increasing the use of automatic stabilizers. And certainly, whatever the levels of the neutral rate, it is essential that the Fed keep inflation expectations near target, defending against inflation shortfalls as vigorously as it defended against too-high inflation in the past.

My simulation results apply only to the United States and cannot be directly extended to other countries. Two conclusions of this lecture can safely be extended, however: that the new monetary tools are effective and should remain in the policy toolbox; and that the ability of those tools to overcome the (possibly negative) lower bound on rates is greater, the higher the nominal neutral rate in the jurisdiction in question. In that respect, it is interesting that (other than Kiley, 2019), many current estimates place the real neutral rate in major foreign economies above zero. For example, the New York Fed reports estimates (based on Holston, Laubach, and Williams, 2017) of the real neutral rates of Canada, the euro area, and the United Kingdom of 1.6, 0.2, and 1.4 percent, respectively. Using the methods of Laubach and Williams (2003) as well as a DSGE model, Okazaki and Sudo (2018) estimate the real neutral rate in Japan to be close to 1.0 percent. Estimates by Davis, Fuenzalida, and Taylor (2019) of the real neutral rate in six advanced economies range between roughly zero and modestly positive. If the real neutral rate is zero or above, and with most countries targeting inflation around 2 percent, then shortfalls of the nominal neutral rate from 2 percent or so primarily reflect shortfalls of inflation expectations. In other words, the current constraints on monetary policy in several regions, notably the euro area and Japan, arguably arise in substantial part from the fact that, for various reasons, inflation expectations in those regions have fallen too low. The challenge for those central banks, perhaps in collaboration with the fiscal authorities, is to move inflation expectations closer to target. If that can be achieved, then monetary policy, augmented by the new policy tools, could regain much of its potency.

III. Conclusions

This lecture has reviewed the experience with, and the future potential of, the new monetary tools, especially quantitative easing and forward guidance. Although there are dissenting views, most research finds that QE has significant and persistent effects on financial conditions, even when financial markets are not dysfunctional. Forward guidance can help inform financial markets about policymakers' likely responses to economic developments and allow them to commit to future policy actions, including lower-for-longer rate policies, that create greater stimulus today.

Major central banks actively used both QE and forward guidance following the financial crisis. Although these tools helped cushion the economic effects of the crisis, their application was hindered at times, with the benefit of hindsight, by excessive concern about the costs and risks of the new tools and by policymakers' need to learn how better to structure and to implement these policies, and how to communicate about them. Better execution of the new policy tools, together with increased public understanding and acceptance, should make these tools more effective in the future. For example, policy frameworks that lay out in advance the nature of the forward guidance policymakers expect to use at the lower bound will make that guidance clearer, more credible, and more effective when it is needed. New tools other than QE and forward guidance, such as funding-for-lending programs, negative policy rates, and yield curve control, could in some circumstances be useful as well. In particular, the Federal Reserve should maintain constructive ambiguity about negative policy rates and consider yield curve control at shorter horizons as a means of reinforcing forward guidance. However, although the new tools can be used with the knowledge that their costs and risks have generally proved moderate, vigilance against risks to financial stability remains essential.

How much policy space can the new monetary tools provide? The answer depends on the level of the nominal neutral interest rate, the interest rate consistent with full employment and inflation at target in the long run. If that rate is in the range of 2 to 3 percent or higher, consistent with most estimates for the United States, then simulations of the Fed's FRB/US model suggest that a combination of QE and forward guidance can largely compensate for the effects of the lower bound, providing about 3 percentage points of additional policy space. In these circumstances, the use of new policy tools seems clearly preferable to raising the inflation target, a measure that may increase policy space by a comparable amount but that carries with it the additional costs of the transition to the higher target and of the higher long-run inflation rate.

However, if the nominal neutral interest rate is much lower than 2 percent, then the model simulations imply that the new monetary tools—while still providing valuable policy space—can no longer fully compensate for the effects of the lower bound. Moreover, in that case, any monetary policy approach, with or without the new tools, is likely to involve extended periods of short rates at the lower bound, as well as longer-term yields that are often very low or negative, which may pose risks to financial stability or impose other costs. Should the neutral rate ultimately prove to be that low, then additional measures to increase policy space, including a moderate increase in the inflation target or significantly greater reliance on active fiscal policy for economic stabilization, might become necessary. For now, though, major changes seem premature. A reasonable interim approach could involve working to increase the countercyclicality of fiscal policy, for example, through increased use of automatic stabilizers. And, of course, in any case, the Fed must work to keep inflation expectations from falling below target, which would bring down the neutral interest rate and limit policy space.

I began this lecture by referring to the victory over inflation under Fed chairs Volcker and Greenspan, an experience that promoted the view among central bankers that lower inflation is always better. We have come almost full circle: In a world in which low nominal neutral rates threaten the capacity of central banks to respond to recessions, too-low inflation can be dangerous. Consistent with their declared "symmetric" inflation targets, the Federal Reserve and other central banks should defend against inflation that is too low as least as vigorously as they resist inflation that is too high.

References

Aaronson, Stephanie, Mary Daly, William Wascher, and David Wilcox. 2019. "Okun Revisited: Who Benefits Most from a Strong Economy?" *Brookings Papers on Economic Activity* 50 (Spring).

Adrian, Tobias, Richard K. Crump, and Emanuel Moench. 2013. "Pricing the Term Structure with Linear Regressions." *Journal of Financial Economics* 110 (1): 110–38.

Adrian, Tobias, and Nellie Liang. 2018. "Monetary Policy, Financial Conditions, and Financial Stability." *International Journal of Central Banking*, January, 73–131.

Altavilla, Carlo, Luca Brugnolini, Refet Gürkaynak, Roberto Motto, and Giuseppe Ragusa. 2019. "Monetary Policy in Action: Multiple Dimensions of ECB Policy Communication and Their Financial Market Effects." *Center for Economic Policy Research, VOX*.

Altavilla, Carlo, Giacomo Carboni, and Roberto Motto. 2015. "Asset Purchase Programmes and Financial Markets: Lessons from the Euro Area." European Central Bank Working Paper 1864.

Altavilla, Carlo, and Domenico Giannone. 2015. "The Effectiveness of Nonstandard Monetary Policy Measures: Evidence from Survey Data." Federal Reserve Bank of New York Staff Report 752.

Ampudia, Miguel, Dimitris Georgarakos, Jiri Slacalek, Oreste Tristani, Philip Vermeulen, and Giovanni Violante. 2018. "Monetary Policy and Household Inequality." European Central Bank Working Paper 2170.

Andrade, Philippe, Christophe Cahn, Henri Fraisse, and Jean-Stéphane Mésonnier. 2019. "Can the Provision of Long-Term Liquidity Help to Avoid a Credit Crunch? Evidence from the Eurosystem's LTRO." *Journal of the European Economic Association* 17 (4): 1070–1106.

Arteta, Carlos, M. Ayhan Kose, Marc Stocker, and Temel Taskin. 2018. "Implications of Negative Interest Rate Policies: An Early Assessment." *Pacific Economic Review* 23 (1): 8–26.

Banerjee, Ryan N., David Latto, and Nick McLaren. 2014. "Using Changes in Auction Maturity Sectors to Help Identify the Impact of QE on Gilt Yields." *The Economic Journal* 124 (576): 453–79.

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

Bernanke, Ben S., Michael T. Kiley, and John M. Roberts. 2019. "Monetary Policy Strategies for a Low-Rate Environment." Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2019-009.

Bernanke, Ben S., and Frederic S. Mishkin. 1997. "Inflation Targeting: A New Framework for Monetary Policy?" *Journal of Economic Perspectives* 11 (2): 97–116.

Bhattarai, Saroj, and Christopher J. Neely. 2016. "An Analysis of the Literature on International Unconventional Monetary Policy." Federal Reserve Bank of St. Louis Working Paper 2016-21.

Bivens, Josh. 2015. "Gauging the Impact of the Fed on Inequality during the Great Recession." Hutchins Center on Fiscal and Monetary Policy at Brookings Working Paper 12.

Black, Fischer. 1995. "Interest Rates as Options." *The Journal of Finance* 50 (5): 1371–76.

Bonis, Brian, Lauren Fiesthumel, and Jamie Noonan. 2018. "SOMA's Unrealized Loss: What Does It Mean?" *FEDS Notes* (blog). August 13, 2018.

Bonis, Brian, Jane Ihrig, and Min Wei. 2017. "Projected Evolution of the SOMA Portfolio and the 10-Year Treasury Term Premium Effect." *FEDS Notes* (blog). September 22, 2017.

Borio, Claudio, and Haibin Zhu. 2012. "Capital Regulation, Risk-Taking and Monetary Policy: A Missing Link in the Transmission Mechanism?" *Journal of Financial Stability* 8 (4): 236–51.

Bowman, David, Christopher Erceg, and Mike Leahy. 2010. "Strategies for Targeting Interest Rates Out the Yield Curve." Board of Governors of the Federal Reserve System.

Brainard, Lael. 2019. "Federal Reserve Review of Monetary Policy Strategy, Tools, and Communications: Some Preliminary Views." Speech presented at the Presentation of the 2019 William F. Butler Award, New York Association for Business Economics, New York, November 26.

Brunnermeier, Markus K., and Yann Koby. 2017. "The 'Reversal Interest Rate': An Effective Lower Bound on Monetary Policy." *Princeton University*, May.

Bundick, Brent, Trenton Herriford, and Andrew Lee Smith. 2017. "Forward Guidance, Monetary Policy Uncertainty, and the Term Premium." Federal Reserve Bank of Kansas City Research Working Paper 17-07.

Caballero, Ricardo J, and Gunes Kamber. 2019. "On the Global Impact of Risk-off Shocks and Policy-Put Frameworks." National Bureau of Economic Research Working Paper 26031.

Cahill, Michael E., Stefania D'Amico, Canlin Li, and John S. Sears. 2013. "Duration Risk Versus Local Supply Channel in Treasury Yields: Evidence from the Federal Reserve's Asset Purchase Announcements." Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2013-35.

Cahn, Christophe, Julien Matheron, and Jean-Guillaume Sahuc. 2017. "Assessing the Macroeconomic Effects of LTROs during the Great Recession." *Journal of Money, Credit and Banking* 49 (7): 1443–82.

Campbell, Jeffrey, Charles L. Evans, Jonas Fisher, and Alejandro Justiniano. 2012. "Macroeconomic Effects of Federal Reserve Forward Guidance." *Brookings Papers on Economic Activity* 43 (1 (Spring)): 1–80.

Campbell, Jeffrey R., Jonas D. M. Fisher, Alejandro Justiniano, and Leonardo Melosi. 2017. "Forward Guidance and Macroeconomic Outcomes Since the Financial Crisis." *NBER Macroeconomics Annual 2016* 31 (May): 283–357.

Carvalho, Carlos, Eric Hsu, and Fernanda Nechio. 2016. "Measuring the Effect of the Zero Lower Bound on Monetary Policy." Federal Reserve Bank of San Francisco Working Paper 2016-06.

Cavallo, Michele, Marco Del Negro, W. Scott Frame, Jamie Grasing, Benjamin Malin, and Carlo Rosa. 2018. "The Fed - Fiscal Implications of the Federal Reserve's Balance Sheet Normalization." *FEDS Notes* (blog). January 9, 2018.

Charbonneau, Karyne B., and Lori Rennison. 2015. "Forward Guidance at the Effective Lower Bound: International Experience." Bank of Canada Discussion Paper 15-15.

Chaurushiya, Radha, and Ken Kuttner. 2003. "Targeting the Yield Curve: The Experience of the Federal Reserve, 1942-51." Board of Governors of the Federal Reserve System.

Chodorow-Reich, Gabriel. 2014. "Effects of Unconventional Monetary Policy on Financial Institutions." *Brookings Papers on Economic Activity* 45 (Spring): 155–204.

Christensen, Jens H. E., and Signe Krogstrup. 2016. "Transmission of Quantitative Easing: The Role of Central Bank Reserves." Federal Reserve Bank of San Francisco Working Paper 2014-18.

Chung, Hess. 2015. "The Effects of Forward Guidance in Three Macro Models." *FEDS Notes* (blog). February 26, 2015.

Chung, Hess T., Etienne Gagnon, Taisuke Nakata, Matthias O. Paustian, Bernd Schlusche, James Trevino, Diego Vilan, and Wei Zheng. 2019. "Monetary Policy Options at the Effective Lower Bound: Assessing the Federal Reserve's Current Policy Toolkit." Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2019-003.

Churm, Rohan, Michael Joyce, George Kapetanios, and Konstantinos Theodoridis. 2018. "Unconventional Monetary Policies and the Macroeconomy: The Impact of the UK's QE2 and Funding for Lending Scheme." *The Quarterly Review of Economics and Finance*, October.

Committee on the Global Financial System. 2019. "Unconventional Monetary Policy Tools: A Cross-Country Analysis." Bank for International Settlement CGFS Paper 63.

Curcuru, Stephanie E., Steven B. Kamin, Canlin Li, and Marius del Giudice Rodriguez. 2018. "International Spillovers of Monetary Policy : Conventional Policy vs. Quantitative Easing." Board of Governors of the Federal Reserve System International Finance Discussion Paper 1234.

D'Amico, Stefania, and Iryna Kaminska. 2019. "Credit Easing versus Quantitative Easing: Evidence From Corporate and Government Bond Purchase Programs." Bank of England Staff Working Paper 825.

D'Amico, Stefania, and Thomas 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.

Davis, Josh, Cristian Fuenzalida, and Alan Taylor. 2019. "The Natural Rate Puzzle: Global Macro Trends and the Market-Implied R*." National Bureau of Economic Research Working Paper 26560.

De Santis, Roberto A. 2019. "Impact of the Asset Purchase Programme on Euro Area Government Bond Yields Using Market News." *Economic Modelling*, June.

Debortoli, Davide, Jordi Galí, and Luca Gambetti. 2019. "On the Empirical (Ir)Relevance of the Zero Lower Bound Constraint." National Bureau of Economic Research Working Paper 25820.

Del Negro, Marco, Marc Giannoni, and Christina Patterson. 2012. "The Forward Guidance Puzzle." Federal Reserve Bank of New York Staff Report 574.

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

Di Maggio, Marco, Amir Kermani, and Christopher Palmer. 2015. "Unconventional Monetary Policy and the Allocation of Credit," December.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl. 2018. "Liquidity, Risk Premia, and the Financial Transmission of Monetary Policy." *Annual Review of Financial Economics* 10 (1): 309–28.

Eberly, Janice C, James H Stock, and Jonathan H Wright. 2019. "The Federal Reserve's Current Framework for Monetary Policy: A Review and Assessment." National Bureau of Economic Research Working Paper 26002.

Eggertsson, Gauti B., and Michael Woodford. 2003. "The Zero Bound on Interest Rates and Optimal Monetary Policy." *Brookings Papers on Economic Activity* 34 (Spring): 139–211.

Engen, Eric M., Thomas Laubach, and David Reifschneider. 2015. "The Macroeconomic Effects of the Federal Reserve's Unconventional Monetary Policies." Board of Governors of the Federal Reserve System Finance and Discussion Series 2015-005.

Eser, Fabian, Wolfgang Lemke, Ken Nyholm, Sören Radde, and Andreea Liliana Vladu. 2019. "Tracing the Impact of the ECB's Asset Purchase Program on the Yield Curve." European Central Bank Working Paper 2293.

Fawley, Brett W., and Christopher J. Neely. 2013. "Four Stories of Quantitative Easing." *Federal Reserve Bank of St. Louis Review* 95 (1): 51–88.

Femia, Katherine, Steven Friedman, and Brian P. Sack. 2013. "The Effects of Policy Guidance on Perceptions of the Fed's Reaction Function." Federal Reserve Bank of New York Staff Report 652.

Fernald, John G., Robert E. Hall, James H. Stock, and Mark W. Watson. 2017. "The Disappointing Recovery of Output after 2009." *Brookings Papers on Economic Activity* 48 (Spring): 1–58.

Feroli, Michael, David Greenlaw, Peter Hooper, Frederic S. Mishkin, and Amir Sufi. 2017. "Language After Liftoff: Fed Communication Away from the Zero Lower Bound." *Research in Economics*, Special issue on Macroeconomics, 71 (3): 452–90.

Gagnon, Joseph E. 2016. "Quantitative Easing: An Underappreciated Success." Peterson Institute for International Economics Policy Brief 16-4.

———. 2018. "QE Skeptics Overstate Their Case." Peterson Institute for International Economics. *Realtime Economic Issues Watch* (blog). July 5, 2018.

Gagnon, Joseph E., Matthew Raskin, Julie Remache, and Brian P. Sack. 2011. "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases." *International Journal of Central Banking* 7 (1): 3–43.

Gertler, Mark. 2017. "Rethinking the Power of Forward Guidance: Lessons from Japan." National Bureau of Economic Research Working Paper 23707.

Gertler, Mark, and Peter Karadi. 2013. "QE 1 vs. 2 vs. 3. . . : A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool." *International Journal of Central Banking* 9 (1): 5–53.

Gilchrist, Simon, and Egon Zakrajsek. 2013. "The Impact of the Federal Reserve's Large-Scale Asset Purchase Programs on Corporate Credit Risk." *Journal of Money, Credit and Banking* 45 (s2): 29–57.

Gourio, François, Anil K Kashyap, and Jae Sim. 2017. "The Tradeoffs in Leaning Against the Wind." National Bureau of Economic Research Working Paper 23658.

Greenlaw, David, James D Hamilton, Ethan Harris, and Kenneth D West. 2018. "A Skeptical View of the Impact of the Fed's Balance Sheet." National Bureau of Economic Research Working Paper 24687.

Greenwood, Robin, Samuel G. Hanson, Joshua S. Rudolph, and Lawrence H. Summers. 2014. "Government Debt Management at the Zero Lower Bound." Hutchins Center on Fiscal and Monetary Policy at Brookings Working Paper 5.

Greenwood, Robin, Samuel G. Hanson, and Jeremy C. Stein. 2016. “The Federal Reserve’s Balance Sheet as a Financial-Stability Tool.” In *2016 Economic Policy Symposium Proceedings*. Jackson Hole: Federal Reserve Bank of Kansas City.

Greenwood, Robin, Samuel G. Hanson, and Dimitri Vayanos. 2015. “Forward Guidance in the Yield Curve: Short Rates versus Bond Supply.” National Bureau of Economic Research Working Paper 21750.

Greenwood, Robin, and Dimitri Vayanos. 2014. “Bond Supply and Excess Bond Returns.” *The Review of Financial Studies* 27 (3): 663–713.

Grisse, Christian, Signe Krogstrup, and Silvio Schumacher. 2017. “Lower-Bound Beliefs and Long-Term Interest Rates.” *International Journal of Central Banking* 13 (3): 165–202.

Gürkaynak, Refet S., Brian Sack, and Eric 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): 55–93.

Gust, Christopher, Edward Herbst, David López-Salido, and Matthew E. Smith. 2017. “The Empirical Implications of the Interest-Rate Lower Bound.” *American Economic Review* 107 (7): 1971–2006.

Guthrie, Graeme, and Julian Wright. 2000. “Open Mouth Operations.” *Journal of Monetary Economics* 46 (2): 489–516.

Hamilton, James D, and Jing Cynthia 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.

Hartmann, Philipp, and Frank Smets. 2018. “The First 20 Years of the European Central Bank: Monetary Policy.” *Brookings Papers on Economic Activity* 2018 (2 (Fall)): 1–118.

Hattori, Masazumi, Andreas Schrimpf, and Vladyslav Sushko. 2016. “The Response of Tail Risk Perceptions to Unconventional Monetary Policy.” *American Economic Journal: Macroeconomics* 8 (2): 111–36.

Holston, Kathryn, Thomas Laubach, and John C. Williams. 2017. “Measuring the Natural Rate of Interest: International Trends and Determinants.” *Journal of International Economics* 108 (Supplement 1 (May)): S59–75.

Hubert, Paul, and Fabien Labondance. 2018. “The Effect of ECB Forward Guidance on the Term Structure of Interest Rates.” *International Journal of Central Banking* 14 (5): 194–222.

Ihrig, Jane, Elizabeth Klee, Canlin Li, and Joe Kachovec. 2018. “Expectations about the Federal Reserve’s Balance Sheet and the Term Structure of Interest Rates.” *International Journal of Central Banking* 14 (2): 341–90.

International Monetary Fund. 2017. “Negative Interest Rate Policies - Initial Experiences and Assessments.” International Monetary Fund Staff Report.

Joyce, Michael A. S., Ana Lasaosa, Ibrahim Stevens, and Matthew Tong. 2011. “The Financial Market Impact of Quantitative Easing in the United Kingdom.” *International Journal of Central Banking* 7 (3): 113–61.

Joyce, Michael A. S., and Matthew Tong. 2012. “QE and the Gilt Market: A Disaggregated Analysis.” *The Economic Journal* 122 (564): F348–84.

Karson, Evan, and Christopher J. Neely. “More Stories of Unconventional Monetary Policy.” Forthcoming in the *Review of the FRB of St. Louis*.

Kiley, Michael T. 2014. “The Aggregate Demand Effects of Short- and Long-Term Interest Rates.” *International Journal of Central Banking* 10 (4): 69–104.

———. 2018. “Quantitative Easing and the ‘New Normal’ in Monetary Policy.” Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2018-004.

———. 2019. “The Global Equilibrium Real Interest Rate: Concepts, Estimates, and Challenges.” Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2019-076.

Kiley, Michael T., and John M. Roberts. 2017. “Monetary Policy in a Low Interest Rate World.” *Brookings Papers on Economic Activity* 48 (Spring): 317–72.

Krippner, Leo. 2015. “A Comment on Wu and Xia (2015), and the Case for Two-Factor Shadow Short Rates.” Center for Applied Macroeconomic Analysis, Australian National University Working Paper 48/2015.

Krishnamurthy, Arvind, and Annette Vissing-Jorgensen. 2011. “The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy.” *Brookings Papers on Economic Activity* 42 (Fall): 215–65.

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

Kuttner, Kenneth N. 2018. “Outside the Box: Unconventional Monetary Policy in the Great Recession and Beyond.” *Journal of Economic Perspectives* 32 (4): 121–46.

Kydland, Finn E., and Edward C. Prescott. 1977. “Rules Rather Than Discretion: The Inconsistency of Optimal Plans.” *Journal of Political Economy* 85 (3): 473–91.

Laubach, Thomas, and John C. Williams. 2003. “Measuring the Natural Rate of Interest.” *The Review of Economics and Statistics* 85 (4 (November)): 1063–70.

L'Huillier, Jean-Paul, and Raphael Schoenle. 2019. "Raising the Target: How Much Extra Room Does It Really Give?" Center for Economic Policy Research Discussion Paper 14142.

Li, Canlin, and Min 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): 3–39.

Lo Duca, Marco, Giulio Nicoletti, and Ariadna Vidal Martínez. 2016. "Global Corporate Bond Issuance: What Role for US Quantitative Easing?" *Journal of International Money and Finance* 60 (February): 114–50.

McKay, Alisdair, Emi Nakamura, and Jón Steinsson. 2016. "The Power of Forward Guidance Revisited." *American Economic Review* 106 (10): 3133–58.

Meaning, Jack, and Feng Zhu. 2011. "The Impact of Recent Central Bank Asset Purchase Programmes." *BIS Quarterly Review*, December, 73–83.

Nakata, Taisuke. 2015. "Credibility of Optimal Forward Guidance at the Interest Rate Lower Bound." Board of Governors of the Federal Reserve System. *FEDS Notes* (blog). August 27, 2015.

Neely, Christopher J. 2010. "Unconventional Monetary Policy Had Large International Effects." Federal Reserve Bank of St. Louis Working Paper 2010-018G.

———. 2016. "How Persistent Are Unconventional Monetary Policy Effects?" Federal Reserve Bank of St. Louis Working Paper 2014-004.

Okazaki, Yosuke, and Nao Sudo. 2018. "Natural Rate of Interest in Japan -- Measuring Its Size and Identifying Drivers Based on a DSGE Model." Bank of Japan Working Paper 18-E-6.

Pugh, Alice, Philip Bunn, and Chris Yeates. 2018. "The Distributional Impact of Monetary Policy Easing in the UK Between 2008 and 2014." Bank of England Working Paper 720.

Raskin, Matthew. 2013. "The Effects of the Federal Reserve's Date-Based Forward Guidance." Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2013-37.

Reifschneider, David L. 2016. "Gauging the Ability of the FOMC to Respond to Future Recessions." Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2016-068.

Rey, Héléne. 2013. "The Federal Reserve's Balance Sheet as a Financial-Stability Tool." In *2013 Economic Policy Synompsium Proceedings*. Jackson Hole: Federal Reserve Bank of Kansas City.

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

Sims, Eric R, and Jing Cynthia Wu. 2019. "Evaluating Central Banks' Tool Kit: Past, Present, and Future." National Bureau of Economic Research Working Paper 26040.

Stein, Jeremy C. 2013. "Overheating in Credit Markets: Origins, Measurement, and Policy Responses." Speech presented at the "Restoring Household Financial Stability After the Great Recession: Why Household Balance Sheets Matter" research synopsium sponsored by the Federal Reserve Bank of St. Louis, St. Louis, Missouri, February 7.

Svensson, Lars E.O. 2016. "Cost-Benefit Analysis of Leaning Against the Wind." National Bureau of Economic Research Working Paper 21902.

Swanson, Eric T. 2017. "Measuring the Effects of Federal Reserve Forward Guidance and Asset Purchases on Financial Markets." National Bureau of Economic Research Working Paper 23311.

Swanson, Eric T. 2018. "The Federal Reserve Is Not Very Constrained by the Lower Bound on Nominal Interest Rates." *Brookings Papers on Economic Activity* 49 (Fall): 555–72.

Swanson, Eric T., and John 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, John B. 1993. "Discretion Versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39 (December): 195–214.

Vayanos, Dimitri, and Jean-Luc Vila. 2009. "A Preferred-Habitat Model of the Term Structure of Interest Rates." National Bureau of Economic Research Working Paper 15487.

Williams, John C. 2016. "Discussion of 'Language after Liftoff: Fed Communication Away from the Zero Lower Bound.'" Presentation presented at the U.S. Monetary Policy Forum, New York, New York, February 26.

———. 2018. "The Future Fortunes of R-Star: Are They Really Rising?" Federal Reserve Bank of San Francisco. *FRBSF Economic Letter* (blog). May 2018.

Woodford, Michael. 2012. "Methods of Policy Accommodation at the Interest-Rate Lower Bound." In *2013 Economic Policy Symposium Proceedings*. Jackson Hole: Federal Reserve Bank of Kansas City.

———. 2013. "Forward Guidance by Inflation-Targeting Central Banks." In *Two Decades of Inflation Targeting: Main Lessons and Remaining Challenges*. Sveriges Riksbank.

———. 2016. "Quantitative Easing and Financial Stability." National Bureau of Economic Research Working Paper 22285.

Wright, Jonathan H. 2011. "What Does Monetary Policy Do to Long-Term Interest Rates at the Zero Lower Bound?" National Bureau of Economic Research Working Paper 17154.

Wu, Jing Cynthia, and Fan Dora Xia. 2016. "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound." *Journal of Money, Credit and Banking* 48 (2–3): 253–91.

Wu, Tao. 2014. "Unconventional Monetary Policy and Long-Term Interest Rates." International Monetary Fund Working Paper 14/189.

Yellen, Janet. 2017. "The Economic Outlook and the Conduct of Monetary Policy." Speech, Stanford Institute for Economic Policy Research, January 19.

———. 2018. "Comments on Monetary Policy at the Effective Lower Bound." *Brookings Papers on Economic Activity* 49 (Fall): 573–79.