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at the
ZERO LOWER BOUND

Putting Theory into Practice

BROOKINGS

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It has been said, "An economist is a man who, when he finds something works in practice, wonders if it works in theory."[1] The study of the zero lower bound (ZLB) on nominal interest rates is an example of precisely the opposite: economists first figuring out what works in theory and then seeing if it works in practice. Japan's experience with price deflation and zero short-term interest rates beginning in the 1990s led to a flurry of economic research on the ZLB and its implications for monetary policy (see, for example, Benhabib, Schmitt-Grohé, and Uribe 2001; Eggertsson and Woodford 2003; Reifschneider and Williams 2000; and references therein). This research came to a number of concrete conclusions and policy prescriptions that influenced policymaking during and after the global financial crisis.

One conclusion from the precrisis research was that the ZLB was a problem that could potentially afflict any economy with a sufficiently low inflation target, but that the episodes at the ZLB would be relatively infrequent and generally short-lived. For example, Reifschneider and Williams (2000) found that under a standard Taylor (1993) monetary policy rule and a 2 percent inflation target, monetary policy would be constrained at the ZLB about 5 percent of the time, and ZLB episodes would typically last just one year. Other research came to even more sanguine conclusions regarding the likely effects of the ZLB, in part because that research was often predicated on an economic environment similar to the tranquil Great Moderation period of the 1980s and 1990s in the United States (see, e.g., Adam and Billi 2006; Coenen, Orphanides, and Wieland 2004; Schmitt-Grohé and Uribe 2007).

Second, this research identified monetary policy strategies that should be effective at reducing most of the adverse effects of the ZLB. Specifically, short-term rates should be cut aggressively when deflation or a severe downturn threatens (Reifschneider and Williams 2000, 2002). That is, do *not* "keep your powder dry." In addition, short-term rates should be kept "lower for longer" as the economy recovers (Eggertson and Woodford 2003; Reifschneider and Williams 2000, 2002). In theory, the expectation of a sustained low level of short-term interest rates reduces longer-term yields and eases financial conditions more broadly. In these two ways, the maximal amount of monetary stimulus can be put into place quickly. Indeed, this research found that such strategies should, in most cases, be sufficient to nearly fully offset the effects of the ZLB on the economy.

"An economist is a man who, when he finds something works in practice, wonders if it works in theory."

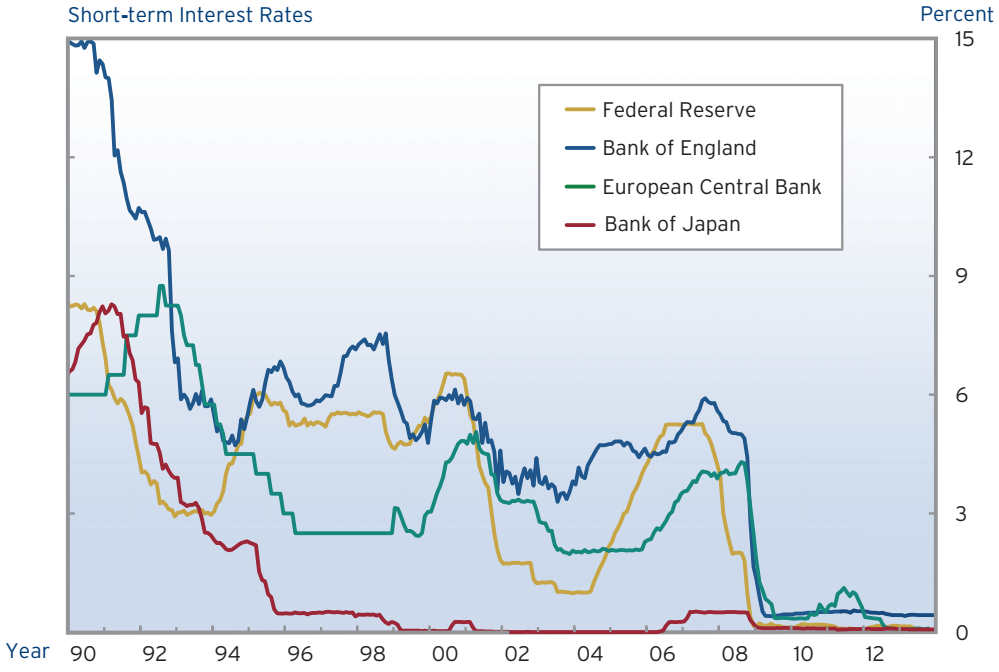
Third, some researchers argued that unconventional policy actions such as central bank large-scale asset purchases (LSAP) of longer-term securities or foreign exchange can complement conventional policy actions by making financial conditions more favorable for growth even when short rates are constrained by the ZLB (Bernanke and Reinhart 2004; Bernanke, Reinhart, and Sack, 2004; McCallum 2000; Svensson 2001).

Of course, within a few years of this research being written, the ZLB went from being a theoretical concern to a very real practical problem for many central banks across the globe. FIGURE 1 shows the policy rates for four major advanced economies since 1990. The Bank of England, the Bank of Japan, the European Central Bank, and the Federal Reserve all brought their policy rates to their respective effective lower bounds in late 2008 or early 2009. Central banks quickly sought to put into practice many of the prescriptions that researchers had identified.

The experiences of the past six years provide a wealth of data on what works and what doesn't, which theories have proved useful, and which need to be reconsidered. This essay reexamines the three key issues outlined above that research highlighted related to the ZLB, and ends by laying out three still unanswered questions for monetary policy in a world where the ZLB is an ongoing concern.

[1] This quotation is often attributed to the economist Walter Heller.

FIGURE 1. The ZLB: Not Just an Academic Concern



Sources: Board of Governors of the Federal Reserve System (2013); Organisation for Economic Co-operation and Development (OECD; 2013).

History Matters: Reassessing the Risk of the Zero Lower Bound

The events of the past six years have called into question some of the assumptions that went into previous research that found that episodes of hitting the ZLB would likely be relatively infrequent and short-lived. Chung et al. (2012) show that a wide range of modern macroeconomic forecasting models constructed based on postwar U.S. data predict that the probability of recent events, including multiple years stuck at the ZLB, is extremely remote—essentially nonexistent. The overwhelming falsification of this prediction can be interpreted in one of two ways. Either recent events represent an extraordinary run of horribly bad luck—a 100-year flood, if you will—or the models are badly misspecified, in particular with regard to their implications for negative tail risk.

Given the limited real-world empirical evidence on the frequency and severity of ZLB episodes, researchers have had to rely on artificial data generated by stochastic simulations of macroeconomic models to infer these probabilities and effects. Although the results depend on the details of the model specification and other assumptions, two key factors affect the simulated probability of hitting the ZLB and the resulting effects of the ZLB on the macroeconomy: (1) the size and (2) the duration of the shocks hitting the economy. If the shocks are assumed to be typically small, then the monetary policy response will be correspondingly small and the ZLB will rarely come into play. Similarly, if the shocks are assumed to be transitory, episodes of the ZLB will also tend to be short and will have relatively modest effects on the economy.

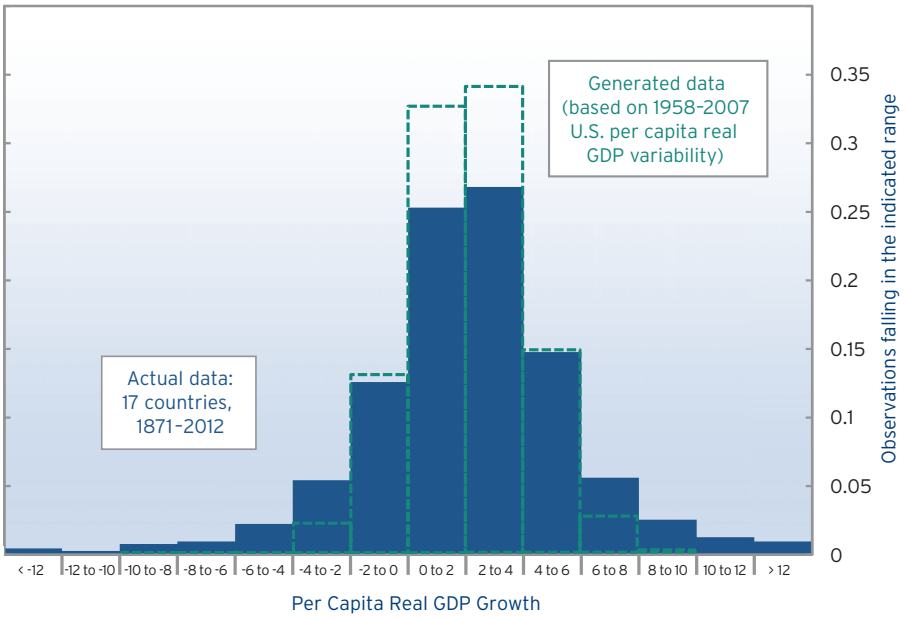
The standard approach in the research literature has been to estimate the shock processes based on historical data. They key issue is this: What data should one use? Lack of availability of consistent time series of data covering a very long time period and a concern that structural change has made data from long ago no longer relevant caused most researchers to focus on evidence on macroeconomic disturbances from the past twenty-five to fifty years. The advantage of this approach is that it provides consistent, reasonably accurate data for analysis. The downside to relying on data from recent decades is that a relatively small sample can provide a misleading view of the frequency of tail events. This is particularly

true for the unusually tranquil quarter century before the recent global financial crisis, which contributed to a false sense that the business cycle had been tamed.

How can we avoid overreliance on short samples in evaluating tail risks while basing our analysis on the empirical evidence? One alternative approach that is arguably more robust to overconfidence based on small samples is to look at much broader historical experience across a wide range of economies. This approach explicitly rejects the "this time is different" view that downplays old or distant events, and instead treats a wide range of historical experience as potentially informative in describing the types of risks that the future may hold.

FIGURE 2 illustrates how that a broader historical perspective can paint a picture that is very different from the postwar U.S. data. The blue bars show the distribution of annual per capita real GDP growth from a sample of seventeen advanced countries over 1871–2012, excluding years of major wars.[2] The x-axis indicates ranges for annual per capita real GDP growth (measured in log differences). The y-axis shows the share of observations from the sample where the observed data lie in the indicated range. I am not arguing that we should blithely base conclusions on this particular dataset, but rather that we use it to illustrate the broader point that a larger sample may provide insights into tail events that small samples miss.

FIGURE 2. History Matters a Lot



Source: Barro and Ursúa (2010), updated by the author.

One aspect of the broad historical data stands out: sharp declines in economic activity occur relatively frequently. To put this in perspective, per capita real U.S. GDP fell by 3.7 percent in 2009. In the broad historical experience

[2] Following Jordà, Schularick, and Taylor (2011), the data are taken from Barro and Ursúa (2010), and updated for 2007–2012 using data from World Bank (2013). For the United States, data for 1930–2012 are the current national income and product data from the Bureau of Economic Analysis. The countries in the sample are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Great Britain, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United States.

represented by these seventeen countries, a decline of that magnitude or larger occurs 5.2 percent of the time—that is, about once every nineteen years on average. Even if one abstracts from the experiences of the other countries and looks only at the U.S. data from 1871 to 2012, a decline of this magnitude occurs in 7.8 percent of the sample years, or about once every thirteen years. Based on these metrics, recent events would scarcely be considered rare or unprecedented. Instead, history teaches us that very large downturns are not only possible—they are probable.

It is interesting to note that these large declines in output do not represent extreme tail events relative to the rest of the distribution. If one takes the mean and variance of the observations from the broad historical sample, the normal distribution implies a probability of declines of 3.7 percent or greater 8.2 percent of the time, somewhat higher than the observed rate of 5.2 percent. Thus, one does not need to resort to arguments about fat-tailed distributions to understand the data: it suffices to allow for a sufficiently large variance.

A very different perspective on the likelihood of recent events is provided if one instead looks exclusively at the postwar U.S. experience. In the fifty years before the crisis, there was no year in which U.S. per capita real GDP fell by more than 3 percent. Given the dearth of extreme tail events, one is forced to construct a theoretical probability based on the available data. The green dashed lines in figure 2 illustrate one such attempt. The red lines show the histogram for a hypothetical economy with the same sample mean growth rate as the long sample of seventeen countries, but with the variance of the growth rate set equal to that observed in the U.S. data over 1958–2007. The distribution of outcomes is assumed to be normally and independently distributed. This distribution illustrates the types of assumption regarding macroeconomic variability typically used in past research on the ZLB.

The downside to relying on data from recent decades is that a relatively small sample can provide a misleading view of the frequency of tail events.

Based on the experience of the postwar period, the probability of experiencing a year as bad as 2008 is exceedingly low. Using the variance in the U.S. data over the fifty years prior to the crisis, one would expect a downturn as bad as occurred in 2008 less than one-quarter of 1 percent of the time, or about once every 430 years. The corresponding figure based on variance in the data during the Great Moderation period is essentially zero, at 0.003 percent, or once every 33,000 years! These overly optimistic predictions are due to the historically low variance in per capita real output growth during the decades before the crisis. The numbers tell the story. The standard deviation of the U.S. per capita GDP growth over 1958–2007 is 2.1 percentage points, half that of the broad historical data (4.2 percentage points). The difference is even greater if one looks at data from the Great Moderation period: the standard deviation of per capita real GDP growth over 1983–2007 is a mere 1.45 percentage points, about one third that of the broad historical experience. The miniscule implied probabilities of a severe downturn simply reflect the predicted rarity of approximately three and four standard deviation tail events.

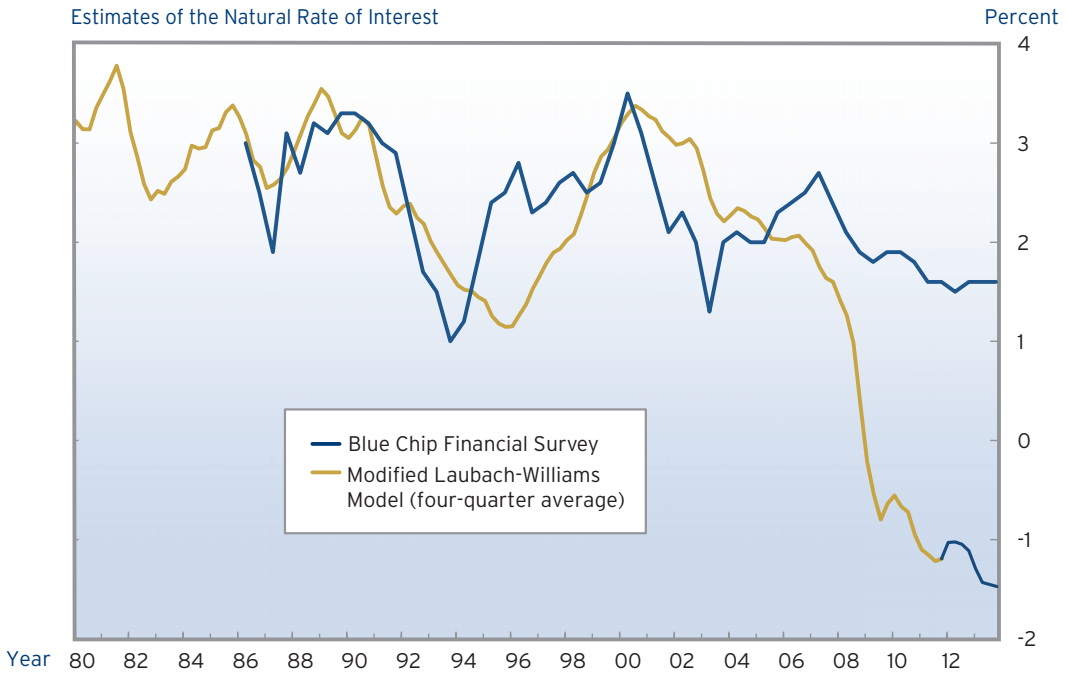
In addition to the size of the shocks, the duration of shocks matters for considering the repercussions of the ZLB. Macroeconomic models typically build in a great deal of correction to the mean, consistent with the behavior of postwar U.S. data. This contrasts with a key lesson from history that banking and financial crises are often followed by slow recoveries (Jordà, Schularick, and Taylor 2011; Reinhart and Rogoff 2009). As a result, standard models systematically underpredict the length of ZLB episodes.

One approach to look at duration of shocks is to examine multiyear declines in output. For example, consider the two-year decline in output during the recent financial crisis, when per capita real GDP fell by about 5 percent over 2008–2009. In the broad historical experience represented by the seventeen countries, a two-year decline of that magnitude or larger occurs 4.4 percent of the time—that is, about once every twenty-three years on average. Not a common occurrence, but nor is it unheard of. Based on the variance in the U.S. data over the fifty years prior to the crisis, one would expect a two-year decline downturn of that magnitude once every 570 years. Once again, if one bases one's

views on the Great Moderation period, the probability of such an outcome is virtually nonexistent, occurring on average about once every 6,800 years.

One does not need to look at distant history to see the effects of highly persistent shocks on the economy. A useful summary statistic for the extent of such shocks is the natural rate of interest, which measures the real interest rate consistent with the economy being at equilibrium. A number of factors—including persistent changes in productivity growth, preferences, and fiscal policy—affect the natural rate of interest over time. Laubach and Williams (2003) develop a model that estimates the medium-term natural rate of interest for the United States. FIGURE 3 shows estimates of the medium-term natural rate of interest from a version of this model.[3] For comparison, the figure also shows the medium-term forecasts of the real federal funds rate from the Blue Chip Financial Survey (2013) of economic forecasters.

FIGURE 3. The Duration of Macroeconomic Shocks



Source: **Blue Chip Financial Survey (2013); Laubach and Williams (2003), modified by the author.**

Both the model-based and survey-based estimates of the medium-term natural rate of interest show significant variation over time. In particular, those estimates show persistent declines following the savings and loan crisis of the late 1980s and since the onset of the global financial crisis, reflecting the persistent headwinds to economic growth that typically follow banking and financial crises.

In summary, when looked at through the lens of the postwar U.S. experience, the depth and duration of the recent recession may appear extraordinary. However, a broader look at economic history and events around the world teach us that deep and long-lasting downturns are not that rare.

[3] The model-based estimate is based on a modified version of the Laubach and Williams (2003) model. The modification is that the average of gross domestic product and gross domestic income is used as the output measure in the model, instead of gross domestic product as in the original.

Conventional Monetary Policy and the Zero Lower Bound

As noted above, the research on conventional monetary policy in the vicinity of the ZLB yielded two strong policy prescriptions. First, policymakers should act aggressively in cutting rates to maximize the monetary stimulus when deflation or a sharp decline in output threatens. Second, monetary policy should remain more accommodative than implied by standard policy prescriptions after a period when the ZLB constrains policy. This is often referred to as a "lower for longer" strategy. The logic behind this approach is to lower future expected interest rates and thereby boost spending immediately, thereby reducing the lost output resulting from the shock and avoiding disinflation. Moreover, in theory it can be advantageous to lower interest rate expectations to the point that inflation is expected to rise above the target for some time, thereby lowering real interest rates and further reducing lost output.

As seen in figure 1, major central banks followed the first prescription, aggressively cutting rates as the crisis emerged. All four major central banks brought their policy rates to their effective lower bounds by early 2009. Other central banks in advanced economies—including Australia, Canada, Israel, New Zealand, Norway, and Sweden—also brought rates down quickly as the global financial crisis unfolded.

The prescription of lower for longer was less actively employed during the recession and early stages of the recovery. In the United States, the Federal Open Market Committee (FOMC) communicated a general expectation of low rates in the future. For example, in its December 2008 statement the FOMC stated that it expected to keep the funds rate low "for some time" (Board of Governors of the Federal Reserve System 2008) This represented a throwback to the qualitative forward guidance used by the FOMC in 2003 and 2004. (See Rudebusch and Williams 2008 for a detailed discussion of this earlier episode.)

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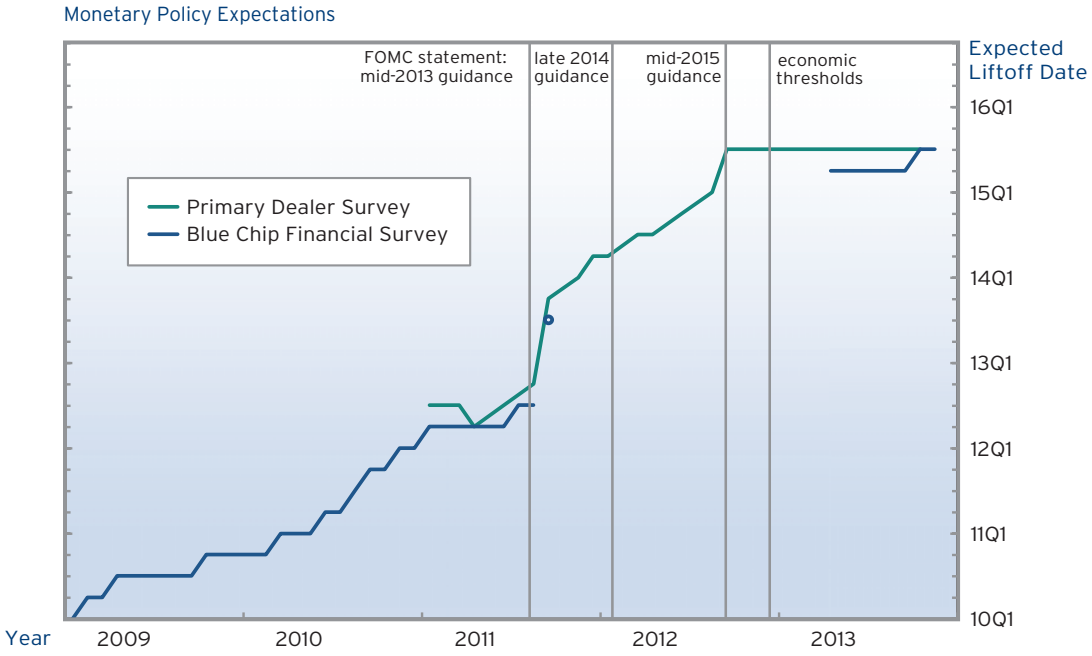
Despite this qualitative forward guidance, the public held the view that a policy tightening was just around the corner. From the beginning of 2009 to mid-2011, expectations from financial markets and surveys of economists consistently showed the federal funds rate lifting off from the zero bound within a year or so. The leftmost blue line in FIGURE 4 shows the evolution of Blue Chip consensus real-time forecasts from January 2009 through August 2011 for the date of the funds rate liftoff from its 0–25 basis point range that was instituted in December 2008. The x-axis indicates the date the forecast was published. The y-axis indicates the date at which forecasters predicted the FOMC would raise the funds rate for the first time. For example, in the first half of 2011 the consensus forecast in the Blue Chip Financial Survey was for liftoff in the second quarter of 2012. Note that the Blue Chip Financial Survey forecast horizon is typically limited to seven quarters. The blue dot shown in the figure corresponds to the September 2011 survey. It indicates that liftoff was not expected to occur within the reported forecast horizon (which ended in the second quarter of 2013 for that survey). This remained true until the Blue Chip Financial Survey started explicitly asking about the timing of liftoff in early 2013; the results from these questions are shown in the rightmost blue line segment in figure 4.

What is striking about this early period is the public's conviction that the Federal Reserve would quickly raise rates again. This belief persisted despite the efforts of many on the FOMC to communicate the severity of the downturn and the resulting need for highly accommodative monetary policy for quite some time. Evidently, the public simply did not know what to expect given that short-term rates were at zero and policymakers couldn't shift expectations simply by cutting rates further.[4] The same pattern is seen in the U.K. forecast data (Swanson and Williams 2013).

[4] See Reifschneider and Roberts (2006) and Williams (2006) for further discussion of the problem of expectations formation at the ZLB.

FIGURE 4. Expectations of Federal Reserve Funds Rate Liftoff



Source: Blue Chip Financial Survey (2013); Federal Reserve Bank of New York (2013).

To push back against these excessively tight expectations, the FOMC made its forward guidance more explicit and forceful. In August 2011 it announced that economic conditions were "likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013" (Board of Governors of the Federal Reserve 2011). In so doing, the FOMC mimicked the approach taken earlier by the Bank of Canada in April 2009, which proved effective at modestly shifting interest rate expectations (Carney 2012).

The FOMC's August 2011 announcement had a dramatic effect on financial market expectations. It caused an immediate 10 basis point drop in two-year Treasury yields and a greater than 20 basis point decline in longer-term yields. This shift in policy expectations is also evident in market expectations of the future path for the funds rate, shown in figure 4. Before the August FOMC announcement, the Blue Chip consensus was that the FOMC would raise rates in the third quarter of 2012. In the survey following the announcement, expectations in the Blue Chip forecast were for no rate increase over the next seven quarters (the limit of the forecast horizon). Similarly, the Federal Reserve Bank of New York's survey of primary dealers shows the expected time of liftoff from the zero bound jumping from late 2012 to late 2013 following the FOMC's August 2011 announcement.[5]

The FOMC's quantitative forward guidance was extended further in January 2012 to "late 2014" and again in September 2012 to "mid-2015," also with significant effects on policy expectations and yields. Directly following these announcements, longer-term rates fell by between 3 and 9 basis points. As seen in figure 4, the primary dealer survey shows expectations of funds rate liftoff being pushed out farther during 2012 in line with FOMC communications. In addition, in January 2012 the FOMC started publishing its projections of the federal funds rate for the next few years (along with those for GDP unemployment and inflation), providing further information on the likely future path of short-term interest rates. The FOMC policy projections should help the public understand the Federal Reserve's reaction function—that is, how policy changes as economic conditions evolve (Rudebusch and Williams 2008).

[5] See Femia, Friedman, and Sack (2013) for analysis of the effects of FOMC communications on market expectations.

In December 2012 the FOMC replaced the date-based guidance with language that explicitly ties its forward guidance to the state of the economy. The FOMC stated it was likely to keep the funds rate near zero, "at least as long as the unemployment rate remains above 6 1/2 percent" (Board of Governors of the Federal Reserve System 2012) and as long as inflation is not expected to exceed 2.5 percent over the next year or two and inflation expectations remain anchored. In December 2013 the FOMC statement language was modified to indicate that liftoff was likely to occur well after the time when the unemployment rate falls below 6 1/2 percent. This state-based forward guidance is still a relatively new experiment in FOMC transparency, but it has already proven to be an effective communication tool, focusing public attention on economic milestones in contemplating future policy decisions. Subsequent to the Federal Reserve's use of state-based policy guidance, the Bank of England has followed suit in its policy communications.

Beyond the shifts in policy expectations following these announcements, the introduction of explicit forward guidance has fundamentally changed the behavior of public expectations of future interest rates. This can be seen in the Treasury market reaction to economic news that normally would cause medium-term interest rates to change in anticipation of monetary policy responses. Swanson and Williams (2012) look at how market reactions to news have changed since the federal funds rate has fallen to almost zero. From January 2009 through August 2011, one-year Treasury yields responded about half as much as they responded in times when short-term interest rates were not close to zero. Since the introduction of explicit forward guidance in August 2011, one-year yields respond one-tenth as much as usual. The shift in expectations of interest rates out two years is even more dramatic: from January 2009 to August 2011, responsiveness to news was only slightly muted, at about 85 percent of the usual response. Following the August announcement, responsiveness fell to one-quarter as much as usual. A similar pattern is seen in the expectations of future short-term interest rates as measured by the responsiveness of Eurodollar futures to economic news (Swanson and Williams 2012). This evidence demonstrates that explicit forward guidance can effectively anchor interest rate expectations out two years.

An international comparison is illuminating regarding the effects of quantitative forward guidance.

An international comparison is illuminating regarding the effects of quantitative forward guidance. As noted, the Bank of Canada was an early adopter, but Canada's spell at the ZLB lasted only a year. In the United Kingdom, forward guidance was introduced only recently. Until the summer of 2011, forecasters expected the Bank of England to raise interest rates within a few quarters. Interestingly, expectations shifted dramatically around the same time as they did in the United States. The same shift in expectations is in evidence in a sharp decline in the responsiveness of one- and two-year gilt yields since the summer of 2011 (Swanson and Williams 2013). Despite the lack of quantitative forward guidance, in the United Kingdom interest rate expectations appear to be very well anchored.

The euro area provides a stark contrast. One- and two-year German bund yields showed no significant decline in responsiveness to news until 2012, suggesting that market participants viewed the European Central Bank (ECB) as being on the cusp of changing rates during that period (Swanson and Williams 2013). That perception was likely reinforced when the ECB increased the main refinancing rate in 2011. Interestingly, the responsiveness of these yields fell to close to zero in 2012, similar to the experience in the United States and United Kingdom, possibly reflecting the change in the tone of communication from the ECB regarding monetary policy.

Overall, consistent with the prescription of research, central banks acted to cut rates very aggressively during the financial crisis. It took longer to effectively manage policy expectations. In the end, quantitative forward guidance proved highly effective at anchoring interest rate expectations consistent with policymakers' intentions.

Into the Great Unknown: Large-Scale Asset Purchases

Standard textbook theory based on frictionless financial markets and the absence of arbitrage tells us that large-scale asset purchases by central banks should have no effect on asset prices or the broader economy, all else equal. According to this theory, the price of an asset depends solely on its expected future returns, adjusted for risk. Since asset purchases by the central bank don't fundamentally change the risk-adjusted returns to assets, they should have no direct effect on asset prices or the economy.

Running against the grain of this conventional wisdom, a number of economists studied the potential role of alternative policy instruments—including expanding the central bank balance sheet by purchasing foreign and domestic sovereign debt—when the short-term interest rate was constrained by the ZLB. They focused on two potential ways such alternative policy instruments could affect the economy: (1) a signaling channel and (2) a preferred habitat channel.

According to the signaling channel, central bank asset purchases provide an indirect signal of the central bank's objectives and future conventional policy actions. This approach maintains the assumption of frictionless financial markets, so asset purchases on their own have no direct effect on financial conditions, economic activity, or inflation. Instead, they work solely by affecting public expectations of future short-term interest rates. For example, Svensson's (2001) recommendation to target an exchange rate works in his model because it anchors the price level and thereby promises earlier policy in the future needed to generate higher inflation following a ZLB episode. The proposals of targeting money supply or longer-term Treasury yields by Auerbach and Obstfeld (2005) and McGough, Rudebusch, and Williams (2005) respectively, can be interpreted similarly.

The second hypothesized channel abandons the frictionless financial market assumption and posits a direct effect of central bank purchases on asset prices. McCallum (2000), Coenen and Wieland (2004), and Bernanke, Reinhart, and Sack (2004) are precrisis examples of research based on this approach. The basic insight underlying this approach dates back to Modigliani and Tobin, who argued that certain financial markets are segmented. (See Vayanos and Vila 2009 for a modern treatment.) Some investors, such as pension funds, have strong preferences or even legal restrictions on where they put their money. Such so-called preferred habitats for certain types of investments can interfere with the equalization of risk-adjusted returns to different assets. As a result, the relative supply and demand of assets, which are imperfect substitutes for each other, affects their prices.

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Before the crisis, almost everything we knew about the effects of large-scale asset purchases came from studies of the Japanese lost decade and a few scattered episodes in the United States, such as Operation Twist in the 1960s and changes in the demand or supply of Treasury securities (Bernanke, Reinhart, and Sack 2004; Modigliani and Sutch 1966, 1967). That void was filled once the Federal Reserve and other central banks introduced large-scale asset purchase programs and economists were able to carefully study their effects.[6] TABLE 1 summarizes the results from a large number of research papers that differ in methodology and data.[7]

[6] In addition, in September 2011 the Swiss National Bank announced a floor on the euro–Swiss franc exchange rate of 1.2, which they have subsequently defended through foreign exchange operations.

[7] This table is taken from Williams (2013b). Modigliani-Sutch (1966, Sections 3–4); Bernanke-Reinhart-Sack (2004, Table 7, Figure 6, and author's calculations); Greenwood-Vayanos (2008, Table 2); Krishnamurthy–Vissing-Jorgensen (2011, Section 4); Gagnon et al. (2011, Tables 1-2); D'Amico-King (2013, Figure 5); Hamilton-Wu (2011, Figure 11); Hancock-Passmore (2011, Table 5); Swanson (2011, Table 3); Joyce et al. (2011, Chart 9); Neely (2013, Table 2); Christensen-Rudebusch (2012, Table 8); D'Amico et al. (2012, Conclusions); Bauer-Rudebusch (forthcoming, Table 6); Li-Wei (2013, Tables 3, 6). Nearly all these estimates involve author's calculations to renormalize the effect to a $600 billion U.S. LSAP.

TABLE 1. **Estimates of LSAP Effects on Longer-Term Interest Rates**

Study	Sample	Method	Representative estimates of effect of $600 billion LSAP (+2 std errors if avail.)
Modigliani-Sutch (1966, 1967)	Operation Twist	time series	0 bp (±20 bp)
Bernanke-Reinhart-Sack (2004)	Japan, United States	event study	400 bp (±370 bp), 40 bp (±60 bp)
Greenwood-Vayanos (2008)	postwar United States (precrisis)	time series	14 bp (±7 bp)
Krishnamurthy–Vissing-Jorgensen (2011, 2012)	postwar U.S., LSAP1, and LSAP2	time series	15 bp (±5 bp)
Gagnon-Raskin-Remache-Sack (2011)	LSAP1	event study, time series	30 bp (±15 bp), 18 bp (±7 bp)
D'Amico-King (2013)	LSAP1 Treasury purchases	security-specific event study	100 bp (±80 bp)
Hamilton-Wu (2011)	U.S., 1990–LSAP2	affine no-arbitrage model	17 bp
Hancock-Passmore (2011)	LSAP1 MBS purchases	time series	30 bp
Swanson (2011)	Operation Twist	event study	15 bp (±10 bp)
Joyce-Lasaosa-Stevens-Tong (2011)	U.K. LSAPs	event study, time series	40 bp
Neely (2013)	effect of U.S. LSAP1 on foreign bond yields	event study	17 bp (±13 bp)
Christensen-Rudebusch (2012)	LSAP1, LSAP2, and U.K. LSAPs	event study, affine no-arbitrage model	10 bp
D'Amico et al. (2012)	United States, precrisis	weekly time series	45 bp
Bauer-Rudebusch (forthcoming)	LSAP1, LSAP2	event study, affine no-arbitrage model	16 bp
Li-Wei (2013)	United States, precrisis	affine no-arbitrage model	26 bp

Note:
bp = basis point
LSAP1, LSAP2, etc. = large-scale asset purchase (LSAP) program 1, 2, etc.
MBS = mortgage-backed securities

Two themes emerge from this research on the effects of asset purchases on asset prices. First, although individual estimates differ, this analysis consistently finds that asset purchases have sizable effects on yields on longer-term securities. Second, there remains a great deal of uncertainty about the magnitude of these effects and their impact on the overall economy.

The central tendency of the estimates reported in table 1 indicates that $600 billion of Federal Reserve's asset purchases lowers the yield on ten-year Treasury notes by around 15 to 25 basis points. To put that in perspective, that is roughly the same size move in longer-term yields one would expect from a cut in the federal funds rate of 3/4 to 1 percentage point (Chung et al. 2012; Gürkaynak, Sack, and Swanson, 2005, Table 5).

We recently witnessed a case study of how changes in expectations of the Federal Reserve's asset purchases affect longer-term interest rates and financial conditions more broadly. After the FOMC's announcement on September 18 that it would not change the pace of asset purchases, the yield on the ten-year Treasury note fell by 18 basis points. The

effects didn't stop there. The stock market rose about 1.25 percent and the value of the dollar against the euro fell by around 1 percent.

Although research consistently finds sizable effects on asset purchases on longer-term yields, there is a great deal of uncertainty about the magnitude of these effects and the impact on the economy. For estimates for which we have estimated standard errors, the estimates are generally not very precise, with associated t-statistics often equal to or less than two. In addition, looking across the studies, the estimated effects vary considerably. For example, if one drops the two highest and two lowest estimates, the remaining thirteen estimates reported in the table range from 14 to 45 basis points.

Although this literature provides information on the magnitude of the effects of asset purchases, it is still unclear to what extent these effects are due to the signaling or preferred habitat channels. Krishnamurthy and Vissing-Jorgensen (2011, 2012) find incomplete pass-through from asset purchases to prices of other securities. Because the signaling channel implies a broad effect across securities, this provides indirect evidence in favor of a role for the preferred habitat view that some assets are imperfect substitutes for others. Bauer and Rudebusch (forthcoming) find that it is very difficult to disentangle the effects from the two channels, but conclude that the preponderance of evidence suggests both channels play a significant role in the United States. In contrast, Christensen and Rudebusch (2012) find that asset purchases in the United Kingdom had little signaling effect and worked primarily through the preferred habitat channel.

Estimating the effects of large-scale asset purchases on the economy—as opposed to financial markets—is inherently much harder to do and is subject to greater uncertainty. The effects of lower longer-term interest rates take place over the course of many months and even years; over those longer horizons it is hard to know how much of the change in economic activity was due to the effects of monetary policy or other factors. In addition, standard macroeconomic models assume frictionless financial markets and therefore do not allow for imperfect substitutability of assets. Theories about the effects of movements in asset prices caused by changes in relative supply and demand are still in their infancy.[8] Until these models are more fully developed, one must make do with the models at hand, appropriately modified to incorporate asset purchases.

One such study is Chung et al. (2012); these authors use the Federal Reserve Board's large-scale macroeconomic model to estimate the effects of the Federal Reserve's $600 billion large-scale asset purchase initiated in 2011 (often referred to as QE2). They find that the program lowered the unemployment rate by about 1/4 percentage point. This model assumes that changes in Treasury yields due to the asset purchase program fully spill over to other asset prices, and that private spending depends directly on these asset prices. For comparison, Chen, Cúrdia, and Ferrero (2012) (building on the model of Andrés, López-Salido, and Nelson, 2004) stipulate segmented markets for ownership of different types of assets. They find smaller effects of asset purchases on the economy. Despite these differences, both analyses find that asset purchases are most effective at stimulating the economy when they work in concert with expectations of sustained easy conventional monetary policy.

Even for a given model, the estimated effects of asset purchases on the economy are subject to considerable uncertainty. One estimate is that the degree of uncertainty regarding the macroeconomic effects of asset purchases is at least twice as large as that for conventional monetary policy (Williams 2013a). Although researchers have made great strides in measuring the effects of these policies on financial conditions, considerably more research is needed into understanding their effects on the real economy and inflation.

[8] See Araújo, Schommer, and Woodford (2013) for a discussion of the issues and one approach to modeling the effects of asset purchases on the economy.

Unresolved Issues

The experience of the past six years has demonstrated the valuable contributions of economic theory and research in thinking through abstract economic issues before they became reality. It has also provided a store of new information regarding the incidence and consequences of the ZLB. In particular, we have learned that the ZLB is a serious practical issue that is very likely to constrain policy in the future, and that there are implementable policy actions that can help offset some, if not all, of the deleterious effects from the ZLB.

Looking ahead, there remain a number of key unresolved issues related to the ZLB. Three come immediately to mind. First, should central banks change their policy frameworks from inflation targeting to one of price-level or nominal-GDP targeting in order to better anchor expectations of future policy actions? One lesson from the recent past is the difficulty in anchoring policy expectations when the short-rate is at the ZLB. Although quantitative forward guidance has proven a useful tool, it suffers from a number of limitations. Experience has shown that it is impossible to convey the full reach of factors that influence the future course of policy. As a result, forward guidance ends up being overly simplified and prone to misinterpretation. Moreover, forward guidance several years in advance may not be credible, especially in light of the change in policymakers over time. In theory, alternative frameworks such as nominal GDP targeting, if fully understood by the public, could help resolve these communication difficulties (Williams 2006; Woodford 2013), but at some potential cost.

What is needed now . . . is a new flurry of research on these issues that takes into account the lessons of the past six years, and helps provide concrete prescriptions for future policymakers.

Second, should large-scale asset purchases be a standard tool of monetary policy at the ZLB, and, if so, how should they be implemented? As noted above, asset purchases have proven a potent but blunt tool, with uncertain effects on financial markets and the economy. In addition, there are nagging concerns that large-scale asset purchases carry with them particular risks to the economy or the health of the financial system that we still don't understand well. Although most central banks used a quantity-based approach to implementing asset purchases, the Swiss National Bank used a price-based approach. These are issues that require further study and analysis.

Finally, and most controversially, in light of the experience of the costs of the ZLB and central banks' abilities to counter them, does the 2 percent inflation target adopted by many central banks provide a sufficient cushion to allow monetary policy to successfully stabilize the economy and inflation in the future?[9] On one side of the ledger, recent experience proves that the ZLB is a worse problem than previously imagined; consideration of the implications of the ZLB in the future will need to take this into account. On the other side, forward guidance, large-scale asset purchases, and, in some cases, fiscal policy have proven to be effective partial antidotes for the ZLB. Even if one views the risks from the ZLB to be greater than before, there are alternatives to raising the inflation target. More-effective financial regulation may diminish the potential for a severe crisis for the foreseeable future. And, as noted above, adoption of a price-level or nominal GDP targeting regime could potentially further reduce the costs of the ZLB. What is needed now, like the surge in research on the ZLB in the decade before the crisis, is a new flurry of research on these issues that takes into account the lessons of the past six years, and helps provide concrete prescriptions for future policymakers.

[9] See Blanchard, Dell'Ariccia, and Mauro 2010; Reifschneider and Williams 2000; Williams 2009.

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