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Optimal Inflation and the Zero Lower Bound

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Abstract

This paper reexamines the implications of the zero lower bound on interest rates for monetary policy and the optimal choice of steady-state inflation in light of the experience of the recent global recession. There are two main findings. First, the zero lower bound did not materially contribute to the sharp declines in output in the United States and many other economies through the end of 2008, but it is a significant factor slowing recovery. Model simulations imply that an additional 4 percentage points of rate cuts would have kept the unemployment rate from rising as much as it has and would bring the unemployment and inflation rates more quickly to steady-state values, but the zero bound precludes these actions. This inability to lower interest rates comes at the cost of $1.7 trillion of foregone output over four years. Second, *if* recent events are a harbinger of a significantly more adverse macroeconomic climate than experienced over the preceding two decades, then a 2 percent steady-state inflation rate may provide an inadequate buffer to keep the zero bound from having noticeable deleterious effects on the macroeconomy assuming the central bank follows the standard Taylor Rule. In such an adverse environment, stronger systematic countercyclical fiscal policy and/or alternative monetary policy strategies can mitigate the harmful effects of the zero bound with a 2 percent inflation target. However, even with such policies, an inflation target of 1 percent or lower could entail significant costs in terms of macroeconomic volatility.

KEYWORDS: Liquidity trap, monetary policy, fiscal policy.

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Icarus, my son, I charge you to keep at a moderate height, for if you fly too low the damp will clog your wings, and if too high the heat will melt them.

Daedalus' warning

1 Introduction

Japan's sustained deflation and near-zero short-term interest rates beginning in the 1990s ignited an outpouring of research on the implications of the zero lower bound (ZLB) on nominal interest rates for monetary policy and the macroeconomy. In the presence of nominal rigidities, the ZLB will at times constrain the central bank's ability to reduce nominal interest rates in response to negative shocks to the economy. This inability to reduce real interest rates as low as desired impairs the ability of monetary policy to stabilize output and inflation. The quantitative importance of the ZLB depends on the frequency and degree to which the constraint binds, a key determinant of which is the steady-state, or "target," inflation rate. If the steady-state inflation rate is sufficiently high, the ZLB will rarely impinge on monetary policy and the macroeconomy. With a sufficiently low steady-state inflation rate, however, the ZLB may have more deleterious effects. All else equal, the presence of the ZLB argues for a higher steady-state inflation rate. Of course, not all else is equal. Since Bailey (1956), economists have identified and studied other sources of distortions related to inflation besides the ZLB.

Balancing these opposing influences on the choice of the optimal inflation rate, central banks around the globe have sought to heed Daedalus' advice by choosing an inflation goal neither too low nor too high. In practice, many central banks have articulated inflation goals centered on 2 to 3 percent (Kuttner 2004). Simulations of macroeconomic models where monetary policy follows a version of the Taylor (1993) rule indicate that an inflation target of 2 percent will entail relatively frequent episodes of the ZLB acting as a binding constraint on monetary policy (Reifschneider and Williams 2000, Coenen, Orphanides and Wieland 2004; and Billi 2008). Nonetheless, these simulations predict that with an inflation target as low as 2 percent, the deleterious effects of the ZLB on macroeconomic volatility would be relatively modest because the magnitude and duration of the constraints on policy actions are relatively mild. Only with inflation targets of 1 percent or lower does the ZLB engender significantly higher variability of output and inflation in these simulations. In summary, a 2 percent inflation target was found to be an adequate buffer from the point of view of the ZLB.

The economic tumult of the past two years, with short-term rates near zero in most major industrial economies, has challenged the conclusion that a 2 percent inflation target is sufficiently high to avoid substantial costs from the ZLB. As shown in Figure 1, the global financial crisis and recession has driven many major central banks to cut short-term interest rates effectively to zero. Other central banks constrained by the ZLB include the Swedish Riksbank and the Swiss National Bank. Despite these monetary policy actions and considerable stimulus from fiscal policy, these economies are suffering their worst downturns in memory. Figure 2 shows the actual and forecasted paths for real GDP for major industrial economies. In addition, fears of deflation have intensified as falling commodity prices and growing slack put downward pressure on prices. As shown in Figure 3, overall consumer price index (CPI) inflation rates have fallen sharply in all major economies. Much of this decline is due to commodity prices, especially energy prices, but core measures of CPI inflation have come down in these economies over the past year as well.

Given these conditions, a strong case can be made for the desirability of additional monetary stimulus in the United States and in many other countries. But, with rates already effectively at zero, this is not an option, at least in terms of conventional monetary actions. Several central banks have therefore implemented unconventional monetary actions, such as changes in the composition and size of the asset side of their balance sheets. But, the short- and long-term effects of these unconventional monetary policies remain highly uncertain and such policies are at best imperfect substitutes for standard interest rate cuts.

This paper examines the effects of the ZLB on the current recession and reevaluates the expected future effects associated with the ZLB and the optimal inflation rate in light of new information and research.[1] There are two main findings. First, the ZLB did not

[1] I do not examine issues related to multiple equilibria studied by Benhabib et al (2001). Instead, as in

materially contribute to the sharp declines in output in the United States and many other economies through the end of 2008, but it is a significant factor slowing recovery. Model simulations imply that an additional 4 percentage points of rate cuts would have kept the unemployment rate from rising as much as it has and would bring the unemployment and inflation rates more quickly to steady-state values, but the ZLB precludes these actions. This inability to lower interest rates comes at the cost of $1.7 trillion of foregone output over four years. Second, *if* recent events are a harbinger of a significantly more adverse macroeconomic climate than experienced over the preceding two decades, then a 2 percent steady-state inflation rate may provide an inadequate buffer to keep the ZLB from having noticeable deleterious effects on the macroeconomy, assuming the central bank follows the standard Taylor Rule. In such an adverse environment, stronger systematic countercyclical fiscal policy and/or alternative monetary policy strategies can mitigate the harmful effects of the ZLB with a 2 percent inflation target. However, even with such policies, an inflation target of 1 percent or lower could entail significant costs in terms of macroeconomic volatility.

The paper is organized as follows. Section II examines the effects of the ZLB on the U.S. economy during the current episode. Section III reexamines the assumptions and results from past calculations of the macroeconomic effects of the ZLB under the Taylor Rule. Section IV evaluates alternative monetary and fiscal policies designed to mitigate the effects of the ZLB. Section V concludes.

2 Lessons from the Current Recession

The ongoing global recession provides compelling proof that the ZLB can be a significant constraint on monetary policy with potentially enormous macroeconomic repercussions. This section investigates two questions regarding the role of the ZLB in the current episode. First, how should one interpret the widespread occurrence of central banks lowering rates to near zero? Second, what are the consequences of the ZLB in terms of the depth of the recession and the speed of recovery?

Evans et al (2008), I assume that discretionary fiscal policy will intervene to assure that a unique steady-state exists and the economy tends back to that steady state.

The fact that central banks have been constrained by the ZLB should not not surprising; in fact, one of the three main "lessons" of Reifschneider and Williams (2000) was that central banks that pursue inflation goals of around 2 percent would encounter the ZLB relatively frequently.[2] For example, Reifschneider and Williams (2002) find that with a 2 percent inflation target, roughly in line with the practices of many major central banks, a calibrated version of the Taylor rule (1993) hits the ZLB about 10 percent of the time in simulations of the Federal Reserve Board's FRB/US macroeconometric model. Given that inflation has been centered around 2 percent in the United States since the early 1990s, it was fully predictable that the ZLB would become an issue–either as a threat, as in 2004, or as a reality, as it is today.

Indeed, the widespread occurrence of central banks running into the ZLB is evidence that they have learned a second lesson from research that policymakers should not shy away from the ZLB, but should instead "embrace" it. A common theme in research on the ZLB is that when the economy weakens significantly or deflation risks arise, central banks should act quickly and aggressively to get rates down as soon as possible to maximize the monetary stimulus in the system when the economy is weakening. "Keeping your powder dry" is precisely the worst thing to do. Figure 4 shows nominal and ex post real rates on short-term Treasury securities going back to the 1920s. Despite the low rate of inflation and three recessions, nominal interest rates did not once approach the ZLB back then. That the ZLB appears to be a greater problem today than in the 1950s and early 1960s, when inflation was also low, may reflect "better" monetary policy in the more recent period. Indeed, a comparison of estimated Taylor-type rules covering that period and the more recent past indicates that short-term interest rates were far less sensitive to movements in output and inflation during the earlier period (Romer and Romer, 2002). Of course, the

[2]Note that the lower bound does not necessarily equal zero. On one hand, lowering the interest rate below a small positive value may incur costly disruptions to money and other short-term financing markets. In this case, central banks may choose not to lower rates all the way to zero, making the effective lower bound a small positive number. On the other hand, a central bank can in principle lower interest rates below zero by charging interest on reserves. However, there are still limits to how low interest rates can go because banks and other agents can choose to hold currency instead, which yields zero interest less an holding cost κ, equal to the cost of safely storing and transporting cash). So, instead of a "zero bound," there is a $-\kappa$ lower bound on short-term interest rates.

U.S. economy and financial system were very different 50 years ago so other factors may also explain the differences in interest rate behavior.

To answer the second question, I conduct counterfactual simulations of the Federal Reserve's FRB/US model where the Federal Reserve is not constrained by the ZLB.[3] The simulations are best thought of as scenarios where the economy entered the current episode with a higher steady-state inflation rate and therefore the Federal Reserve had a large interest rate buffer to work with. I consider experiments in which the Federal Reserve is able to lower the funds rate by up to 600 basis points more than it has. For comparison, Rudebusch (2009) finds that the funds rate would be predicted to fall to about -5 percent based on an estimated monetary policy rule and FOMC forecasts. Of course, these experiments are not real policy options available to the Fed. But they allow me to quantify the effects of the ZLB on the evolution of the U.S. economy.

In evaluating the role played by the ZLB, it is important to get the timing of events correctly. Private forecasters did not anticipate that the ZLB would be a binding constraint on monetary policy until very late in 2008. Figure 5 shows the expected path of the fed funds rate according to the Blue Chip forecasts at various points in 2008 and 2009. At the beginning of September 2008–right before the failure of Lehman Brothers and the ensuing panic–forecasters did not expect the funds rate to fall below 2 percent. It was not until early December 2008, when the full ramifications of the panic became clear, that forecasters came to anticipate a sustained period of rates below 1 percent and the zero lower bound clearly came into in play. In fact, the Federal Open Market Committee (FOMC) cut the target funds rate from 1 percent to a 0 to 1/4 percentage point range on December 16, 2008. A similar pattern is seen in forecasts of policy rates in other major industrial economies, where central banks except for Japan made their final rate cuts later than the FOMC.

The preceding argument is based on evidence from point forecasts, which typically correspond to modal forecasts. In theory, economic decisions depend on the full distribution

[3] See Brayton et al 1997 for a description of the FRB/US model. In the counterfactual simulations I use the version of FRB/US with VAR expectations. In the stochastic simulations used to evaluate alternative policy rules discussed in Sections III and IV of the paper, I use the version of FRB/US with rational expectations.

of the forecasts, not just the mode. The possibility that the ZLB could bind in the future may have introduced significant downward asymmetry in forecast distributions of output and inflation in late 2008. Such an increase in the tail risk of a severe recession could have caused households and businesses to curtail spending more than they would have if the ZLB was not looming on the horizon. Although the evidence is not definitive, forecasts in late 2008 do not appear to provide much support for such a channel. Based on options on fed funds futures (see Carlson et al 2005), even as late as early November 2008, market participants placed only about a 25 percent probability of a target rate equal of 50 basis points or lower in January 2009. In addition, the distribution of forecasts for real GDP growth in 2009 from the Survey of Professional Forecasters in the fourth quarter of 2008 does not display obvious signs of asymmetric downside risks.

In summary, the available evidence suggests that through late 2008, that is, until the ramifications of the financial panic following the failure of Lehman Brothers were recognized, the ZLB was not viewed by forecasters as a binding constraint on policy. Therefore, it is unlikely that it had a major impact on the economy before that time outside Japan. Importantly, this is the period in which the economy was contracting most rapidly. According to monthly GDP figures constructed by Macroeconomic Advisors, the period of sharp declines in real GDP ended in January 2009, with real GDP falling by 2 percent in December 2008 and 0.7 percent in January 2009. Real GDP was roughly flat from January through July 2009.

Since early 2009, however, the ZLB has clearly been a constraint on monetary policy in the United States and abroad. Interestingly, forecasters and market participants expect the ZLB to be a relatively short-lived problem outside Japan. The dashed lines in Figure 1 show market expectations of overnight interest rates derived from future contracts as of September 2009. Market participants expect major central banks except for the Bank of Japan to start raising rates by early 2010. As seen in Figure 5, Blue Chip forecasters have likewise consistently predicted that the Fed would start raising rates after about a year of near-zero rates. Even those forecasters in the bottom tail of the interest rate forecast distribution of the Blue Chip panel expect the ZLB to constrain policy for only about a year and a half. Based on these expectations that central banks will raise rates relatively soon, one might be tempted to conclude that the effects of the ZLB have been relatively modest. Arguing against that conclusion is that four quarters is the mean duration in which the ZLB constrained policy in model simulations with a 2 percent inflation target reported in Reifschneider and Williams (2000) and that such episodes can inflict costs on the macroeconomy. Moreover, these forecasts of the future paths of interest rates may prove to be inaccurate.

I construct the counterfactual simulations based upon a baseline forecast set equal to the August 2009 Survey of Professional Forecasters (SPF) forecast (Federal Reserve Bank of Philadelphia, 2009). The baseline forecast for the short-term interest rate, the unemployment rate, and the core personal consumption price (PCE) index inflation rate are shown in Figures 6, 7, and 8, respectively.[4] The SPF also foresees the unemployment rate remaining above 7 percent through 2012 and core PCE price inflation remaining below the median value of the FOMC's long-run inflation forecasts of 2 percent through 2011. Interestingly, this forecast has the core inflation rate rising over 2010-11 despite the high rate of unemployment during that period. Such a forecast is consistent with a Phillips curve model of inflation in which inflation expectations are well anchored around 2 percent (Williams 2009). Note that these forecasts incorporate the effects of the fiscal stimulus and unconventional monetary policy actions taken in the United States and abroad.

I consider three alternative paths for the nominal funds rate and examine the resulting simulated values of the unemployment rate and the core PCE price inflation rate. Based on the evidence presented above that the ZLB was not a binding constraint until the very end of 2008, I assume that the additional nominal rate cuts occur in 2009q1. I assume the entire additional cut occurs in that quarter and that the rates are held below the baseline values through 2010q4, after which the short-term nominal rate returns to its baseline (SPF

[4] The SPF does not provide a forecast for the fed funds rate, but does provide a forecast for the 3-month Treasury rate, which I use as a proxy for the fed funds rate. In addition, the SPF does not report quarterly figures for 2011 and 2012. I interpolated quarterly figures based on annual figures for those years and the multi-year forecasts for PCE price index inflation.

forecast) value. I assume no modifications of the discretionary fiscal policy actions and unconventional monetary policy actions that are assumed in the baseline forecast. I further assume that the monetary transmission mechanism works as predicted by the FRB/US model; that is, the disruptions in financial sectors do not change the marginal effect of additional rate cuts.[5] Admittedly, these are strong assumptions, but I do not see better alternatives. The results of the simulations are shown in Figures 6, 7, and 8.

I evaluate the simulated outcomes using a standard ad hoc loss function of the form:

$$\mathcal{L} = \sum_{t=2009q1}^{2012q4} \left\{ (\pi_t - 2)^2 + \lambda (u_t - u^*)^2 \right\}, \tag{1}$$

where π is the core PCE price index inflation rate, u is the unemployment rate, and u^* is the natural rate of unemployment. The inflation goal is assumed to be 2 percent. The SPF forecast only runs through late 2012, so I cannot extend the calculation of the loss beyond that point, nor can I use the optimal control techniques developed by Svensson and Tetlow (2005). Table 1 summarizes the outcomes for the baseline forecast and the alternative policy simulations. The first four columns of numbers in the table report the central bank losses for different weights on unemployment stabilization in the loss function, λ, and different values for the natural rate of unemployment, u^*, assumed in the loss function.[6] The values for the natural rate included in the table cover the range of recent estimates. The median estimate of the natural rate of unemployment in the most recent SPF survey percent was 5 percent, while the highest reported estimate was 6 percent. Weidner and Williams (2009) provide evidence suggesting the natural rate of unemployment may currently be as high as 7 percent. The final two column report the simulated values of the unemployment and inflation rates at the end of the forecast period (2012q4).

The additional 200 basis points of rate cuts speeds the pace of economic recovery relative to the baseline forecast, bringing the unemployment rate near 6-1/2 percent by the end of

[5]Some argue that monetary policy may be more or less effective than usual in the current environment, but there is little empirical evidence to guide any modifications of the model.

[6]Note that I assume the same baseline forecast independent of the value of the natural rate of unemployment used in computing the central bank loss. That is, I treat the natural rate of unemployment as an unobservable variable that underlies the baseline forecast. In particular, I do not consider alternative baseline forecasts predicated on alternative views of the natural rate of unemployment.

Table 1: Effects of Alternative Monetary Policy Paths

Simulation	$\mathcal{L}$ $\lambda = 0$	$\lambda = 1$ $u^* = 5$	$\lambda = 1$ $u^* = 6$	$\lambda = 1$ $u^* = 7$	2012q4 Value u	2012q4 Value π
Baseline forecast	4.4	248.0	142.0	68.0	7.3	2.0
2 percentage point lower interest rate	2.5	193.5	103.8	46.1	6.6	2.2
4 percentage point lower interest rate	1.4	151.0	77.5	36.0	5.9	2.3
6 percentage point lower interest rate	1.3	120.2	63.0	37.8	5.2	2.5

This table reports the central bank losses and the simulated unemployment and inflation rates in 2012q4 from FRB/US model simulations of alternative monetary policy paths over 2009-2012. The baseline is the August 2009 Survey of Professional Forecasters forecast. The natural rate of unemployment is denoted by u^*. The assumed inflation target is 2 percent.
The loss is given by: $\mathcal{L} = \sum_{t=2009q1}^{2012q4} \left\{ (\pi_t - 2)^2 + \lambda (u_t - u^*)^2 \right\}$

2012. The reduction in slack and the lower exchange value of the dollar cause core price inflation to rise more quickly back to 2 percent. In fact, core inflation slightly overshoots 2 percent by the end of 2012. As seen in the second row of the table, this policy reduces the central bank loss function by a considerable amount, for all combinations of parameters reported in the table. In the baseline forecast, inflation is below target for nearly the entire forecast period and the unemployment rate is consistently above the natural rate, so the 200 basis points of rate cuts move both objective variables closer to target. Only in the final few quarters of the simulation do tradeoffs materialize.

The second simulation of 400 basis points of easing relative to baseline is more effective at bringing the unemployment rate down and inflation closer to the assumed 2 percent target over most of the forecast period. This policy yields a much lower central bank loss for all parameter combinations reported in the table. The results are striking. Even when the sole objective is the stabilization of inflation, an additional 400 basis points of easing is called for. Similarly, when the central bank cares about stabilizing unemployment around its natural rate, even with a 7 percent natural rate of unemployment, 400 basis points of easing reduces the central bank loss. One concern with this policy is that inflation is above 2 percent by the end of 2012 and trending upward. Policy needs to be tightened at some point to bring inflation back down to 2 percent. Of course, in all cases, the appropriate path for policy in 2012 and beyond depends on the natural rate of unemployment and the evolution of the economy in later years.

The third simulation of 600 basis points of easing relative to baseline yields mixed results. It yields a smaller loss over the simulation period as long as the natural rate of unemployment is below 7 percent. But, it accomplishes this at the cost of an inflation rate that is 1/2 percent above the assumed target at the end of 2012. Based on these results, such a sharp reduction in rates would only be beneficial if the natural rate of unemployment is not much higher than 5 percent and if it were followed by a much sharper increase in interest rates in 2011 and 2012 than assumed in the simulation.

Based on these results, a compelling case can be made that at least an additional 400 basis points of rate reductions would have been beneficial in terms of stabilizing inflation around a 2 percent target and the unemployment around its natural rate. The magnitude of the costs of the ZLB can be measured in terms of the differences in real output between the baseline forecast and the alternative simulation of an additional 400 basis points of rate cuts. In that simulation, real GDP averages about 3 percent above the baseline forecast over 2009-2012 (the unemployment rate averages about 1 percentage point below baseline over this period). An additional 4 percentage points of monetary stimulus yields a total increase in output over these four years of about $1.7 trillion. This translates to an increase in per capita output of a total of about $5500, summing over these four years. The implied increase in consumption is about 2 percent on average, which translates into total increase in per capita consumption of about $2600, again summing over the four years. These calculations abstract from the additional effects on output outside the forecast window. By any measure, these are sizable losses from the ZLB and much larger than estimates of the typical cost of business cycles.[7]

A final caveat regarding these simulations is in order. A notable feature of these alternative scenarios is that they entail sizable negative real interest rates for two years. In the second alternative scenario of a 400 basis point reduction in interest rates, the real

[7] The current episode, as projected by the SPF forecast, is an outlier in both depth and duration compared to past post World War II recessions. But, as argued in this paper, the ZLB has played a key role in this outcome, a situation that has not occurred since the Great Depression.

funds rate averages below -5 percent during 2009 and 2010. As seen in Figure 4, there have been few peacetime episodes of large sustained negative real interest rates. Although clearly helpful from the perspective of stimulating the economy, there is the possibility that such a lengthy period of very negative real interest rates could have harmful unintended consequences, such as fueling another speculative boom and bust cycle (see, for example, Taylor 2007).

3 Reexamining the Lessons from Research

These simulations illustrate the large costs associated with the ZLB in the current situation. If this recession represents a unique, extraordinary incident, it has had no implications for the choice of inflation goal or design of a policy rule regarding the ZLB. Indeed, a third "lesson" from Reifschneider and Williams (2000) is that there will be rare instances when the ZLB is very destructive to the macroeconomy, requiring fiscal or other policies to avoid a complete economic collapse. The recent episode–characterized by reckless risk taking on a global scale, poor risk management, lax regulatory oversight, and a massive asset bubble–may be such a 100-year flood. Alternatively, this episode may have exposed some cracks in the analysis of the ZLB's effects on the ability of central banks to achieve their macroeconomic stabilization goals. In this section, I review key assumptions from the literature and conduct "stress tests" of past research, applying lessons from the past few years.

The magnitude of the welfare loss owing to the ZLB depends critically on four factors: the model of the economy, the steady-state nominal interest rate buffer (equal to the sum of the steady-state inflation rate, π^*, and the steady-state, or "equilibrium," real interest rates, r^*), the nature of the disturbances to the economy, and the monetary and fiscal policy regime. Recent events have challenged a number of assumptions regarding the structure of the macro models used in past research on the ZLB. Eventually, new models will emerge from the experience of the past few years, but for now I am limited to the models that exist.[8] Because the effects of the ZLB depend on the extent of nominal and real frictions

[8]Beyond the need for better models of financial frictions, the global nature of the crisis has important

(Coenen 2003) and the full set of shocks buffeting the economy, quantitative research into the effects of the ZLB is best done with richer models that incorporate such frictions. For this reason, in this paper, I use the Federal Reserve Board's FRB/US model for my analysis, rather than a small-scale stylized model.

One critical aspect of model specification is the assumption that inflation expectations would remain well anchored. As discussed in Reifschneider and Williams (2000) and Evans et al (2008), absent anchored inflation expectations, the ZLB could give rise to a calamitous deflationary spiral with rising rates of deflation sending real interest rates soaring and the economy into a tailspin. In the event, inflation expectations have been remarkably well behaved in all major industrial economies. The dashed lines in Figure 3 show consensus forecasts of overall inflation in several countries. Despite the severity of the downturn, forecasters expect inflation rates to bounce back up over this year and next. Long-run inflation expectations in these countries, shown in Figure 9, have also been very stable over the past several years, despite the large swings in commodity prices and the severe global recession. Thus far, at least, inflation expectations appear to be well anchored. But, there remains a risk that inflation expectations could become unmoored, in which case the ZLB poses a larger threat.

A second key assumption is the steady-state real interest rate, which, along with the steady-state inflation rate, provides the buffer for monetary policy actions to stabilize the economy. A worrying development over the past decade is a decline in real interest rates. The long-run average of the real interest rate–defined to be the nominal federal funds rate less the PCE price index inflation rate–is about 2-1/2 percent, the figure used by Reifschneider and Williams (2000). But, the Kalman filter estimate of the equilibrium real rate of interest has fallen to about 1 percent, as shown in Figure 10. Other time-series based estimates show similar, or even larger, declines. For example, the trend real interest rate computed using the Hodrick-Prescott filter (with smoothing parameter of 1600) is around zero in the second quarter of 2009.

implications for the effects of the ZLB and the ability of monetary policy to stabilize the economy (Bodenstein et al 2009).

As seen in Figure 10, the decline in the Kalman filter estimate of the equilibrium real interest rate is associated with the recent severe downturn and may prove to be an overreaction to the deep recession. This conclusion receives some support from data from inflation-indexed Treasury securities. Evidently, investors expect real interest rates to remain low over the next five years, but to be closer to historically normal levels thereafter. Nonetheless, given the massive loss in wealth here and abroad and the resulting increase in private saving, there is a risk that the steady-state real interest rate will remain low for some time (Glick and Lansing, 2009). Based on this evidence, a reasonable point estimate of the steady-state real fed funds rate is about 2-1/2 percent, but there is a real risk that it could be as low as 1 percent. Of course, the steady-state real rate could be higher than 2-1/2 percent, possibly owing to large fiscal deficits in the United States and abroad (Laubach 2009). In that case, the effects of the ZLB would be correspondingly muted.

The third key assumption is the nature of the disturbances to the economy. Because the ZLB affects events in the lower tail of the distribution of interest rates, the distribution of the shocks is a critical factor determining the effects of the ZLB. Reifschneider and Williams (2000, 2002) based their analysis on the covariance of estimated disturbances from the mid-1960s through the 1990s. Other research is based on disturbances from the period of the Great Moderation from the early 1980s on (Coenen, Orphanides, and Wieland 2004; Adam and Billi 2006; Williams 2006). Recent events hint that what were once thought to be negative "tail" events may occur frequently and that the period of the Great Moderation may provide an overly optimistic view of the future macroeconomic landscape. Given the limited number of observations since the start of the financial crisis, it is not yet possible to ascertain whether these events represent a sustained break from the past behavior of disturbances.

Given the great deal of uncertainty–much of it difficult or even impossible to quantify–regarding the future economic environment, I take a minimax approach to evaluating policies. Specifically, I look for policies that perform well in very adverse or "worst-case" scenarios as well as in the baseline scenario. I take the baseline scenario to be a steady-state real interest rate of 2-1/2 percent and disturbances drawn from a joint normal distribution based on model disturbances from 1968-2002. I consider alternative adverse scenarios characterized by a steady-state real interest rate of 1 percent and disturbances drawn from more adverse distributions. Of course, these two sources of uncertainty represent only a slice of the spectrum of uncertainty relevant for the ZLB. By taking worst cases from these two sources, the aim is provide insurance against a wide variety of other forms of uncertainty, including model misspecification, unanchored inflation expectations, etc..

I follow the simulation methodology of Reifschneider and Williams (2000) with two relatively minor modifications. First, the simulation results reported here are based on a more recent vintage of the FRB/US model from 2004. Second, following Orphanides et al (2000) and Reifschneider and Williams (2002), I assume that the output gap included in the monetary policy rule is subject to exogenous, serially-correlated mismeasurement. The estimates of the simulated moments are based on two sets of stochastic simulations, lasting a total of 25,000 years of simulated data.[9] The use of such extremely long simulations provides reasonably accurate estimates of model-implied moments, effectively eliminates the effects of initial conditions, and implies that rare events occur in the simulations. Finally, I assume that automatic stabilizers and other endogenous responses of fiscal variables behave as usual, but that discretionary fiscal policy is not used except in extreme downturns.

In the following, unless otherwise indicated, monetary policy is assumed to follow a Taylor-type policy rule of the form:

$$i_t = \max\left\{0, r_t^* + \bar{\pi}_t + 0.5(\bar{\pi}_t - \pi^*) + \phi y_t\right\}, \tag{2}$$

where i_t is the nominal interest rate, r_t^* is the steady-state real interest rate, $\bar{\pi}$ is the four-quarter percent change in the PCE price index, π^* is the inflation target, and y_t is the output gap. [10] Following Orphanides and Williams (2002), I refer to the specification with $\phi = 0.5$ as the "Classic" Taylor (1993) rule and other specifications as "Taylor-type" rules.

[9]In the simulations using disturbances following the t distribution, I conduct twice the normal number of simulations.

[10]I have included an upward bias in the notional inflation target in the policy rule that is needed for the inflation rate to equal the true target level. As discussed in Reifschneider and Williams (2002) and Coenen, Orphanides, and Wieland (2004), the asymmetric nature of the ZLB implies that the inflation rate will on average be lower than the inflation target in the rule. The magnitude of this upward bias is larger, the more

The simulated outcomes are evaluated using a central bank loss function (that slightly differs from that used earlier)of the form:

$$\mathcal{L} = E\left\{(\pi - \pi^*)^2 + y^2 + 0.25 * (i - i^*)^2\right\}, \quad (3)$$

where π is the overall PCE price index inflation rate, $i^* = \pi^* + r^*$ is the unconditional mean of the nominal short-term interest rate, and E denotes the unconditional expectation. Note that I consider only the costs of inflation variability and not the costs of steady-state inflation, on the grounds that our understanding of the costs of steady-state inflation is very limited.[11] Thus, I stop short of finding optimal inflation targets. I return to the issue of the costs of steady-state inflation briefly in the conclusion.

The upper panel of Table 2 reports the simulated outcomes under the classic Taylor rule assuming the shocks are drawn using a normal distribution from the covariance matrix computed from the full sample of disturbances (1968-2002). The first two columns report the steady-state inflation rates corresponding to alternative values of the steady-state real interest rate, r^*. In terms of the model simulations, the key statistic is the nominal interest rate buffer, which equals the sum of the steady-state inflation rate, π^*, and the steady-state real interest rate, r^*. In the baseline scenario, the steady-state real interest rate is assumed to be 2-1/2 percent. For this case, the numbers indicated in the first column of the table correspond to the values of the steady-state inflation target. In the case of a steady-state real interest rate of 1 percent, the numbers in the second column of the table correspond to the values of the steady-state inflation target. The third and fourth columns report the share of time that the nominal federal funds rate is below 0.1 and 1 percentage points, respectively. The fifth column reports the share of the time that the output gap is below -4 percent, representing a major recession of the type that has occurred in 1958, 1975, 1982-83, and 2009. For comparison, over 1955q1-2009q2 about 6 percent of the time, the CBO estimate of the output gap was below -4 percent. The sixth through ninth columns

the ZLB constrains policy. I correct for this downward bias by adjusting the inflation target in the policy rule.

[11]Alternatively, this approach can be justified by assuming that firms increase prices at the steady-state inflation rate without occurring adjustment costs (in an adjustment cost model) or reoptimizing (in a Calvo model).

report the standard deviations of the output gap, the PCE price index inflation rate, and the nominal federal funds rate. The final column reports the central bank loss.

In the baseline scenario, if policy follows the classic Taylor rule, then the ZLB has only minor affects on the magnitude of macroeconomic fluctuations if the inflation target is 1-1/2 percent or higher. Under these assumptions, a 1-1/2 percent inflation target implies that the funds rate will fall below 1 percent 10 percent of the time, and will be below 10 basis points 6 percent of the time. The standard deviation of the unconstrained interest rate is only about 2-1/2 percent. So, with a 4 percentage point buffer, most episodes where the ZLB is binding are relatively mild and effects are minor. These results are consistent with those of many studies that with a steady-state nominal interest rate of 4 percent or higher, the ZLB has very modest macroeconomic effects under the Taylor rule.

If the steady-state real interest rate is only 1 percent, then under the classic Taylor rule a 3 percent inflation objective is sufficiently high to avoid most costs from the ZLB. With a 2 percent inflation goal, the ZLB binds 13 percent of the time and causes a more noticeable rise in output gap variability (a rise of 0.3 percentage points relative to a 5 percent or higher inflation goal). The incidence of deep recessions rises as well, but remains below 10 percent. Based on this evidence, a lower steady-state real interest rate argues for a higher inflation goal to reduce the costs associated with the ZLB. But, it alone does not overturn the basic result of past research that a 2 percent inflation goal is associated with relatively modest costs from the ZLB. This conclusion is reinforced when one considers alternative policy rules that mitigate the problems associated with the ZLB, as discussed below.

As noted above, the assumption of normally distributed disturbances may understate the likelihood of tail events of the type that we have recently experienced. To gauge the sensitivity of the results to this assumption, I conduct simulations where the disturbances have the same covariance as before (that is, based on the full 1968-2002 sample), but are assumed to follow the t distribution with 5 degrees of freedom. This distribution is characterized by excess (relative to the normal distribution) kurtosis of 6; that is, it displays significantly fatter tails than the normal distribution. For example, the probability of a three

Table 2: Outcomes for Different Shock Distributions

Inflation Target		Probability			Std. Dev.			
$r^* = 2.5$	$r^* = 1$	$i < 0.1$	$i < 1$	$y < -4$	y	π	i	$\mathcal{L}$
Shocks drawn from 1968-2002 covariance; normally distributed								
-0.5	1	.23	.31	.12	3.1	1.5	2.4	13.3
0.5	2	.13	.20	.08	2.8	1.5	2.4	11.5
1.5	3	.06	.10	.06	2.6	1.5	2.5	10.6
2.5	4	.04	.08	.06	2.6	1.5	2.6	10.5
3.5	5	.02	.03	.06	2.5	1.5	2.6	10.1
5.5	7	.00	.00	.05	2.5	1.5	2.6	9.9
7.5	9	.00	.00	.05	2.5	1.5	2.6	9.9
Shocks drawn from 1968-2002 covariance; t(5) distributed								
-0.5	1	.24	.33	.13	3.1	1.5	2.4	13.2
0.5	2	.13	.20	.08	2.8	1.5	2.5	11.5
1.5	3	.08	.13	.07	2.7	1.5	2.5	10.8
2.5	4	.04	.07	.06	2.6	1.5	2.7	10.6
3.5	5	.03	.05	.06	2.6	1.5	2.7	10.6
5.5	7	.00	.00	.05	2.5	1.5	2.6	9.9
7.5	9	.00	.00	.05	2.5	1.5	2.6	9.9
Shocks drawn from 1968-1983 covariance; normally distributed								
-0.5	1	.29	.38	.18	3.7	1.7	2.6	18.4
0.5	2	.16	.23	.12	3.3	1.6	2.8	15.5
1.5	3	.09	.14	.11	3.2	1.6	2.8	14.5
2.5	4	.04	.07	.09	3.0	1.6	2.8	13.6
3.5	5	.03	.06	.09	2.9	1.6	2.9	13.4
5.5	7	.02	.03	.08	2.9	1.6	2.9	13.0
7.5	9	.00	.00	.08	2.9	1.6	2.9	13.0

Notes: This table reports simulated moments for different assumptions regarding the distribution of shocks. Results are shown for two values of the steady-state real interest rate, r^*. The first column indicates the inflation target assuming $r^* = 2.5$; the second column indicates the inflation target assuming $r^* = 1$.
Monetary policy rule: $i_t = \max\{0, r_t^* + \bar{\pi}_t + 0.5(\bar{\pi}_t - \pi^*) + 0.5y_t\}$.
Central bank loss: $\mathcal{L} = E\left\{(\pi - \pi^*)^2 + y^2 + 0.25 * (i - i^*)^2\right\}$, where $i^* = \pi^* + r^*$.

standard deviation (or greater) event is over 4 times greater with this $t(5)$ distribution than the normal distribution.[12]

Allowing for a fatter-tailed distribution of distributions does not materially affect the results regarding the effects of the ZLB. The middle panel of Table 2 reports the results from these simulations. The ZLB is encountered slightly more often, and the standard deviations of the output gap are in some cases higher, but these effects are nearly lost in rounding. Note that the shocks being used differ from those used in the other simulations,

[12]The choice of the degrees of freedom of 5 is somewhat arbitrary, but near the lower bound of allowable values for the purpose at hand. In particular, the degrees of freedom of the t distribution must exceed 4 for finite second and fourth moments to exist.

so comparison to the simulations using normally distributed disturbances is not exact due to the finite samples of the simulations. Similar results (not reported) were obtained when the disturbances were assumed to follow a Laplace distribution, which has excess kurtosis of 3. There may be more exotic distributions with even greater kurtosis that would have greater effects on these results, but a more critical issue appears to be the covariance of the shocks, rather than the precise shape of the distribution.

The effects of the ZLB are far more pronounced when the shocks are drawn from the pre-Great Moderation period. In the simulations reported in the lower portion of the table, the disturbances are drawn from a normal distribution where the covariance of disturbances is estimated from the 1968-1983 sample of model disturbances. As a result, the ZLB is encountered more frequently and with greater costs in terms of stabilization of the output gap. With a steady-state real interest rate of 2-1/2 percent, a 2 percent inflation target is just on the edge of the region where the ZLB has nontrivial costs in terms of macroeconomic variability. Inflation goals of 1-1/2 percent or lower entail moderate increases in output gap variability.

The combination of a 1 percent steady-state real interest rate and greater volatility of disturbances poses the greatest threat to macroeconomic stabilization in a low inflation environment. Inflation goals of 2 to 3 percent are associated with some increase in output gap variability, while a 1 percent inflation goal entails a significant increase in output gap variability. Even in these extreme cases, the effects on inflation variability are quite modest, reflecting the effects of assumption of well-anchored expectations.

How big are these losses? One metric is the fraction of the time the output gap is below -4 percent. In the adverse environment of shocks drawn from the 1968-1983 shock covariance and a steady-state real interest rate of 1 percent, this figure rises from 9 percent to 18 percent when the inflation target is reduced from 4 to 1 percent. The standard deviation of the output gap rise by 0.7 percentage point. For comparison, the standard deviation of the output gap during the “Great Moderation” period of 1985-2006 was 2 percentage points, according to CBO estimates. The comparable figure for 1965-1980 was

2.7 percentage points. Thus, moving from a 4 percent inflation target to a 1 percent inflation target yields an increase in output gap variability in these model simulations comparable to switching from the Great Moderation period to the 1965-1980 period. Moving from a 4 percent inflation target to a 2 percent target entails an increase in output gap variability comparable to switching from the Great Moderation period to the period of 1955-1965, when the standard deviation of the output gap was 2.3 percentage points, 0.3 percentage points above that during the Great Moderation period.

4 Alternative Monetary and Fiscal Policies

The results reported above indicate that in a particulary adverse macroeconomic environment of large shocks and a low steady-state real interest rate, the ZLB may cause a significant deterioration in macroeconomic performance when monetary policy follows the classic Taylor rule with a very low inflation target. As discussed in Reifschneider and Williams (2000, 2002) and Eggertsson and Woodford (2003), alternative monetary policy strategies improve upon the performance of the classic Taylor rule in a low inflation environment. Several such modifications are examined here. In addition, I consider the use of countercyclical fiscal policy to mitigate the effects of the ZLB. Throughout the following discussion, I assume the worst-case adverse macroeconomic environment of a 1 percent steady-state real interest rate and disturbances drawn from the covariance matrix computed from the shocks of the pre-Great Moderation period.

4.1 Modifying the Taylor rule

One way to achieve greater stabilization of the output gap even at low steady-state inflation rates and in an adverse environment is for the policy rule to respond more aggressively to movements in the output gap. Table 3 reports simulation results for alternative values of the coefficient on the output gap, ϕ, in the monetary policy rule. A larger response to output gap reduces output gap variability and allows the central bank to reach output and inflation goals at some cost of interest rate variability, even at inflation goals as low as 2 percent. For example, assume the goal is to have outcomes like those under classic Taylor rule ($\phi = 0.5$)

unconstrained by the ZLB, but with an inflation target of 2 percent. The Taylor-type rule with the stronger response to the output gap of $\phi = 1.5$ yields outcomes for output gap and inflation rate variability close to that of the Classic Taylor rule unconstrained by the ZLB, at the cost of somewhat greater interest rate variability. Similarly, outcomes similar to the unconstrained classic Taylor rule can be achieved with an inflation goal of 3 percent by setting $\phi = 1$.

Interestingly, too strong a response to the output gap can be counterproductive at very low steady-state interest rates. This outcome likely reflects the asymmetry of the policy response resulting from the ZLB. When the output gap is positive, policy tightens sharply. But, when the output gap is negative, the policy response is more likely to be truncated by the ZLB. This strongly asymmetric response causes output gap variability to rise at very low inflation targets in the adverse macroeconomic environment. A stronger response to inflation in the Taylor-type rule does not have much effect on the effects of the ZLB (not shown).[13]

None of these modified Taylor Rules performs well with an inflation target of 1 percent in the adverse macroeconomic environment. In all three cases, the standard deviation of the output gap rises sharply with an inflation target of 1 percent. The fraction of time that the output gap is below -4 percent is extremely high, between 17 and 20 percent. These figures decline dramatically when the inflation target is raised to 2 percent.

Other modifications to the Taylor-type rule can also be effective at offsetting the effects of the ZLB in low inflation environments. The upper panels of Table 4 report the results from a modified Taylor-type rule proposed by Reifschneider and Williams (2000). According to this policy rule, realized deviations of the interest rate from that prescribed by the rule owing to the ZLB are later offset by negative deviations of equal magnitude. Note that this does not necessarily imply the central bank is promising to raise inflation above its target in the future, but only that it makes up for "lost monetary stimulus" by holding the interest

[13] There are other reasons, however, for a stronger response to inflation, such as the better anchoring of inflation expectations in an economy with imperfect knowledge, as discussed in Orphanides and Williams 2002, 2007.

Table 3: Alternative Responses to Output Gap (ϕ) in Adverse Environment

(1968-83 shock covariance and $r^* = 1$)

Inflation Target	Probability $i < 0.1$	Probability $i < 1$	Probability $y < -4$	Std. Dev. y	Std. Dev. π	Std. Dev. i	$\mathcal{L}$
			$\phi = 0.5$				
1	.29	.38	.18	3.7	1.7	2.6	18.4
2	.16	.23	.12	3.3	1.6	2.8	15.5
3	.09	.14	.11	3.2	1.6	2.8	14.5
4	.04	.07	.09	3.0	1.6	2.8	13.6
5	.03	.06	.09	2.9	1.6	2.9	13.4
7	.02	.03	.08	2.9	1.6	2.9	13.0
9	.00	.00	.08	2.9	1.6	2.9	13.0
			$\phi = 1$				
1	.34	.41	.17	4.6	2.1	2.6	27.3
2	.16	.22	.08	3.1	1.7	3.3	15.2
3	.11	.15	.06	2.7	1.6	3.4	13.1
4	.08	.12	.06	2.6	1.6	3.4	12.4
5	.06	.10	.06	2.5	1.6	3.5	12.0
7	.02	.03	.05	2.5	1.6	3.6	12.0
9	.00	.01	.05	2.5	1.6	3.6	12.0
			$\phi = 1.5$				
1	.42	.49	.20	4.9	2.1	3.3	31.2
2	.24	.30	.09	2.9	1.7	3.8	17.1
3	.19	.24	.06	2.6	1.6	4.0	13.4
4	.17	.22	.06	2.5	1.6	4.0	12.8
5	.11	.15	.05	2.3	1.6	4.2	12.5
7	.05	.07	.04	2.3	1.7	4.4	13.0
9	.02	.03	.04	2.3	1.7	4.6	13.2

Notes: This table reports simulated moments for different assumptions regarding the response of monetary policy to the output gap (ϕ) in the adverse economic environment, characterized by shocks drawn from the 1968-1983 covariance and an steady-state real interest rate (r^*) of 1 percent.
Policy follows Taylor-type rule: $i_t = \max\{0, r_t^* + \bar{\pi}_t + 0.5(\bar{\pi}_t - \pi^*) + \phi y_t\}$.
Central bank loss: $\mathcal{L} = E\left\{(\pi - \pi^*)^2 + y^2 + 0.25 * (i - i^*)^2\right\}$, where $i^* = \pi^* + r^*$.

rate low for a period after the ZLB no longer binds.

This modified rule nearly eliminates the effects of the ZLB for inflation targets as low as 3 percent, and significantly reduces them for lower inflation targets. If the inflation goal is 2 percent, the modified rule with a greater response to output of $\phi = 1$ yields the same outcomes as the unconstrained Taylor rule in this adverse environment.

In rational expectations models like FRB/US, policies with inertial responses to movements in inflation and output gaps perform much better than static Taylor-type rules and closely approximate the outcomes under fully optimal policies (Woodford 2003, Levin and

Table 4: Alternative Monetary Policy Rules in Adverse Environment

(1968-83 shock covariance and $r^* = 1$)

Inflation Target	Probability $i < 0.1$	$i < 1$	$y < -4$	Std. Dev. y	π	i	$\mathcal{L}$
	Classic Taylor rule with lagged adjustment ($\phi = 0.5$)						
1	.18	.26	.12	3.7	1.6	2.8	19.4
2	.12	.19	.10	3.2	1.6	2.8	14.7
3	.07	.13	.09	3.0	1.6	2.8	13.6
4	.04	.08	.08	3.0	1.6	3.0	13.7
5	.03	.05	.08	2.9	1.6	2.9	13.0
7	.00	.01	.08	2.9	1.6	2.9	13.0
9	.00	.00	.08	2.9	1.6	2.9	13.0
	Taylor-type rule with lagged adjustment ($\phi = 1$)						
1	.32	.40	.12	3.6	1.6	3.2	27.6
2	.21	.28	.07	2.9	1.6	3.4	13.6
3	.16	.22	.06	2.5	1.6	3.4	11.7
4	.05	.15	.06	2.5	1.6	3.5	11.7
5	.02	.09	.06	2.5	1.6	3.5	11.8
7	.00	.03	.05	2.5	1.6	3.6	12.0
9	.00	.01	.05	2.5	1.6	3.6	12.0
	Optimized inertial policy rule						
1	.24	.33	.10	3.4	1.4	2.4	14.5
2	.15	.22	.08	2.9	1.4	2.6	11.9
3	.11	.16	.07	2.7	1.4	2.6	11.0
4	.05	.08	.06	2.5	1.4	2.6	10.2
5	.02	.04	.06	2.5	1.4	2.7	10.1
7	.00	.01	.06	2.5	1.4	2.7	10.2
9	.00	.00	.06	2.5	1.4	2.7	10.2

Notes: This table reports simulated moments for different assumptions regarding the response of monetary policy to the output gap (ϕ) in an adverse economic environment, characterized by shocks drawn from the 1968-1983 covariance and an steady-state real interest rate (r^*)of 1 percent.
Alternative monetary policies are described in the text.
Inertial policy: $i_t^u = 0.96 i_{t-1}^u + 0.04 * (r^* + \pi_t) + 0.04(\bar{\pi}_t - \pi^*) + 0.12 y_t$,

Williams 2003). In particular, I examine the performance of the policy rule taking the form:

$$i_t^u = 0.96 i_{t-1}^u + 0.04 * (r^* + \pi_t) + 0.04(\pi_t - \pi^*) + 0.12 y_t, \quad (4)$$

where i_t^u is the prescription for the federal funds rate unconstrained by the ZLB. The coefficient on the lagged interest rate of near unity imparts a great deal of inertia policy (also frequently referred to as “interest rate smoothing”). The actual setting of the interest rate must satisfy the ZLB:

$$i_t = \max\left\{0, i_t^u\right\}. \quad (5)$$

As shown in Reifschneider and Williams (2000), policy rules like this perform very well in the presence of the ZLB because they promise to keep interest rates low in the future and to allow inflation to rise above its long-run target following bouts of excessively low inflation.

This inertial policy rule delivers better macroeconomic performance with a 2 percent inflation target than the classic Taylor rule unconstrained by the ZLB. The lower part of Table 4 reports the simulated outcomes from inertial version of the Taylor-type rule where the parameters of the rule were chosen to yield minimum weighted variances of inflation, the output gap, and the nominal interest rate. Nonetheless, in this worst case adverse environment, there are limits to what this simple rule can accomplish, and performance suffers noticeably as the inflation goal is lowered to much below 2 percent. I obtain very similar results for a policy rule that targets the price level growing at a deterministic trend rather than the inflation rate, which Eggerston and Woodford (2003) find to perform well in the presence of the ZLB. Based on this evidence, there is little gain from switching from an optimized inertial policy to an explicit price-level targeting regime, even with very low steady-state inflation rates.

A potential problem with these alternative policy approaches is that the public may be confused by monetary policy intentions in the vicinity of the ZLB. For example, the asymmetric policy rule described represents a significant deviation from the standard reaction function, which could have unintended undesirable consequences(Taylor 2007). More generally, all of these alternative policies rely extensively on the expectations of future policy actions to influence economic outcomes. As shown by Reifschneider and Roberts (2006) and Williams (2006), if agents do not have rational expectations, episodes of the ZLB may distort expectations, reducing the benefits of policies that work very well under rational expectations. In particular, inertial and price-level targeting policies cause inflation to rise above the long-run target following an episode where the ZLB constrains policy. Such a period of high inflation could conceivably undermine the public's confidence in the central bank's commitment to price stability and lead to an untethering of inflation expectations. Indeed, central banks have averse to declaring a desire to see a sustained rise in inflation rise above the target level (Kohn 2009, Walsh 2009).

One method to minimize the public confusion is for the central bank to clearly communicate the central bank's expectations, including the anticipated policy path, as discussed by Woodford (2005) and Rudebusch and Williams (2008).[14] Another approach is to back up the communication with interventions in foreign exchange–as proposed by McCallum (2000), Svensson (2001), and Coenen and Wieland (2003)–or by targeting the short to middle end of the yield curve of Treasury securities as analyzed by McGough, Rudebusch and Williams (2005).

An additional potential problem with highly inertial and price-level targeting policies is that historically, the price level and interest rates tend to be relatively high as the economy enters a recession because of high inflation rates near the end of expansions.[15] In these circumstances, such policies imply delayed policy responses early in a downturn. The current episode illustrates this dilemma. As seen in Figure 3, inflation had been consistently running above 2 percent in several countries well into 2008. Although model simulations do not bear out these concerns, perhaps there is something missing from the dynamics in the models or the assumed monetary policies.

4.2 Counter-cyclical Fiscal Policy

The active use of counter-cyclical fiscal policy was excluded from consideration in most quantitative research on the ZLB and the simulations reported above. The experience of the past decade suggests that this assumption is too stringent. In this respect, by ignoring the ways in which fiscal policy is used to substitute for monetary policy, the future effects of the ZLB may be overstated. The past decade has seen the active use of sizable discretionary countercyclical fiscal policy in many countries. Japan aggressively used fiscal policy to stimulate the economy during the 1990s and the current recession. The

[14] Although a few central banks publish interest rate paths and the Bank of Canada recently made clear statements about its intended path, most central banks remain unwilling to provide such clear communication of their future policy intents.

[15] This observation is related to the strong correlation between the slope of the yield curve and recessions (Rudebusch and Williams, 2009). Past recessions are preceded by periods of monetary tightening in response to periods of high inflation.

International Monetary Fund (IMF, 2009) expects discretionary fiscal policy to average 1 percent of GDP in the G-20 economies over the period of 2008-2010, above and beyond automatic stabilizers and measures to support the financial sector.

Economic theory is clear that in the presence of nominal rigidities government spending can be useful at reducing the macroeconomic costs associated with the ZLB (see, for example, Eggertsson 2009; Christiano, Eichenbaum, and Rebelo 2009; and Erceg and Lindé 2009). Consider the case where, due a negative shock to the economy, the short-term interest rate declines but cannot fall enough to offset the shock. As a result, the real interest rate rises, consumption falls, and inflation falls. These consequences reduce household welfare. A temporary increase in government purchases increases output and raises wages and thereby marginal cost. This increase in marginal cost boosts the inflation rate and the expected rate of inflation. Given a fixed short-term nominal interest rate constrained by the ZLB, the rise in expected inflation lowers the real interest rate, causing consumption to rise. As a result, the increase in government spending reduces the fluctuations in inflation and the output gap and raises welfare.[16]

In principle, any number of ways of strengthening automatic stabilizers or introducing stronger counter-cyclical fiscal policy more generally could help mitigate the problems caused by the ZLB. Reifschneider and Roberts (2006) provide an example of the effects of fiscal policy stimulus when the ZLB is constraining policy using simulations of the FRB/US model. I consider one simple experiment based on a systematic fiscal policy rule for the category of federal government purchases excluding employee compensation and investment purchases (a category that makes up about one half of federal government purchases). The estimated fiscal reaction function for this category in the FRB/US model is given by:

$$g_t = 0.55 g_{t-1} + 0.07 g_{t-2} + 0.19 g_{t-3} - 0.0004 y_t + 0.0027 y_{t-1} + \gamma(i_{t-1} - i^u_{t-1}) + \epsilon_t, \quad (6)$$

where g is the log of government purchases in this category, yh is the output gap, and i^u

[16]In contrast to the case of government spending, the effects of income taxes with respect to the ZLB can be counterintuitive. In models without credit and liquidity constraints, lowering income taxes can be counterproductive because it lowers marginal costs and and inflation (Eggertsson and Woodford 2004). In such a model, raising taxes during a downturn can improve welfare. In models with liquidity-constrained consumers, tax cut can also raise demand.

is the setting of the unconstrained federal funds rate that would occur absent the ZLB. In the baseline model, $\gamma = 0$. I consider the effects of a sustained increase in federal government purchases when the ZLB constrains monetary policy by setting $\gamma = 0.02$. This value implies that a one percentage point interest rate gap owing to the ZLB causes overall federal government purchases to rise by 1 percent in the next period. Lags in fiscal policy implementation are approximated by the lag structure of this equation.

The modified fiscal reaction function cuts in half the macroeconomic effects of the ZLB for low steady-state interest rates of 3 and 4 percent. The lower part of Table 5 shows the outcomes from this experiment for the Taylor-type rule with $\phi = 1$. The upper part of the table shows the same rule without the fiscal response. In the worst case scenario, an inflation target of 3 percent is sufficient to avoid effects from the ZLB. An inflation target of 2 percent suffers a small increase in output variability. This specification for the fiscal reaction function is in no way meant to be optimal or even desirable, but rather to illustrate the effects of countercyclical fiscal policy aimed at mitigating the effects of the ZLB on the economy. Further research is needed in this area to devised better countercyclical fiscal policy rules.

4.3 Unconventional monetary policy actions

The preceding discussion and analysis abstracted from unconventional monetary actions, implicitly assumes that these are not used or are ineffective. However, the events of the past year provide ample evidence that central banks possess and are willing to use tools other than the overnight interest rate. Clouse et al (2003) and Bernanke and Reinhart (2004) describe alternative policy tools available to the Federal Reserve. In the current crisis, a number of alternative approaches have been put to use. Several central banks, including the Bank of England, the European Central Bank, the Federal Reserve, and the Bank of Japan, have instituted programs to buy or guarantee assets such as commercial paper and mortgage-backed securities. Finally, the Bank of Japan, the Bank of England ,and the Federal Reserve have expanded their holdings of longer-term securities through the creation of reserves. Many of these programs are aimed at improving the functioning

Table 5: Alternative Fiscal Policy in Adverse Environment

(1968-83 shock covariance and $r^* = 1$)

Inflation Target	Probability $i < 0.1$	Probability $i < 1$	Probability $y < -4$	Std. Dev. y	Std. Dev. π	Std. Dev. i	$\mathcal{L}$
			Baseline fiscal policy				
2	.34	.41	.17	4.6	2.1	2.6	27.3
3	.16	.22	.08	3.1	1.7	3.3	15.2
4	.11	.15	.06	2.7	1.6	3.4	13.1
5	.08	.12	.06	2.6	1.6	3.4	12.4
6	.06	.10	.06	2.5	1.6	3.5	12.0
8	.02	.03	.05	2.5	1.6	3.6	12.0
10	.00	.01	.05	2.5	1.6	3.6	12.0
			Government spending increase at zero bound				
2	.31	.39	.12	3.9	2.0	2.8	21.2
3	.16	.23	.07	2.8	1.6	3.2	13.3
4	.12	.17	.06	2.6	1.6	3.3	12.2
5	.08	.12	.06	2.5	1.6	3.4	11.8
6	.06	.10	.06	2.5	1.6	3.5	11.9
8	.02	.03	.05	2.5	1.6	3.6	12.0
10	.00	.01	.05	2.5	1.6	3.6	12.0

Notes: This table reports simulated moments for different assumptions regarding the response of fiscal policy in the presence of the ZLB, in an adverse macroeconomic environment, characterized by shocks drawn from the 1968-1983 covariance and an steady-state real interest rate (r^*)of 1 percent.
Monetary policy rule: $i_t = \max\{0, r_t^* + \bar{\pi}_t + 0.5(\pi_t - \pi^*) + y_t\}$.
Central bank loss: $\mathcal{L} = E\left\{(\pi - \pi^*)^2 + y^2 + 0.25 * (i - \bar{i})^2\right\}$, where $i^* = \pi^* + r^*$.

of impaired or distressed markets. Similarly, the Federal Reserve's purchases of agency debt and mortgage-backed securities were aimed at market segment that appeared to be functioning poorly. Future recessions may not be accompanied by severe financial market disruptions, in which case these tools would not be as useful at offsetting the shocks hitting the economy.

An open question is whether balance sheet policies such as quantitative easing or purchases of longer-term government securities are effective at stimulating the economy. Bernanke et al (2004) provide evidence that shocks to the supply of government securities affect their price and yield. Announcements by the Bank of England and the Federal Reserve regarding plans to buy longer-term government securities were followed by large movements in yields, providing additional support that such policy actions can affect yields (see Meier 2009, for a summary of the experience in the UK). Nonetheless, there is a great deal of uncertainty regarding the magnitude and duration of these effects. In addition, some observers fear adverse consequences of such actions if taken on a large scale, including the risk of large losses and the concerns that inflation expectations may become unmoored. Further careful study and analysis is needed before these policy options can be counted on as effective substitutes for more traditional monetary policy actions.

5 Conclusion

The zero lower bound has significantly constrained the ability of many central banks to stimulate the economy in the current recession. Counterfactual simulations suggest that the ZLB will impose significant costs on the U.S. economy in terms of lost output. Although these simulation focus on the effects of lower U.S. interest rates on the U.S. economy, comparable simulations for other economies where the ZLB has constrained monetary policy–such as in Japan and Europe–would no doubt show that the ZLB has also entailed significant costs in those places during the recent episode. A useful extension of the simulations reported in this paper would be to calculate the costs of the ZLB in a model of the global economy.

If the recent recession represents an unique, extraordinary incident, it has no particular implications for future monetary policy with respect to the ZLB. In particular, a 2 percent inflation target should provide an adequate buffer for monetary policy in the future. If, however, the era of the Great Moderation is over and the steady-state real interest rate remains very low, then the ZLB may regularly interfere with the ability of central banks to achieve macroeconomic stabilization goals. The analysis in this paper argues that an inflation target of 2 percent may be insufficient to keep the ZLB from imposing sizable costs in terms of macroeconomic stabilization in a much more adverse macroeconomic climate if monetary policy follows the standard Taylor Rule.

Given these results, it is important to study and develop monetary and fiscal policies that effectively counter the effects of the ZLB in preparation for the contingency of an adverse macroeconomic environment. Arguably, the application of aspects of many of these approaches over the past two years has helped combat the massive shocks that have buffeted the global economy. Improving these policies and developing new ones into systematic, predictable responses to economic conditions will help make them more effective in the future. An important lesson from the financial crisis, not addressed in this paper, is the critical need for effective regulation and supervision of financial markets to avoid the shocks to the global economy that ignited the current global financial crisis and recession.

Finally, this paper examines only the costs associated with the ZLB, abstracting from the many other sources of distortions related to steady-state inflation. Several of these–including transaction costs, real distortions associated with non-zero rates of inflation, and non-neutralities in the tax system–argue for zero or negative steady-state inflation rates. Others–including asymmetries in wage setting, imperfections in labor markets, distortions related to imperfect competition, and measurement bias–argue for positive steady-state inflation (see, for example, Akerlof et al 1996). Unfortunately, there has been relatively little research that weighs the costs of the ZLB against these other influences in a coherent, empirically-supported framework (see Billi and Kahn, 2008, for a review).[17] More research on these issues is needed.

[17] Much of the literature focuses on welfare costs related to holding zero interest bearing assets, which both Feldstein (1997) and Attansio et al (2002) convincing show are trivial. These costs are even lower now that the Federal Reserve and many other central banks pay interest on reserves.

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Figure 1: The Zero Lower Bound in the Current Global Recession

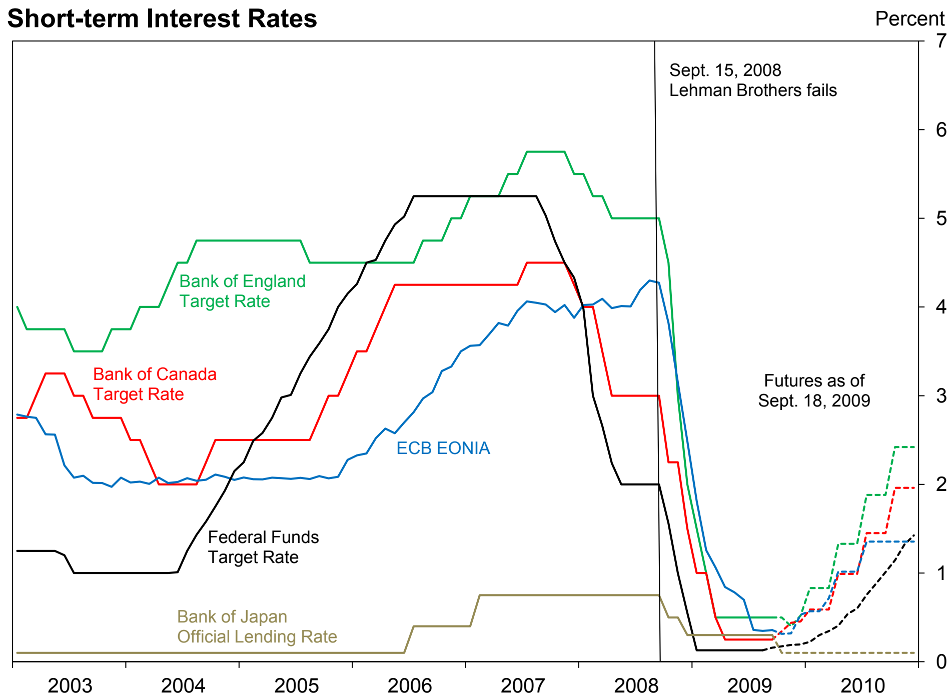

Figure 2: Global Recession

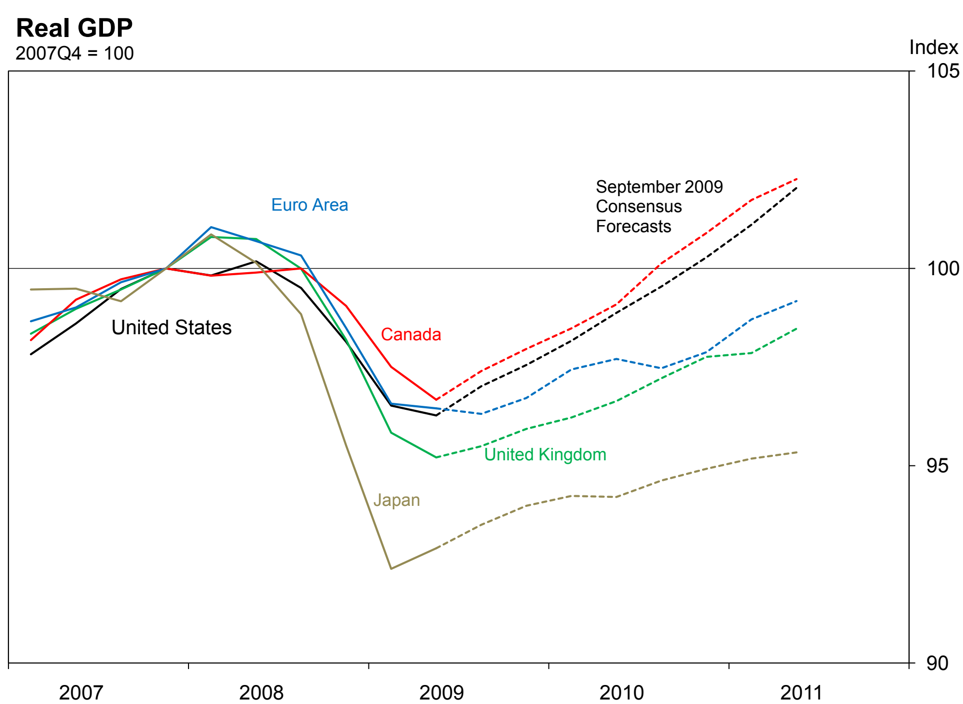

Figure 3: Inflation

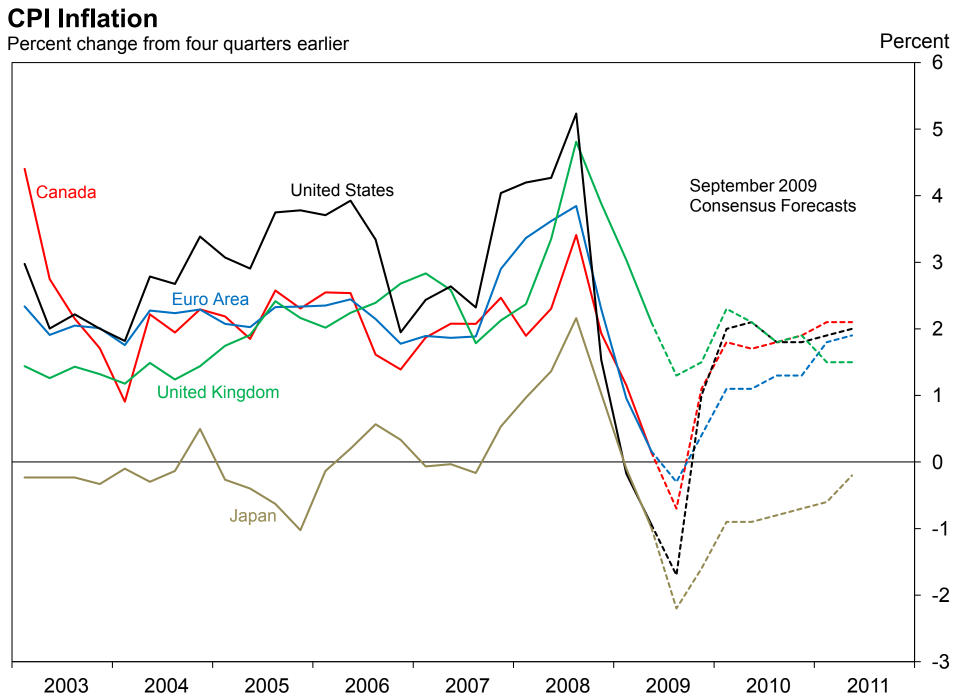

Figure 4: A Longer View of the Zero Lower Bound

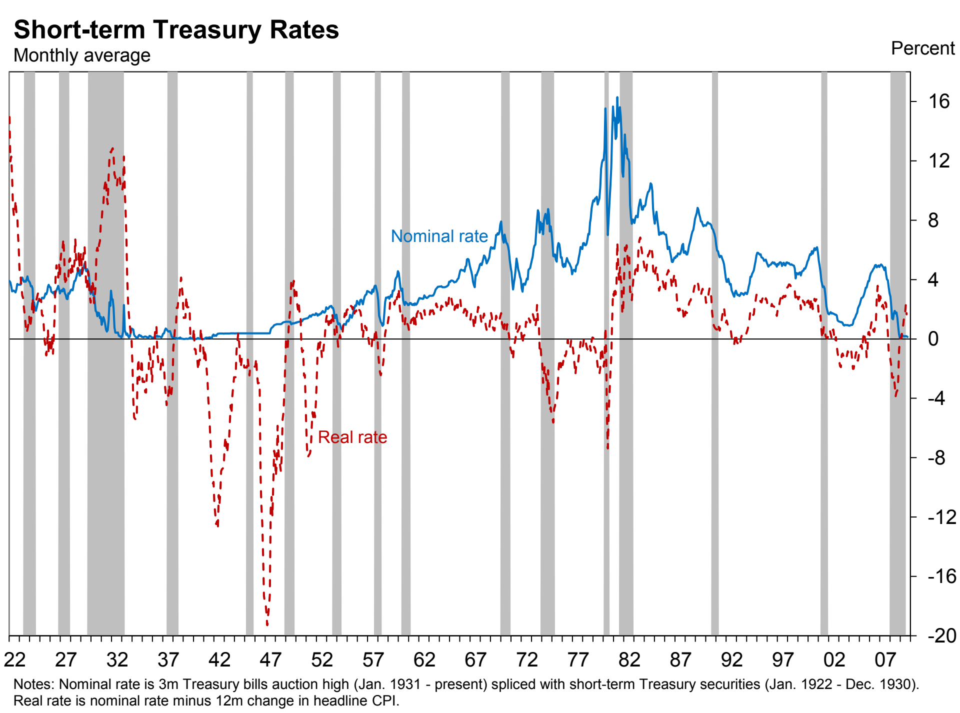

Figure 5: Evolution of U.S. Policy Expectations

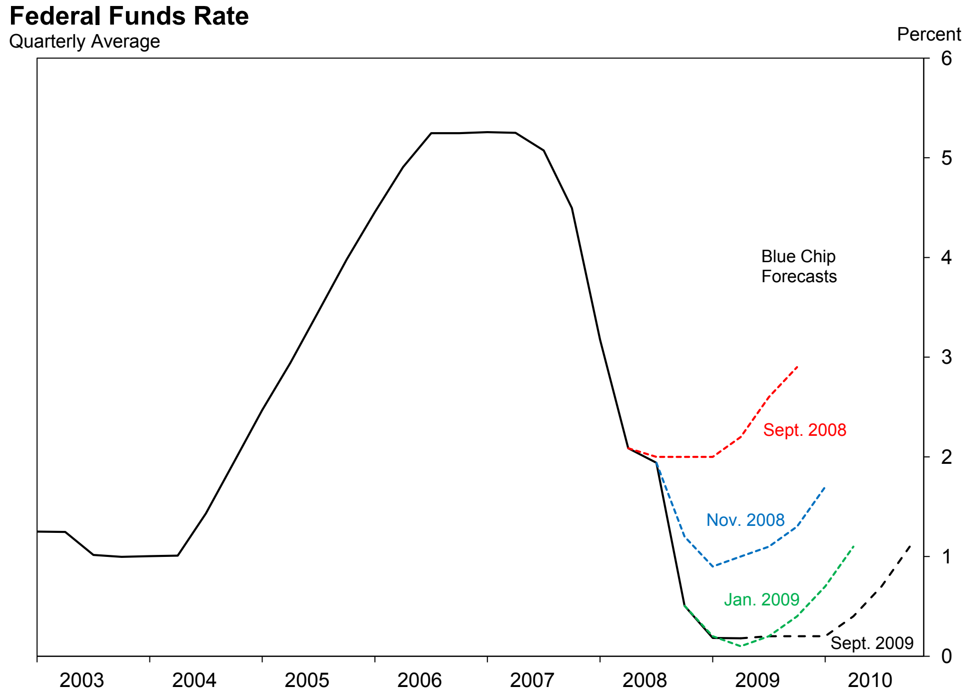

Figure 6: Counterfactual Simulations of Lower Funds Rates

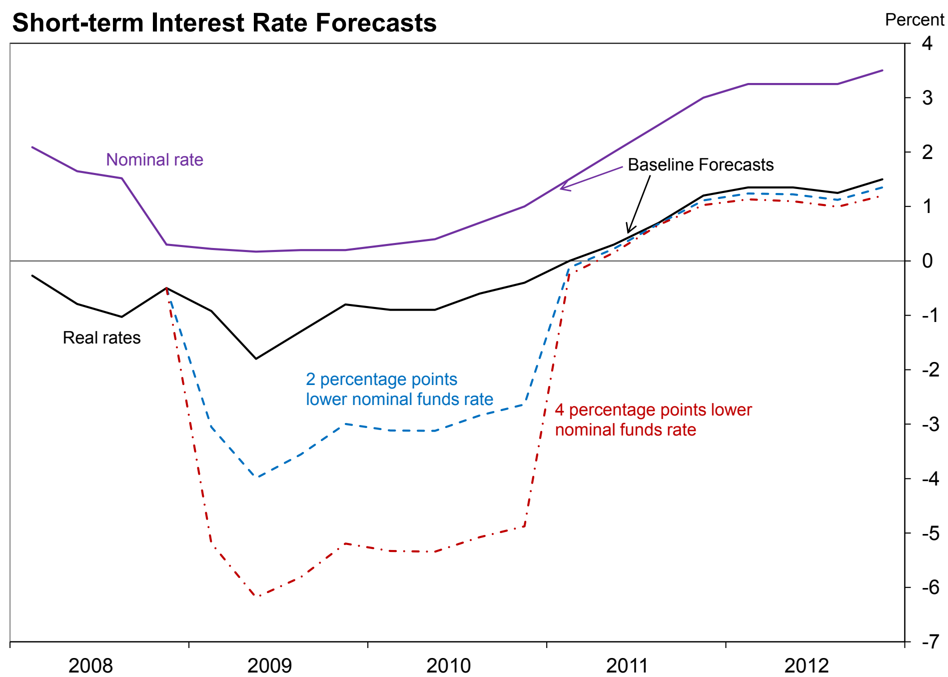

Figure 7: Counterfactual Simulations of Lower Funds Rates

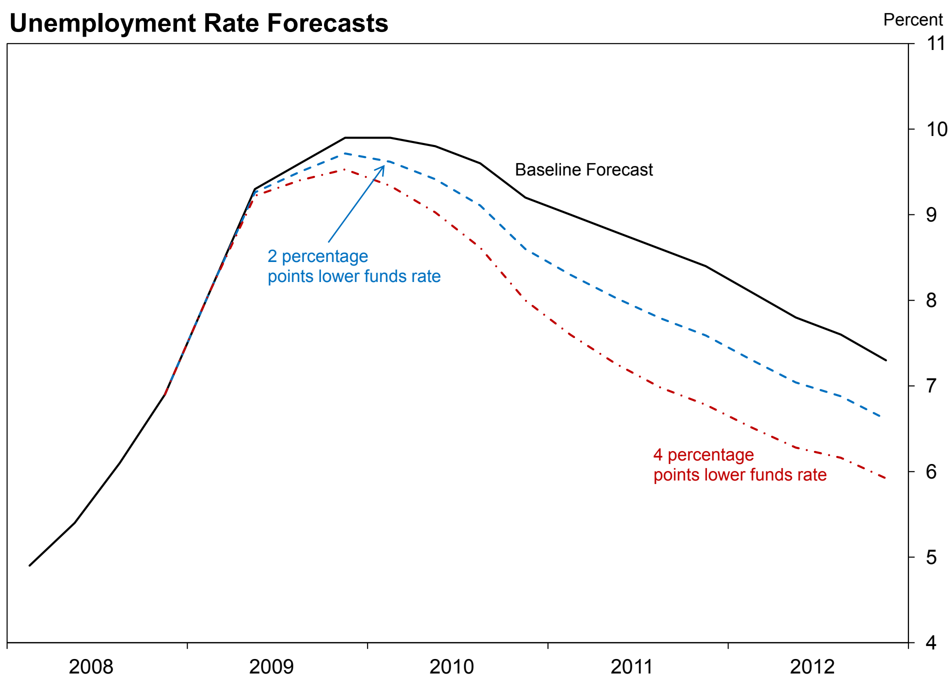

Figure 8: Counterfactual Simulations of Lower Funds Rates

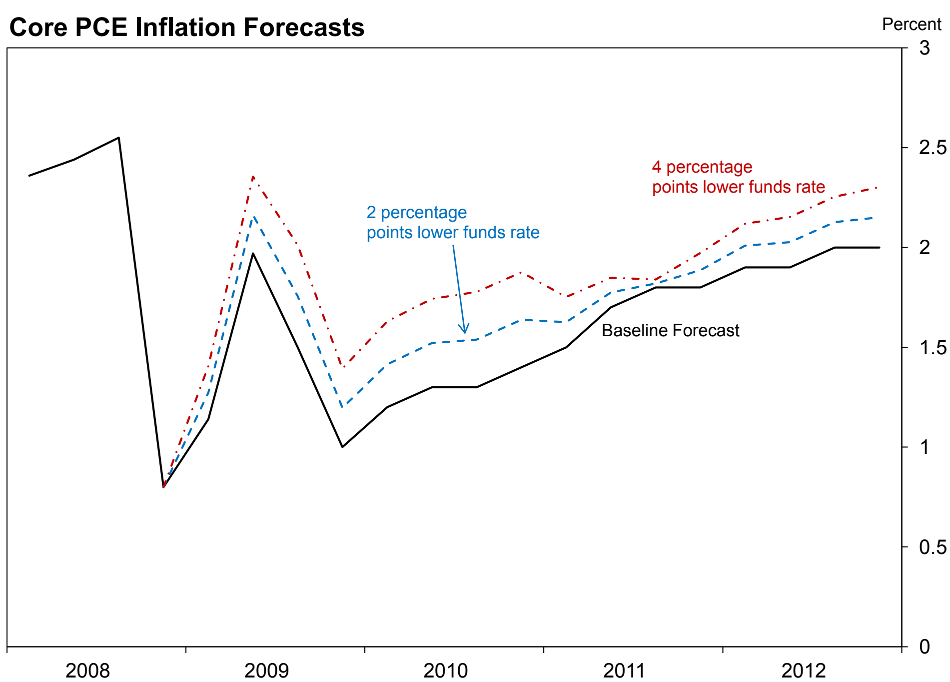

Figure 9: Long-Run Inflation Expectations

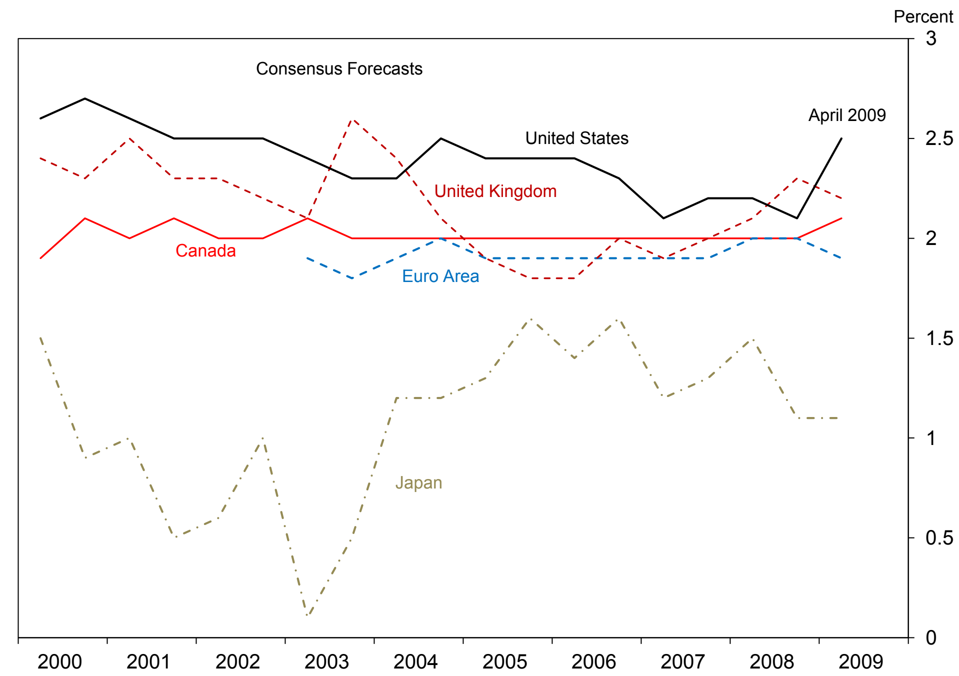

Figure 10: Equilibrium Real Interest Rates