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Monetary Policy Strategies for Limiting the Consequences of the Zero Bound on Interest Rates

by

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In this paper, we explore the efficacy of a number of recent proposals for ameliorating the consequences of the zero lower bound on interest rates using simulations of the Federal Reserve's FRB/US model. The zero bound on interest rates is a concern because central banks typically respond to weak aggregate demand conditions by lowering short-term interest rates. But nominal interest rates cannot be reduced below zero, so some change in monetary-policy strategy may be needed at low levels of interest rates. Interest in such strategies has increased in recent years because short-term interest rates have been very low in a number of countries: In Japan, the call money rate has been at or below 50 basis points since late 1995; in the United States, the federal funds rate was below 150 basis points from late 2002 to mid-2004.

Our focus in this note will be on strategies that alter expectations of future monetary policy when current interest rates are pinned at zero; such policies have been discussed by, among others, Krugman (1998), Reifschneider and Williams (2000), and Eggertson and Woodford (2003). Most alternative policies that have been proposed operate through liquidity or portfolio-balance channels for affecting, for example, long-term interest rates exchange rates (see, for example, Clouse et al., 2000). But most empirical studies suggest that such channels are not very large, if they exist at all. Because of the lack of strong empirical support for such effects, they are not part of the FRB/US model, and so, given our focus on that model, we are not well-suited to evaluate them.

The strategies we focus on work by promising to keep real future short-term interest rates lower than otherwise, which, under the expectations hypothesis of the term structure, will lower real long-term interest rates today. Such a strategy works because in FRB/US, as in many other macroeconomic models, current real long-term interest rates have important effects on current spending. Of course, future real short-term rates are the difference between expected nominal rates and expected inflation, and future monetary policy can work on both of these pieces: Although current nominal interest rates may be pinned at zero, policy can work to lower expectations of future short-term rates. And by promising looser policy in the future, the central bank can hope to raise inflation expectations.

Some earlier studies have examined the effects of changes in monetary policy using stylized models—for example, Wolman (2004) and Eggertson and Woodford (2003). We believe that using a model such as FRB/US has advantages relative to these other models. In FRB/US, a much-richer range of economic mechanisms is at work, and these additional mechanisms can point to drawbacks and advantages of certain policies. For example, FRB/US includes many channels through which fiscal policy can affect the economy, and we use these to show how the efficacy of fiscal policy can be affected by the zero bound. Moreover, the FRB/US model is estimated, and thus may provide a more-realistic platform for policy evaluation.

We limit ourselves to monetary policies that are similar in spirit to the well-known Taylor rule. In particular, we do not consider policies that have been chosen to optimize a particular social welfare function given the structure of the economy. One reason for focusing on Taylor-rule-type policies rather than optimized policies is that the work of Levin, Wieland, and Williams (1999) and Taylor (1999) has suggested that there may be a good reason for central banks to eschew optimized rules: It appears that rules that have been optimized for one model may perform quite poorly in another model. Given that there is a great deal of uncertainty about the true structure of the economy, a central bank would thus be ill-advised to choose any particular optimized policy. By contrast, Taylor-type rules appear to provide at least adequate performance in a broad range of models (Taylor, 1999). In addition, a variety of studies—such as Clarida, Gali, and Gertler (2000) and English, Nelson, and Sack (2003)—have argued that Taylor-type rules are a good approximation to actual central bank behavior.

We consider a number of policies that have been proposed to mitigate the effects of the zero bound:

- Reifschneider and Williams (2000) and Reinhart (2004) have argued that a more-aggressive monetary policy can reduce the adverse effects of the zero bound. We model this more-aggressive policy as larger coefficients on output and, especially, inflation in a Taylor rule.

- A central bank may promise to make up any shortfall in short-term nominal interest rates relative to the Taylor rule that occurs during a zero-bound period. (Reifschneider and Williams, 2000). Under such a policy, future short-term interest rates will be lower than they would be under the Taylor rule, and, in particular, will stay at zero beyond the period suggested by the Taylor rule.
- A more-radical departure from the Taylor rule would be to replace the inflation-target component of the Taylor rule with a price-level target. Such a policy has been advocated by Wolman (2004) and Eggertson and Woodford (2003).
- Another more-radical departure is the adoption of rules that link the *change* in the short-term interest rate to deviations of inflation and the output gap from their target levels. Such rules have been advocated by Levin, Wieland, and Williams (2003).
- Krugman (1998) has advocated raising the central bank's inflation target permanently, or for a very long period, as a way of escaping a zero-bound episode.
- And we consider proposals to limit the effects of the zero bound on nominal interest rates by reducing short-term interest rates more rapidly when the zero bound is imminent.

In this paper, we focus on the effects of these various policies on the response of the economy to a specific shock. In particular, we examine the effects of each policy in response to a shock that, under a baseline Taylor rule policy, would pin the short-term interest rate at zero for a period of four to five years. We believe that such an approach is a useful complement to work such as Reifschneider and Williams (2000), which used stochastic simulations to consider how useful various policies might be at minimizing the consequences of the zero bound for economic outcomes under a full range of shocks. The present approach allows us to more closely examine the economic mechanisms at work under the different policies.

In considering the effects of such policies, we do not consider the question of central bank credibility in adopting a special strategy near the zero bound; in our formal analysis, we assume that the central bank has complete credibility, in the sense that once the central bank announces a new policy, all agents are assumed to believe it. It is clear why credibility may be an issue once the zero bound has been reached: Short-term interest rates are the usual way in which the central bank communicates its monetary-policy actions, and once the zero bound has been reached, this channel can't be used. Of course, if a policy has been in place for some time, then it is more reasonable to assume that expectations formation has adapted to the policy environment. This is the implicit assumption behind the model-consistent expectations we assume in most of the simulations we run.

While we think it is reasonable to suppose that such expectations are likely to be consistent with the typical dynamics produced by a monetary policy that has been in place for a long time, there is little evidence to suggest that the expectations of households and firms adjust quickly to an announced change in monetary policy. This calls into question how worthwhile the kind of policy changes that we are considering would be if adopted for the first time once the zero bound of interest rates has been reached. However, one group of agents in the economy appears to be highly attuned to central bank statements: Financial markets appear to adjust very rapidly both to changes in policy rates and to statements about the central bank's future intentions.

We thus think it reasonable to assume that financial markets can respond rapidly to changes in monetary policy but that other agents in the economy may not respond as quickly. Here, we have in mind expectations of firms and households in the setting of wages and prices, as well as expectations of future inflation that are used to determine the value of real interest rates used in investment decisions and similar calculations. To explore the consequences of different degrees of rationality on the part of different agents in the economy, in section 3, we consider the possibility that while financial markets may fully adjust their expectations formation in the aftermath of a policy change, other agents continue to use expectations based on the average historical experience of the U.S. economy.

1. Background and baseline simulations

We use the Federal Reserve Board's FRB/US model. FRB/US is described in detail in Brayton et al. (1997). For the present discussion, some important features of FRB/US are:

- The main behavioral relationships in FRB/US are derived from explicit optimization problems.
- Most key relationships in FRB/US are estimated. In particular, considerable care has been taken to ensure that the key correlations among variables, including persistence, observed in the U.S. data are matched.
- In financial markets, standard arbitrage pricing is assumed. Hence, a key element in the determination of long-term interest rates is current expectations of short-term interest rates; in addition, risk premiums are modeled as serially correlated and related to the expected state of the economy.
- We initially consider simulations in which expectations are model consistent (or "rational"). In particular, in section 2, we assume that when monetary policy changes, expectations formation—and thus the dynamics of the economy—change accordingly. In section 4, we relax this assumption.

We have chosen as our baseline assumption about monetary policy what we term the revised Taylor rule proposed in Taylor (1999).[1] In particular, the Taylor rule can be written as:

$$r_t = r^* + \pi_t + \alpha\,(\pi_t - \pi^*_t) + \beta\, gap_t\,, \tag{1}$$

where r_t is the short-term policy rate (for the United States, the federal funds rate), r^* is the equilibrium real interest rate, π_t is inflation, here defined to be the lagging four-quarter percent change, and *gap* is the output gap, defined to be the percent deviation of GDP from an estimate of its trend or potential level. In the revised Taylor rule, $\alpha = 0.5$ and $\beta = 1.0$ (in Taylor's original rule, $\alpha = 0.5$ and $\beta = 0.5$). Taylor (1999) argues that the revised rule has been a good

1. We discuss our fiscal policy assumptions in section 4.

representation of U.S. monetary policy since the mid-1980s. In addition, Taylor argues that this rule does at least an adequate job of stabilizing the U.S. economy based on simulations of a broad range of models.[2]

We have chosen to evaluate policies with respect to how they perform in the face of a particular shock to the economy. This shock is a large, adverse shock to consumer spending that is assumed to persist for a number of years: The initial shock is equal to 1.2 percent of consumer spending and fades linearly to zero over the next six years. In the base case, agents are assumed to know the duration of the shock. The shock was chosen so that, under the baseline monetary policy, the federal funds rate is pinned at zero for four years.[3]

Figure 1 shows the effect of the shock both with and without the zero bound on nominal interest rates imposed. Looking first at the case in which the zero bound is not a constraint, the funds rate would drop below -2 percent, reaching a trough in the third year after the shock. The zero bound exacerbates the depth of the recession: Without the zero bound, the output gap would widen by about 3-1/2 percentage points; with the zero bound imposed, the output gap is worsened to almost 5 percentage points. While the outcome for output is affected importantly by the zero bound, the outcome for inflation is not much affected, with the economy experiencing four years of deflation in each case, and inflation reaching a minimum of -3/4 percent. The interest rate on ten-year Treasuries falls sharply once the shock hits the economy, reflecting the assumption that the duration of the shock is immediately understood. If agents took time to learn about the duration of the shock, long-term interest rates would decline more gradually. Long-term rates fall about 75 basis points less when the zero bound is binding, consistent with agents' (rational) expectations of future short-term interest rates.

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2. Some have argued that a more-realistic representation of U.S. monetary policy in recent years would incorporate the lagged funds rate in addition to the output and inflation gaps. For example, Clarida, Gali, and Gertler (2000) find a coefficient of 0.8 on the lagged funds rate and English, Nelson, and Sack (2003) find a coefficient of 0.7. We experimented with equations such as this and found that, for present purposes, they made little difference.

3. Of course, even though the shock fades out linearly, its effects on the economy are more attenuated than this, owing to the dynamics of the model.

2. Implications of alternative policy rules under model-consistent expectations

In this section, we consider the effects of various alternatives to the baseline monetary policy.

a. More-aggressive Taylor rule

The first set of policies that we consider maintain the general structure of the Taylor rule of equation 1 but use different parameters. In particular, we consider more-aggressive parameters on both output and inflation, along the lines suggested by Henderson and McKibbin (1993). We first consider a policy in which we raise the coefficient on inflation, α, from 0.5 to 2.0. We then also raise the coefficient on the output gap, β, from 1.0 to 2.0.

As can be seen in figure 1, a more aggressive Taylor rule helps mitigate the adverse effects of the zero bound on the output gap. In the policy represented by the blue line, the coefficient on inflation is boosted from 0.5 to 2.0. This policy change eliminates about half the adverse effects of the zero bound on the output gap. Nonetheless, the period over which the interest rate is at zero is extended only slightly—by a quarter or two. As a consequence, the interest rate on ten-year Treasuries is little different. Inflation is higher in this case, with the period of deflation now reduced to less than two years, because the central bank now pursues a policy that keeps inflation closer to its target. Because expectations are forward-looking and current inflation is affected by expectations, this more-aggressive policy also boosts inflation even when interest rates are at zero. Note, however, that inflation never exceeds the target level of 1-1/2 percent, so even though inflation is higher, this outcome should be welcomed. With nominal long-term interest rates little different from the base case, it is the lower real interest rates brought on by higher inflation for that is the source of the extra stimulus in this case. In the simulation represented by the green line, the coefficient on output in the Taylor rule is also boosted, from 1.0 to 2.0. As can be seen, these results are little different from those which only the inflation parameter was boosted.

In other results, not shown here, we found that boosting the coefficient on inflation to 4.0 roughly undoes the effects of the zero bound on output under the baseline policy. Hence, if a central bank wanted to maintain a policy that had the general structure of a Taylor rule, it could largely eliminate the adverse effects of the zero bound in the face of this sort of shock by adopting a policy that reacts more strongly to inflation.

One advantage of such a policy is that a central bank could demonstrate that it has adopted it prior to a zero-bound episode, and thus could establish, through experience, that it had changed its policy. As we noted in the introduction, it is likely that, aside from financial markets, agents learn about how monetary policy affects inflation through experience and not by working through the implications of a newly announced policy in their mental DGE models. As we discuss in section 3, if expectations formation does not adjust to the new policy, then the benefits of the policy are greatly diminished.

b. Make-up rules

We next consider a policy in which the central bank pledges to "make up" any shortfall in the interest rate once nominal interest rates reach zero. As in Reifschneider and Williams (2000), we specify this policy as:

$$r_t = r^* + \pi_t + 0.5\,(\pi_t - \pi^*_t) + 1.0\,gap_t - \gamma\, Z_t\,, \qquad (2)$$

where Z is the cumulated past deviations of the short-term interest rate from the prescriptions of the standard Taylor rule. In our simulations, we use $\gamma = 0.5$.

The blue line in figure 2 shows the implications of the interest-rate make-up policy. As can be seen, this policy prolongs the period that the interest rate stays at the zero bound by nearly two years. It thus has a noticeable effect on the ten-year Treasury rate. The policy is quite effective at reducing the effect of the zero bound on the output gap, leading to an output trough that is only slightly deeper than when the zero bound is not binding, and, about three-and-a-half years after the shock, implying a somewhat higher level of output than under the baseline policy. The period of deflation is less than three years in this case. Over the ten-year horizon shown here, inflation never exceeds its long-run target. The real ten-year Treasury rate falls considerably more than in the baseline case, and initially makes up about half the shortfall owing to the zero bound. Note that both higher inflation expectations and a lower long-term nominal interest rate play a role in the reduction of the real long-term rate, with higher expected inflation playing a somewhat more important role.

At first glance, an advantage of the funds-rate make-up policy is that once sufficient time has past, monetary policy reverts to what it would otherwise have been. This would be an advantage for a central bank that prefers a Taylor rule most of the time, and only wants to deviate from such a policy in exceptional circumstances. But a corresponding disadvantage is that it is not possible to establish a reputation prior to the advent of a zero-bound episode. Hence, the efficacy of this policy would depend heavily on the ability of the central bank to explain the policy once the zero bound on nominal interest rates has been reached.

c. Giving up too soon

The green line in figure 2 illustrates the consequences of a central bank that abandons a make-up policy prematurely. The motivation behind this scenario is that the central bank prefers the Taylor rule and, once the economy has largely recovered, reverts to its preferred policy. In modeling this policy, we assume that private-sector agents correctly anticipate the central bank's premature dropping of the policy.

In this simulation, the central bank begins to raise rates two quarters earlier than in the full make-up case, and fully reverts to the Taylor rule a year-and-a-half earlier. At the point that the central bank reverts to the Taylor rule, the output gap has recovered more than 90 percent of its loss at the trough and inflation is back above ½ percent. Although this early move back to the Taylor rule may seem like a small deviation from the full make-up rule, as can be seen from the output gap, it turns out to undo much of the benefit of the make-up policy. One part of the story is that nominal long-term interest rates fall by less. But inflation, which is considerably lower in the partial make-up case, has an even larger effect on real long-term interest rates.

d. Two additional modest departures from the Taylor rule: Pre-emptive policy and a permanently higher inflation target

In figure 3, we consider two other policies that are relatively modest departures from the Taylor rule: Moving aggressively to the zero bound, and, raising the long-run inflation target. As can be seen, neither policy has much of an effect on the output gap over the first five years following the shock relative to the baseline. The reason the preemptive move to the zero bound has such a small effect should be clear: With this particular shock, the funds rate gets to zero after three quarters even under the baseline rule, so there is limited scope for improving outcomes by moving aggressively.[4]

In the simulation represented by the blue line in figure 3, the inflation target is raised—permanently—by 1 percentage point to 2.5 percent.[5] As in the other simulations in this section, this change in policy is assumed to be immediately built into agents' expectations. As can be seen in the middle left panel, the increase in long-run inflation expectations under this policy helps reduce real long-term interest rates—although these benefits are limited by the increases in nominal long-term interest rates. Despite this reduction in real long-term interest rates, however, the effects on the output gap are minimal in the FRB/US model. The reason is that the stimulative effects of lower real rates are offset by adverse effects on real wealth caused by higher long-run inflation expectations. We have identified two important through which higher inflation expectations reduce real wealth in FRB/US: First, the real bond holdings of households are reduced by higher long-run inflation expectations. Second, higher inflation interacts with the tax code to reduce the long-run capital stock. While we suspect that the strength of these offsetting effects may be unique to the FRB/US model, they nonetheless illustrate some of the adverse effects that may result from permanently raising the inflation target.

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4. While the policy of moving rapidly to the zero bound had only modest effects in this simulation, we have found is stochastic simulations that an ongoing policy of moving rapidly to the zero bound when aggregate demand is weak can have important benefits in reducing the frequency and severity of zero-bound episodes.
5. Note that this exercise does not consider the efficacy of a general policy of having a higher inflation target. Such a policy has been examined using stochastic simulations by—among others—Reifschneider and Williams (2000) and Coenen, Orphanides, and Williams (2004).

In our view, the results from this simulation reinforce the idea that a permanent increase in the inflation target is a poor way to address the problems created by the zero bound. First of all, if such a target was not deemed appropriate prior to the zero-bound episode, it is difficult to see why it should be thereafter. Second, other policies appear to have better performance in terms of reducing the adverse effects of the zero bound on interest rates while having only transitory effects on inflation. Finally, by its nature, this policy change is not one for which a central bank could gain a reputation before hand. Hence, it would have to rely heavily on direct effects of the announcement on agents' behavior, a potentially less-reliable mechanism than ongoing experience with a policy.

e. Price-level targeting and difference rules

In figure 4, we take up policies that are more radical departures from the Taylor rule. One of these is a price-level targeting rule, in which inflation is dropped from the rule and replaced by the deviation of the price level from a target level:

$$r_t = r^* + \pi_t + \varphi\ 100 \times (p_t - p^*_t) + \beta\ gap_t\ , \tag{3}$$

where p is the log of the price level and p^* is the log of the target price level. We assume that the price-level target increases in line with the target inflation rate of 1.5 percent. Under the price-level targeting rule, any shortfall in inflation during a period of weak aggregate demand will be made up later, thereby boosting expected inflation.

Equation 4 shows the other alternative we consider, a difference rule, in which the level of the nominal funds rate is replaced by the change in the funds rate:

$$r_t - r_{t-1} = \alpha\ (\pi_t - \pi^*_t) + \beta\ gap_t\ . \tag{4}$$

The difference rule ensures a high degree of serial correlation in short-term interest rates. Thus, as discussed in Levin, Wieland, and Williams (1999), it leads to larger movements in long-term interest rates for any given movement in short-term interest rates. Levin, Wieland, and Williams (2003) examined the performance of difference rules in five macroeconomic models, including FRB/US. Averaging over the performance in all five models, they concluded that values of $\alpha = 0.4$ and $\beta = 0.4$ were preferred, and we use those values here.

In the price-level targeting rule, we assume the same coefficient on the output gap as in the Taylor rule, $\beta = 1.0$. For the coefficient on the price-level gap, we choose $\varphi = 0.4$. This choice is motivated in part by the results of Orphanides and Williams (2002), who found that this value was a robust choice in a differenced version of the price-level rule. In addition, we found that this parameter choice led to outcomes for the output gap that were similar to those obtained in the absence of the zero bound on nominal interest rates.

The blue line in figure 4 shows the effects of adopting price level targeting. Under this policy, the peak effect of the shock on the output gap is about the same as in the no-zero-bound case, and output recovers a bit faster. At least by this criterion, then, the price-level-targeting policy can essentially undo the effects of the zero bound. The period for which the interest rate is zero is now about a year *shorter* than in the baseline. As a consequence, the initial decline in the ten-year Treasury rate is a bit smaller. Inflation is considerably higher under this policy—its low point is now +3/4 percent. As is to be expected under a policy in which shortfalls in the price level are eventually made up, beginning about six years after the initial shock, inflation exceeds its long-run target. But the excess inflation is quite mild—only about 1/4 percentage point. And inflation eventually fades back to its target level. Real long-term interest rates fall more sharply than under the baseline; with nominal rate actually a bit higher, the reason for the lower real long rates is higher inflation expectations.

The green line in figure 4 shows the effects of the interest-rate change rule, equation 4. With the parameters we have chosen, the initial shock now has a considerably milder effect on the output gap than under the baseline policy without the zero bound. This result suggests that the parameters we have used in the change rule are qualitatively much more “aggressive” than those in the baseline Taylor rule, and thus may not constitute a fair comparison with the other policies. Nonetheless, this simulation illustrates the potential for the change-type policy to offset the effects of the zero bound. Under the change policy, the short-term interest rate reaches the zero bound more gradually than under the Taylor rule, but it also remains at the zero bound for about a year-and-a-half longer. The nominal ten-year Treasury rate initially drops a bit less than under the Taylor rule, but after a year and a half is about ¼ percentage point lower. Inflation remains remarkably stable in this simulation, in part reflecting the success of this policy in stabilizing aggregate demand. With inflation stable and nominal long-term interest rates dropping substantially, real long-term interest rates drop sharply, and are in fact lower than in the case in which the zero bound is not imposed.

3. How robust are these strategies to different expectational assumptions?

So far, we have assumed that all agents in the economy change their methods for forming expectations in a model-consistent manner when the central bank announces a change in policy. But while one can point to instances in which financial markets appear to have rapidly absorbed the implications of an announced change in monetary policy, there is less evidence that other agents in the economy are as quick to adjust their expectational processes. Thus, while we believe that the simulations we presented in the previous section are good approximations of the average response of the economy to a monetary policy that has been in place for some time, and all agents have had an opportunity to learn its implications, we believe it is an open question whether they would provide a good guide to the economy's behavior in the immediate aftermath of an announced change in policy.

To get a better notion of the importance of expectational assumptions for our results, we run the following experiment. We continue to assume that bond yields, equity prices, and the exchange rate are priced in a rational manner—that is, expectations for the financial variables used in their pricing formulas are fully model-consistent. But we assume that expectations outside the financial sector more closely conform to the average historical behavior of the economy. Specifically, we generate expectations of future income, inflation, and other non-financial factors using the forecasts of an estimated small-scale VAR model. Under many conditions, the predictions from this small model are similar to those generated by the full-scale FRB/US model under model-consistent expectations (Brayton et al, 1997). But this similarity may break down in the circumstances considered here because the simulated zero-bound episode is so atypical from a historical perspective. For example, the VAR forecasts implicitly assume that the aggregate demand shock will be of typical duration when in fact it turns out to be unusually persistent. Moreover, the VAR forecasts do not impose the zero lower bound on the funds rate, implying that agents see the central bank as having more ability to stabilize the economy than it in fact does. Finally, the small-model forecasts are not derived using the actual monetary policy pursued by the central bank, but instead are based on the fixed estimated historical policy rule embedded in the VAR model.

As might be expected, the change in expectational assumptions has important implications for the dynamic response of the economy to the shock. As can be seen in the blue line in figure 5, the zero lower bound is no longer a constraint on monetary policy. The milder response of both output and inflation under these conditions mostly reflects the combination of two factors—investors' recognition that the shock will be unusually persistent; and the failure of agents outside the financial sector to recognize this persistence. Because of the first factor, bond rates immediately drop following the onset of the shock, thereby supporting aggregate spending in a manner similar to what occurs under full model-consistent expectations. However, because households and firms do not recognize the full extent of the future decline in income and earnings implied by the shock, they cut back on spending by less than what occurs in the absence of expectational errors. The net effect of these two events is a much milder recession and a smaller initial decline in inflation. Nonetheless, there is a more pronounced longer-run decline in inflation under VAR-based expectations because long-run inflation expectations outside the financial sector are less firmly anchored.[6]

To evaluate the relative performance in zero-bound episodes of different

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6. As noted, the bond market's immediate recognition of the unusual persistence of the aggregate demand shock is a major factor checking the severity of the resulting economic downturn. However, one can easily think of situations where this might not be the case, in which financial market participants would still form their expectations in a rational model-consistent manner but would mistakenly project the shock at each point in time to fade away in a historically typically manner. In additional simulations (not shown), we have explored the possibility that the financial markets do not have perfect foresight. Under these circumstances, the initial decline in the bond rate is much more gradual, resulting in a downturn in economic activity that is only a little less

monetary policies under the alternative expectational assumption, we recalibrated the aggregate demand shock to yield a zero-bound episode of approximately the same duration as that considered earlier. (The recalibrated shock needs to be approximately twice as large as the original shock under the assumption that investors immediately recognize its true persistence.) The result is shown in figure 6. Compared to the situation in which all agents have model-consistent expectations, the constraint posed by the zero lower bound under the standard Taylor rule is now less detrimental. In part, this is because inflation is more inertial under VAR-based expectations, making the initial fall in inflation less severe and causing the unconstrained Taylor rule to prescribe less of a decline in the nominal funds rate. As a consequence, the decline in output under the constrained Taylor rule is only modestly more severe than the unconstrained result.

Figure 6 also shows that, under the alternative expectational assumptions, policies intended to mitigate the effects of the zero lower bound are considerably less effective. For example, the Reifschneider-Williams rule, despite keeping the nominal funds rate at zero for an additional 2-1/2 years, yields essentially the same decline in output as the constrained Taylor rule during the first three years of the slowdown, and only modestly stronger real activity thereafter. Roughly the same result is obtained under price level targeting: Although this rule still yields better outcomes than either the constrained Taylor rule or the interest-rate make-up rule, it is no longer able to undo the consequences of the zero lower bound.[7]

What accounts for this pronounced change in the relative performance of the alternative policy rules? The main factor is that the promise of future policy actions beyond the zero-bound period no longer exerts as much influence on the longer-run inflation expectations of households and firms under VAR-based expectations. Financial market participants still know that these alternative

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pronounced than the situation under full model-consistent expectations with perfect foresight.
7. It is worth noting that price level targeting yields borderline instability in FRB/US when it is run under these expectational assumptions. For this reason, in the simulation shown in figure 6, we assumed that the central bank pursues price-level targeting for only twenty years (a sufficient time to bring the price level back to baseline); past that point the funds rate is set using the Taylor rule. Such instability problems also arise in the case of the change rule, and are in fact so severe that they make such a rule unusable in FRB/US when run under VAR-based expectations. As noted by Taylor (1999), such instability is often produced by such rules in models run without

policies will result in lower real short-term interest rates and higher inflation down the road relative to what occurs under the Taylor rule, and accordingly price these expectations into nominal bond yields immediately following the onset of the shock. However, because other agents do not recognize that the alternative monetary policies have significantly different implications for future inflation, their long-run inflation expectations are not greatly affected by any promised change in monetary policy. Thus, announcing a switch to the Reifschneider-Williams rule or price-level targeting does not result in a jump in their inflation expectations relative to their expectations under the Taylor rule, and therefore does not result in a lower initial level of real bond rates relative to what happens under the Taylor rule. Given little difference in the *perceived* initial level of real long-term interest rates, outcomes for output and inflation turn out to be almost the same.

These simulations suggest that for the expectations-based policies considered here to be effective, it is not enough to convince the bond market; households and firms need to understand the implications of the change in policy, as well. While history suggests that financial markets pay close attention to announcements of monetary-policy changes, it is less clear that other agents do so. This analysis suggests that it may be well for a central bank pursuing a low inflation target to make clear what policy will be when confronted with the zero bound well before any zero-bound episode occurs. Furthermore, it suggests that policies that allow the central bank to demonstrate the new policy before interest rates hit zero—such as a more-aggressive policy or a price-level target—may be preferable to policies such as the make-up rule that only come into play once the zero bound is hit.

4. Fiscal policy under the zero bound

Although the ability of conventional monetary policy to stabilize the economy is greatly diminished during zero-bound episodes, there is no obvious reason why similar concerns should apply to fiscal policy. And in fact, there are even reasons to believe that the potency of fiscal policy should be enhanced at such times. To see this, note that an expansionary shift in fiscal policy, if sustained, raises the economy's equilibrium real interest rate. As a result, the enactment of a

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model-consistent expectations.

persistent increase in government spending or cut in taxes generally leads to an immediate rise in both nominal and real long-term interest rates (all else equal) because investors foresee a higher future path for the real funds rate. This revision in financial conditions, in turn, limits the net stimulus from fiscal expansion. However, when short-term interest rates are pinned at zero, monetary policy may not turn more restrictive for a considerable time because nominal short-term rates are starting out higher than an unconstrained policy rule would prescribe. Understanding this, investors would mark up their expectations for the future path of the funds rate by less than they would in the absence of the zero bound, resulting in a smaller rise in the bond rate and more net stimulus to aggregate demand from the fiscal policy action.

Based on these considerations, it would not be surprising to find that fiscal policy has an important influence on the evolution of the overall economy during zero-bound episodes. To illustrate this influence, we now consider results from simulations in which fiscal policy accommodates the aggregate demand shock to varying degrees.

In the baseline fiscal response—which has been incorporated in all the simulations discussed to this point—fiscal policy is modestly accommodative. Specifically, real government spending on goods and services is held constant at its baseline path, while government transfer payments respond to changes in the cyclical state of the economy by the amount observed historically. Interest expense evolves endogenously in response to changes in interest rates and the outstanding stock of government debt. On the revenue side, effective tax rates respond to cyclical changes in economic activity to the degree observed historically, but are otherwise unchanged during the first fifteen years of the simulation. As a result, the government's budget deficit widens for a considerable time following the aggregate demand shock, increasing the stock of government debt relative to GDP by about 9 percentage points after six years. Note that in these simulations—including those in earlier sections—personal income tax rates adjust endogenously starting in the fifteenth year to push the government debt-to-GDP ratio gradually back to baseline.

We now consider two alternative fiscal policies. Under the easy fiscal policy response, conditions are the same as under the baseline policy except that the government enacts a major cut in personal income taxes. Because of delays in the legislative process, the tax cut is assumed to begin one year after the aggregate demand shock first hits the economy; however, in the prior year all agents correctly anticipate the legislation's enactment. The tax cut amounts to 1 percent of GDP as computed on an ex ante basis, and lasts for five years. Although the easy fiscal policy yields a larger rise in the debt-to-GDP ratio in the medium term (11 percentage points), all agents understand that tax rates will be adjusted beginning in the fifteenth year to eventually return the ratio to baseline.

Conditions are reversed under the tighter fiscal policy response, in that the government enacts a personal income tax increase worth 1 percent of GDP (ex ante). As before, the change in fiscal policy begins one year after the aggregate demand shock first hits the economy and lasts five years. Although fiscal policy is tighter, the government budget deficit still swells during the economic slowdown. However, the medium-term rise in government indebtedness is substantially smaller, amounting to only 7 percent of GDP.

Simulation results under the three alternative fiscal policies are shown in figure 7; all results are generated using the Taylor rule and full model-consistent expectations. As expected, the easier fiscal policy shortens the duration of the zero-bound episode and shifts up the subsequent path of the federal funds rate, thereby reducing the initial fall in the nominal bond rate that follows the onset of the aggregate demand shock. However, because long-run inflation expectations rise by a corresponding amount, the change in the real bond rate is about the same under the baseline and easier fiscal policies. Thus, the greater stimulus provided by the tax cuts of the easier fiscal policy is not appreciably offset by higher real interest rates, and the fall in the output gap is smaller.[8]

Although one might expect the opposite situation to hold in the case of a tighter fiscal policy, in fact the economy turns out to respond in a somewhat asymmetric

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8. If the fiscal simulations are re-run removing the zero-lower-bound constraint on nominal interest rates, the asymmetric response of output and inflation between the easier and tighter fiscal policies is eliminated. In addition, the differences in economic outcomes under the three fiscal policy assumptions are sharply reduced because endogenous movements in long-term interest rates largely offset changes in fiscal policy. This property of the FRB/US model is discussed at length

fashion. By reducing the deterioration in the government budget balance, the duration of the zero-bound episode is increased and the subsequent path of the nominal funds rate is reduced, the reverse of what occurs under the easier fiscal policy. Symmetrically, this causes the initial decline in the nominal funds rate to be greater than under the baseline fiscal policy. However, inflation expectations do not respond in a symmetric manner. Because of the zero lower bound, the central bank cannot readily adjust to tighter fiscal policy by running a marginally easier monetary policy. As a result, inflation expectations fall by a proportionally greater amount under the tighter fiscal policy, causing the initial decline in real bond rates to be less than under the baseline fiscal policy even though taxes are higher. Accordingly, the magnitude of the economic slump is greatly increased.

Three lessons from these simulations seem clear. First, even if the central bank's ability to stabilize the economy is constrained by the zero lower bound on nominal interest rates, fiscal policy can still be used to stimulate real activity and limit any undesirable declines in inflation. Second, the effectiveness of fiscal policy as a stabilization tool is probably enhanced by the zero lower bound, not diminished. Third, tightening the stance of fiscal policy during a zero-bound episode is potentially quite destabilizing because of asymmetries in inflation and output dynamics under such conditions.

5. Conclusions

The simulations we have presented suggest that a central bank has a number of options that can significantly mitigate the implications of the zero bound on nominal interest rates for the severity of recessions. Policy changes that seemed particularly effective include a more-aggressive inflation-targeting policy; a monetary policy that promises to make up any shortfall in interest rates induced by the zero bound; and a policy of price-level targeting.

These policies, however, rely critically on firms and households forming inflation

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in Elmendorf and Reifschneider (2002).

expectations in a manner that is fully consistent with these policies. We found that it is not enough for financial markets to understand the implications of these policies for future monetary policy; it is also important for households and firms to understand their implications for future policy, and thus for future inflation.

Our results are thus more sanguine for general changes in policy than changes made once the zero bound is reached. In particular, our results suggest that a central bank that wishes to operate with a low inflation target should also make other changes to policy—such as adopting a more-aggressive policy or to a price-level target. Because changing the inflation target is already an important change in monetary policy, adopting other changes at the same time would be opportune. At a minimum, a central bank with a low inflation target should make clear what their policies would be in the event of a zero-bound episode, perhaps along the lines of the interest-rate make-up policy.

A central bank that finds itself already confronted with the zero bound must rely to a greater extent on persuasion so as to affect the inflation expectations of households and firms. A strategy of talking up inflation expectations—within the context of one of the general strategies we have discussed—would be important. Nonetheless, our results also suggested that announcing a *permanent* change in the inflation target is neither necessary nor particularly effective, at least in the context of the FRB/US model. Rather, announcing that policy will be looser than usual for a period that is sustained but ultimately finite would be sufficient.

Finally, we would like to indicate that a useful supplement to the kind of analysis we have undertaken here would be stochastic simulations. Based on earlier work by Reifschneider and Williams (2000), we believe that our main conclusions would be supported by such an exercise. In particular, Reifschneider and Williams found that aggressive Taylor rules and interest-rate make-up policies were effective at reducing the consequences of the zero bound on nominal interest rates in the FRB/US model. In future work, we hope to explore the implications of price-level targeting using stochastic simulations and also to explore the implications of imperfect rationality both for price-level targeting and other policies.

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Figure 1

Macroeconomic Effects of a Large Demand Shock
Under Taylor Rules with Alternative Degrees of Aggressiveness

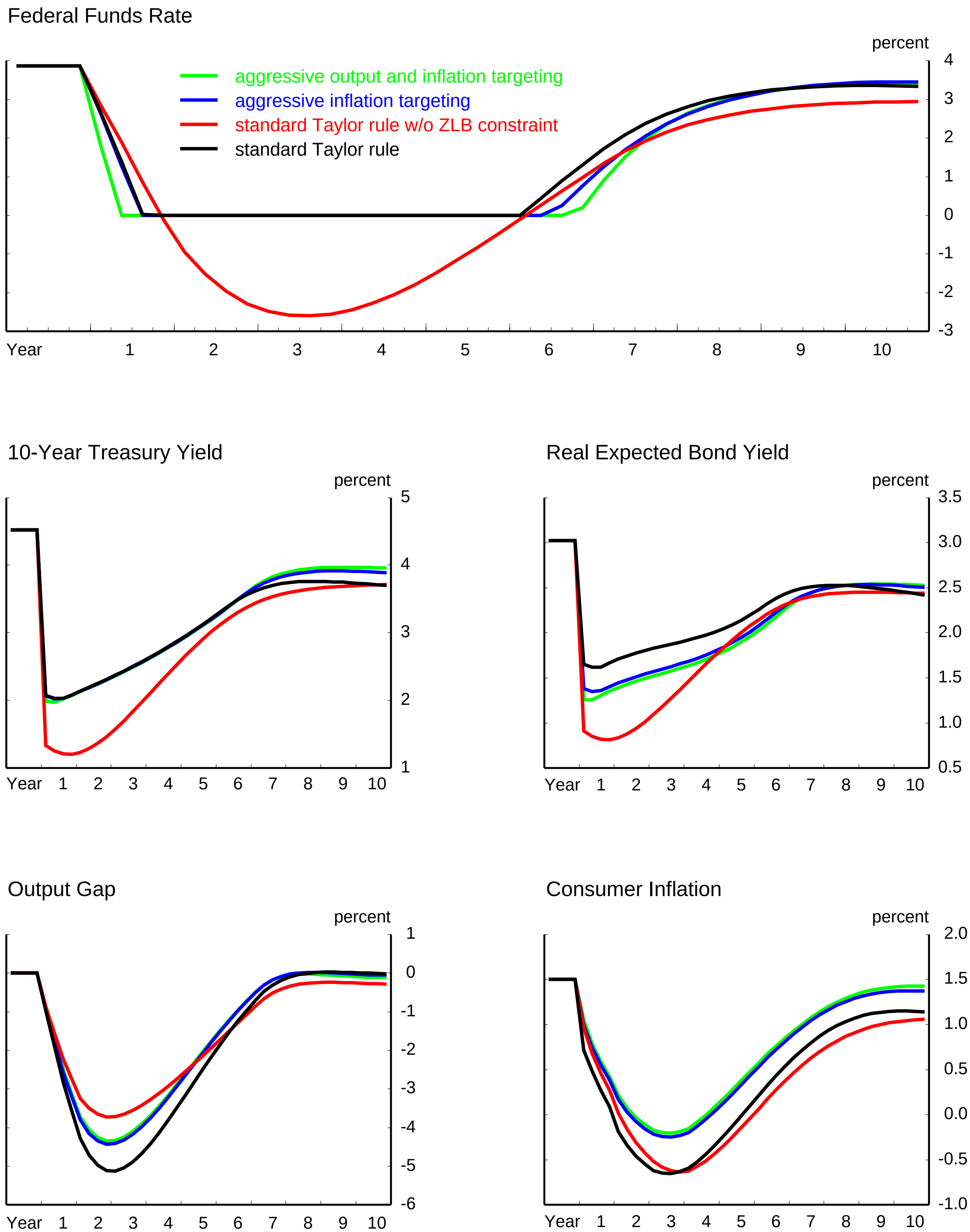

Figure 2

Macroeconomic Effects of a Large Demand Shock Under the Reifschneider-Williams Rule, With and Without Full Makeup of Past Funds Rate Shortfalls

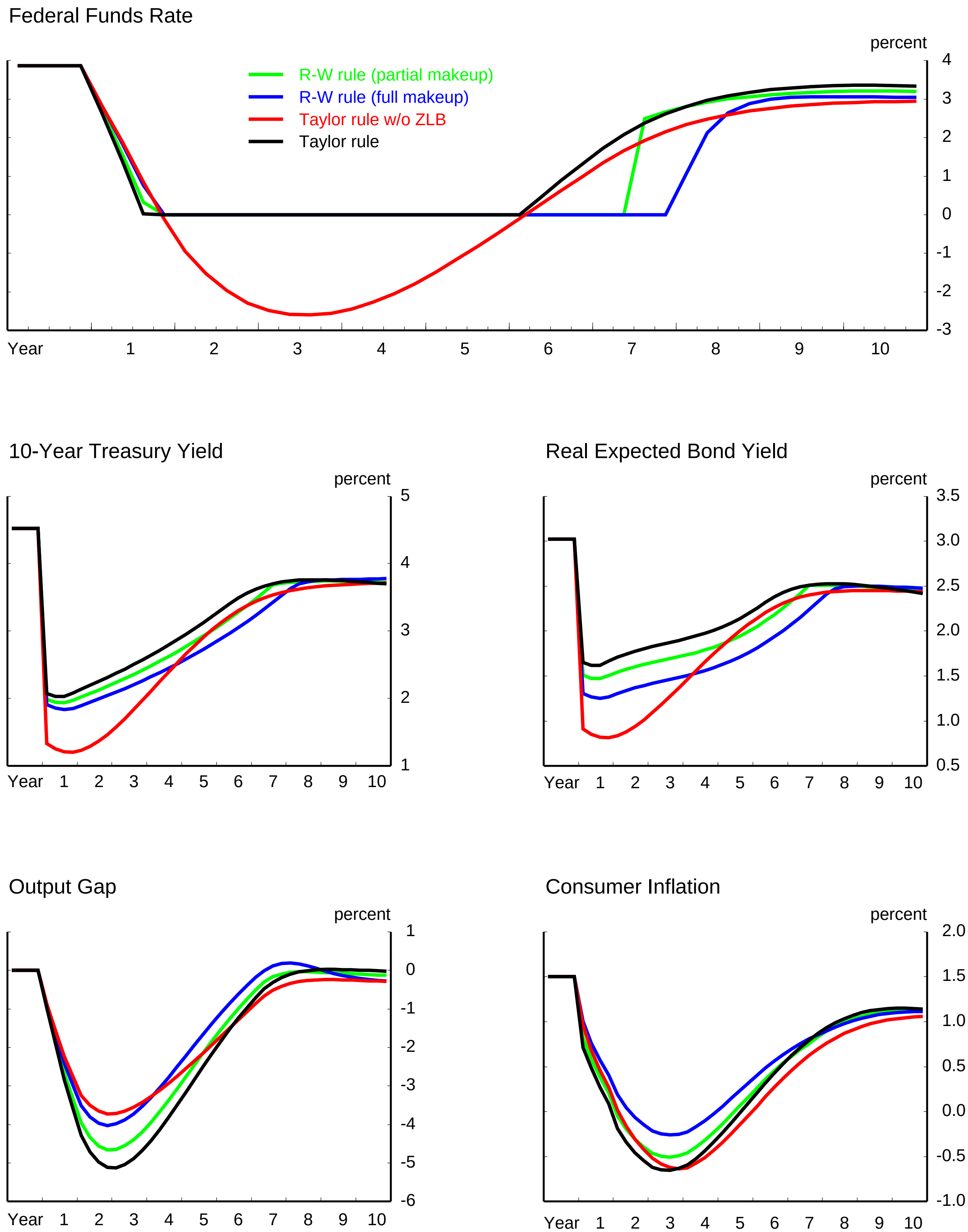

Figure 3

Macroeconomic Effects of a Large Demand Shock Under the Taylor Rule with Either a Preemptive Policy Response or an Announced Change in the Inflation Target

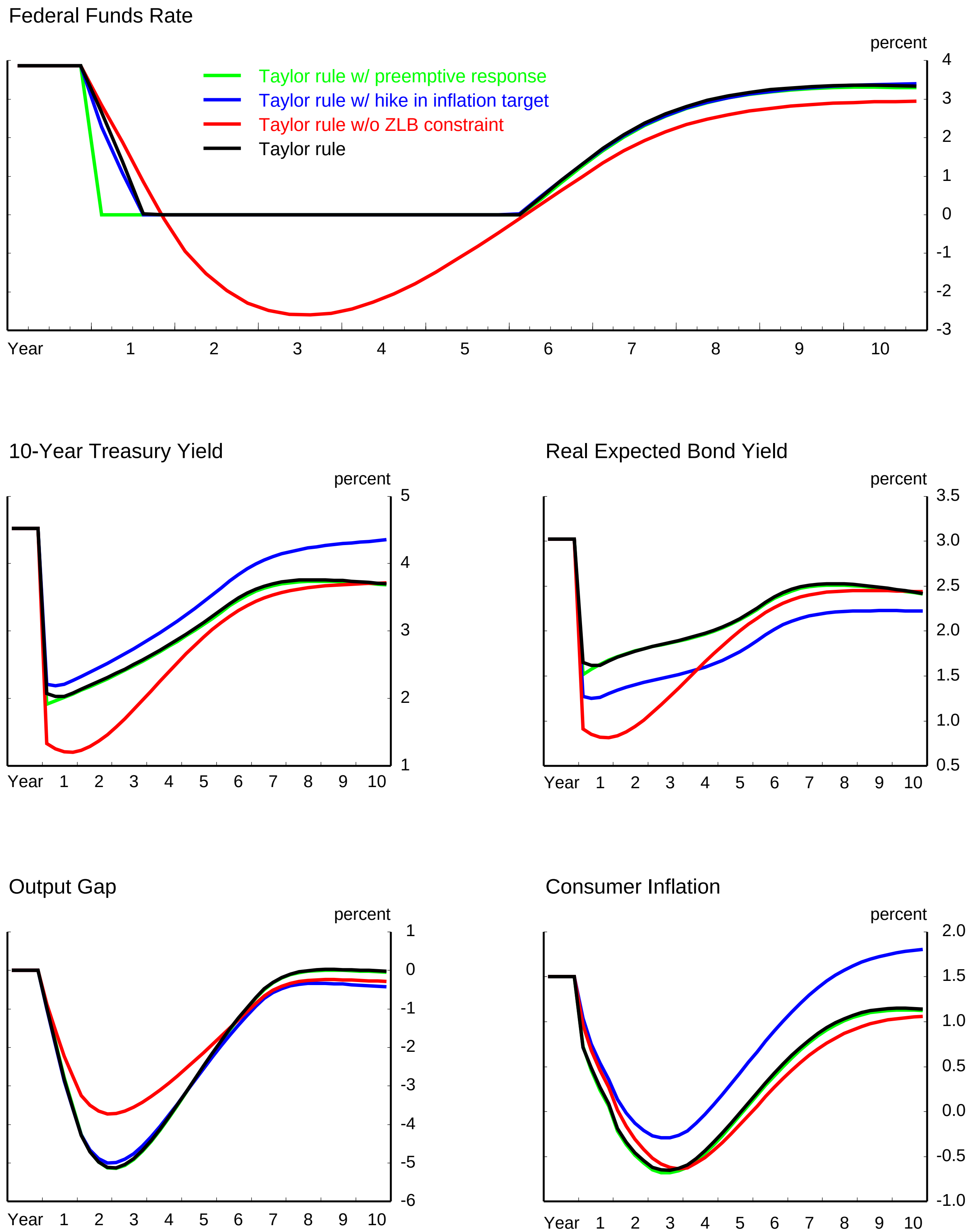

Figure 4

Macroeconomic Effects of a Large Demand Shock Under Price Level Targeting and the Change Rule or an Announced Change in the Inflation Target

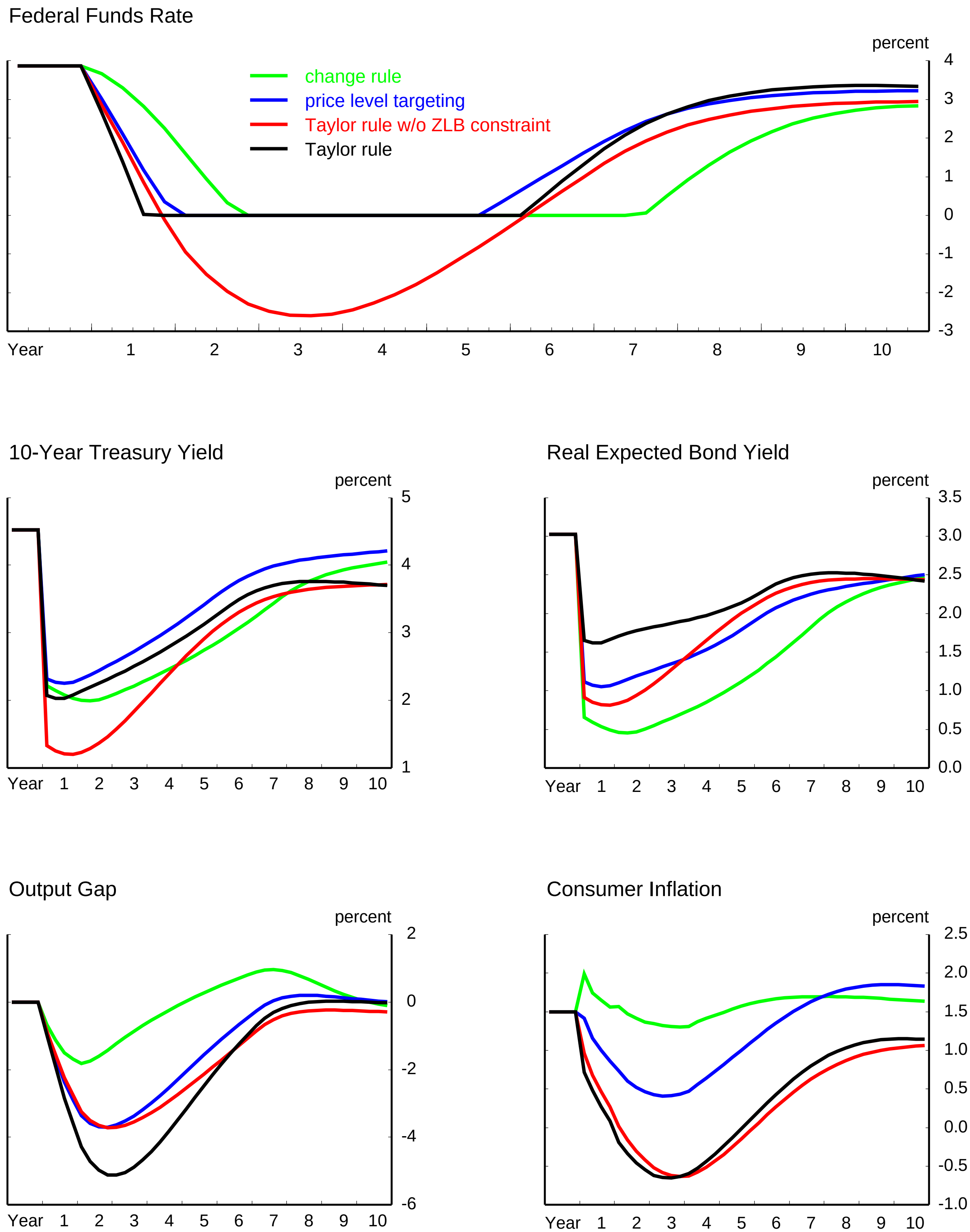

Figure 5

Implications of Replacing Model-Consistent Expectations With VAR-Based Expectations Outside the Financial Sector for the Effects of a Large Demand Shock Under the Taylor Rule

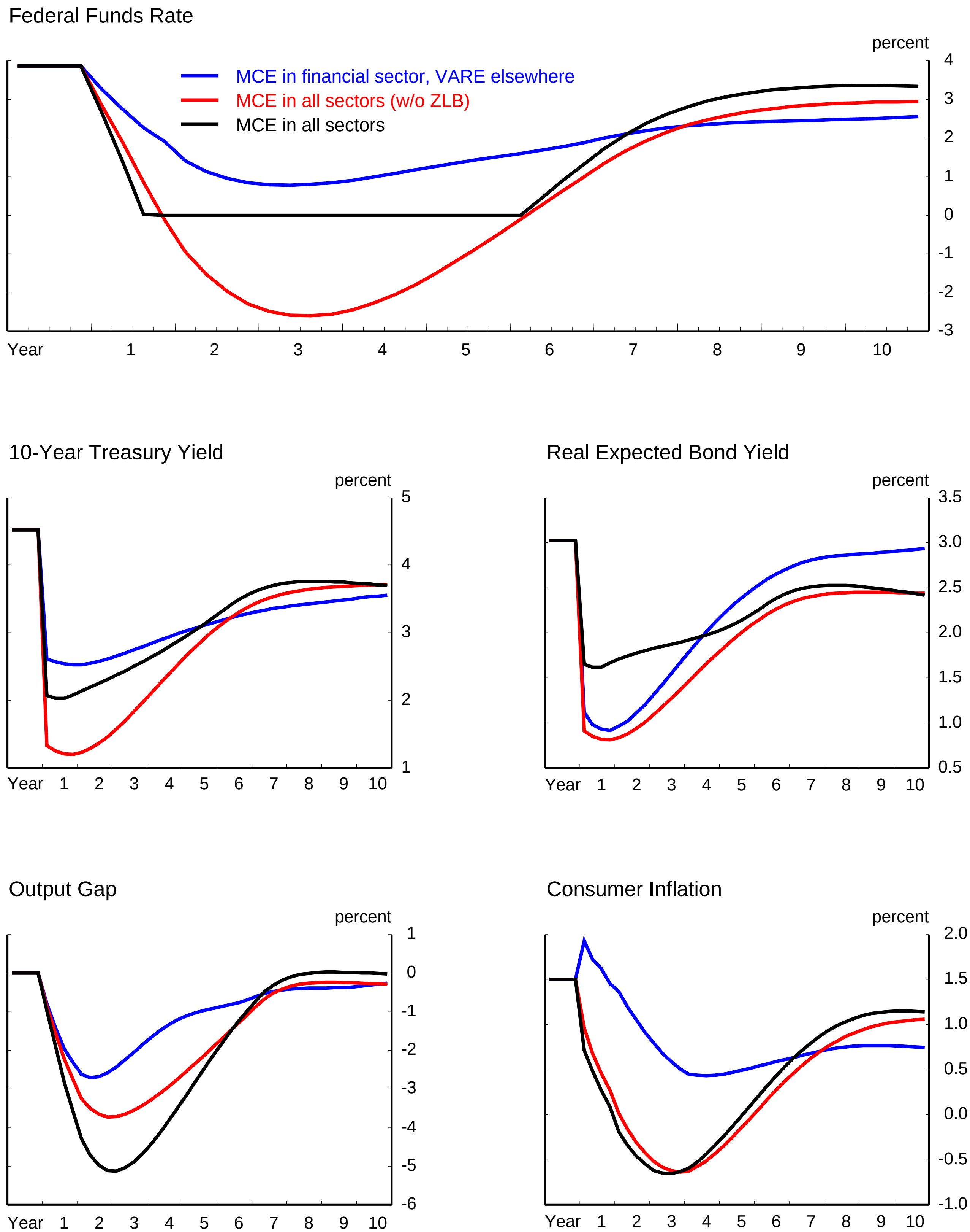

Figure 6

Comparative Performance of the Taylor Rule, Price Level Targeting, and the Reifschneider-Williams Rule in the Face of a Large Demand Shock When Only Financial Market Expectations are Model-Consistent

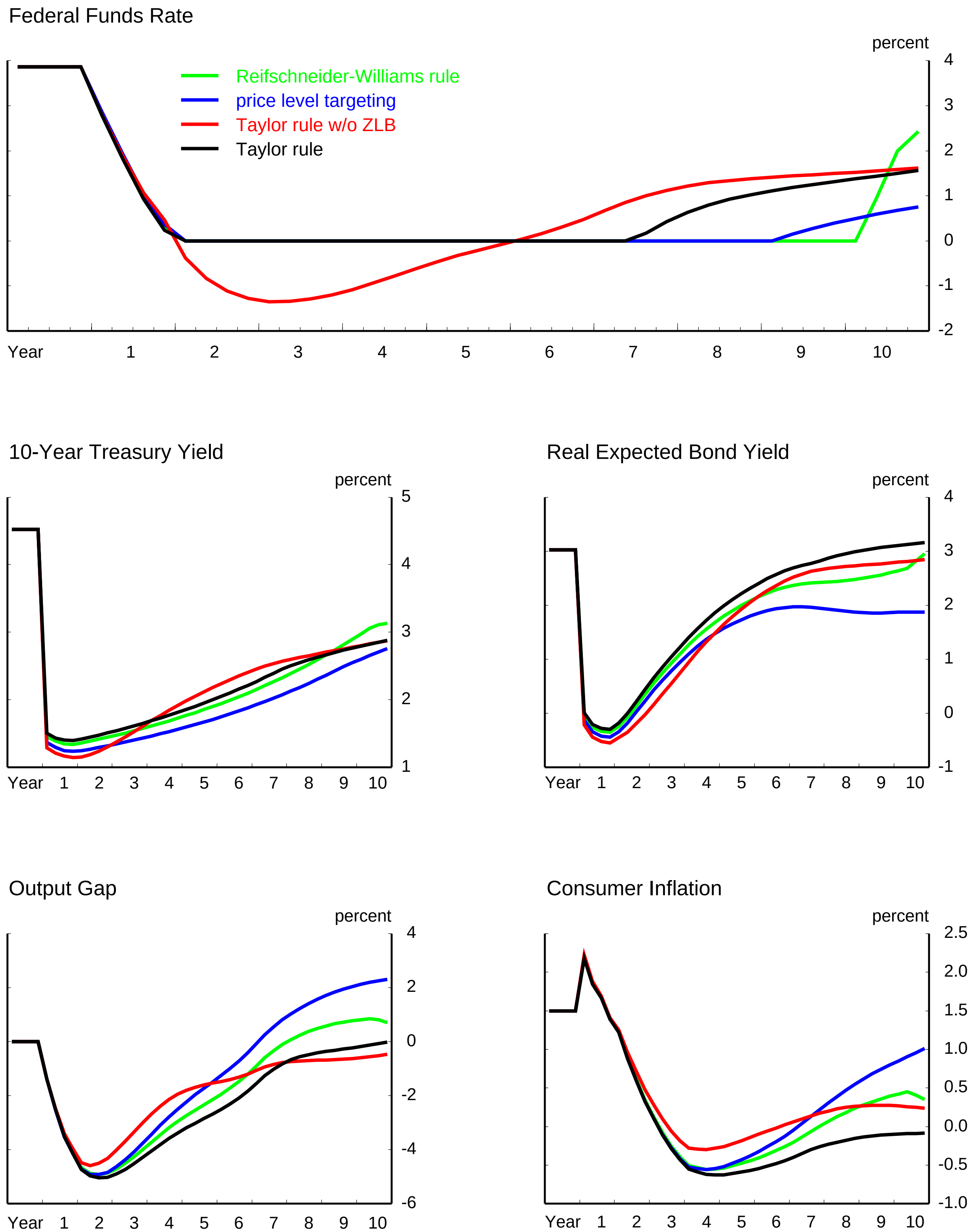

Figure 7

Macroeconomic Effects of a Large Demand Shock Under the Taylor Rule, Full Model-Consistent Expectations, and Alternative Fiscal Policies