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## BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM

DIVISION OF RESEARCH AND STATISTICS

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**Date:** April 20, 2009  
**To:** Federal Open Market Committee  
**From:** Dave Reifschneider and John Roberts  
**Subject:** Large-Scale Asset Purchases and Inflation Expectations in the FRB/US Model

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### Introduction

At the March FOMC meeting, a short summary of recent staff analysis of various considerations related to purchases of long-term Treasury securities and agency debt and MBS was presented to the Committee.<sup>1</sup> One of the exhibits in this presentation, replicated here as figure 1, illustrated how the staff outlook for the unemployment rate and inflation would be affected by a further expansion of the Federal Reserve's large-scale asset purchase (LSAP) program. Specifically, the figure compares macroeconomic outcomes under four different monetary policies:

- (1) constrained conventional optimal monetary policy, under which the federal funds rate is subject to the zero lower bound (the solid blue line);
- (2) unconstrained conventional optimal policy, under which the federal funds rate is allowed for illustrative purposes to fall below zero (the dotted red line);
- (3) constrained conventional optimal policy combined with an additional \$1 trillion in asset purchases (the dash-dot green line); and
- (4) constrained conventional optimal policy combined with an additional \$2 trillion in asset purchases (the dashed black line).<sup>2</sup>

As President Evans noted, a somewhat surprising aspect of these FRB/US simulation results is that the purchase of an additional \$2 trillion in long-term assets, even though it yields a path for the unemployment rate similar to that produced by unconstrained

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<sup>1</sup> This presentation drew upon two memos to the FOMC: "Economic Effects of Large-Scale Purchases of Long-Term Treasury Securities and Agency Debt and MBS," by Eileen Mauskopf and David Reifschneider (March 9, 2009); and "Expanding Large-Scale Asset Purchases: Effectiveness, Benefits, Risks and Strategies," by Joseph Gagnon, David Lucca, Jonathan McCarthy, and Jennifer Roush (March 11, 2009). In addition, the presentation referenced material presented in a box in the March Bluebook, "Large-Scale Asset Purchases and Unconstrained Monetary Policy."

<sup>2</sup> In all four cases, the optimal path for the federal funds rate is that which minimizes a loss function under which policymakers place equal weight on keeping unemployment close to the NAIRU, core PCE inflation close to 2 percent, and on avoiding changes in the nominal federal funds rate. Each optimal path is conditional on the assumptions underlying the March Greenbook forecast, the dynamics of the FRB/US model, whether or not the zero lower bound is imposed, and whether or not an LSAP program is in place.

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optimal policy, generates a markedly lower and hence less desirable path for inflation. Further discussion at the meeting highlighted the source of this differential response: In the version of the FRB/US model used for this analysis, long-term inflation expectations—or alternatively put, the public’s perception of the FOMC’s inflation objective—do not respond directly to large-scale asset purchases but do react to movements in the federal funds rate. As shown in the bottom panel of figure 1, this asymmetric specification implies that an LSAP program results in only a modest boost in long-run inflation expectations.

This memo explores how these results would change if we used alternative specifications for the way agents form their expectations for future inflation—in particular, specifications in which large-scale asset purchases and conventional monetary policy actions are treated symmetrically. This issue is particularly germane at present because the standard FRB/US specification, even though it accords reasonably well with historical experience, may no longer be a reliable guide now that the federal funds rate is likely to remain near zero for some time and the Federal Reserve has instituted a variety of unconventional policy programs. That said, determining the most appropriate expectational assumption under current circumstances is an extremely difficult task given that we have no experience to gauge the effects of the unprecedented policy actions now under way.

### **Alternative specifications for inflation expectations**

In FRB/US, wages and prices are determined by a system of equations that is similar in spirit to a standard new Keynesian Phillips curve. Abstracting from special transitory influences such as movements in relative prices for food, energy and imports, current inflation depends on lagged inflation, expected future inflation, current and expected markups, and current and expected resource utilization. Thus, any simulation of the model involves generating explicit expectations for future wages, prices, productivity, and resource utilization. In the simulations regularly presented in the Greenbook and Bluebook, the standard approach is to assume that wage and price setters base their expectations for the future on the predictions of a small-scale VAR model. A key variable in this model is a survey-based measure of the public’s expectations for long-run inflation,  $ptr$ . This variable serves as the implicit inflation target in the VAR’s estimated Taylor rule, and so ensures that the VAR model always predicts inflation to converge eventually to  $ptr$ .

In simulations of FRB/US, the public’s perception of the FOMC’s long-run inflation objective is not typically assumed to be fixed, but instead to evolve slowly in response to changes in economic conditions, as follows:

$$(1) \quad ptr_t = 0.9 ptr_{t-1} - 0.0106 (rff_{t-1} - rtr_{t-1}) + 0.1 pi_{t-1} + 0.0137 gap_{t-1}$$

Here,  $rff$  is the federal funds rate,  $rtr$  is an estimate of the equilibrium nominal federal funds rate,  $pi$  is the annualized percent change in the national accounts price index for core consumer prices, and  $gap$  is the output gap (multiple lags of these variables in the

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equation are suppressed for simplicity). While this model can be viewed as a simple reduced-form model of the evolution of the survey-based expectations data underlying  $ptr$ , it can also be given a formal justification in a framework in which monetary policy is set according to a Taylor rule subject to two shocks, one a random shock and the other a more persistent shock to the inflation target. If wage- and price-setters see only the arguments of the Taylor rule—the federal funds rate, the output gap, and inflation—but not the two shocks separately, they will be forced to infer movements in the inflation target from surprise movements in the funds rate.<sup>3</sup> In equation 1, if the federal funds rate is elevated relative to what might be expected relative to typical behavior—as captured by the variant of the Taylor rule embedded in equation 1—agents take it as a signal that the FOMC has lowered its inflation target. Conversely, if the funds rate is low relative to historical experience given current economic conditions, agents infer that the FOMC has raised its target.

One problematic aspect of equation 1 in present circumstances is that, with monetary policy constrained by the zero lower bound, co-movements of the federal funds rate, resource utilization and inflation are no longer particularly informative about the FOMC's inflation objectives. In fact, given the current weakness in real activity, the equation on its own would interpret the inability of the FOMC to cut short-term interest rates further as a signal that it wants inflation to move lower. In addition to this problem, equation 1 offers no mechanism through which unconventional policy actions can influence public perceptions of the FOMC's long-run goal for inflation. We therefore now consider alternatives to the standard specification that address one or both of these problems.

In our first alternative, the public updates its long-run inflation expectations simply on the basis of recent developments in actual inflation:

$$(2) \quad ptr_t = 0.97 ptr_{t-1} + 0.03 pi_t .$$

In equation 2, if core inflation is below the current estimate of long-run inflation expectations, expectations are revised down somewhat, whereas if inflation is higher than current expectations, long-run expectations are revised up somewhat. Over time, this model of inflation expectations will lead expectations to be a moving average of past inflation. This approach was used in the FRB/US model for many years prior to the adoption of the current specification, and it does a reasonably good job of explaining historical movements in survey measures of expected long-run inflation.<sup>4</sup> Moreover, equation 2 has the advantage in current circumstances of not relying on the federal funds rate for signals about the direction of monetary policy.

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<sup>3</sup> For more details, see Michael J. Kiley (2008), "Monetary Policy Actions and Long-Run Inflation Expectations," FEDS working paper no. 2008-03 (February).

<sup>4</sup> For a discussion of this model of inflation expectations, see Sharon Kozicki and Peter A. Tinsley (2001), "Shifting Endpoints in the Term-Structure of Interest Rates," *Journal of Monetary Economics* 47, 613-52. Kozicki and Tinsley provide evidence suggesting that this model does a good job of capturing movements in survey measures of long-run inflation expectations in the 1980s and early 1990s.

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In contrast, our next alternative goes in the opposite direction and assumes that wage- and price-setters use the volume of large-scale asset purchases to help infer the Committee's long-run inflation goals, in a manner similar to the way they use the federal funds rate in normal circumstances. In particular, we assume that the public is able to infer the hypothetical unconstrained movement in the federal funds rate that would have had the same effect on long-term interest rates as the large-scale asset purchase. We then assume that the public updates its long-run inflation expectations using this inferred movement in the funds rate in place of the actual movement in the funds rate.

Specifically, we assume that an LSAP program of \$1 trillion evenly divided between Treasuries and agency MBS will lower both 10-year Treasury yields and corporate bond yields by 80 basis points, consistent with the assumptions used in the box on pp. 31-32 of the March Bluebook.<sup>5</sup> As for the relationship between movements in the federal funds rate and long-term interest rates, simulations of the FRB/US model under VAR-based expectations suggest that reducing the federal funds rate 100 basis points lowers the yield on 10-year Treasury securities roughly 15 to 20 basis points. But under model-consistent expectations, a similar cut in the federal funds rate reduces this yield 30 to 40 basis points, assuming that the cut is expected to last for three or four years. If we assume that the average reduction in bond yields is 25 basis points—between these two estimates—then a \$1 trillion LSAP program would be equivalent to a 300-basis-point reduction in the federal funds rate with regards to its effect on long-term interest rates. Thus, if  $A$  is the amount of longer-term Treasuries and agency securities acquired as part of the LSAP program and expressed in trillions of dollars, then a deviation in the federal funds rate from its equilibrium value can be related to  $A$  by the following expression:

$$(3) \quad (r_{ff_t} - r_{tr_t}) = -3.0 A_t .$$

Substituting into equation 2, we can rewrite the specification for long-run inflation expectations as:

$$(4) \quad ptr_t = 0.9 ptr_{t-1} + 0.0106 (3.0 A_t) + 0.1 pi_{t-1} + 0.0137 gap_{t-1} .$$

Our third approach to this issue is to assume that wage- and price-setters have model-consistent expectations (MCE) and that monetary policymakers enjoy perfect credibility, and so wage and price setters always expect inflation to return to 2 percent in the long run. In this case,  $ptr$  no longer plays an important role, as long-run inflation expectations are fixed. Short-run inflation expectations—which enter the MCE version of the FRB/US model much as in standard New Keynesian models—will evolve with the state of the economy, but in a way consistent with the knowledge that inflation will eventually return to 2 percent. Under these assumptions, wage and price setting fully takes into account the implications of both conventional and unconventional monetary policy actions for future real activity and inflation.

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<sup>5</sup> As discussed in a forthcoming memo to the Committee by Joseph Gagnon, "The Effects of Long-Term Asset Purchases on Bond Yields," the staff has noticeably lowered its estimates of these interest rate effects since the March FOMC meeting.

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### **Simulation results using the alternative expectational specifications**

We now show how the simulation results presented in figure 1 change when re-run using these alternative specifications for inflation expectations. Starting with the simplest case in which long-run inflation expectations are updated using only core inflation, we find that a simple and symmetric pattern emerges across the different monetary policies with regard to the outcomes for unemployment, inflation, and inflation expectations (figure 2). As before, unconstrained optimal policy leads to the lowest unemployment rate, the highest inflation, and thus the highest path for inflation expectations; constrained optimal policy leads to the least-favorable macroeconomic outcomes; and optimal policy combined with either of the two LSAP programs produces intermediate results. But now the relative differences across policies on the dimension of unemployment are similar to the relative differences on the dimension of inflation. In addition to this greater symmetry in results between real activity and inflation, inflation outcomes are generally lower under this model of long-run expectations than in figure 1, and particularly so in the case of unconstrained optimal policy. This latter result is not especially surprising because inflation expectations are no longer directly boosted by an extremely large (but infeasible) drop in the federal funds rate.

Figure 3 presents simulation results using the specification in which asset purchases directly influence long-run inflation expectations. Because of this direct expectational effect, large-scale asset purchases now generate considerably higher inflation outcomes than occurs under either the standard specification (figure 1) or the simple specification (figure 2), even though outcomes for the unemployment rate are broadly similar. Moreover, the outcomes under the constrained optimal policy combined with a \$2 trillion LSAP program now have a straightforward relationship: Unemployment is slightly lower under the unconstrained policy and inflation is slightly higher.

Figure 4 shows results under MCE and a fixed inflation target; note that long-run inflation expectations are omitted from this figure because they are equal to the assumed long-run inflation objective of 2 percent in all the simulations. This perfect-foresight approach to expectations puts conventional and unconventional monetary policies on an equal footing, in the sense that policies which produce similar improvements in future economic conditions will move short-run inflation expectations in similar ways. Thus, to the degree the policies create similar outcomes for real activity, they will also have similar effectiveness with regard to stabilizing prices. And indeed, the unconstrained optimal policy (the dotted red line) and the \$2 trillion LSAP program (the dashed black line) produce similar outcomes for both the unemployment rate and inflation.

One somewhat surprising effect of switching to model-consistent expectations is the elevated level of inflation during the first few years of the simulation. To a degree, this occurs because the optimal-control procedure recognizes that, under these expectational conditions, policymakers have the ability to boost expected inflation and hence actual inflation in the near term by running an unusually accommodative monetary policy for a time in the longer run when policy is no longer constrained by the zero lower bound. The optimal-control procedure therefore opts for this strategy because it works to lower real

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interest rates and therefore stimulate real activity in the near term when the economy is especially weak. (Under VAR-based expectations, policymakers lack this ability because wage- and price-setters expect monetary policy to behave as it has on average over history.)<sup>6</sup> In addition, inflation is initially boosted more under model-consistent expectations because they account more fully for the persistent price effects of the large depreciation of the dollar which occurs under unconstrained optimal policy or an LSAP program than is the case in the simulations employing VAR expectations.<sup>7</sup>

## Implications

For most Greenbook and Bluebook simulation purposes, we anticipate that we will now use the first alternative specification of long-run inflation expectations, which updates only according to movements in lagged core inflation. We lean to this specification for several reasons. First, with the funds rate pinned at its effective lower bound, we believe that the specification we have been using—which takes from the funds rate some signal of the FOMC’s inflation goals—may be misleading. Second, the simple specification has reasonable empirical underpinnings. Third, we are skeptical that households and firms—even if they did soon come to understand that asset purchases are temporarily substituting for the federal funds rate as a primary monetary policy tool—would be able to infer the likely implications of such purchases for the FOMC’s inflation objective in the absence of any historical experience with LSAP programs. We suspect that, under such conditions, wage- and price-setters are likely to adopt simple rules of thumb for gauging trends, such as the rule laid out in the first alternative specification. That said, we recognize the enormous uncertainty that surrounds this question, and we will be monitoring the data for hints about the appropriate specification of determinants of longer-run inflation expectations.

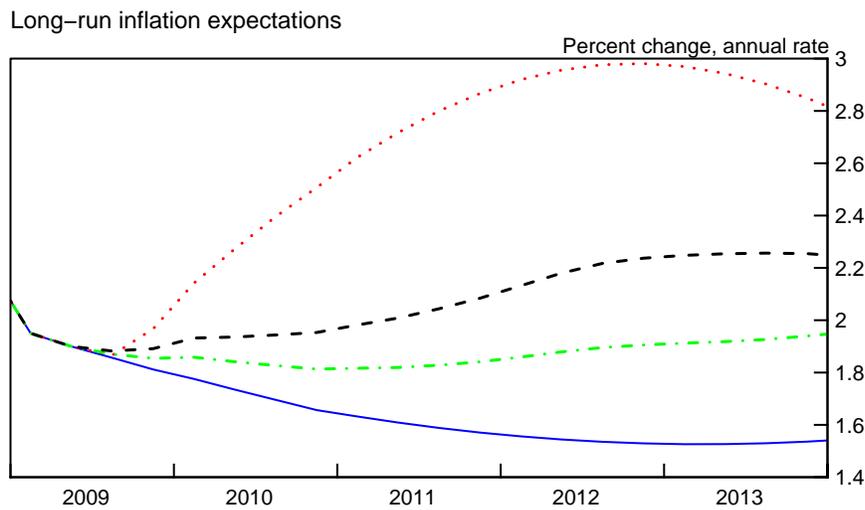
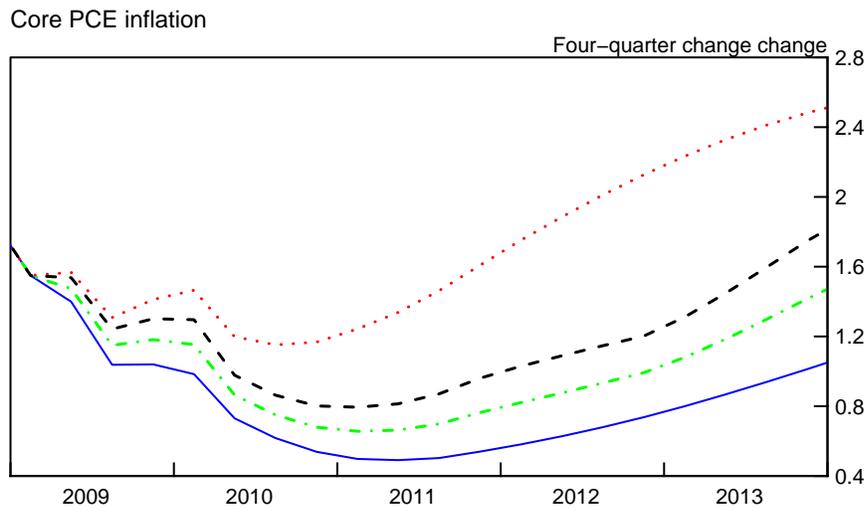
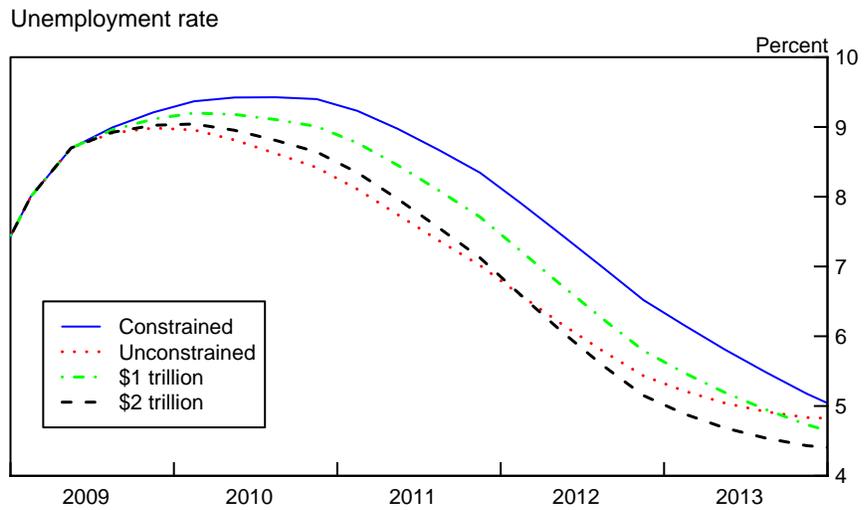
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<sup>6</sup> Even after taking account of these factors, the initial change from baseline of inflation under model-consistent expectations is considerably more than most new Keynesian Phillips curve models would predict given the change from baseline in current and future resource utilization. We are currently exploring the reasons underlying the relative steepness of the Phillips curve in FRB/US.

<sup>7</sup> Another surprising result involves the constrained policy (the solid blue line) in 2012 and 2013, which has both the highest unemployment rate and the highest inflation of any of the simulations. However, beyond the horizon shown, unemployment drops further and runs below the paths in the other simulations for several years. The higher inflation in 2012-13 reflects the anticipation of this higher aggregate demand. Eventually, unemployment is near the NAIRU and inflation is near the target in all of the scenarios.

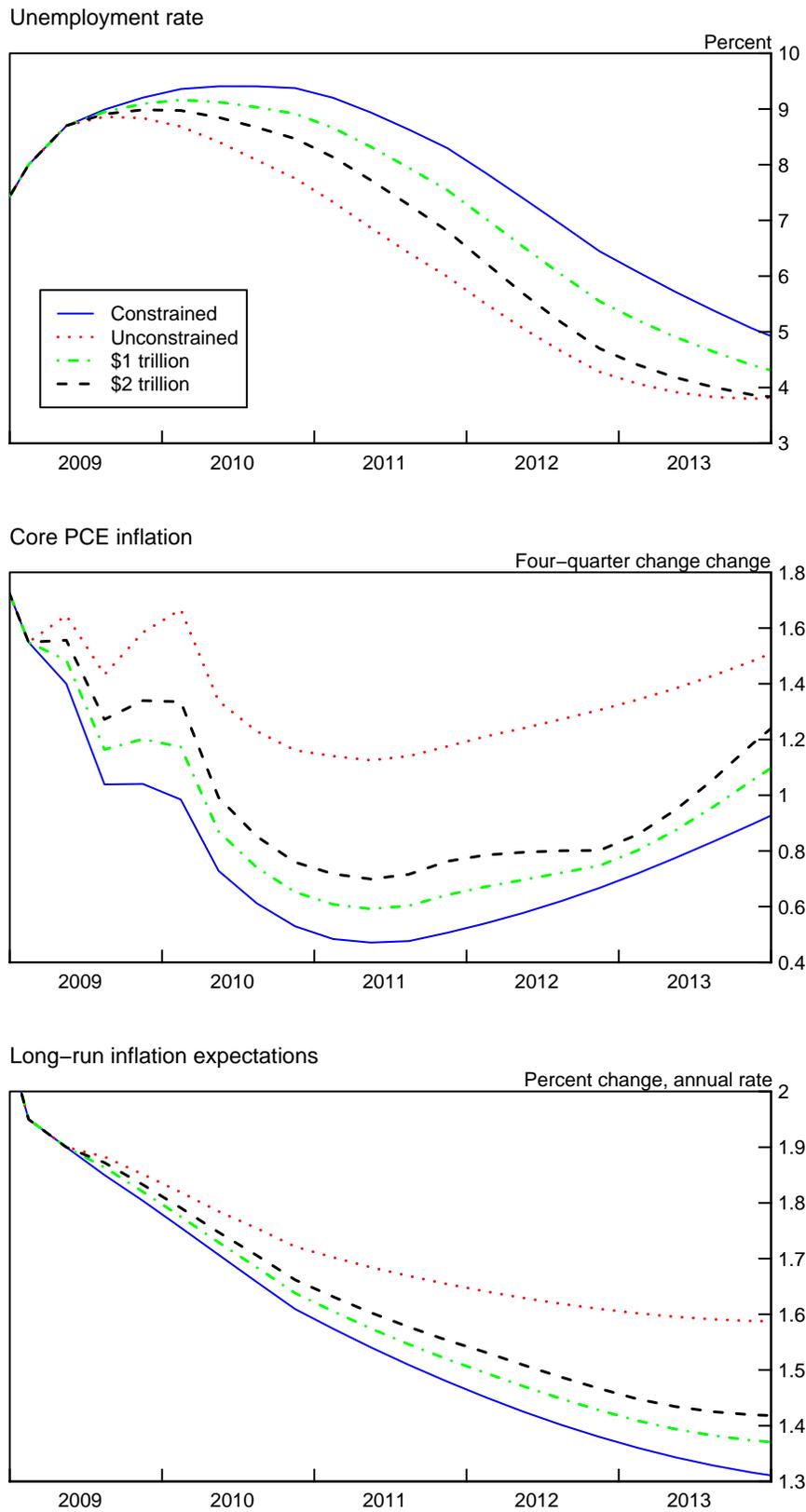
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Figure 1: Monetary Policy Simulations under March Baseline Assumptions



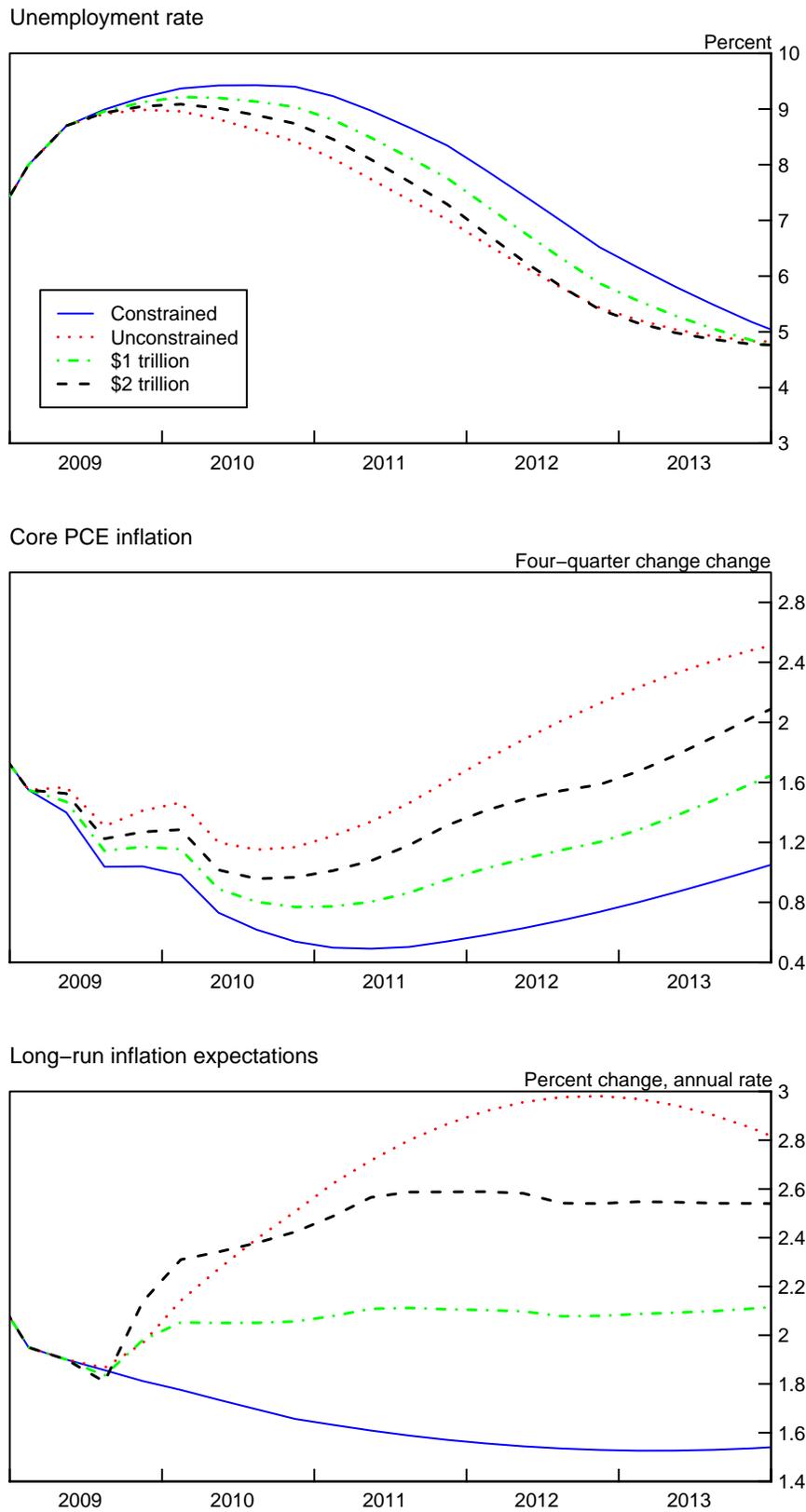
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Figure 2: Monetary Policy Simulations When Inflation Expectations React only to Lagged Inflation



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Figure 3: Monetary Policy Simulations When Inflation Expectations React to Asset Purchases



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Figure 4: Monetary Policy Simulations Under Model-Consistent Expectations and a Fixed Inflation Target

