Stochastic Implications of Alternative Strategies for the Beginning of Policy Normalization

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1. Introduction and Summary

Over the past several years, the FOMC has provided guidance in its public communications regarding the length of time that the federal funds rate will likely remain near its effective lower bound (ELB). In contrast, communications on the likely behavior of the federal funds rate after the first tightening have been both less extensive and less specific.[2] However, as the likely date for the first tightening draws closer, choices regarding the post-departure policy-rate path have taken on greater importance.

In many macroeconomic models, a relatively-early departure from the ELB, followed by a gradual increase in the federal funds rate, can produce similar levels of policy accommodation—and thus similar macroeconomic outcomes—as a strategy that prescribes a later departure from the ELB combined with a relatively rapid increase in the funds rate thereafter. As a consequence, the choice between alternative combinations of departure dates and subsequent planned rates of tightening will depend on considerations other than the degree of policy accommodation in the baseline outlook.

As background for the Committee's discussion of the appropriate timing of departure from the ELB, this memo uses stochastic simulations of the FRB/US model to examine two policy strategies that differ in terms of the timing of the first increase in the federal funds rate and the subsequent pace of tightening. Under what we call the *earlier and gradual* (E&G) strategy, the date of the first rate increase occurs in the current quarter and subsequent increases are relatively small. In the construction of the *later and steep* (L&S) strategy, we add-factor the policy rule such that the first rate increase is deferred for a year, with larger increases for a time thereafter.[3] Except where otherwise noted, the monetary policy response to shocks after departure from the ELB reflects the prescriptions of an inertial version of the Taylor (1999) policy rule. We first verify that, despite the differences in policy paths, the two strategies produce similar

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[1] We are grateful to Tim Grunwald, Tilda Horvath, and Luke Van Cleve for their dedicated work in helping to design and run our stochastic simulations and preparing the exhibits. At one level of abstraction, this memo can be thought of as the modeling counterpart to the memo "Potential Implications of Alternative Approaches to the Time and Pace of Tightening" by Christopher Erceg, Michael T. Kiley, and Robert Tetlow (sent to the Committee on September 6, 2014).

[2] Since December 2012, the FOMC postmeeting statements have indicated that, when the Committee "decides to begin to remove policy accommodation," it will take a "balanced approach consistent with its longer-run goals." In March 2014, the Committee added wording relaying its expectation that "economic conditions may, for some time, warrant keeping the target federal funds rate below levels the Committee views as normal in the longer run."

[3] For clarity, we discuss these two alternatives as if they were binary choices, but we acknowledge that there is no particular reason why intermediate cases could not be considered. Similarly, there is no particular reason why scenarios could not feature a first departure from the ELB that is later than 2016:Q1.

macroeconomic outcomes, given the baseline outlook that underpins their construction. We then consider the distribution of possible macroeconomic outcomes under the two strategies using stochastic simulations of the FRB/US model.

We measure the strategies' performance using two criteria. The first criterion is a familiar one: The distribution of economic losses incurred in this stochastic environment, as evaluated by the loss function the staff uses to construct the optimal control scenarios that appear in the Tealbook.[4] The second criterion is a notion of *regret*, that is, outcomes in which policymakers come to wish they had not followed either the E&G or L&S strategies, either because the prescribed federal funds rate returns in fairly short order to the ELB, or because the strategy calls for the policy rate to climb "too much, too quickly." Regret, in this sense, may be associated with outsized economic losses, a possibility we investigate below. However, our interest is broader, and includes consequences that might not be well captured by the model, such as reputational damage or financial instability risks. These, too, are examined below.[5]

Subject to the usual caveats that pertain to any model-based analysis, the main lessons from our analysis are:

- Conditional on the outlook and the assumed policy rule, the distribution of economic losses in stochastic trials are similar under E&G and L&S strategies.
- Unforeseen exogenous shocks to the model tend to push the dates of first tightening under each strategy toward one another; that is, the distribution of first departure under the E&G strategy moves a bit later in time and that of the L&S strategy a fair amount earlier in time, compared with their baseline constructions. This result is robust to the alterative assumptions we tested, but the magnitude of the effect is sensitive to alternative assumptions; in general, the more inertial the policy rule, the smaller the effect.
- There are distinct tradeoffs associated with the two types of regret we explore. The probability, under the E&G strategy, of returning to the ELB within eight quarters is moderate, at 10 percent, and falls to only about 5 percent under the L&S strategy; however, the chance of the prescribed federal funds rate climbing to at least 3 percent within a year of initial departure is negligible under the E&G strategy, and about 10 percent under the L&S strategy.
- Regrets are associated with outsized economic losses, on average, in that sequences of shocks that produce early returns to the ELB, or large increases of the federal funds rate within a year, also tend to produce poor economic outcomes. The prospect of returning early to the ELB appears to be modestly more costly than that of having the federal funds rate rise

[4] For an example of the use of the assessment of policy performance by the evaluation of a loss function in a stochastic environment, see "Using Thresholds to Clarify the Conditionality in the Committee's Forward Guidance for the Federal Funds Rate" by Eric Engen, David Lopez-Salido, Jean-Philippe Laforte, Edward Nelson, Dave Reifschneider, and Robert Tetlow (memo sent to the Committee on October 16, 2012).

[5] Moreover, the memo "Issues Concerning the Timing and Pace of Policy Firming" by Michael Kiley, Edward Nelson, and Dave Reifschneider, also sent to the Committee on January 16, 2015, discusses some of the reasons why policymakers may attach costs to some events that differ from those assumed in the optimal control simulations.

rapidly, with some evidence that this is particularly so for the E&G strategy. It seems clear, however, that the quantification of such costs and benefits will vary in important ways with the model and with the baseline.

- Examining the stochastic draws in which policymakers might regret the E&G strategy reveals these cases to be dominated by sequences of particularly negative shocks to wages and prices. In contrast, the cases in which policymakers might regret the L&S strategy are a mix of large positive shocks to wages and prices as well as to private-sector spending.
- Smoothing of the policy rate is helpful for reducing the likelihood of poor economic outcomes as well as for minimizing the likelihood of regret. This is true for either strategy.

The remainder of this memo proceeds as follows. The next section lays out the two baseline strategies, reviews the computational exercises undertaken, and discusses the criteria used for assessing performance. The third section presents our main results. The fourth section explores the robustness of our results to the specification of the monetary policy rule and to the assumed method of expectations formation. The fifth section concludes.

2. Policy strategies and performance criteria

2.1 Policy strategies and baselines

We compare the potential macroeconomic effects of pursuing two policy strategies that differ in the timing and pace of policy rate firming. Our analysis is explicitly stochastic; that is to say, we examine distributions of economic outcomes based on random draws from the historical shocks to the model. Under both strategies, the economic outlook is summarized by the December 2014 Tealbook forecast; the simulations differ only in their assumptions about monetary policy. The inertial version of the Taylor (1999) policy rule, subject to some adjustments implemented with policy rule add-factors early on, is used to construct both baselines and, except where otherwise noted, is the rule that is assumed to govern policymaker decisions in terms of their responses to shocks.[6]

The E&G strategy calls for the federal funds rate to depart from the ELB in first quarter of 2015, and then climb at the modest pace of 25 basis points per quarter, summing to 2 percentage points over two years. The baseline is constructed by a straightforward application of the inertial Taylor rule to the December 2014 Tealbook outlook. The L&S strategy uses the same inertial

[6] The inertial Taylor (1999) rule is defined as $R_t = 0.85R_{t-1} + 0.15[rr_t^* + 1.5\pi_t - 0.5\pi^* - \tilde{y}_t]$, where R is the nominal federal funds rate target, rr^* is the equilibrium real short-term interest rate, π is the four-quarter headline PCE inflation rate, π^* is the inflation target, and $\tilde{y}$ is the output gap, that is, the percent difference between actual real GDP and the staff's estimate of its potential level. Unless otherwise stated, all the simulations in this memo are carried out under the assumption that financial market participants and wage- and price-setters form model-consistent expectations, meaning that policymakers are assumed to adhere to the rule in the future and that the private sector fully understands the policy that will be pursued and its implications for real activity and inflation. Other expectations in the model are derived from a small-scale VAR, rather than from the full FRB/US model. Our experience has been that extending model-consistent expectations to a wider set of economic agents is not likely to make a significant difference to the results discussed here.

Taylor rule as the E&G strategy, except that policy rule residuals are added to keep the federal funds rate at the ELB through the end of 2015, and then climb at the relatively rapid pace of 50 basis points per quarter in 2016.[7] The upper-left panel of figure 1 shows the prescribed paths for the federal funds rate associated with these two strategies; the other panels of the figure show the economic outcomes associated with these policies. The two strategies produce similar economic outcomes. The reason is that the real longer-term rates that influence economic activity in the model are nearly identical, as the upper-right panel shows. Therefore, the losses associated with the two policy strategies under these assumptions, as measured by the staff's conventional loss function, indicate highly similar economic performance.[8]

Our results and conclusions depend on some key assumptions and, in section 4, we consider some alternatives. In particular, we step back from model-consistent expectations by assuming that all agents formulate their expectations using a small scale vector-autoregressive (VAR) model. The assumption that the inertial Taylor rule governs monetary policy is also investigated. Our results also depend, as in any model-based analysis, on the structure of the model and the underlying outlook.

2.2 Stochastic simulations and performance criteria

Conditional on these two baselines, and the policy strategies that implement them, we employ stochastic simulations in which the model is repeatedly subjected to shocks of the sort experienced since the late 1960s. These stochastic simulations allow us to construct probability distributions for future economic conditions, conditional on the particular characterization of monetary policy used in the simulations and the dynamics of the model.[9]

We examine the performance of our strategies using two criteria. One is the staff's standard measure of economic loss described in footnote 8. The other is our notion of regret of certain extreme scenarios. We have in mind two such scenarios, the early return of the funds rate to its ELB, and a rise in the federal funds rate that is "too much, too fast." Such events might be expected to be costly in their own right. That an early return to the ELB might be economically costly is fairly obvious: Monetary policy at the ELB is often thought to be less effective than otherwise. Rapid increases in the federal funds rate could also be costly, according to the model,

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[7] Our methodology assumes that E&G policymakers and L&S policymakers have the same preferences but employ different policy tactics. An alternative approach would have been to estimate a policy rule for L&S policymakers and characterize such policymakers as being substantially different than E&G policymakers. Doing so, however, would have obscured the basis of comparison of outcomes under the two strategies.

[8] The economic loss function is $L_t = \sum_{i=0}^{T} \beta^i \left[\tilde{y}_{t+i}^2 + (\pi_{t+i} - \pi^*)^2 + (\Delta R_{t+i})^2 \right]$, where $\beta = 0.99$ is the quarterly discount factor and T is the time horizon. In this memo, we report average quarterly losses, adjusted for discounting, over the 2015:Q1–2020:Q4 period.

[9] The stochastic simulations are run by shocking various components of aggregate spending, productivity and employment, wages and prices, asset prices, and other variables from 2015:Q1 through 2020:Q4. The shocks in each quarter are randomly drawn from the set of FRB/US model equation residuals from 1969:Q1–2013:Q4. The forward-looking nature of the problem requires that the model be solved for an extended path of 200 periods, so a stochastic trial comprises 24 nonlinear, perfect-foresight simulations, one for each of the quarters for which a vector of stochastic shocks is drawn. A complete set of stochastic simulations includes 4,000 stochastic draws, from which we construct distributions for endogenous variables.

to the extent that the assumed inertia in monetary policy might leave policymakers "behind the curve" in re-equilibriating the economy following shocks. And so we provide an analysis of these costs, as measured by the economic loss function.

However, our focus on these scenarios also reflects another concern, namely that the model (and any model) might not properly capture the full implications of such events. An early return to the ELB, for example, could undermine confidence in policymakers' judgment and the effectiveness of their policies, particularly if it were to come after a lengthy period of forward guidance that has focused on the date of first departure. A rise in the federal funds rate that is "too much, too fast" could precipitate financial stability risks.[10] The common thread shared by these two scenarios is that their costs are outside of the purview of the model, and would not be adequately captured by evaluations of standard loss measures given the model.

3. Performance of the E&G and L&S strategies in stochastic simulations

3.1 Economic outcomes

Figure 2 shows the 70- and 90-percent confidence intervals for our stochastic simulations. Both strategies lead to dispersed outcomes. In particular, the confidence intervals around the date of first departure of the federal funds rate from the ELB are quite wide and differ markedly depending on the strategy. The 70-percent confidence intervals for the federal funds rate in the first year overlap very little, although the 90-percent intervals are more similar. Despite the differences in monetary policy, the confidence intervals for the rates of unemployment and inflation are very similar.[11] This similarity of outcomes reflects the fact that policy is no better, or worse, at serving this role in the L&S strategy than it is in the E&G strategy. When policy is seen to be systematically and effectively responding to shocks, a strategy that turns out to have been somewhat late in departing from the ELB can be offset by more aggressive subsequent policy actions, and vice versa for a start that turns out to have been somewhat early.

Figure 3 shows the distribution of dates for first departure from the ELB, with the corresponding date in the baseline scenario noted by the vertical line. In the case of the E&G strategy, a small percentage of draws results in a slightly later departure from the ELB than in the baseline. In contrast, about half of the draws under the L&S strategy features an earlier departure than in the baseline. Taken together, these results show that the response to shocks tends to drive the two strategies toward greater similarity in terms of departure dates. This result turns out to be quite

[10] See, for example, the analysis of endogenous financial crisis probabilities in "Financial Stability Implications for Simple Interest Rate" by Andrea Ajello, Thomas Laubach, David Lopez-Salido, and Taisuke Nakata (memo sent to the Committee on March 5, 2014).

[11] The unemployment rate and inflation through 2017 under each strategy's baseline are nearly identical to their corresponding median values in the stochastic simulations. This similarity demonstrates that nonlinearities, whether originating from the model or from the effect of the ELB, have little influence on the central tendency of economic outcomes in current circumstances. Had there been a material effect of the ELB on outcomes, it would have captured the associated downside risk by pushing the median for the unemployment rate above the baseline value. The median for inflation would have been pushed below its baseline, although only by little due to the low sensitivity of inflation to slack. See, for example, the memo "How Asymmetric are the Risks in the Macroeconomic Outlook?" by Oliver de Groot, Etienne Gagnon, and Mike Kiley (sent to the Committee on June 6, 2014).

general.[12] The stochastic performance of the two strategies in terms of the distribution of economic losses is also similar.

3.2 Regret

Figure 4 shows probabilities of experiencing our two regret scenarios under each policy strategy. The left panel displays the probability of our first regret scenario, namely that the federal funds rate will return to the ELB within four, eight, and twelve quarters. To cite one example, the probability of returning to the ELB within eight quarters under the E&G strategy is about 10 percent. The probability of that outcome under the L&S strategy is only half that, at 5 percent. Turning to the right panel, we see the likelihood of our second regret scenario, which is the policy rate rising, over the first four quarters after its initial departure from the ELB, to at least 2½, 3, and 3½ percent. The 3 percent figure is an interesting benchmark for this notion of regret because it closely matches the FOMC's pace of tightening between February 1994 and February 1995, a policy sequence that received a lot of criticism at the time.[13] In our stochastic simulations, the probability that the federal funds rate will climb to at least 3 percent within a year after the initial departure from the ELB is very low in the case of the E&G strategy, but is about 10 percent under the L&S strategy. These results show that policymakers, in choosing a policy strategy, face a tradeoff between the likelihood of experiencing one type of regret versus the other.

In terms of making these tradeoffs, it is useful for policymakers not only to know the likelihood of scenarios but also how costly they are when they occur. Table 1 provides summary statistics on the stochastic distribution of economic costs of two particular regret scenarios—a return to the ELB within eight quarters of initial departure from the ELB and an increase in the federal funds rate to 3 percent or more within a year of departure from the ELB—along with the associated unemployment rate and inflation outcomes. Policymakers endowed with the usual economic loss function would judge the median economic loss associated with a return to the ELB as only somewhat more costly, at 4.8 (column H, lines 2 and 5) than the median loss associated with a rapid increase in the federal funds rate, at 4.5 (column H, lines 3 and 6). Perhaps remarkably, the median loss of these two regret scenarios are essentially the same whether policymakers follow the E&G strategy or the L&S strategy.

Given the above findings, it might be tempting to conclude that policymakers would see a return to the ELB in the near term as no less undesirable than a situation calling for a steep and rapid increase in the funds rate. Such a conclusion would be premature for at least two reasons. First, the two regret situations are associated with quite different macroeconomic outcomes. If policymakers have different loss functions than our model assumes, the differences in results between the two regret scenarios would likely be exacerbated. For instance, we find that draws that lead to a return to the ELB within eight quarters are associated with median unemployment rates of 5.8 percent and 6.0 percent, by the end of 2016, under the E&G strategy and L&S

[12] It is true for the Taylor (1999) rule and it is true under VAR-based expectations. Indeed, the inertia in the inertial Taylor rule reduces the extent to which this convergence of departure dates occurs.

[13] This tightening episode is a natural historical reference point. That said, whereas in the FRB/US model (as in other models) the ELB introduces an unmistakable nonlinearity, nowhere in the model is it the case that tightening in the federal funds rate beyond some pace would distort economic dynamics.

strategy, respectively, (column F, lines 2 and 5). By contrast, the draws that lead to an increase in the federal funds rate that is "too much, too fast" result in an unemployment rate that tends to fall below the staff's estimate of the natural rate by the end of next year (column F, lines 3 and 6). Overall, our statistics suggest that negative shocks to wages and prices play a large role in episodes in which the policy rate returns to the ELB, and especially so when policy follows the E&G strategy. For large, rapid increases in the federal funds rate, our statistics suggest that positive shocks to wages and prices are an important trigger when policy follows the E&G strategy whereas positive expenditure shocks tend to be relatively important under the L&S strategy. Because the configuration of unemployment and inflation rates differs depending on which policy strategy is adopted, policymakers may further differ in their preference for one policy strategy over the other. For example, a return to the ELB within eight quarters when policymakers follow the E&G strategy is associated with a mild deflation in 2015 (column D, line 2) but modest inflation, at 0.7 percent (column D, line 5), when policymakers follow the L&S strategy.

The second reason why policymakers might see the two regret scenarios differently is that median statistics, such as those reported in Table 1, may hide especially adverse events. Figure 5 analyzes the full distributions of economic losses conditional on satisfying of one of our definitions of regret, for both strategies, along with the unconditional distribution of losses. The upper panel, which shows losses conditional on an early return to the ELB, indicates that this class of regret is associated with larger economic losses, whether under the E&G or the L&S strategies. This fact is demonstrated by the area under the dashed lines that is above and to the right of the solid black line. At the same time, however, the small second mode, well to the right in the conditional distribution of losses under the E&G strategy, suggests there is a modest but non-trivial incidence of sequences of shocks that produce large losses under that strategy that do not occur under the L&S strategy.[14] Policymakers whose loss functions place substantially more weight on such outcomes than the model may thus want to delay the first rate increase to reduce the adverse consequences. Turning to the regret associated with an outsized increase in the funds rate, the panel to the right demonstrates an effect that is broadly similar to that in the left panel, but less consequential: Sequences of shocks that push the federal funds rate above 3 percent within four quarters do produce larger losses than otherwise, but the effect is less impressive than with a return to the ELB, and the difference between the two strategies in this case is smaller.

4. Robustness

In this section, we briefly report on the robustness of the results to relaxing two key modeling assumptions: First, that policy is governed by the inertial version of the Taylor (1999) policy rule and, second, that agents' expectations are model consistent.[15]

[14] Indeed, we find evidence that the L&S policymakers would have suffered smaller losses when incurring the shocks that drive E&G policymakers to an early return to the ELB in the simulations. The converse case of E&G policymakers gaining protection against shocks that would have driven the federal funds rate to rise "too much, too fast" is less clear.

[15] Figures analogous to figures 2–5 for these robustness exercises are available for interested readers upon request from the authors.

First, we explore the importance of the assumed policy rule by repeating our experiments with policy governed by the original Taylor (1999) rule. This alternative rule removes the interest-rate-smoothing term present in the inertial Taylor rule, and thus allows us to isolate the effect of the inertia in our assumed policy rule. Inertia is a desirable feature of simple policy rules if, as our economic loss function posits, there are welfare costs associated with volatility in the movement of the policy rate. Even so, some policymakers might wish to eschew such inertia, perhaps on the grounds that it seems less data dependent than is desirable—inertia has a way of looking nonresponsive—or on the grounds that it makes the communication of that data dependence more complicated than otherwise. Second, we explore the issue of expectations formation. Whether private agents form model-consistent expectations is a contentious issue even under normal monetary conditions; that they would do so when the federal funds rate has been at the ELB for six years is more contentious still. To investigate this issue, we repeat our computational experiments using VAR-based expectations for financial market participants and wage- and price-setters. The main upshot of this alternative assumption is that the precise reaction function of policymakers is not fully incorporated into private agents' decision rules, which would normally be thought of as making monetary policy less effective than otherwise.

Using the Taylor (1999) rule in place of the inertial Taylor rule results in markedly different distributions for the paths for the prescribed federal funds rate, but produces few differences in the confidence intervals for dual-mandate variables. Even so, the probabilities of both types of regret studied in section 3 are much higher with the Taylor (1999) rule. However, largely because regrets are so prevalent and short-lived, they are not associated with particularly-large economic losses. The unconditional distribution of economic losses under the Taylor (1999) rule is shifted a bit to the right compared with the inertial Taylor rule case, implying somewhat-larger losses on average. Put differently, in the FRB/US model, persistence in policy-rate setting has beneficial effects, both in avoiding regret, and in lowering economic losses.

Turning to our results for VAR-based expectations, the confidence intervals are, on many dimensions, remarkably similar to those presented earlier. In particular, the confidence intervals for the federal funds rate and the distribution of dates of first tightening differ only modestly, and the distribution of outcomes for the unemployment rate is also similar. A difference arises, however, for inflation; in this case, with the assumption of VAR-based expectations there is considerably more variation in inflation than is the case under model-consistent expectations. The probabilities of regret are also similar across the two classes of experiments. The similarity of results under VAR-based expectations with those obtained under model-consistent expectations is, however, less surprising than it might appear. The FRB/US model's core VAR-based expectations block contains an equation for the expected federal funds rate in the future. That equation embodies an expectation that the setting of the federal funds rate will be highly persistent. Thus, when actual policy is persistent—as is the case under the inertial Taylor rule—VAR-based expectations perform reasonably well.

What each of these deviations from our base case assumptions have in common is that the choice of strategy has only minor implications for the economic outcomes, but it has in some cases large effects on the likelihood of either an early return of the federal funds rate to the ELB, or of a rapid increase in the policy rate after first departure from the ELB.

5. Concluding remarks

This memo has explored the implications of two policy strategies for the Committee's decision on the date of first tightening in the federal funds rate and the subsequent pace of tightening in a stochastic environment. We compared the performance of an *earlier and gradual* strategy with a *later and steep* strategy on the basis of two criteria: the desirability of their economic outcomes as measured by a standard quadratic loss function, and their propensity to result in *regrets* that might not be well captured by our models and the standard loss function.

Our principal finding is that the choice between the two strategies is of relatively minor importance for economic outcomes in most scenarios, as measured by the economic loss function. This result holds because, under our assumption that agents form expectations that are consistent with the decision rules set out by policymakers, and that these rules are maintained over time and are seen as credible, policy actions are highly substitutable over time. That is, a foregone amount of policy tightening (or easing) today can readily be offset by extra tightening (easing) some time in the future. What is more important than the precise timing of the departure from the effective lower bound is the adoption of a policy, supported by public communications, that will establish beliefs on the part of private agents that are consistent with that policy.

In our examination of the likelihood of incurring scenarios that some policymakers might want to particularly avoid for reasons that may not be well-captured by our model, for one reason or another—specifically, an early return of the funds rate to the ELB or an overly rapid climb in the federal funds rate following departure from the ELB. Our model simulations suggest a moderate likelihood of such events and clear tradeoffs between the two strategies regarding which risk policymakers might bear. An earlier and gradual strategy accepts a higher probability of returning to the ELB than does a later and steep strategy; whereas the probability of an overly rapid funds rate climb is more likely under the later and steep strategy than an earlier and gradual strategy. How to balance the prospective costs, if any, of these two events is difficult to assess.

Finally, we found that, measured in terms of both economic losses and in the avoidance of regret, persistence in the setting of monetary policy, as embodied for example in a sizable coefficient on the lagged federal funds rate in the inertial Taylor rule, improves economic outcomes.

As with any model-based analysis, our results are subject to caveats, of which we note three here. First, the results could be sensitive to the structure of the model used. In particular, as we noted above, the FRB/US model contains only a rudimentary financial block and more generally does not include risk-sensitive agents whose responses to some of the scenarios we have discussed might be understated. Second, we have maintained the assumption, standard in macroeconomics, that expectations are model consistent, and we have also assumed that agents accept that policymakers are committed to the policies they adopt for responding to economic shocks. Together, these two assumptions endow monetary policy with considerable power. And while our main conclusions with regard to expectations formation were largely resilient to our consideration of an alternative method of expectations formation, it is not hard to believe that other plausible formulations could lead to more consequential differences. Third and finally, we have maintained throughout the formal part of our analysis, the assumption that policymakers view economic losses through the lens of the standard quadratic loss function that is employed in the construction of optimal control scenarios that are frequently prepared for the Committee.

Table 1

Economic Outcomes under Two Regret Scenarios*

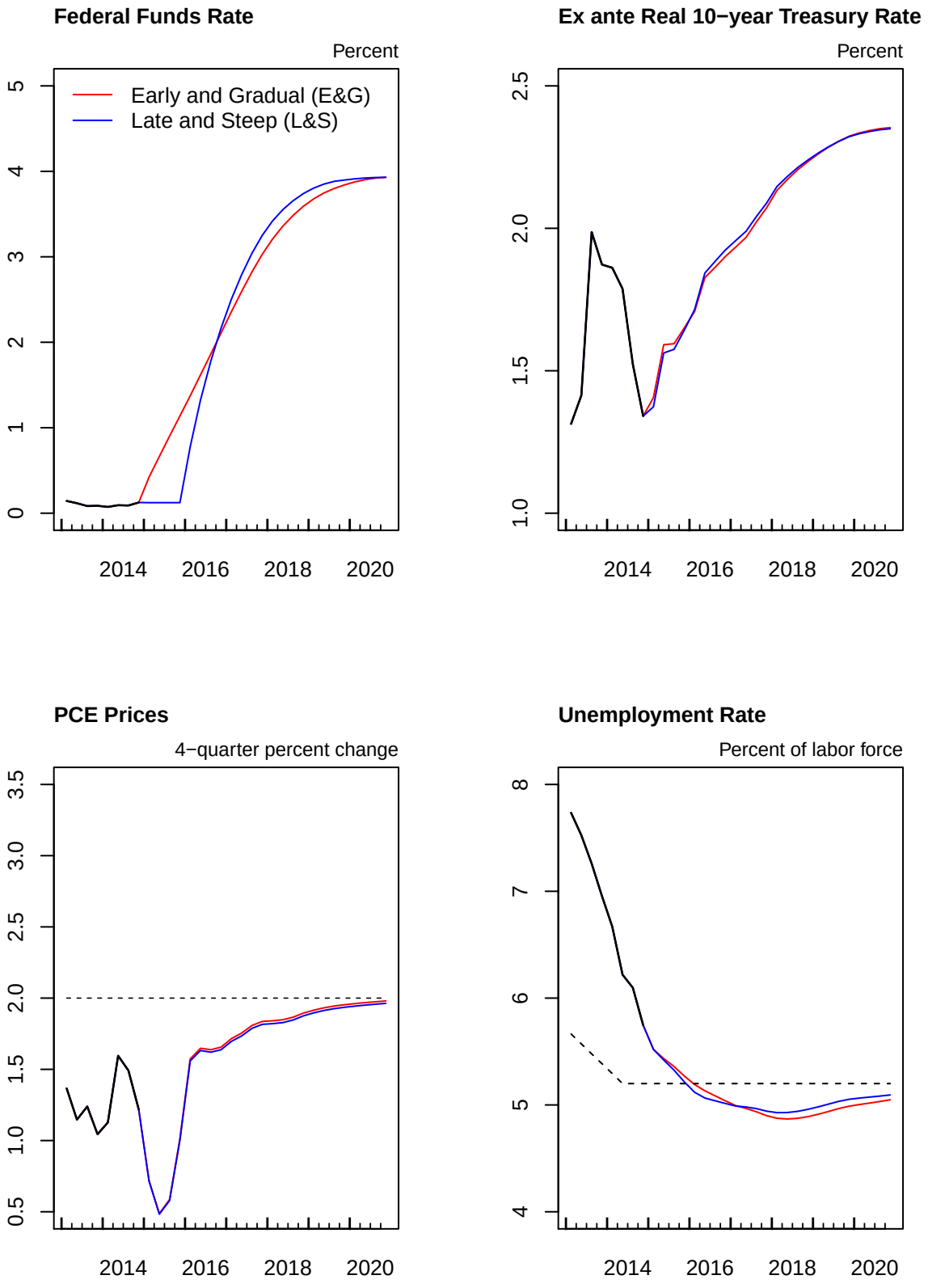
	Percent of draws	Median value in 2015:Q4			Median value in 2016:Q4			Median economic loss (2015:Q1–2020:Q4)**
		Funds rate	Unemploy-ment rate	PCE inflation	Federal funds rate	Unemploy-ment rate	PCE inflation	
	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]
Earlier and gradual strategy								
1. All draws	100.0	1.2	5.2	0.9	2.2	4.9	1.6	3.8
2. Return to ELB within 8 quarters	9.7	0.3	5.7	-0.1	0.3	5.8	0.4	4.8
3. Funds rate is greater than 3 percent four quarters after ELB exit	0.6	3.1	5.4	3.8	3.2	5.1	2.2	4.5
Later and steep strategy								
4. All draws	100.0	0.2	5.2	0.9	2.3	5.0	1.6	3.7
5. Return to ELB within 8 quarters	5.1	0.1	5.5	0.7	0.7	6.0	0.4	4.8
6. Funds rate is greater than 3 percent four quarters after ELB exit	9.9	0.2	4.9	0.9	3.6	4.2	2.9	4.5

* The results are based on 4,000 stochastic simulations of the FRB/US model.

** The economic loss function is $L_t = \sum_{i=0}^{T} \beta^i \left[\tilde{y}_{t+i}^2 + (\pi_{t+i} - \pi^*)^2 + (\Delta R_{t+i})^2 \right]$, where $\beta=0.99$ is a quarterly discount factor and T is the time horizon.

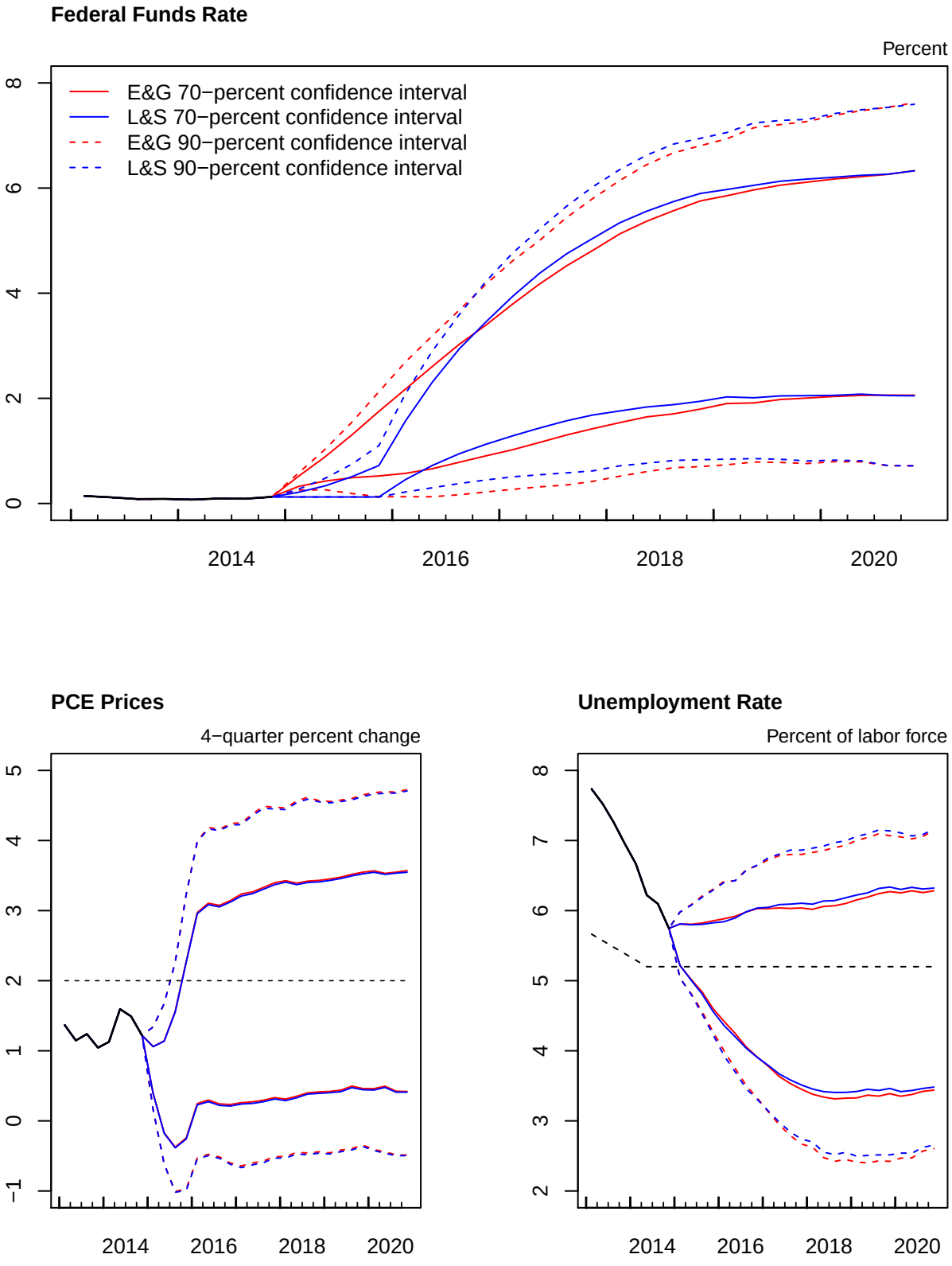
In column H of the table, we report average quarterly losses, adjusted for discounting, over the 2015:Q1–2020:Q4 period.

Figure 1
Summary of Alternative Strategies



Note: Dotted lines are the Committee's inflation objective and the staff's natural rate of unemployment.

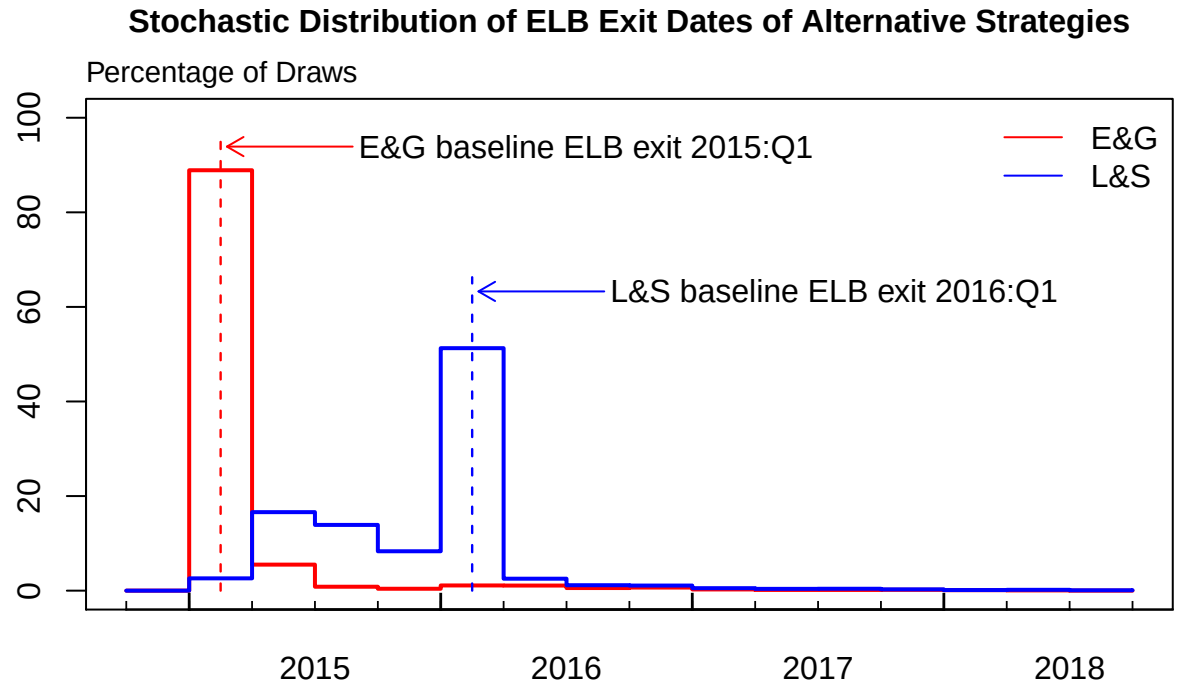
Figure 2
Stochastic Distributions of Alternative Strategies



Note: Stochastic distributions based on 4000 draws for 24 dates from 2015:Q1 to 2020:Q4.

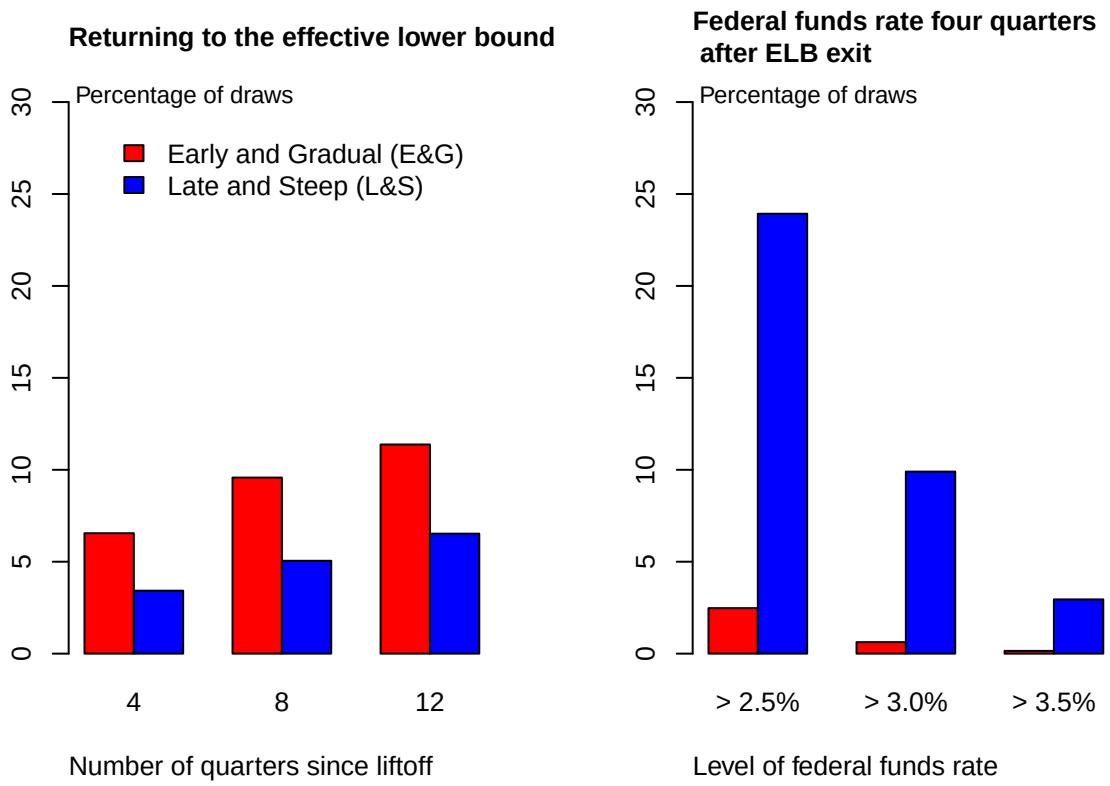
Figure 3

Alternative Strategies and Comparable Economic Performances



Note: E&G and L&S baseline liftoff dates are 2015:Q1 and 2016:Q1, respectively.

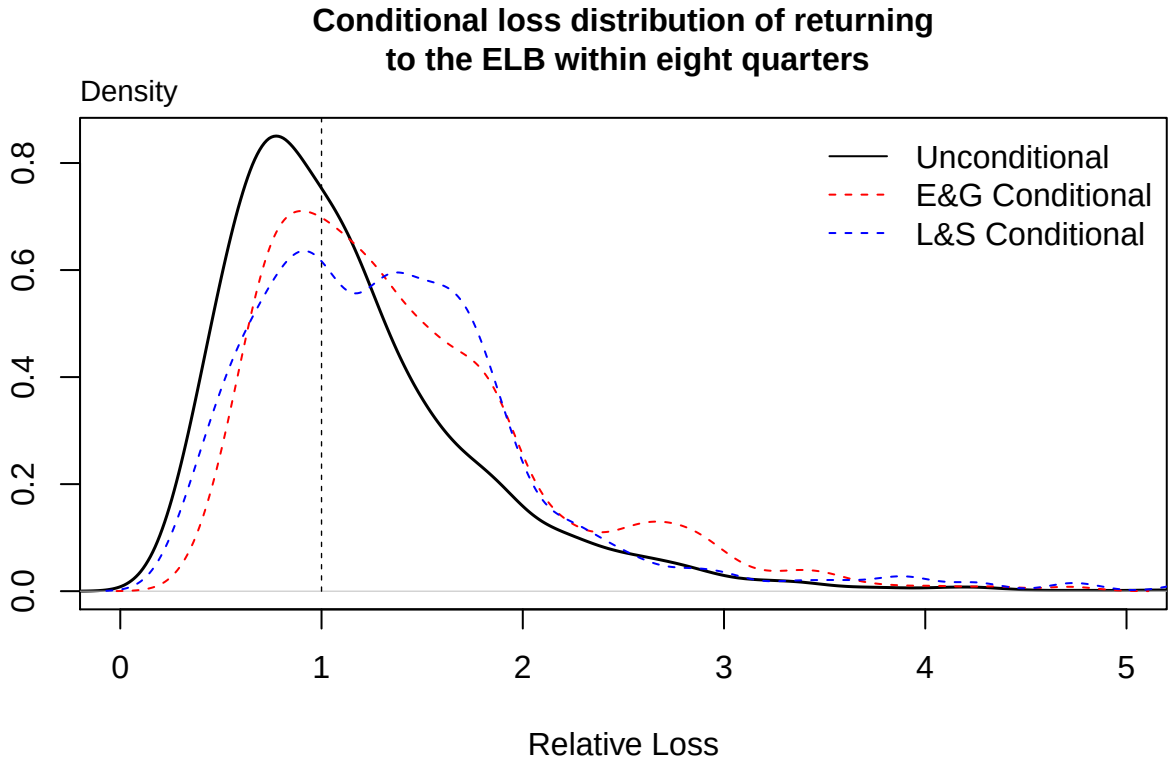
Figure 4
Probabilities of Selected Events

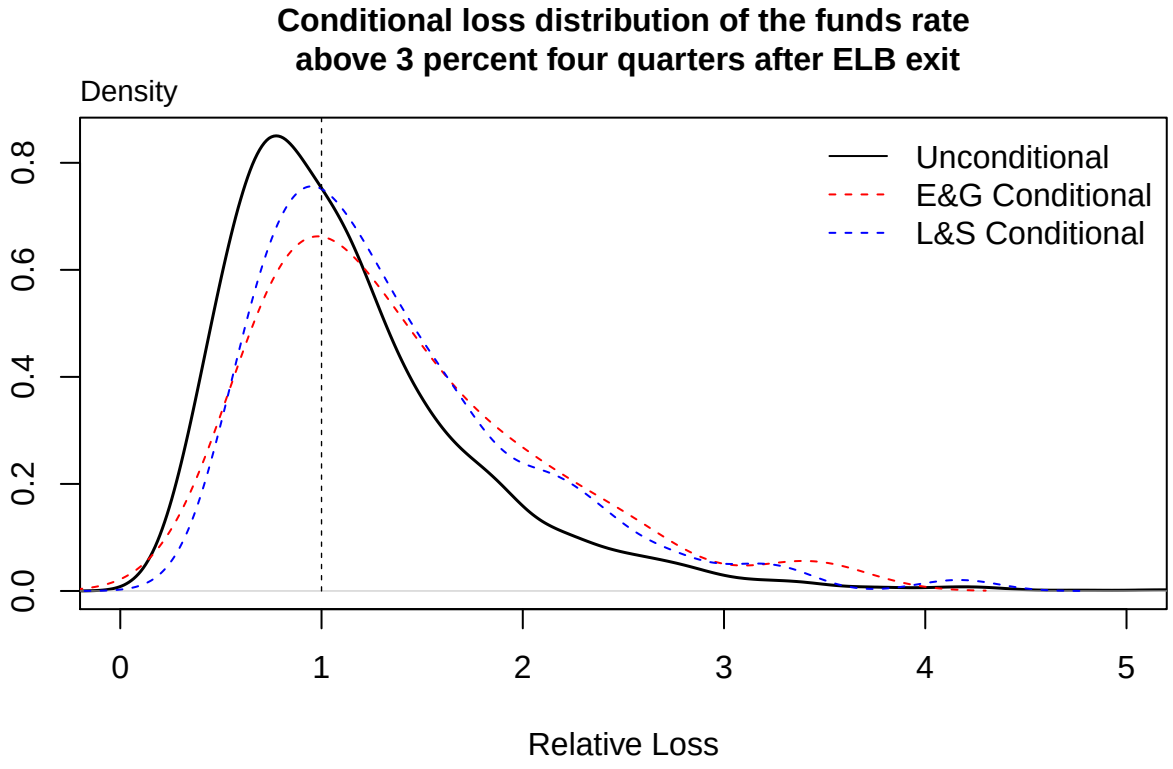


Note: The ELB is defined to be binding if the federal funds rate is below 30bp. Left panel: If, for example, exit from the ELB occurs in 2015:Q4 and the federal funds rate drops below 30bp in any quarter in 2016, then the funds rate is deemed to have returned to the ELB within 4 quarters. Subsequent exits from and returns to the ELB in any given simulation are ignored. Right panel: If, for example, ELB exit occurs in 2015:Q4, the federal funds rate in 2016:Q3 is deemed the relevant metric.

Figure 5

Loss distribution of alternative strategies & selected events





Note: Losses calculated up to 2020q4, presented as relative to median E&G loss. Density estimation uses a Gaussian kernel.