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DIVISION OF MONETARY AFFAIRS
FOMC SECRETARIAT

Date: December 3, 2012

To: Federal Open Market Committee

From: Deborah J. Danker

Subject: DSGE Memos

Attached are two memos that report on results from System DSGE models. The first provides the usual quarterly update on the projections of the models. The second uses the DSGE models to trace through the effects on the economy of changes in the Committee's forward guidance and in its reaction function.

System DSGE Project Forecasts

November 30, 2012

Michael Dotsey[1]

Federal Reserve Bank of Philadelphia

[1] I thank Scott Brave, Jeff Campbell, Hess Chung, Michael Kiley, J.P. Laforte, Marco Del Negro, Marc Giannoni, Argia Sbordone, Pablo Guerron, and Keith Sill for their contributions.

This memo describes the economic forecasts of the four models that are currently part of the System project on dynamic stochastic general equilibrium (DSGE) models. These are the EDO (Board), PRISM (FRB Philadelphia), FRBNY and Chicago models. We first present a summary of the forecasts and then provide detail about each model's projections.

Forecasts Summary

The current forecasts for real GDP growth, core PCE inflation, and the federal funds rate, as well as those presented at the September FOMC meeting, are displayed in the table and figure at the end of this summary section. These forecasts are obtained using actual data through 2012Q3 and projections of key model variables for 2012Q4. EDO, FRBNY, and PRISM all use current Board staff projections of real GDP and inflation made during the first week of November for 2012Q4. Forecasts of other 2012Q4 model variables are obtained in a variety of ways across the different models, and these projections are treated by the models as if they were data. The forecasts are also conditioned on the anticipation that the federal funds rate will remain exceptionally low through at least mid-2015 in the FRBNY, Chicago, and PRISM models and until 2015Q1 in EDO. The specific measure of market expectations adopted by each model is explained in the detailed forecasts below. In all the models the federal funds rate path is flatter than the one incorporated in the September forecasts.

There is a good deal of dispersion in the forecasts for growth in 2013, ranging from a growth rate of 1.6 percent in EDO to 4.3 percent in PRISM. However, PRISM has noticeably reduced its growth forecast since September and is now much less of an outlier. Also relative to September, FRBNY and Chicago foresee somewhat stronger growth over the entire forecast horizon, while PRISM and EDO have lowered their projections. Only FRBNY continues to forecast a very sluggish recovery. The other three models anticipate growth at or above trend by 2015.

The continued weakness in the FRBNY forecast is explained in large part by the persistent effects of financial headwinds. Over 2013 and the first half of 2014, this is true of the EDO model as well. In part, due to the extension of forward guidance, the model accounts for the lower funds rate path by attributing to private agent's expectations that financial conditions will be relatively adverse. Additionally, in EDO lower-than-expected labor productivity and higher-than-anticipated inflation have resulted in weaker aggregate supply conditions. The primary drivers in the Chicago forecast are accounted for by recent adverse demand shocks, which are attributed to weaker government spending and net exports. These shocks tend to reverse

themselves quickly in the model, leading to a bounce back in economic activity in 2013. In PRISM, the strength of the forecast is due to the unwinding of the shocks responsible for the recent weakness in economic activity, namely, shocks to the productivity of investment that have caused investment activity to decline, labor supply shocks that help account for the slow recovery in hours worked, and aggregate demand shocks that have adversely affected recent economic growth. The unwinding of these shocks, as well as the model's propensity to return to its longer-run path, is responsible for the relative strength of PRISM's forecast.

EDO, which explicitly models unemployment, projects a gradual increase in the unemployment rate throughout 2014, with a peak at 8.9 percent before declining to 8.1 percent by the end of 2015. The initial increase is due to both adverse financial conditions and adverse supply conditions that are causing near-term weakness in the projection of GDP growth. The lack of any significant progress toward a lower unemployment rate is accounted for by a persistent shift in households' labor supply.

All models forecast either fairly low or declining inflation, and these forecasts are noticeably weaker than those reported in September. The Chicago model predicts a fairly significant decline in inflation, which is due to decreases in long-run inflation forecasts in the Survey of Professional Forecasters. Inflation is also declining in FRBNY and EDO through the first half of 2013, before gradually rising to 1.6 percent and 1.7 percent, respectively, in the two models. PRISM predicts a fairly constant inflation path and all three models' prediction of inflation is very similar by 2015Q4. The initial decline in inflation FRBNY and EDO occurs because the weakness in economic activity contributes to low wage growth and the absence of any significant price pressure. In PRISM, inflation remains subdued largely because highly persistent negative discount factor shocks restrain consumption growth and put significant downward pressure on inflation. This pressure is not fully offset by the rebound in real wages and marginal cost as the labor market recovers. Finally, in EDO, as in PRISM, a significant fraction of the persistently low inflation path is accounted for by labor supply shocks.

In terms of interest rates, by construction all four models project extremely low interest rates over the forecast horizon and significantly lower rates than were anticipated in September. The lower projected path results from the flattening of the market expectations that anchor the forward guidance until mid-2015. As soon as this conditioning is lifted and policy is expected to be conducted according to each model's estimated policy rule, the projections imply a gradual tightening of policy, with some differences across models. There is very little tightening of

policy in the Chicago model, because the output gap remains significantly negative. In EDO the federal funds rate remains below 1 percent by the end of 2015, while in the FRBNY and PRISM models it increases to 1.25 and 1.5 percent, respectively.

Forecast Summary

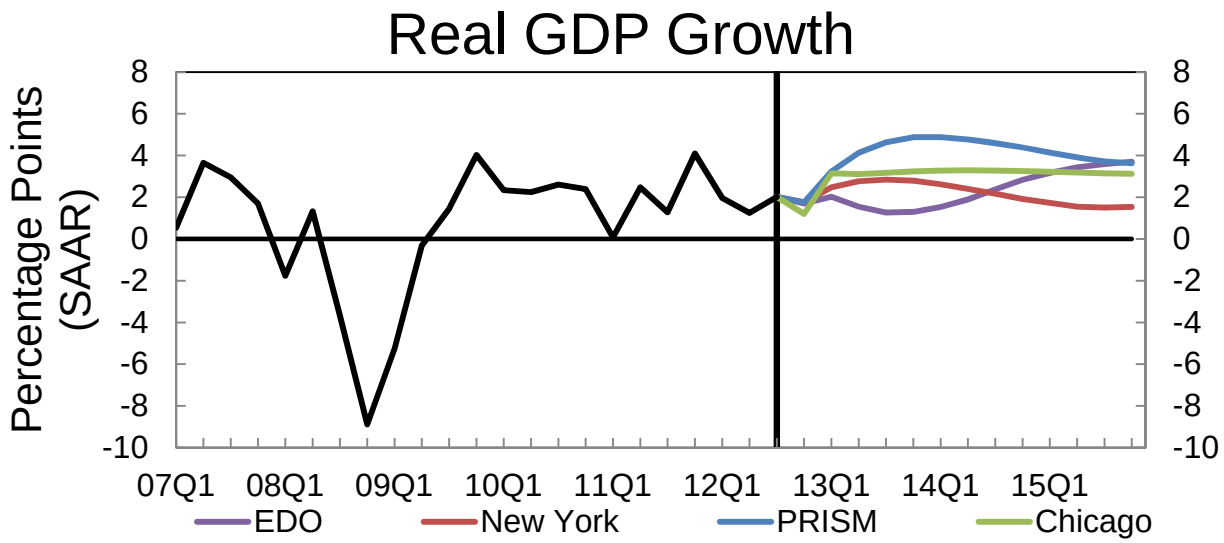
Model	Output Growth (Q4/Q4)							
	2012		2013		2014		2015	
	Dec	*Sept*	Dec	*Sept*	Dec	*Sept*	Dec	*Sept*
EDO - Board of Governors	**1.7**	*2.1*	**1.6**	*2.1*	**2.2**	*3.3*	**3.5**	*3.5*
		(-0.3,4.5)	**(-1.7,4.9)**	*(-0.1,4.3)*	**(0.2,4.2)**	*(1.1,5.3)*	**(1.4,5.6)**	*(1.5,5.6)*
New York Fed	**1.8**	*2.0*	**2.7**	*2.4*	**2.3**	*1.8*	**1.6**	*1.3*
	(1.8,1.8)	*(1.3,2.5)*	**(-0.3,4.6)**	*(-0.9,4.6)*	**(-1.4,4.9)**	*(-1.8,4.6)*	**(-1.9,4.5)**	*(-2.0,4.4)*
PRISM - Philadelphia Fed	**1.8**	*2.4*	**4.3**	*6.1*	**4.7**	*5.7*	**3.9**	*4.1*
	(1.8,1.8)	*(1.7,3.2)*	**(1.0,7.9)**	*(2.0,10.4)*	**(0.9,8.7)**	*(1.2,9.9)*	**(0.1,8.0)**	*(-0.2,8.6)*
Chicago Fed	**1.6**	*2.2*	**3.2**	*2.8*	**3.3**	*2.7*	**3.2**	*2.6*
Median Forecast*	**1.7**	*2.2*	**2.9**	*2.6*	**2.8**	*3.0*	**3.3**	*3.1*

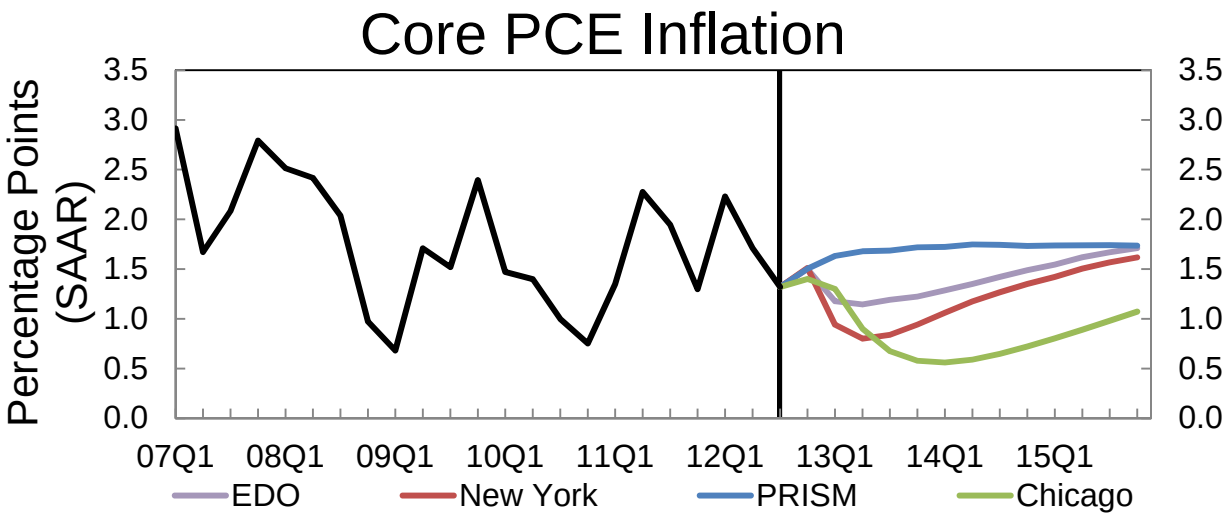
Model	Inflation (Q4/Q4)							
	2012		2013		2014		2015	
	Dec	*Sept*	Dec	*Sept*	Dec	*Sept*	Dec	*Sept*
EDO - Board of Governors	**1.6**	*1.8*	**1.2**	*1.6*	**1.4**	*1.7*	**1.6**	*1.9*
		(1.5,2.0)	**(0.6,1.8)**	*(0.9,2.2)*	**(0.7,2.1)**	*(1.0,2.5)*	**(0.9,2.4)**	*(1.1,2.6)*
New York Fed	**1.7**	*1.7*	**0.9**	*1.3*	**1.2**	*1.5*	**1.5**	*1.6*
	(1.7,1.7)	*(1.6,1.9)*	**(0.2,1.4)**	*(0.5,1.8)*	**(0.3,1.8)**	*(0.5,2.1)*	**(0.5,2.2)**	*(0.6,2.3)*
PRISM - Philadelphia Fed	**1.8**	*1.9*	**1.7**	*1.8*	**1.7**	*1.8*	**1.7**	*1.8*
	(1.8,1.8)	*(1.6,2.1)*	**(0.5,2.9)**	*(0.7,3.0)*	**(0.2,3.4)**	*(0.6,3.2)*	**(0.0,3.5)**	*(0.4,3.1)*
Chicago Fed	**1.7**	*1.4*	**0.9**	*1.0*	**0.6**	*1.3*	**0.9**	*1.5*
Median Forecast*	**1.7**	*1.8*	**1.0**	*1.5*	**1.3**	*1.6*	**1.6**	*1.7*

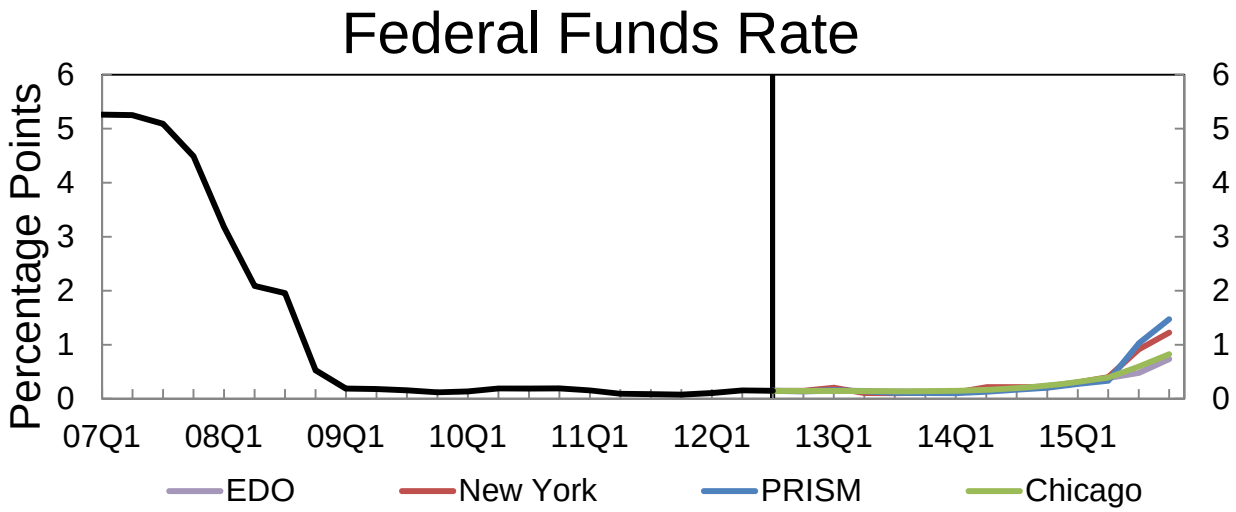
Model	Federal Funds Rate (Q4)							
	2012		2013		2014		2015	
	Dec	*Sept*	Dec	*Sept*	Dec	*Sept*	Dec	*Sept*
EDO - Board of Governors	**0.2**	*0.2*	**0.3**	*0.3*	**0.5**	*0.5*	**1.0**	*1.3*
		(0.0,1.0)	**(0.0,1.5)**	*(0.0,1.8)*	**(0.0,2.0)**	*(0.0,1.9)*	**(0.0,2.5)**	*(0.1,2.8)*
New York Fed	**0.1**	*0.1*	**0.1**	*0.2*	**0.2**	*0.4*	**1.2**	*1.3*
	(0.1,0.1)	*(0.1,0.7)*	**(0.1,1.2)**	*(0.2,1.3)*	**(0.2,1.5)**	*(0.3,1.8)*	**(0.3,2.7)**	*(0.3,2.8)*
PRISM - Philadelphia Fed	**0.1**	*0.1*	**0.1**	*0.2*	**0.2**	*0.4*	**1.5**	*1.2*
	(0.1,0.1)	*(-0.5,0.6)*	**(-1.5,1.6)**	*(-1.5,2.0)*	**(-2.3,2.6)**	*(-1.9,3.1)*	**(-1.5,4.5)**	*(-1.5,4.3)*
Chicago Fed	**0.1**	*0.1*	**0.1**	*0.2*	**0.3**	*0.4*	**0.8**	*1.4*
Median Forecast*	**0.1**	*0.1*	**0.1**	*0.2*	**0.2**	*0.4*	**1.1**	*1.3*

For each individual forecast, the numbers in parentheses represent 68% probability bands.

* The median forecast is calculated as the median of the Q4/Q4 projections from the forecasters.







Detailed Descriptions of Individual Model Forecasts

The EDO Model

The EDO model projects real GDP growth below trend on average until the end of 2014 and unemployment around 8 percent until the end of 2015. This subdued pace of real activity is accompanied by inflation gradually accelerating from a low of 1.5 percent at the end of 2012 to slightly below 2 percent by the beginning of 2015. Private agents do not expect the federal funds rate to lift appreciably above its effective lower bound until the first quarter of 2015.

The weak activity forecast is heavily shaped by the model's interpretation of the anticipated path of the federal funds rate inferred from interest rate caps, which is considerably lower than the model would have anticipated given other data. In part, the model accounts for this lower path by attributing to private agents the expectation of relatively adverse financial conditions over the forecast horizon. The aggregate risk premium remains in the neighborhood of its early 2012 levels, lowering GDP growth and boosting unemployment well above its steady state. In addition, lower-than-expected labor productivity and surprisingly high inflation have led the model to infer a deterioration of aggregate supply conditions since the beginning of 2011.

Given these adverse aggregate supply developments, the path of the funds rate remains only modestly below the level consistent with the model's estimated policy rule, despite the weakness of aggregate demand in the forecast. The additional stimulus from monetary policy boosts growth noticeably through the end of 2012. Inflation is held below target by muted pressure on wages in the labor market.

The unemployment rate rises slowly through mid-2014, reaching a peak of 8.9 percent, before declining to 8.1 percent by the end of 2015. The initial rise in unemployment reflects the above-mentioned high risk premiums and adverse supply conditions. By the end of the forecast, however, a substantial portion of the elevated unemployment rate is accounted for by a highly persistent shift in household labor supply. Given the nominal rigidities in the model, labor supply shocks affect households' willingness to work much more strongly than firms' willingness to hire and thus affect unemployment much more than other measures of activity. The model, therefore, naturally attributes a large share of low-frequency variation in unemployment to this source.

The FRBNY Model

The FRBNY model forecast is obtained using data released through 2012Q3, augmented for 2012Q4 with the Board staff forecast for real GDP growth and core PCE inflation. Additionally the model uses the FRBNY staff forecast for growth in total hours, values of the federal funds rate, and the spread between Baa corporate bonds and 10-year Treasury yields based on 2012Q4 observations. The expected future federal funds rates are constrained to equal market expectations for the federal funds rate, as measured by the OIS rates, through 2015Q2. The 2012Q4 projections, OIS rates, interest rate spread, and FFR data are those available on November 7, 2012.

Output growth in 2012Q3 and 2012Q4 (as projected by the Board staff) was roughly in line with the DSGE model forecasts produced in September; hence, our output projections are quite similar to those produced in September. In particular, the model still projects a lackluster recovery in economic activity, with output growth in the neighborhood of 2 percent throughout the forecast horizon. Growth forecasts for 2013, 2014 and 2015 (Q4/Q4) are 2.7, 2.3, and 1.6 percent, respectively, marginally above the rates of 2.4, 1.8, and 1.3 percent reported in September. Core PCE inflation in 2012Q3 and 2012Q4 (again, as projected by the Board staff) turned out slightly different than the DSGE projections, weaker by about 25 basis points in Q3, and just a bit stronger in Q4. The model attributes the over-prediction in Q3 to an over-estimation of the impact of forward guidance on inflation, and the under-prediction in Q4 to a mark-up shock, which captures high frequency movements in inflation such as those due to energy prices. Since forward guidance has a more persistent effect on inflation than mark-up shocks, the projections for inflation are weaker than in September. The model predicts that core PCE inflation will remain below the FOMC long-run goal of 2 percent throughout the forecast horizon. Specifically, core PCE inflation projections for 2013, 2014 and 2015 (Q4/Q4) are 0.9, 1.2, and 1.5 percent, respectively, compared to 1.3, 1.5, and 1.6 percent in September.

There is significant uncertainty around real GDP forecasts, with 68 percent bands covering the interval -0.3 to 4.6 percent in 2013 (Q4/Q4), -1.4 to 4.9 percent in 2014 (Q4/Q4), and -1.9 to 4.5 percent in 2015 (Q4/Q4). The forecast distribution for inflation moved down relative to September, and the 68 percent probability bands are still within the 0-2.1 percent interval throughout 2014.

The FRBNY forecast is driven by two main factors. On the one hand, the headwinds from the financial crisis, as captured by the effect of both spread and MEI (marginal efficiency of

investment) shocks, result in a subdued recovery, low real marginal costs, and consequently low inflation. The impact of these shocks on the recovery is long-lasting and starts to wane only in mid-2013. On the other hand, accommodative monetary policy, and particularly the forward-guidance, plays an important role in counteracting the financial headwinds and lifts up output and inflation. The impact of policy on the *level* of output starts to wane by the end of 2012, which implies that the effect of policy on *growth* is actually negative after that. This largely explains why growth is still below trend by the end of 2014.

The model views the federal funds rate at the zero lower bound as mostly driven by the endogenous response of policy to the weak economy. In fact, by the end of 2012 the historical rule would imply a rate that is slightly lower than 25 basis points. However, by the end of the forecast horizon the policy accommodation provided by forward guidance becomes noticeable, implying a deviation of the federal funds rate path of about one percentage point from the historical rule.

The PRISM Model

The Philadelphia Research Intertemporal Stochastic Model (PRISM) forecast is constructed using data through 2012Q3 that are then supplemented with a 2012Q4 nowcast that uses the Board staff's projection of real GDP growth and core PCE inflation, along with our own nowcast of the federal funds rate. In addition, the forecasted path for the federal funds rate is constrained through 2015Q2 using futures market data.

PRISM forecasts a fairly strong rebound from the moderate pace of growth so far this year. The forecast for 2013Q1 real output growth is 3.3 percent, rising to about 4.9 percent in 2013Q4. Output growth then runs at a 4.7 percent pace in 2014 and a 3.9 percent pace in 2015 (both Q4/Q4). While output growth is projected to be fairly robust, inflation remains contained at close to 1.75 percent through the forecast horizon. The forecast assumes that the funds rate remains in a range of about 0 to 25 basis points through the end of 2015Q1 and then edges up to 1.5 percent in 2015Q4.

According to PRISM, the primary factor that accounted for generally below-trend real output growth over the course of 2012 was negative shocks to the efficiency with which investment is turned into capital, with smaller contributions from labor supply shocks and financial shocks. The model continues to see the de-trended level of output as well below its steady state. An

important factor in accounting for this output gap is the low level of aggregate hours worked, which the model captured through labor supply shocks, financial shocks, and investment shocks. Looking ahead, the unwinding of the labor supply shocks (rebound in hours worked), financial shocks, and marginal efficiency of investment shocks (rebound in investment) is a key factor in accounting for strong output growth over the next three years. Inflation, however, remains contained by the persistent effect of negative discount factor shocks that are not fully offset by the labor market recovery and the ensuing rise in marginal cost. Going forward, the model predicts core PCE inflation will average about 1.75 percent in 2014 and 2015.

The forecast for PRISM obtained without using federal funds rate expectations as conditioning information projects a significantly stronger path for the federal funds rate: the federal funds rate rises to 3 percent by the end of 2014 and 3.5 percent by the end of 2015. The path for real output growth is similar to that under the unconditional forecast, while the path for inflation is a bit higher, averaging 2.2 percent in 2014 and 2.3 percent in 2015.

The Chicago model

The Chicago model forecast incorporates data through 2012Q3 and augments it with nowcasts for several key variables. These include 2012Q4 forecasts for annualized real GDP growth (1.2 percent) and core PCE inflation (1.4 percent). We use forward guidance shocks to help shape the model's expected federal funds rates through mid-2015 based on their implied values from current futures markets prices. The model also includes a slowly drifting inflation anchor (currently 2.3 percent), which dominates changes in long-run expected inflation and is identified by equating the 10-year average of model-based expected consumer price inflation with 10-year-ahead CPI forecasts from the Survey of Professional Forecasters (SPF).

The Chicago forecasts for real GDP growth and inflation have changed substantially from September. Real GDP growth in 2012 Q4/Q4 is projected to be 1.6 percent, down 0.7 percentage point from September. The economy is then projected to grow slightly above potential (2.7 percent in our model) throughout the remainder of the forecast horizon, an upward revision of about 0.3-0.5 percentage point from September. However, the measure of the output gap that enters our Taylor-type policy rule continues to suggest a sizable shortfall of output from potential in 2015. It decreases from -5.5 to -1.1 percent over the forecast horizon.

Adverse demand shocks largely explain the more pronounced near-term weakness in the recovery of economic activity. In particular, a residual shock to the national income and product

accounting identity, embodying a change in the valuation of inventories, net exports, and government expenditures in the model, accounts for much of the recent weakness in GDP growth. Negative serial correlation in this shock then results in a slight boost to GDP growth in 2013 and 2014. Recent adverse technology shocks partially offset this.

The forecasted path for Q4/Q4 core PCE inflation peaks at 1.7 percent in 2012 before receding below 1 percent and remaining there throughout the remainder of the forecast horizon, a downward revision of about 0.5 percentage point from September. Recent positive price mark-up shocks account for the higher inflation projected for the second half of 2012. The markdown in subsequent inflation comes from a moderately lower Q3 and Q4 SPF forecast for 10-year CPI inflation.

Market expectations now hold the funds rate below 0.5 percent through mid-2015 as opposed to late 2014 as in September. In the second half of 2015, the funds rate rises on average just less than 25 bps per quarter, ending 2015 at 0.8 percent down from 1.4 percent in September. This embodies the effects of a more negative projected output gap and lower expected inflation on the systematic component of monetary policy.

DSGE Policy Scenarios Project

December 3, 2012

Marco Del Negro, Michael Dotsey, Marc Giannoni, and Argia Sbordone[1]

Overview

The goal of this memo is to better understand the implications of alternative exit strategies from the zero lower bound. Specifically, using three of the Systems DSGE models the memo investigates the economic effects of changes in forward guidance, as well as the consequences of using alternative reaction functions. As such, this analysis complements a number of studies that have already been presented at recent meetings. Our main findings indicate that the timing of lift-off and the policy after lift-off are intimately linked. In our models, changes in forward guidance may only have temporary effects if policy after lift-off is not sufficiently accommodative. Moreover, policies yielding substantive macroeconomic stimulus generally lead to a temporary overshooting of the long-run inflation target.

We conduct two sets of simulations, using the DSGE models of the Board (EDO), FRB New York, and FRB Philadelphia (PRISM). The first set of simulations investigates the effects of changing the forward guidance as currently given by the FOMC in its October statement, while maintaining each models' estimated rule once the funds rate lifts off from the zero lower bound. The second set examines the consequences of adopting entirely new rules beginning in 2013Q1. The three rules we consider include a Taylor-type rule where the policy rate responds to labor market conditions (specifically, it adjusts to deviations of inflation from target and deviations of per-capita hours from steady state), a nominal GDP targeting rule, and a price level targeting rule. With the first rule we address the concern over labor market conditions by examining the implications of a rule that relates policy directly to the extent of the recovery in the labor market. The other two rules are in part motivated by Michael Woodford's recent Jackson Hole paper that emphasizes the value of history-dependent rules. In each of the latter two rules the farther the

[1] Marco Del Negro, Marc Giannoni, and Argia Sbordone are from the Federal Reserve Bank of New York, and Michael Dotsey is from the Federal Reserve Bank of Philadelphia. We thank Hess Chung, Michael Kiley, J. P. LaForte, Andrea Tambalotti, Pablo Guerron, and Keith Sill for their contributions. We also wish to than Loretta Mester for many useful comments.

economy falls below a desired path for nominal GDP or, in the case of price level targeting, the price level, the more accommodative monetary policy is.

Each set of simulations is evaluated against the 'baseline' model forecasts, which we show in the accompanying "System DSGE Project Forecasts" memo, and reproduced in Figure 1 here. All baseline forecasts are obtained using actual data through 2012Q3 and the Board staff's projections of real GDP growth and core inflation for 2012Q4. Consistent with the forward guidance of the last FOMC statement, the forecasts also incorporate the information contained in market expectations for the federal funds rate through 2015Q2, as measured by the OIS spreads.[2] We show projections for real GDP, core PCE inflation, the federal funds rate, and unemployment. The New York and Philadelphia models, unlike EDO, do not include unemployment among the variables used in the estimation. However, they derive predictions for unemployment using an estimated regression of unemployment on hours worked, which is a variable included in the estimation (the so-called 'bridge equation' is described in Appendix 2).

The broad message from the first set of simulations is that changing forward guidance can have significant short-run effects on both output growth and unemployment, but these effects are temporary and are reversed over the medium run. The effects of forward guidance in these models are temporary because we assume that in each model policy reverts to the estimated reaction function after lift-off. To the extent that this reaction function implies a relatively sharp increase in rates after lift-off, as is the case for instance in both the NY and PRISM models, the impact of forward guidance in the economy is relatively short-lived.

We find that the macroeconomic impact of changing the reaction function is generally stronger, and most importantly more persistent than when changing forward guidance and keeping the reaction function unchanged. This is the case even if the lift-off, as implied by the different rules, occurs *earlier* than currently anticipated by financial markets. This result is due to the fact that a commitment to close a gap in the economy (whether measured by employment, nominal GDP, or the price level) has a significant impact on inflation expectations, thus lowering

[2]All the exercises presented here use the modal parameter estimates, and the baseline forecast is computed accordingly. The Board staff's projections of real GDP growth and core inflation for 2012Q4 and the OIS spreads are as of November 7th, 2012. The growth and inflation projections were 1.75 percent and 1.5 percent, respectively. The current Tealbook projections are likely to be much weaker.

current and future expected real rates, and stimulating the economy. In equilibrium, higher inflation and real activity are associated with an earlier lift-off.

Overall, these simulations show that in the class of models considered, the degree of policy accommodation at the zero lower bound depends not only on agents' expectations about future policy rates up to the lift-off date, but *afterwards* as well. In terms of the current debate on thresholds, one implication of our findings is that the degree of accommodation of a thresholds-based policy would depend among other things on the policy that the FOMC is expected to follow after lift-off. If the public believes that rates are going to be raised rapidly once the thresholds are met, the policy may not provide enough stimulus. Finally, we should caution against taking literally the quantitative predictions we obtain under different policies: these exercises are conditional to a number of critical assumptions, which we highlight in the course of this memo. The main message in our view is mostly qualitative.

Changes in forward guidance

The first set of simulations considers extending, or partially removing, forward guidance relative to what is currently incorporated in market expectations. In all these simulations it is assumed that after lift-off the federal fund rate follows the path implied by the historical policy rule.

As mentioned, the benchmark scenario constrains the federal funds rate to follow market expectations through 2015Q2, after which the funds rate is determined using each particular models' estimated rule. According to market expectations, the lift-off -- defined as a FFR above 25 basis points -- would occur in 2015Q1, although rates remain below 50 basis points in both 2015Q1 and Q2. We consider three alternatives:

(1) Constraining the funds rate to equal 12.5 basis points through 2015Q2 rather than follow market expectations, which implies a lift off two quarters later than the benchmark.
(2) Extend forward guidance by an additional quarter, implying that the funds rate remains at 12.5 basis points through 2015Q3.
(3) Reducing the degree of forward guidance by two quarters, so that the funds rate remains at 12.5 basis points only through 2014Q2.

Forward guidance is implemented by using anticipated policy shocks.[3] However, the implementation differs across models. For the New York and the PRISM models extending the lift-off date to 2015Q4 implies an unconditional commitment to reducing the FFR below the baseline by about 80 and 90 basis points in 2015Q3, respectively. Because in these models such reduction brings down the path of the FFR far into the future, long run rates fall quite dramatically, and by amounts significantly larger than those observed following past extensions of forward guidance. This suggests that a literal extension of the forward guidance in the New York or PRISM models may overstate the effects of FOMC communication. One way to obtain arguably more plausible responses is to recognize that forward guidance provides to market participants more information about short-term interest rates in the next few years than about rates very far into the future. We thus implement forward guidance by constraining the contemporaneous response of the 10-year bond yield to the policy announcement so that this response is in line with past episodes where forward guidance was extended.[4] EDO does not need to impose these additional restrictions because its baseline forecast implies very low interest rates, and therefore deviations from the baseline extending the forward guidance by two or three quarters are so small that the impact on the long rates are already very contained.

Figures 2A, 2B, and 2C show the outcome of the counterfactuals for the EDO, the New York, and PRISM models. In each figure we include each model's baseline forecast for comparison. As mentioned, assuming different extensions of forward guidance affects output growth significantly. In the Board's model, a funds rate lifts off in 2014Q3 implies output growth in 2013 of only 1.80 percent, as opposed to growth of 2.63 percent when lift-off is assumed to occur in 2015Q4. The comparable effects are more dramatic in NY's model with output growth increasing from 1.18 to 3.38 percent, and the differences are extremely large in PRISM, 2.90 percent as opposed to 7.14 percent. The relatively larger effects in PRISM are not

[3]Using the language of J. Campbell, C.L. Evans, J.D.M. Fisher and A. Justiniano ("Macroeconomic effects of FOMC forward guidance," Brookings Institution, Spring Panel on Economic Activity, 2012) this experiment is conducted using only "active" (or "Odyssean") forward guidance, as opposed to the FOMC reacting to bad news about the economy.

[4] This approach is described in M. Del Negro, M. Giannoni, and C. Patterson ("The Forward Guidance Puzzle," FRBNY Staff Report 574, 2012). Our constraints on the long-rate response are informed by recent episodes where the forward guidance was extended (e.g., on Jan 25, 2012, the forward guidance was extended by six quarters, and the 10-year nominal rate fell only by 7 basis points). Specifically, both New York and PRISM assume that the 2014Q3, 2015Q3, and 2015Q4 lift-off dates imply a change in the 10-year nominal rate of +10, -2, and -10 basis points, respectively. Results are not very sensitive to small changes in the long rate impact assumptions.

surprising as changes in forward guidance imply large changes in the funds rate relative to what would be consistent with the model's estimated interest rate rule. Furthermore, PRISM's forecasts are typically the least inertial of the various DSGE models in our group, so that changes in policy elicit fairly aggressive predictions in the model.

Despite its fairly significant effect on output growth, forward guidance has generally transitory effects on the *level* of output: indeed, any short run (2013 and 2014) increase in growth is followed by a medium run (2015 and 2016) decline in growth relative to the baseline.[5] As a consequence, forward guidance has also a limited effect on inflation. The difference in inflation projections across exercises is barely noticeable in EDO, and amounts to at most 50 basis points according to the New York model. In PRISM only the extension of forward guidance by three quarters implies that forecasted inflation would exceed the Committee's target.

Changing forward guidance has also transitory effects on unemployment in all models, although the impact of the policy differs across models. In EDO and the New York model a lift-off in 2015Q4 vs 2014Q3 implies a difference in the unemployment rate at the end of 2014 – roughly the peak of the impact of forward guidance on unemployment – of the order of one percent. The unemployment projections in PRISM are very different and indicate that unemployment continues to fall throughout the forecast horizon. That result is less a feature of forward guidance as it is of the model's somewhat lower long-run unemployment rate and the fact that unemployment converges to its long-run value fairly quickly.

Overall, we find that forward guidance can be a meaningful tool of monetary policy in our models, providing short-run stimulus with little accompanying inflation. However, it does not have long lasting effects because it does not change agents' expectations about how policy will be conducted after lift-off. We should note that this feature of forward guidance is not dependent on the adjustment for the long rate impact discussed earlier. Absent this adjustment, the impact of forward guidance on macroeconomic variables, including inflation, can be quite large (and for some models implausibly so), but nonetheless still transient.

[5] As in the case of standard contemporaneous policy shocks, the response of the level of output to anticipated policy shocks is also hump-shaped, implying growth rates first positive and then negative.

To analyze how important changing expectations are to economic behavior in our models, we now turn to policy alternatives of a different nature, namely to policy rules that differ from the estimated rules of each model.

Changes in the policy rule

In this second part of the analysis we study the effects of implementing various simple rules, which differ from the historical rule estimated in each model. In these simulations, the lift-off date is determined endogenously by the new rule; hence we remove all existing forward guidance as captured by the anticipated policy shocks.[6] We wish to emphasize the qualitative aspect of our results, since the specific quantitative results depend on the particular choice of coefficients.

The first rule we consider is a variant of an inertial Taylor rule, which we label "labor market conditions" rule, since it considers an 'hour-level gap' in lieu of the output gap. We then analyze the consequences of adopting either a nominal GDP targeting rule, or a price level targeting rule.

The rules are specified as follows:

1) Labor Market conditions (L) rule:

$$R(t) = 0.75*R(t-1) + 0.25[\ 2*(\pi^4(t)-\pi^*) + 0.4*h(t)\ ]$$

where R(t) is the annualized federal funds rate (expressed in deviations from its steady state), h(t) is the level of per-capita hours in deviations from steady state, $\pi^4(t)$ is the 4-quarter core PCE inflation rate, and π^* is the inflation objective, set at 2 percent. The coefficient on the hours gap is fairly small, hence this rule responds only mildly to labor market conditions.

2) Nominal GDP targeting (YN) rule:

$$R(t) = 0.75*R(t-1) + 0.25*YN^{gap}(t).$$

[6] We still use anticipated policy shocks in order to prevent the FFR from falling below 12.5 basis points. The estimated state of the model in 2012Q4 is held fixed at its baseline.

YN^{gap} is the nominal GDP gap, which evolves according to $YN^{gap}(t) = YN^{gap}(t-1) +(\Delta YN(t) -\pi^*-\gamma)/4$, where $\Delta YN(t)$ is the annualized growth of per-capita nominal GDP, γ is the annualized growth rate of productivity, as estimated by each model. For this experiment the nominal GDP gap is set at -7.0 percent in 2012Q4. Thus, the nominal GDP rule follows the specification in the Tealbook.[7]

3) Price level targeting (PLT) rule:

$$R(t) = 0.75R(t-1) + 0.25*[2*P^{gap}(t)]$$

where P^{gap} evolves according to $P^{gap}(t)= P^{gap}(t-1)+(\pi (t) – \pi^*)/4$, and $\pi(t)$ is annualized core PCE inflation. Here the price level gap is set at -1.0 percent in 2012Q4.[8] The price level targeting rule uses a coefficient on the gap that is twice as large as that in the YN rule to compensate for the fact that the initial gap is much smaller.

Figures 3A, 3B, and 3C show the outcome of this exercise for the EDO, New York, and PRISM models respectively. As in the previous exercise, each figure also includes each model's baseline forecast. Shifting to an employment rule leads to higher economic growth and higher inflation in both the New York and the PRISM models. However, partly because of the differences in the baseline forecasts between the two models, inflation remains contained in the New York model, but significantly overshoots the FOMC's target in the Philadelphia model. Under the employment rule both models anticipate a lift-off from the zero lower bound in mid-2013; despite the less accommodative policy, though, labor market conditions improve gradually relative to the baseline forecasts. In the New York model, this is because the historical rule features output *growth*, as opposed to a notion of gaps, and therefore leads to relatively rapid

[7] The constant terms are omitted here as the variables are expressed in percent deviations from their steady state. The initial nominal GDP gap was computed in two ways that deliver roughly the same number: either setting the gap at the beginning of the Great Recession to zero and then cumulating nominal GDP growth afterwards (in deviations from trend), or setting the gap to zero in the early nineties and repeating the same exercise.

[8] The initial PLT gap corresponds approximately to the gap between the level of the core PCE deflator at the end of 2012Q3 and a price level path that starts at the same level in January 2006 and that grows at a constant rate of 2 percent from then on.

tightening as the economy recovers. When agents are confronted with alternative rules that respond to gaps – in this case a labor market gap – they expect a more accommodative policy than would occur under the historical rule. This prospect leads to an increase in inflation expectations, and to a decrease in real rates – despite the fact that the nominal rate lift-offs earlier than in the baseline forecasts as policy responds to inflation. The decline in real rates stimulates economic activity, and improves labor market conditions. In the PRISM model, the estimated reaction function responds to an output gap, but with a negligible coefficient. And, as we pointed out, the model baseline projection already features a strong growth and a relatively fast decline in unemployment. As a consequence, adopting a more accommodative rule has real effects similar to the baseline, but features a significantly higher inflation.

The outcome of this first rule experiment is quite different in EDO. This is because EDO uses a measure of hours that removes the low frequency movements, which in practice implies that the hours gap is very small for EDO, while it is large in the other two models.[9] In addition, EDO's baseline rule features a significant response to a measure of the output gap. As a consequence, the new policy rule is actually less accommodative than the baseline rule, leading to an increase in unemployment and a decline in output growth.

Turning to the other history dependent rules, in EDO and the New York models both nominal GDP and price level targeting result in a substantial increase in economic growth and a swift reduction of unemployment, relative to the models' baseline forecasts, with projections that are remarkably similar across the two models. Inflation increases in both models relative to the baseline, and remains modestly above target for some time. However, in the New York model under the YN rule these deviations are more significant. Overall, nominal GDP targeting has larger effects than the PLT rule in both models, because the initial nominal GDP gap is substantially larger than the price level gap that drives the PLT rule leading to a more expansionary policy. Nonetheless, despite the small initial gap and the fact that rates lift-off earlier than in the baseline, the PLT rule provides more stimulus to the economy than the baseline policy, closing the unemployment gap much earlier. This occurs because the price gap would grow in so far as inflation realizations were below target, and therefore a policy aiming at

[9]The estimated per-capita hours gap for the New York and PRISM models are 7 and 15 percent as of 2012Q4, respectively.

closing this gap generates expectations of higher inflation and a lower real rate, stimulating economic activity.

The effects of adopting either a nominal GDP or price level targeting rule are more muted in PRISM. The YN rule delivers economic projections similar to the benchmark, which as we noted is more robust than the benchmarks in the other two models, while output growth is initially weaker under a PLT regime. The difference occurs because the nominal GDP gap is quite significant and results in a path for the funds rate not appreciably different from the benchmark path. Conversely, the small initial price gap and the feature that inflation is closer to target lead to a more restrictive monetary policy under price level targeting.

We should highlight that the quantitative response of the macro economy to any given rule is sensitive to the choice of coefficients in that rule. For example, a more muted (stronger) response to "gaps" produces a smaller (larger) stimulus. If the response coefficient becomes so small that the rule is less accommodative than the baseline rule, the outcome can even be contractionary. In addition, the experiments are conducted under the assumption that the public fully understands the change in the rule, which is undoubtedly an extreme assumption.

Summary

In this exercise we have examined the projected impact of a number of alternative policies, some that merely involve changes in forward guidance and others that are more extreme, as they involve a wholesale change in the way policy is conducted. An overall message of our experiments is that both forward guidance and alternative policy rules can have a meaningful economic impact. We find that changes in the reaction function that emphasize the FOMC commitment to closing the gaps in the US economy are likely to be more effective than changes in forward guidance only: changes in the reaction function lead to more persistent effects on economic activity and inflation, because they involve larger changes in agents' expectations after the lift-off date. The other message is that the effectiveness of alternative policies on real activity may require inflation to rise above target. Any overshooting of inflation is generally temporary, in the sense that inflation eventually reverts to target, but can nonetheless last for quite a long time. Importantly, in these simulations long run inflation expectations remain anchored, as the agents understand that the policymaker is not willing to tolerate their unmooring. In practice,

maintaining long run inflation expectations anchored while inflation is above target for a long time is a non-trivial communication challenge.

Appendix 1: Baseline Policy Rules

This appendix describes the different estimated policy rules used by the various models. In EDO the baseline policy rule is

$$R(t) = .83*R(t-1) + .17*[\ 1.46*(\pi(t)-\pi^*) + .72*(y(t)-y^p(t))\ ]$$

where y(t) measures the logarithm of output and $y^p(t)$ is the logarithm potential output, defined as the level of output attainable under full capital utilization and with labor inputs at steady-state. In the New York model the estimated policy rule is:

$$R(t) = .76*R(t-1) + .24*[\ 2.00*(\pi^4(t)-\pi^*) + .27*\Delta y^4(t)\ ]$$

where $\pi^4(t)$ is the 4-quarter core PCE inflation rate, and $\Delta y^4(t)$ is 4-quarter growth in real GDP, in deviations from the steady state. In PRISM the estimated rule is

$$R(t) = .79*R(t-1) + .21*[\ 2.36*(\pi^4(t)-\pi^*) + .04*(y(t)-y^*(t))\ ]$$

where y(t) measures the logarithm of output and y*(t) the logarithm of the model-implied stochastic trend.

Appendix 2: The Bridge Equation between Hours and Unemployment

For the New York model the bridge equation, which is estimated over the sample 1984Q1-2012Q2, is:

$$u(t) = 14.61+1.01*u(t-1)-0.11*u(t-2)-21.46*h(t)+6.74*h(t-1)+12.8*h(t-2)$$

where u(t) and h(t) are the unemployment rate in percent and the logarithm of per-capita hours, measured as *aggregate hours, wage & salary workers – non-farm payrolls* (seasonally adjusted annual rate) from the BLS, also in percent. The steady state unemployment implied by this bridge equation is 6.1 percent.

For PRISM the bridge equation, which is estimated over the sample 1984Q3-2012Q3, is:

$$u(t) = .66+.88*u(t-1)+0.09*u(t-2)-25.43*h(t)+14.01*h(t-1)+11.32*h(t-2)$$

where u(t) and h(t) are the unemployment rate in percent and the logarithm of per-capita hours, also in percent. The different coefficients in the bridge equation for PRISM are due to the fact that it uses a different measure of per capita hours relative to the New York model, namely *hours of all persons – non-farm business sector* from the BLS Productivity and Cost data. An implication of this is that the steady state unemployment implied by this bridge equation is 3.4 percent.

Figure 1
Baseline

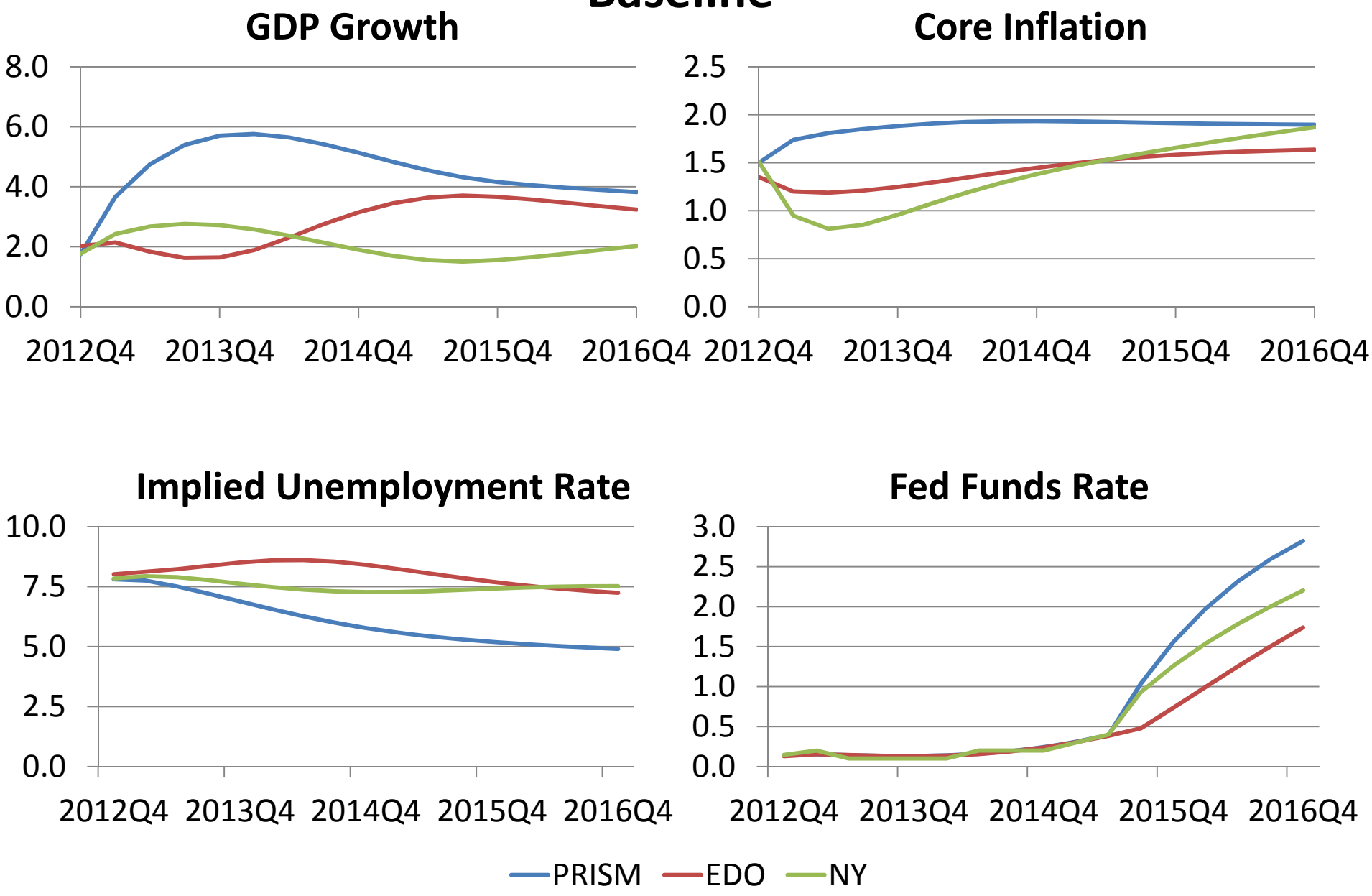


Figure 2a

EDO (Alternative Forward Guidance)

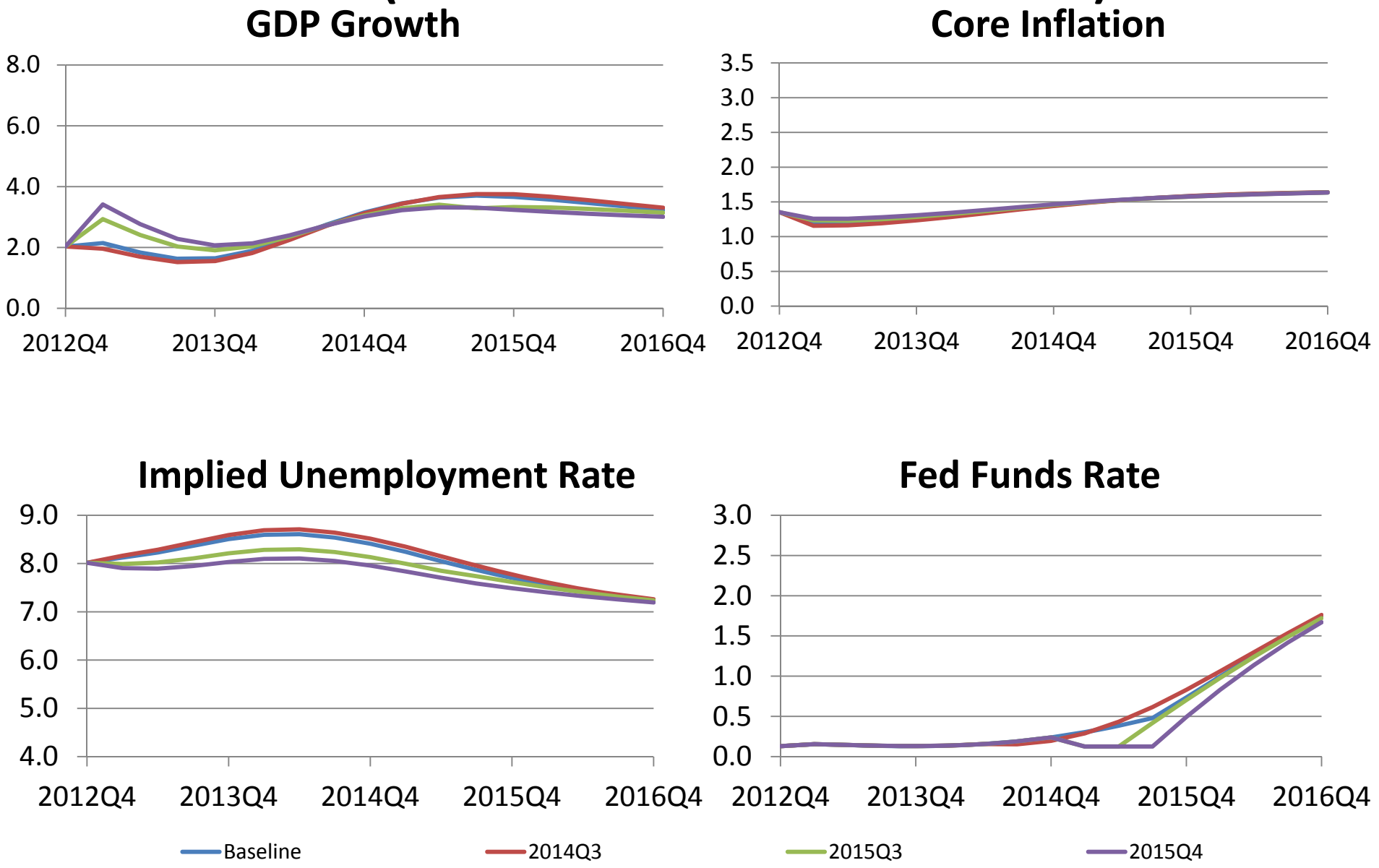


Figure 2b

NY (Alternative Forward Guidance)

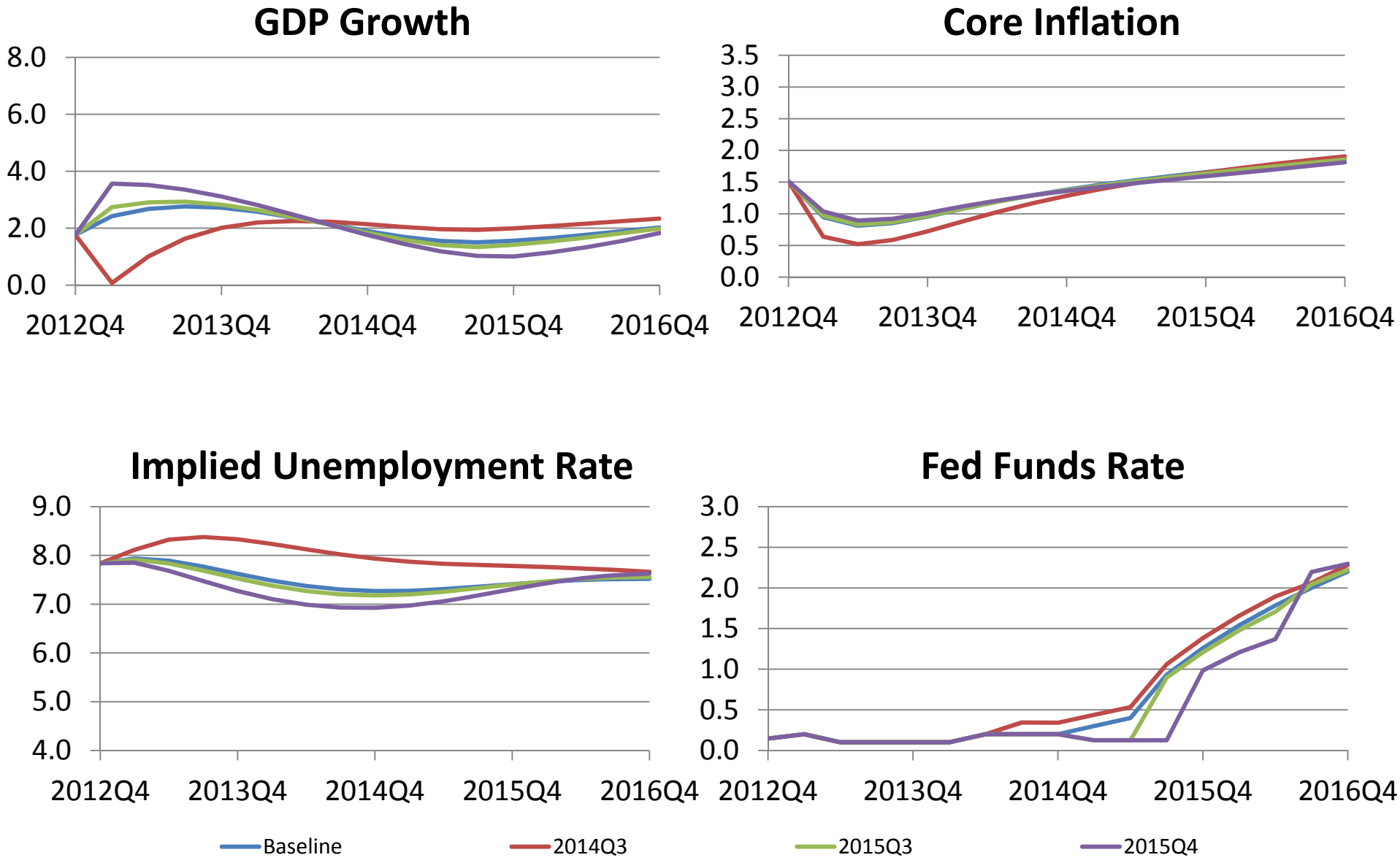


Figure 2c

PRISM (Alternative Forward Guidance)

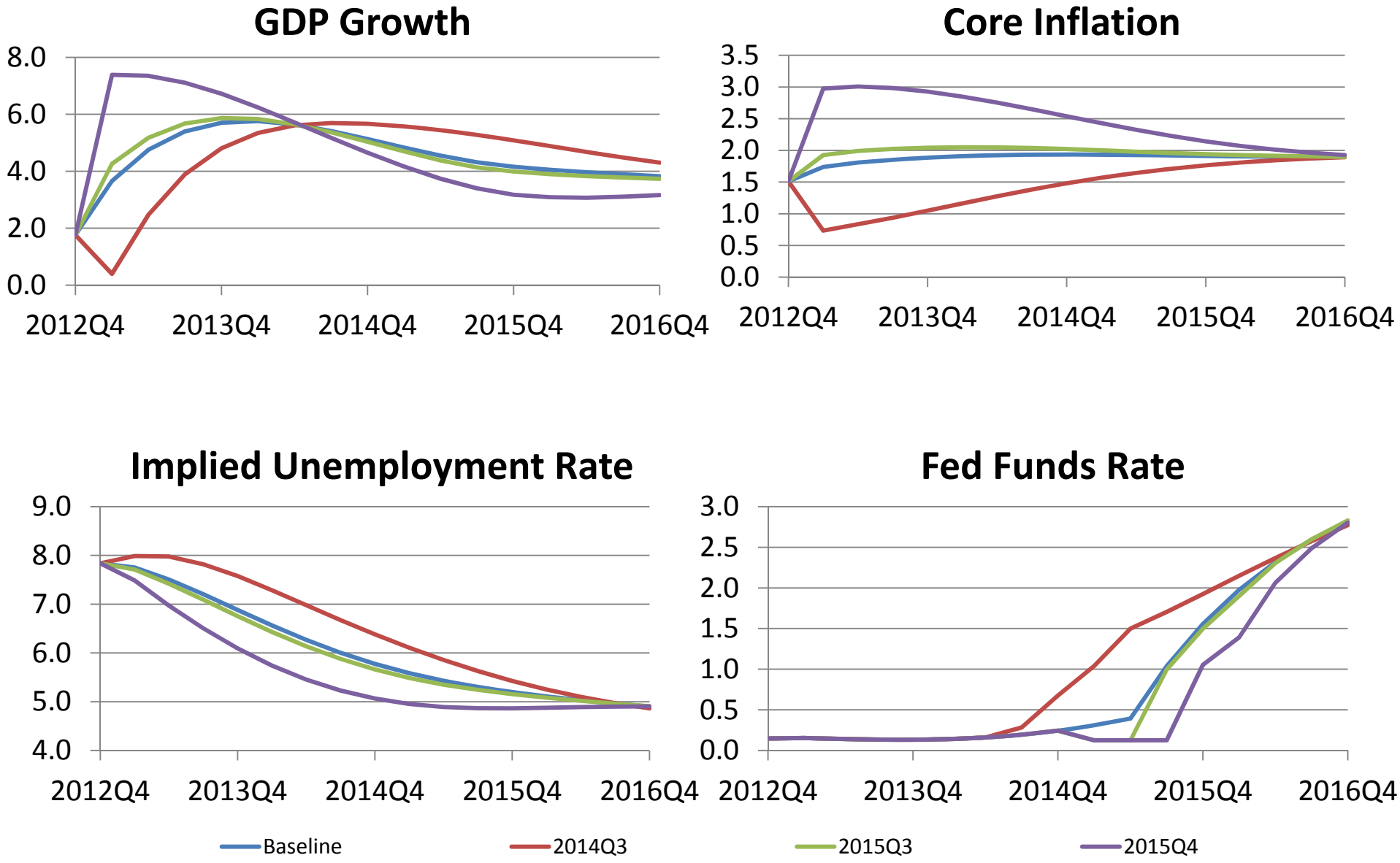


Figure 3a

EDO (Alternative Rules)

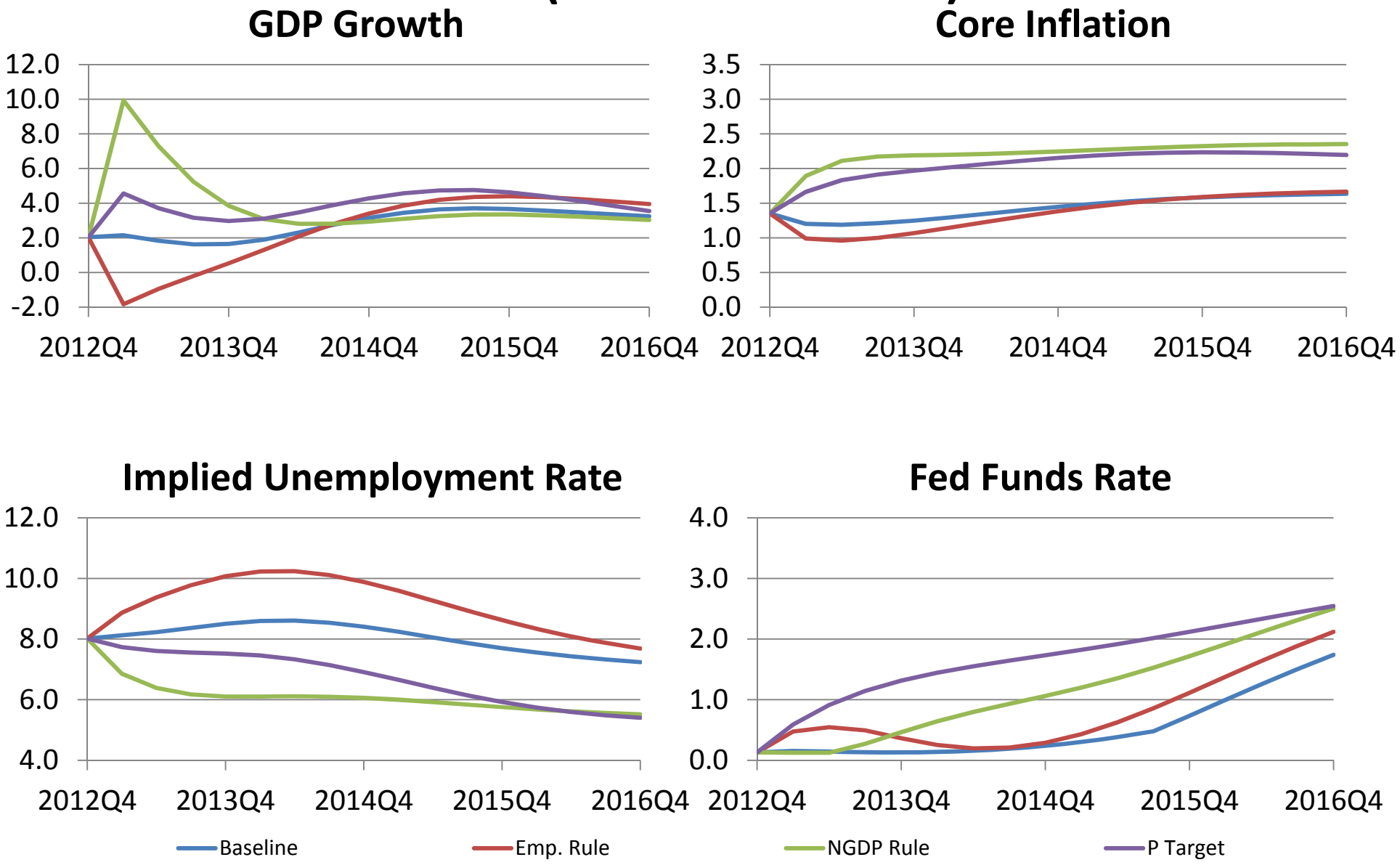


Figure 3b

NY (Alternative Rules)

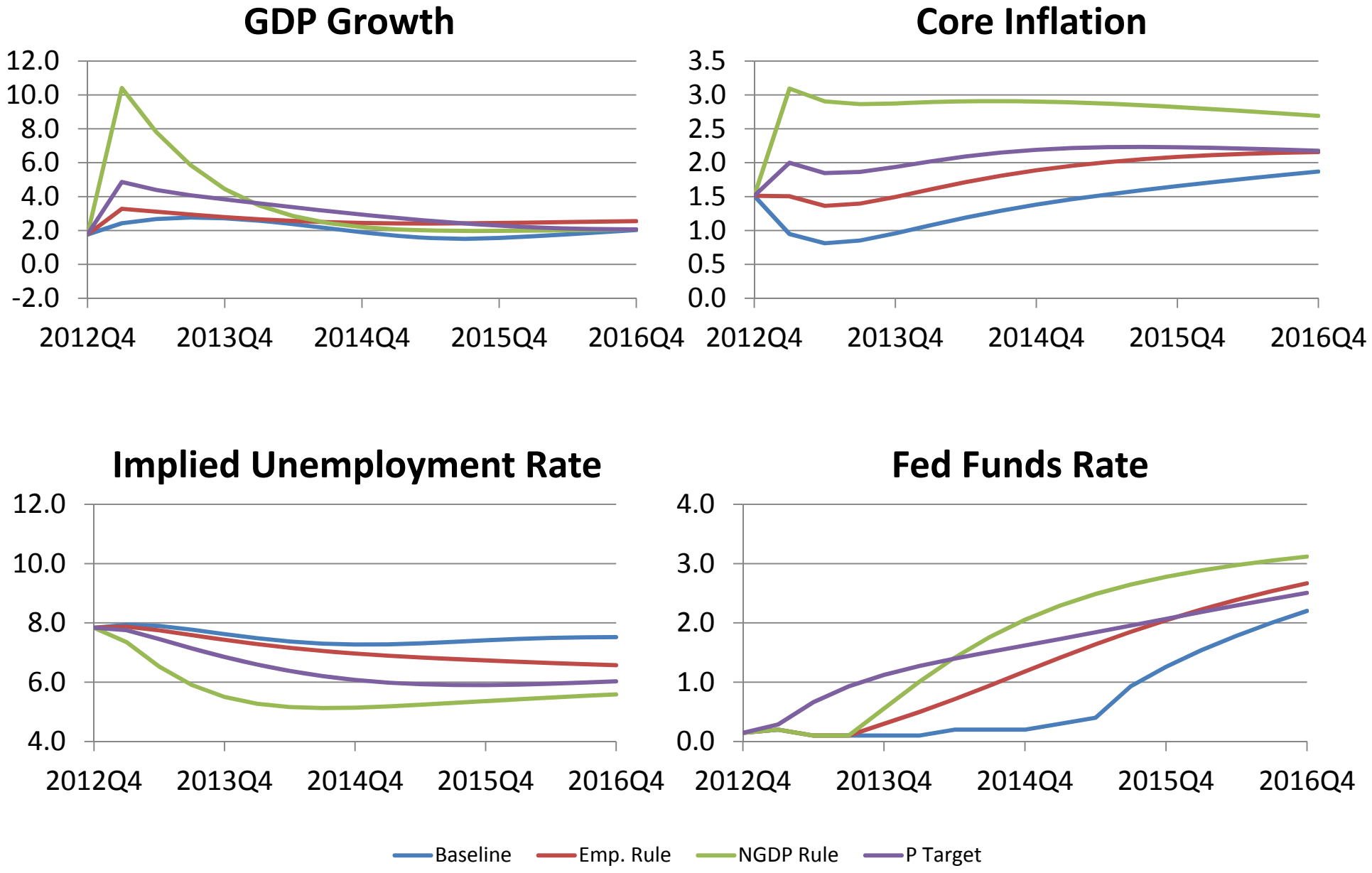


Figure 3c

PRISM (Alternative Rules)