

**BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM**

**DIVISION OF MONETARY AFFAIRS**

**FOMC SECRETARIAT**

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**Date:** December 4, 2015  
**To:** Federal Open Market Committee  
**From:** Brian F. Madigan  
**Subject:** DSGE Models Update

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The attached memo provides an update of the projections of a number of DSGE models. Note that this round, projections of the natural rate of interest and the output gap have been included.

## **System DSGE Project Forecasts**

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This memo describes the economic forecasts of the three models that are currently part of the System project on dynamic stochastic general equilibrium (DSGE) models. These are the EDO (Board), PRISM (FRB Philadelphia), and FRBNY models. We first give a summary of the model forecasts and then describe each model's forecasts in greater detail.

## **Summary of Model Forecasts**

The current forecasts for real GDP growth, core PCE inflation, and the federal funds rate, as well as those prepared for the September FOMC meeting, are displayed in the table and figures at the end of this summary section. These forecasts were obtained using actual data through 2015Q3 and conditioning assumptions or 'nowcasts' for 2015Q4, where the sources of the nowcast vary slightly across the models (EDO, the FRBNY model, and PRISM use forecasts from the Board staff, the FRBNY staff and Macroeconomic Advisers, respectively). For all the models the federal funds rate path is determined by the respective estimated policy reaction function, and is no longer constrained to be consistent with market expectations. For the sake of comparison, the tables and figures also include the October Tealbook forecast (the most recent Tealbook forecast available to us). For the first time this memo includes model-based estimates and forecasts of the real natural rate of interest, defined in each model as the equilibrium real rate of interest that would prevail in the absence of sluggish adjustment of nominal prices and wages. In addition, the memo reports estimates and forecasts of model-based output gaps. These are computed as percent deviation of actual output from its natural level, the latter again defined as the real level of output that would prevail if prices and wages were fully flexible.

The GDP growth forecasts for 2015 are now all between 2.1 and 2.2 percent, a narrower range relative to the one reported in September (2.0 to 2.5 percent). For the rest of the forecasting horizon, two of the three models predict rising growth, with the median of the model projections reaching 2.8 percent in 2016 and 2017, and 2.9 percent in 2018. The median of the growth forecasts reveals a sizeable upward revision for 2016 and 2017, compared to the September projection. This is however due to a change in the EDO model, as explained in the EDO section of the memo. Keeping EDO unchanged would have resulted in a slightly lower growth forecast for all three models compared to September. Even though PRISM's output growth forecasts have

been lowered somewhat, both PRISM and EDO are optimistic, forecasting GDP growth in the range of 2.8 percent to 3.5 percent between 2016 and 2018. In contrast, FRBNY projections continue to be more subdued, and close to the October Tealbook projections, with output growth rising progressively from 1.9 percent in 2016 to 2.3 percent in 2018.

Turning to the inflation projections, the median of the DSGE models' inflation forecast is 1.3 percent for 2015, marginally lower than in September, and slightly below the October Tealbook. Beyond 2015, however, the inflation paths are slightly steeper than in September. Consistent with their projections of a relatively high output growth, EDO and PRISM forecast a notable increase in core PCE inflation. PRISM projects inflation to be around 2.2 percent from 2016 onward, while EDO sees inflation rising progressively to reach the FOMC target of 2 percent in 2017. By contrast, FRBNY projects a significantly weaker inflation path, with core PCE inflation declining to 1.0 percent in 2016, and rising to only 1.3 percent by the end of 2018. The October Tealbook projections for inflation lie in the middle of the DSGE model forecasts.

The broad story behind the forecasts is similar across the different models. The models generally agree on the reason why output gaps are still open: past shocks to financial conditions – so-called headwinds – have a lasting effect on the economy and continue to restrain demand and, in particular, investment. Negative productivity shocks have also held down the level of economic activity. The restraint due to past financial conditions has lessened significantly over the past two years, however, as evidenced by the rise in the estimated real natural rate of interest from very negative territory to approximately zero in the current quarter. Over time, these headwinds will continue to abate and the estimated natural rates in all models are projected to rise to positive territory, albeit slowly.

The models differ however in the estimated level of the output gap and the projected speed at which this gap will close. FRBNY is particularly pessimistic in this regard, attributing to the most recent turbulence in financial markets and the associated widening of credit spreads a further delay in the projected return of output to potential and inflation to mandate consistent levels. EDO is in agreement with FRBNY as to the current level of the output gap, but foresees a

faster speed of improvement than FRBNY over the next three years. PRISM's gap is quite modest to start with.

The expected speed of renormalization in the federal funds rate varies across models, consistent with their different assessments regarding the speed of the rebound in economic activity and inflation. In PRISM, the pace of renormalization is more rapid than in the other models, with the federal funds rate projected to be above 3 percent in the second quarter of 2017. In the EDO model, the projected pace of normalization is slower, with the federal funds rate surpassing 3 percent by mid-2018. That path is close to the one of the October Tealbook. Consistent with the weaker projections for inflation and GDP growth, the FRBNY path is even shallower, with the FFR rising to 1.0 percent by the end of 2016 and 2.3 percent by the end of 2018.

## Forecasts

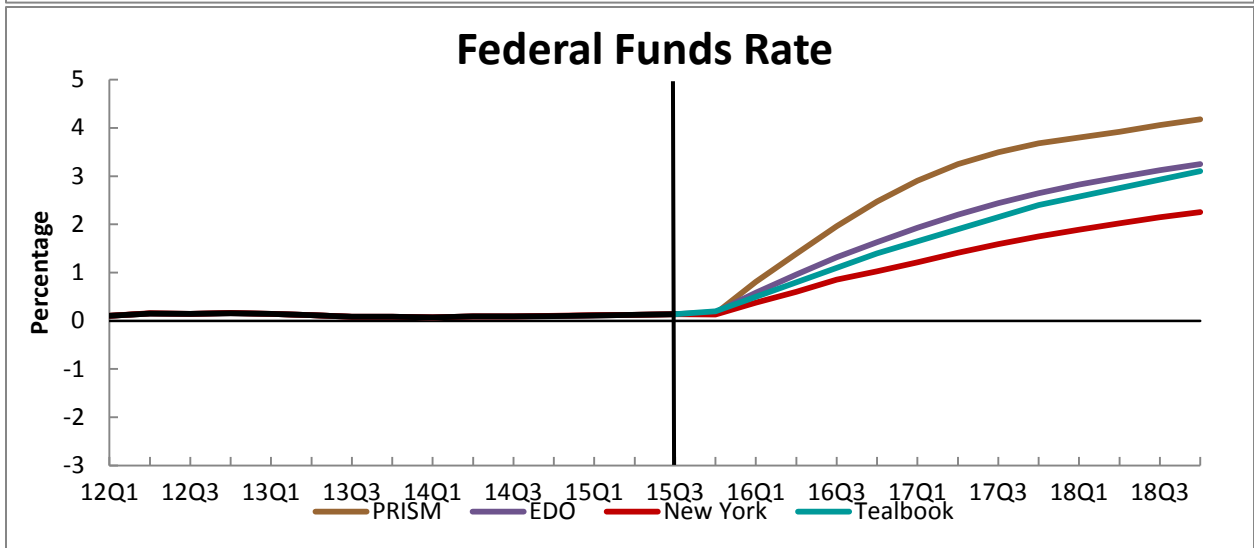
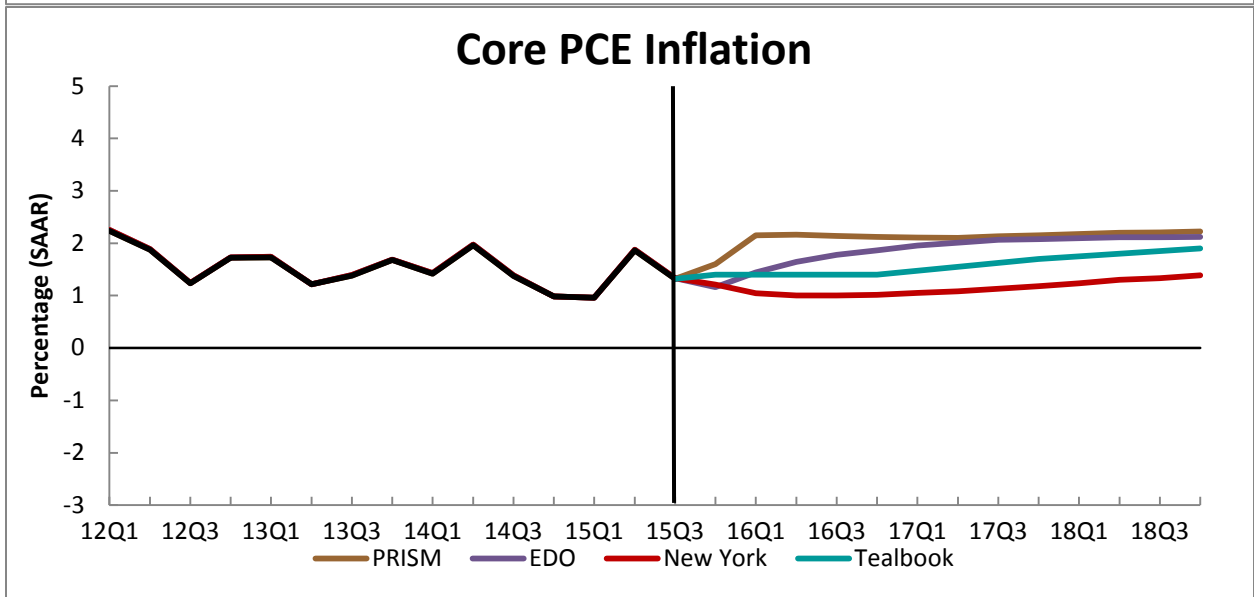
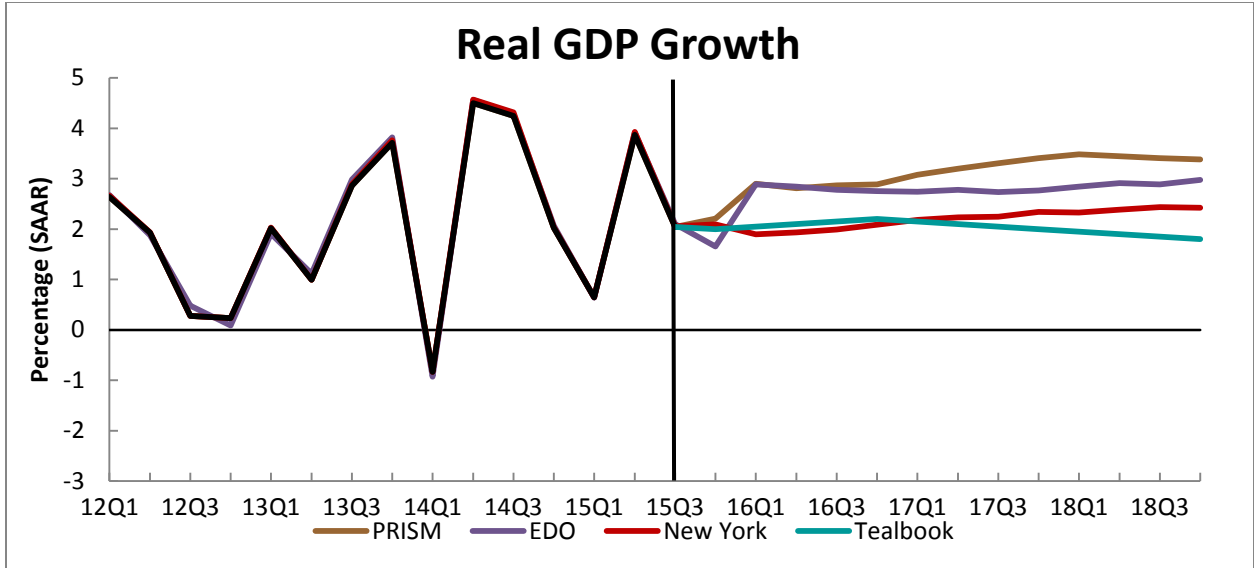
Model	Output Growth (Q4/Q4)							
	2015		2016		2017		2018	
	December	September	December	September	December	September	December	September
EDO - Board of Governors	<b>2.1</b> (2.1,2.1)	2.1 (0.5, 3.8)	<b>2.8</b> (0.9,4.7)	2.1 (-0.3, 4.4)	<b>2.8</b> (0.6,4.9)	2.6 (0.6, 4.6)	<b>2.9</b> (0.8,5.1)	3.1 (1.2, 5.0)
New York Fed	<b>2.2</b> (2.2,2.2)	2.0 (1.0, 2.7)	<b>1.9</b> (-1.0,3.8)	2.1 (-1.0, 4.1)	<b>2.2</b> (-0.8,4.5)	2.3 (-0.5, 4.8)	<b>2.3</b> (-0.4,5.0)	2.5 (-0.2, 5.2)
PRISM - Philadelphia Fed	<b>2.2</b> (2.2,2.2)	2.5 (1.8, 3.2)	<b>2.9</b> (-0.2,6.1)	3.5 (0.3, 7.1)	<b>3.3</b> (-0.1,7.1)	3.8 (0.2, 7.4)	<b>3.5</b> (-0.2,7.2)	3.5 (0.0, 7.3)
Median Forecast*	<b>2.2</b>	2.1	<b>2.8</b>	2.1	<b>2.8</b>	2.6	<b>2.9</b>	<b>3.1</b>
October Tealbook	<b>2.0</b> (1.3,3.2)		<b>2.2</b> (0.5,3.9)		<b>2.0</b> (-0.8,3.8)		<b>1.8</b> (-1.1,3.4)	

Model	Core PCE Inflation (Q4/Q4)							
	2015		2016		2017		2018	
	December	September	December	September	December	September	December	September
EDO - Board of Governors	<b>1.3</b> (1.3,1.3)	1.3 (1.3, 1.5)	<b>1.7</b> (1.1,2.3)	1.6 (1.1, 2.2)	<b>2.0</b> (1.2,2.9)	1.7 (1.1, 2.4)	<b>2.1</b> (1.1,3.1)	1.9 (1.3, 2.6)
New York Fed	<b>1.3</b> (1.3,1.3)	1.4 (1.2, 1.6)	<b>1.0</b> (0.3,1.7)	1.1 (0.4, 1.8)	<b>1.1</b> (0.2,1.9)	1.2 (0.3, 2)	<b>1.3</b> (0.4,2.2)	1.3 (0.4, 2.2)
PRISM - Philadelphia Fed	<b>1.4</b> (1.4,1.4)	1.5 (1.2, 1.7)	<b>2.2</b> (0.9,3.4)	1.7 (0.4, 3.2)	<b>2.1</b> (0.5,3.7)	1.9 (0.3, 3.6)	<b>2.2</b> (0.5,4.0)	2 (0.2, 3.8)
Median Forecast*	<b>1.3</b>	1.4	<b>1.7</b>	1.6	<b>2.0</b>	1.7	<b>2.1</b>	1.9
October Tealbook	<b>1.4</b> (1.2,1.7)		<b>1.4</b> (1.0,2.2)		<b>1.7</b> (1.1,2.5)		<b>1.9</b> (--,--)	

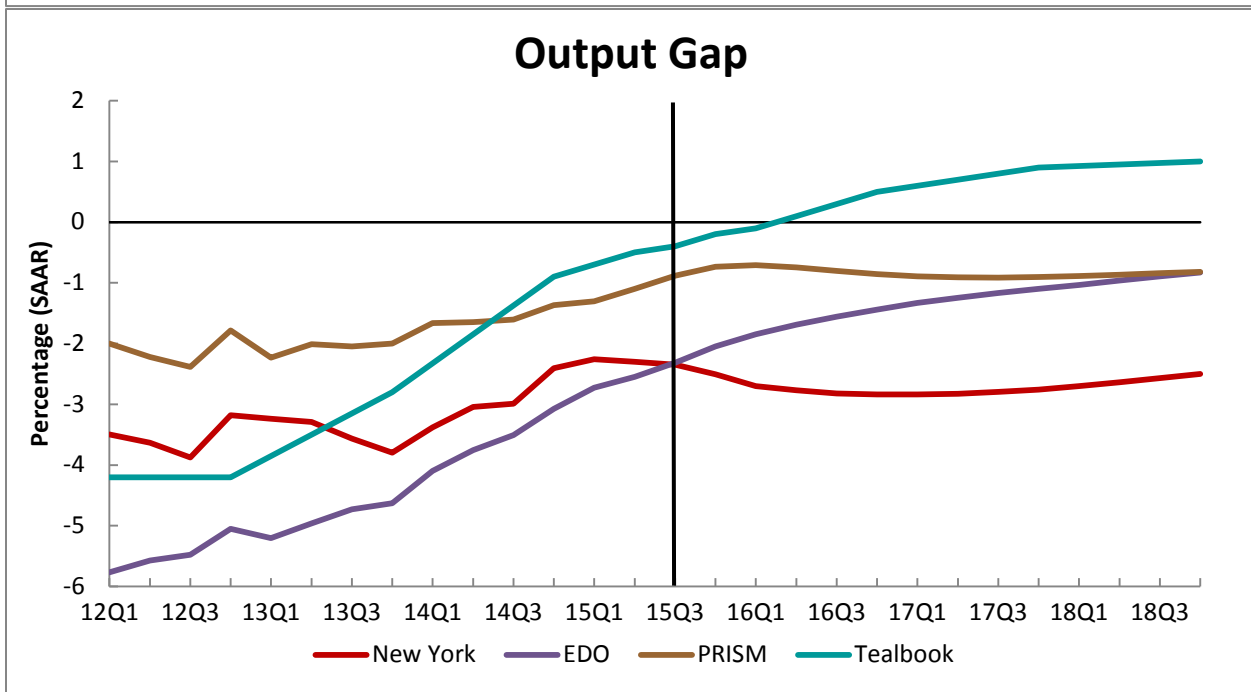
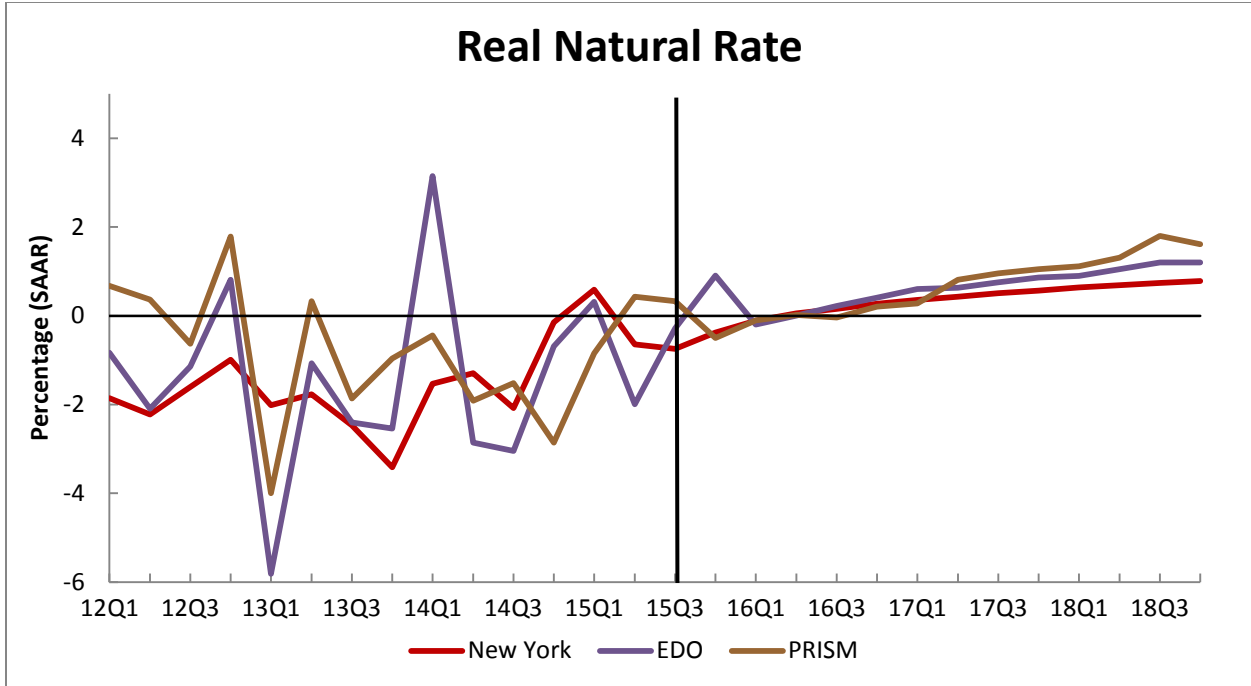
Model	Federal Funds Rate (Q4)							
	2015		2016		2017		2018	
	December	September	December	September	December	September	December	September
EDO - Board of Governors	<b>0.2</b> (0.2,0.2)	0.3 (0.0, 0.7)	<b>1.6</b> (0.4,2.8)	0.8 (0.0, 2.4)	<b>2.6</b> (1.0,4.3)	1.2 (0.0, 3.4)	<b>3.3</b> (1.4,5.1)	1.8 (0.4, 3.8)
New York Fed	<b>0.1</b> (0.1,0.2)	0.4 (0.1, 1.2)	<b>1.0</b> (0.1,2.7)	1.2 (0.1, 3.0)	<b>1.7</b> (0.3,3.8)	1.9 (0.5, 4)	<b>2.3</b> (0.7,4.5)	2.4 (0.8, 4.7)
PRISM - Philadelphia Fed	<b>0.2</b> (0.2,0.2)	0.8 (0.3, 1.4)	<b>2.5</b> (1.0,4.0)	2.5 (0.8, 4.3)	<b>3.7</b> (1.0,5.9)	3.3 (0.9, 6)	<b>4.2</b> (1.3,7.0)	3.7 (0.7, 6.5)
Median Forecast*	<b>0.2</b>	0.4	<b>1.6</b>	1.2	<b>2.6</b>	1.9	<b>3.3</b>	2.4
October Tealbook	<b>0.2</b>		<b>1.4</b>		<b>2.4</b>		<b>3.1</b>	

Model	Real Natural Rate of Interest $r^*$ (Q4)							
	2015		2016		2017		2018	
	December	September	December	September	December	September	December	September
EDO - Board of Governors	0.8 (-0.9,2.7)		0.4 (-4.4,5.2)		0.9 (-4.3,5.8)		1.3 (-3.9,6.3)	
New York Fed	-0.4 (-1.6,0.9)		0.3 (-1.1,1.6)		0.6 (-0.9,2.0)		0.8 (-0.8,2.3)	
PRISM - Philadelphia Fed	-0.5 (-1.2,0.2)		0.2 (-2.9,3.3)		1.0 (-2.3,4.4)		1.6 (-1.7,5.0)	
Median Forecast*	-0.4		0.3		0.9		1.3	
October Tealbook								

Model	Output Gap (Q4)							
	2015		2016		2017		2018	
	December	September	December	September	December	September	December	September
EDO - Board of Governors	-2.0 (-2.6,-1.5)		-1.4 (-2.7,-0.2)		-1.1 (-2.9,0.7)		-0.8 (-2.9,1.2)	
New York Fed	-2.5 (-3.9,-1.1)		-2.8 (-5.6,-1.2)		-2.8 (-7.0,-0.2)		-2.5 (-7.4,0.6)	
PRISM - Philadelphia Fed	-0.7		-0.9		-0.9		-0.8	
Median Forecast*	-2.0		-1.4		-1.1		-0.8	
October Tealbook	-0.2		0.5		0.9		1.0	







## Detailed Descriptions of Individual Model Forecasts

### The EDO Model

The EDO model forecast conditions on data through 2015Q3 and a preliminary Tealbook forecast for the fourth quarter of 2015. Real GDP growth is projected to hover slightly below its trend of 3 percent from 2016 until the end of the forecast period. Inflation increases gradually over the next year from the current level of 1.3 percent, reaching the Committee's 2 percent objective by early 2017. The federal funds rate lifts appreciably above its effective lower bound in the first quarter of 2016, surpassing 3 percent by early 2018.

The model predicts a relatively quick rebound in activity over 2016, discounting recent episodes of weak output growth on the basis of consistent improvements in the labor market. Growth is restrained however by the effects of extremely persistent adverse movements in the capital-specific risk-premium, inferred from the lackluster growth of investment in spite of low real interest rates, as well as by the waning effects of past monetary stimulus.

Largely in reaction to the still-low levels of the employment-population ratio, the model estimates an output gap of -2 percent at the end of 2015. With growth slightly below trend, the output gap closes very slowly and remains at -0.8 percent by the end of 2018. The natural rate of interest in 2015Q4 is 0.8 percent, 1¼ percent below its steady-state value of 2.1 percent. The natural rate is held down in the current quarter by the capital risk-premium shocks, as well as by an elevated aggregate risk premium. As with the output gap, convergence back to steady-state is protracted, with the natural rate reaching only 1.2 percent at the end of the projection period.

We made several changes to the EDO model in order to improve its accounting of labor market dynamics. In addition, we no longer condition on 12 quarters of data on the expected path of the federal funds rate from futures markets. Instead, we use the estimated interest feedback rule. As a result of these changes, the average growth rate of output in 2016 is over ¾ of a percent higher than under the previous version of the model. In addition, the federal funds rate path is steeper, rising on average about 1.1 percent from the path projected in September.

Given that the funds rate is no longer constrained to be as low as the path expected by financial markets, model dynamics are not restricted to deliver a weak economic outlook consistent with an expected slow path for the funds rate. Thus, the EDO model projects that GDP growth and the funds rate converge to their steady state values more rapidly than before.

To separate the effects of news since September from the effects of changes in the model, we generate a forecast using the current model and conditioning on data available at the close of the September Tealbook. The output data received since September has been weaker than the current model expected. Consequently, keeping the model the same the forecast for GDP growth in 2016 and 2017 have been revised down by  $\frac{1}{4}$  of a percent, accounted for by a more adverse path for the capital risk premium.

### **The FRBNY Model**

The FRBNY model forecasts are obtained using data released through 2015Q3, augmented for 2015Q4 with the FRBNY staff forecasts (as of November 25) for real GDP growth and core PCE inflation, and with values of the federal funds rate and the spread between Baa corporate bonds and 10-year Treasury yields based on 2015Q4 averages up to November 25.

The model projects real GDP to grow 2.2 percent in 2015 (Q4/Q4), up slightly from 2.0 percent in September. By contrast, for 2016, 2017 and 2018 the current growth forecasts are revised downward by about two tenths of a percent to, respectively, 1.9, 2.2 and 2.3 percent. Accordingly, inflation forecasts are revised down slightly to 1.3, 1.0 and 1.1, respectively, in 2015, 2016 and 2017. For 2018, the inflation forecast remains unchanged at 1.3 percent.

The changes in the FRBNY DSGE forecasts relative to September are driven by two opposing factors. On the one hand, GDP growth was revised upward for 2015Q2, and the 2015Q3 data printed higher than the September FRBNY staff forecast for that quarter. This boosted the 2015Q4 growth forecast. On the other hand, the Baa-Treasury spread, which in the model measures the tightness of financial conditions, remained elevated in Q4 and actually increased slightly, offsetting the positive impact of the data revisions. As a result, GDP growth

projections have been lowered somewhat through the forecast horizon, as financial conditions are estimated to have persistent effects on economic growth. Regarding core PCE inflation, the 2015Q3 data came in slightly below the September FRBNY staff forecast. Together with a lower projected GDP growth, this surprise results in a slight reduction in the inflation forecast.

Overall, the forecasts remain in line with the narrative that we have been describing in the past. The headwinds that slowed down the economy in the aftermath of the financial crisis are finally abating, but the recent turbulence in financial markets and the associated widening of credit spreads represent a partial set-back to this normalization process. As a result, the output gap – the difference between output and natural output – is moving sideways, and is projected to remain around -2.5 percent through 2018. Uncertainty about the level of the gap is however extremely large, as outlined below. The real natural rate of interest is still slightly negative and is projected to increase very slowly, reaching 0.3, 0.6 and 0.8 percent at the end of 2016, 2017 and 2018, respectively. Although the model at this stage interprets the tightening of financial conditions as temporary, relative to the September projections the natural rate of interest currently remains negative for an extra quarter, and the output gap is projected to be slightly larger over the forecast horizon. In addition, inflation is projected to move even more slowly towards the FOMC longer-term objective.

Consistent with these forecasts, the projected path for the federal funds rate is a tad shallower than forecasted in September. In the current projections the federal funds rate remains below 2 percent through the end of 2018Q1, one quarter longer than forecasted in September. This path reflects in part the endogenous response of policy to lower inflation and a more negative output gap, according to the historical reaction function estimated by the model. Despite this subdued path, the projected FFR implies a path for the ex-ante real interest rate that is close to the estimated natural rate of interest. This suggests that the slow renormalization path for the federal funds rate does not imply a particularly accommodative monetary policy stance.

The projections are surrounded by notable uncertainty. The width of the 68 percent probability interval for GDP growth is 4.8 percentage points in 2016, ranging from -1.0 to 3.7 percent, and widens to 5.5 percentage points in 2018, from -0.4 to 5.0 percent. Uncertainty for the real natural rate and the output gap is also extremely large. For 2018, the 68 percent bands for

the natural rate range from -0.8 to 2.3 percent, while those for the output gap range from -7.4 to 0.6 percent. The 68 percent probability intervals for inflation range from 0.3 to 1.7 percent in 2016 and from 0.4 to 2.2 percent in 2018.

### **The PRISM Model**

The Philadelphia Research Intertemporal Stochastic Model (PRISM) forecast is constructed using data through 2015Q3 that are then supplemented with a 2015Q4 nowcast based on the most recent Macroeconomic Advisers model forecast.

PRISM forecasts that output growth will accelerate gradually from a 2.2 percent pace in 2015 to 3.5 percent in 2018. The nowcast pins down real output growth in 2015Q4 at 2.2 percent, but growth then rises to 2.9 percent in 2016Q1 and then peaks at about 3.5 percent in early 2018. Core inflation remains contained and runs at about 2.2 percent over the next three years. Based on its estimated policy rule, PRISM projects the federal funds rate to rise to 0.8 percent in 2016Q1 and then to advance steadily reaching 4.2 percent in 2018Q4.

The real natural rate of interest is estimated at -0.5 percent in 2015Q4. As output growth strengthens, the natural rate rises over the next three years to reach about 1.6 percent at the end of 2018. Since PRISM doesn't estimate a great deal of wage and price stickiness in the economy, its estimated output gap tends to be modest and is at -0.7 percent in 2015Q4. The output gap rises slightly over the near term to reach -0.9 percent in 2017Q3, and then eases down to -0.8 percent at the end of 2018.

According to PRISM, negative shocks to TFP growth and government spending have been the most important factors dampening real output growth over the course of 2015. Positive and offsetting contributions come from the rebound in hours worked and investment. As TFP shocks wane, output growth rises above steady state growth in 2017. Investment shocks, government spending shocks, and labor supply shocks make a positive contribution to output growth over the forecast horizon, while the rise in the federal funds rate and financial shocks dampens growth over the next three years. Consumption growth remains below its steady state level until mid-

2017, held down by TFP shocks, investment shocks, and the rising federal funds rate. An important factor in accounting for the negative output gap is the low level of aggregate hours worked, which the model generates through a combination of labor supply shocks and government spending shocks.

The 2015Q4 nowcast for core PCE inflation is 1.6 percent. The model predicts that inflation rises to about 2.2 percent in 2016Q1, and then remains near that level over the remainder of the forecast horizon. This is due to the upward pressure on prices from the rebound in the labor market being largely offset by the slow unwinding of past financial shocks and a rising funds rate.

In terms of policy, PRISM projects the funds rate to average 0.15 percent in 2015Q4 and to begin to rise fairly quickly afterwards. By the end of 2016, the funds rate is projected to be at about 2.5 percent, and then rise to 4.2 percent by the end of 2018. The model puts relatively little weight on output dynamics in the estimated policy rule. Consequently, the shocks that account for the dynamics of the federal funds rate are largely the same as those that account for the dynamics of inflation.