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**DIVISION OF MONETARY AFFAIRS**  
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**Date:** September 11, 2017  
**To:** Federal Open Market Committee  
**From:** Brian F. Madigan  
**Subject:** DSGE Models Update

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The attached memo provides an update on the projections of the DSGE models.

## **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 NY Fed models. We first provide a summary of the forecasts and then describe each of them in greater detail.

### **Summary of Model Forecasts**

The current forecasts for real GDP growth, core PCE inflation, and the federal funds rate are displayed in the table and figures at the end of this summary section. These forecasts were obtained using actual data through 2017Q2 and conditioning assumptions or “nowcasts” for 2017Q3 where the sources of the nowcasts vary slightly across the models. (EDO, the NY Fed model, and PRISM use forecasts from the Board staff, the NY Fed staff and Macroeconomic Advisers, respectively.) For all the models, the federal funds rate path is determined by the respective estimated policy reaction function. The memo also presents 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 deviations of actual output from the natural level of output, the latter again defined as the level of output that would prevail if prices and wages were fully flexible. For the sake of comparison, the tables include the September Tealbook forecast, as well as the DSGE model forecasts prepared for the June FOMC meeting.

Turning first to GDP growth, across all three models the projections are generally somewhat stronger than they were in June. The median forecast has growth equal to 2.6, 2.8, and 2.7 percent in 2017, 2018, and 2019, respectively, up from 2.5, 2.7, and 2.6 percent in June. The median forecast for GDP growth in 2020 is 2.8 percent. Disagreement across output growth forecasts, defined as the difference between the highest and lowest forecast, has fallen slightly relative to June. On the low end, NY Fed has output growth at 2.3 percent in 2017 and 2.1 percent in 2020. On the high end, PRISM has output growth at 2.7 percent in 2017, rising to 3.1 percent in 2020. While the Tealbook forecast is close to the more upbeat DSGE forecasts in the near term, it remains weaker than the three models’ projections at a longer horizon, with a growth path that decelerates from 2.6 percent in 2017 to 1.6 percent in 2020.

Turning to inflation, the projections are notably weaker than in June for EDO and PRISM, and are now in line with the NY Fed projections for 2017. The NY Fed model continues to predict that inflation will remain below the Committee's longer-run objective throughout the forecast horizon, rising slowly from 1.4 percent in 2017 to 1.7 percent in 2020. Similarly, PRISM projects that inflation will gradually rise from 1.3 percent in 2017 in 2017 to 1.9 percent in 2020. EDO projects the strongest inflation path – albeit one that is revised down from its prediction in June – rising from 1.4 percent in 2017 to 2.0 percent in 2020. The models agree that weak wage growth is an important factor explaining the weakness in core inflation. All three models predict a weaker path than the September Tealbook, which has inflation rising from 1.5 percent in 2017 to 2.0 percent in 2020.

The forecasts of the real natural rate of interest showed little change for the EDO and NY Fed models. Both models predict a gradual increase in the natural rate, with EDO predicting a natural rate of 1.9 percent and the NY Fed model predicting 1.2 percent in 2020. In contrast, the PRISM model's forecast of the 2017 natural rate fell dramatically relative to June, from 0.1 to minus 0.6 percent. However, the model predicts a strong rebound, with the natural rate rising to 1.8 percent by 2020. As for the output gap, all three models estimate it to be negative at present and to remain so throughout the forecast horizon. Relative to June, all three models predict a somewhat faster contraction of the output gap, with EDO, NY Fed and PRISM predicting output gaps in 2020 of -0.2 percent, -0.6 percent and -0.7 percent respectively. As was the case in June, the models' assessment of economic slack is markedly different from the Tealbook, whose output gap estimate puts more weight on unemployment and remains positive for the entire forecast horizon.

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 aggregate demand. Such restraint has broadly lessened over the past two years, as evidenced by the rise in the estimated real natural rate of interest from very negative territory to zero or higher in the current quarter, and is projected to abate further over the forecast horizon. Negative productivity shocks have also contributed to depress economic activity over the course of the recovery, except in its very early phase.

The expected speed of normalization in the federal funds rate varies across models, consistent with their assessments of the speed at which economic activity and especially inflation rebound. In the near term, the forecasts of all three models are similar, with EDO, NY Fed and PRISM predicting a funds rate of 1.5, 1.4 and 1.4 percent respectively by the end of 2017. Over the medium term, EDO and PRISM continue to predict a relatively rapid normalization, with the federal funds rate reaching 3.8 and 3.5 percent respectively by the end of 2020. These forecasts have been revised down relative to June, due to the weaker outlook for inflation. The NY Fed model continues to expect a more gradual pace of tightening – in line with its more conservative outlook for the path of inflation - with the federal funds rate gradually rising to 2.9 percent at the end of 2020. The September Tealbook forecasts the federal funds rates to be 1.4 percent at the end of 2017. Its pace of normalization thereafter is broadly close to EDO's projections, with the federal funds rate reaching 3.9 percent in 2020.

## Forecasts

Model	Real GDP Growth (Q4/Q4)						
	2017		2018		2019		2020
	Sep	Jun	Sep	Jun	Sep	Jun	Sep
EDO - Board of Governors	2.6 (2.0,3.3)	2.8 (1.6,3.8)	2.8 (0.9,4.8)	2.7 (0.7,4.7)	2.7 (0.6,4.7)	2.6 (0.5,4.8)	2.8 (0.6,4.9)
New York Fed	2.3 (1.3,3.2)	2.0 (0.4,3.4)	2.0 (-0.8,4.4)	2.0 (-0.9,4.5)	2.0 (-0.8,4.7)	2.0 (-0.8,4.8)	2.1 (-0.8,4.8)
PRISM - Philadelphia Fed	2.7 (2.0,3.3)	2.5 (1.2,4.0)	3.4 (0.2,6.7)	3.2 (-0.1,6.5)	3.4 (0.0,7.0)	3.3 (-0.1,6.9)	3.1 (-0.5,6.5)
Median*	2.6	2.5	2.8	2.7	2.7	2.6	2.8
September Tealbook	2.6		2.3		1.9		1.6

Model	Core PCE Inflation (Q4/Q4)						
	2017		2018		2019		2020
	Sep	Jun	Sep	Jun	Sep	Jun	Sep
EDO - Board of Governors	1.4 (1.3,1.6)	1.5 (1.2,1.8)	1.7 (1.0,2.5)	2.1 (1.3,2.8)	2.0 (1.1,2.9)	2.2 (1.3,3.2)	2.0 (1.1,3.0)
New York Fed	1.4 (1.2,1.6)	1.3 (0.9,1.6)	1.3 (0.5,2.2)	1.3 (0.3,2.2)	1.5 (0.4,2.6)	1.4 (0.3,2.6)	1.7 (0.4,2.9)
PRISM - Philadelphia Fed	1.3 (1.1,1.6)	1.9 (1.4,2.4)	1.7 (0.4,3.0)	1.9 (0.5,3.4)	1.8 (0.3,3.4)	2.0 (0.4,3.7)	1.9 (0.2,3.6)
Median*	1.4	1.5	1.7	1.9	1.8	2.0	1.9
September Tealbook	1.5		1.9		2.0		2.0

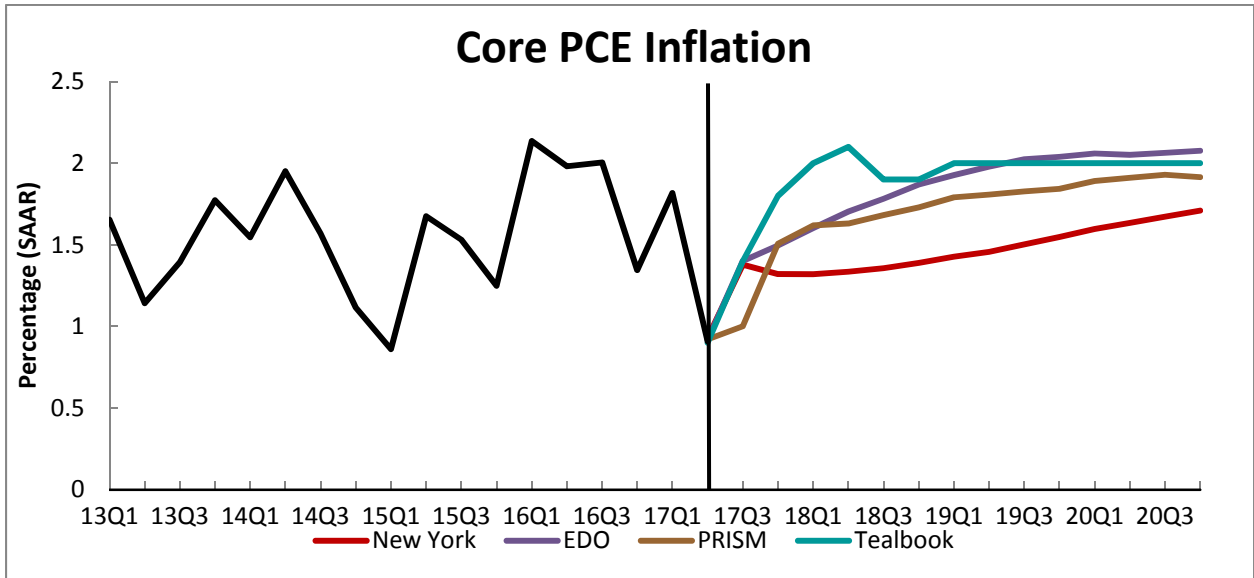
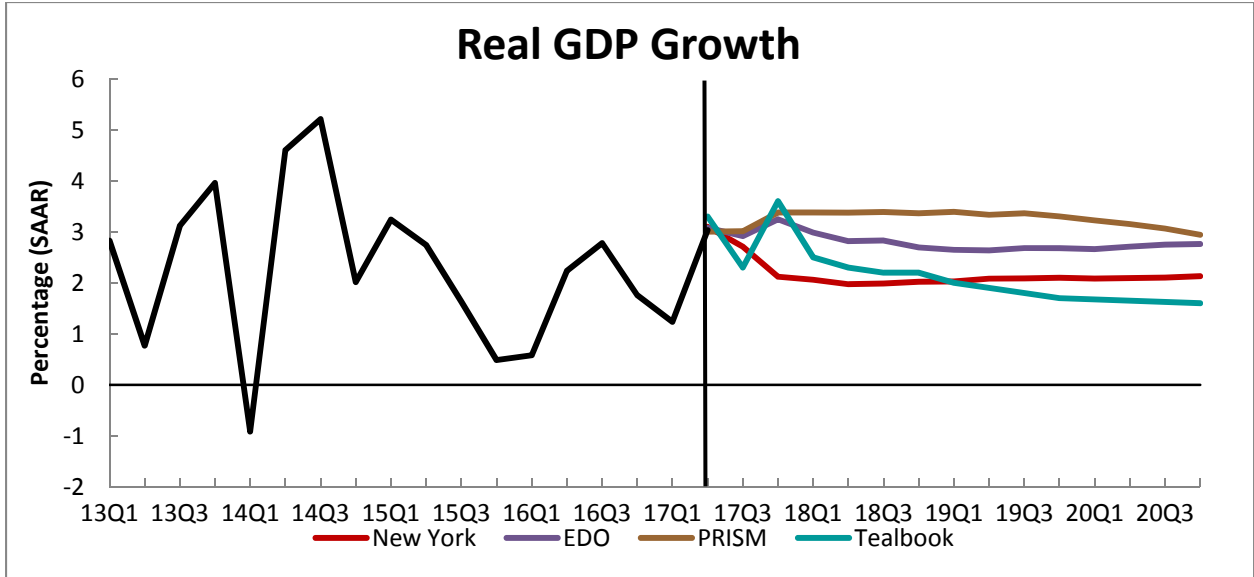
Model	Federal Funds Rate (Q4)						
	2017		2018		2019		2020
	Sep	Jun	Sep	Jun	Sep	Jun	Sep
EDO - Board of Governors	1.5 (1.0,2.1)	1.7 (0.9,2.5)	2.7 (1.3,4.1)	2.9 (1.5,4.4)	3.4 (1.6,5.2)	3.6 (1.8,5.4)	3.8 (1.8,5.7)
New York Fed	1.4 (0.6,2.2)	1.4 (0.3,2.6)	2.1 (0.7,3.8)	2.2 (0.7,3.9)	2.6 (0.9,4.5)	2.6 (0.9,4.5)	2.9 (1.0,4.9)
PRISM - Philadelphia Fed	1.4 (0.9,1.9)	1.9 (1.0,2.8)	2.3 (0.7,4.2)	3 (1.0,4.8)	3.1 (0.9,5.8)	3.5 (0.9,6.0)	3.5 (0.7,6.3)
Median*	1.4	1.7	2.3	2.9	3.1	3.5	3.5
September Tealbook	1.4		2.6		3.5		3.9

Model	Real Natural Rate of Interest r* (Q4)						
	2017		2018		2019		2020
	Sep	Jun	Sep	Jun	Sep	Jun	Sep
EDO - Board of Governors	<b>0.9</b> (-3.3,5.0)	0.8 (-3.8,5.3)	<b>1.4</b> (-3.5,6.2)	1.5 (-3.5,6.3)	<b>1.6</b> (-3.4,6.6)	1.7 (-3.4,6.7)	<b>1.9</b> (-3.2,6.7)
New York Fed	<b>0.5</b> (-0.9,2.0)	0.5 (-1.0,2.0)	<b>0.9</b> (-0.9,2.6)	0.9 (-0.8,2.7)	<b>1.1</b> (-0.7,3.0)	1.1 (-0.8,3.0)	<b>1.2</b> (-0.7,3.2)
PRISM - Philadelphia Fed	<b>-0.6</b> (-3.2,2.2)	0.1 (-2.7,3.0)	<b>0.5</b> (-2.7,3.7)	0.5 (-3.0,3.2)	<b>1.2</b> (-2.8,3.9)	1.3 (-1.7,4.7)	<b>1.8</b> (-1.2,4.9)
Median*	<b>0.5</b>	0.5	<b>0.9</b>	0.9	<b>1.2</b>	1.3	<b>1.8</b>
September Tealbook	-		-		-		-

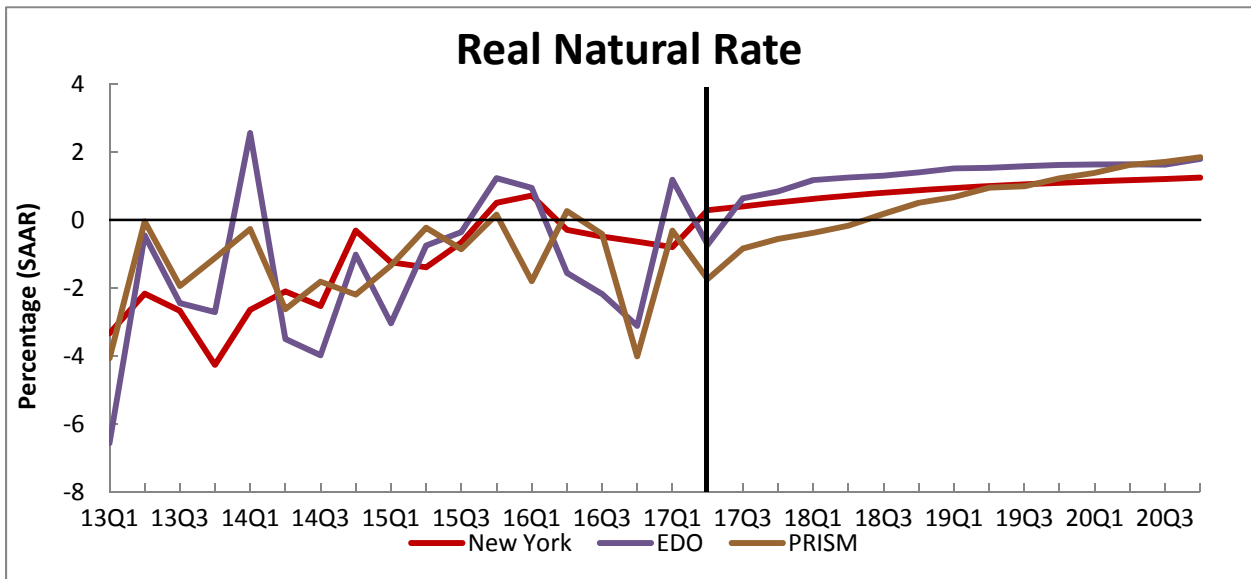
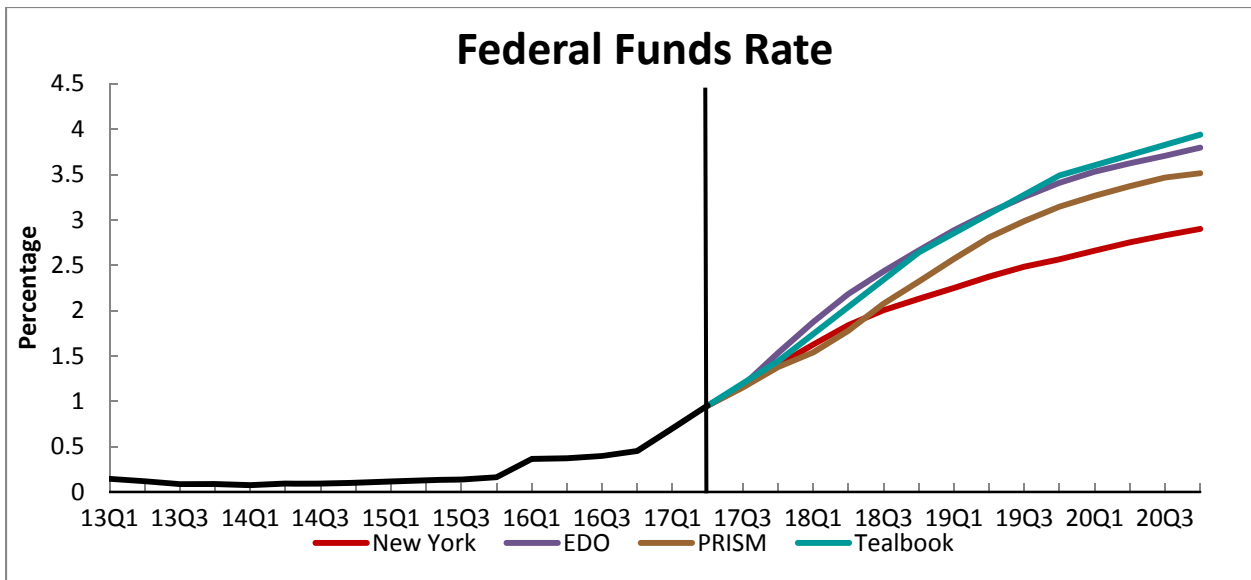
Model	Output Gap (Q4)						
	2017		2018		2019		2020
	Sep	Jun	Sep	Jun	Sep	Jun	Sep
EDO - Board of Governors	<b>-0.9</b> (-1.6,-0.3)	-0.8 (-1.6,0.0)	<b>-0.5</b> (-1.8,1.0)	-0.5 (-2.1,1.1)	<b>-0.3</b> (-2.2,1.6)	-0.4 (-2.3,1.6)	<b>-0.2</b> (-2.3,1.9)
New York Fed	<b>-0.9</b> (-2.2,0.5)	-1.0 (-2.7,0.6)	<b>-0.8</b> (-3.2,1.4)	-1.1 (-3.8,1.3)	<b>-0.6</b> (-3.9,2.1)	-1.1 (-4.6,1.9)	<b>-0.6</b> (-4.3,2.6)
PRISM - Philadelphia Fed	<b>-1.6</b> (-2.5,-0.4)	-1.6 (-2.8,-0.5)	<b>-1.3</b> (-2.5,0.2)	-1.5 (-2.9,-0.1)	<b>-1.0</b> (-2.6,0.3)	-1.3 (-2.8,0.2)	<b>-0.7</b> (-2.5,0.7)
Median*	<b>-0.9</b>	-1.0	<b>-0.8</b>	-1.1	<b>-0.6</b>	-1.1	<b>-0.6</b>
September Tealbook	<b>1.4</b>		<b>2.1</b>		<b>2.2</b>		<b>2.0</b>

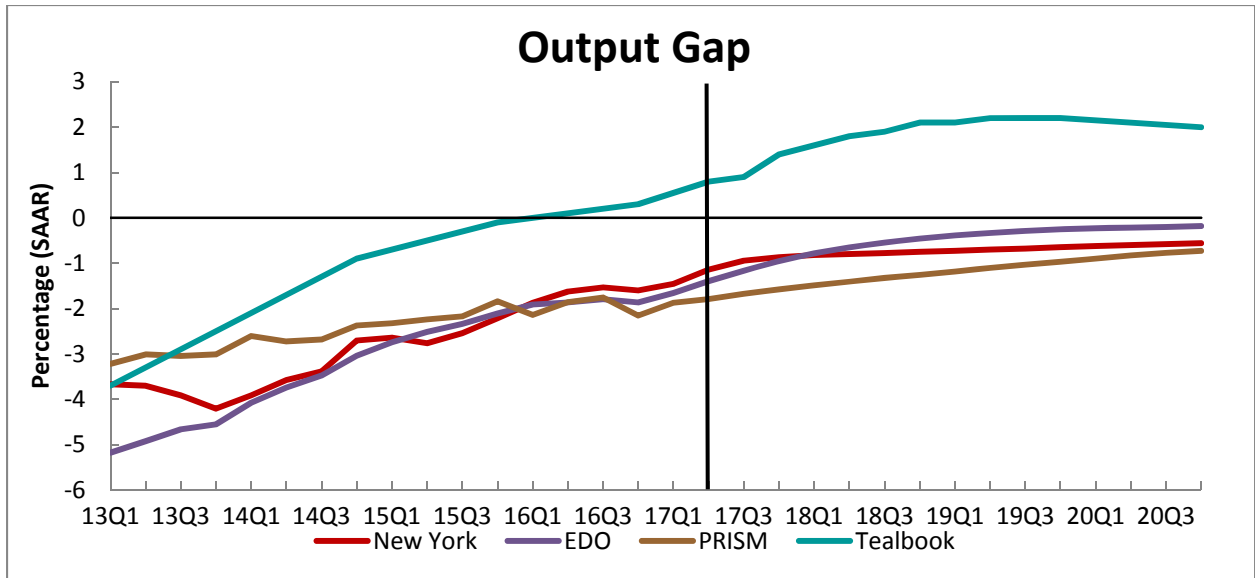
For each individual forecast, the numbers in parentheses represent 68% confidence bands.

\*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's forecast is conditional on data through the second quarter of 2017 and on a preliminary Tealbook forecast for the third quarter of 2017.

Real GDP growth is 2.7 percent on average over the projection horizon, a bit below its long-run value of 3 percent. Inflation reaches the Committee's 2 percent objective in the third quarter of 2019 and then slightly overshoots the target thereafter. Below-trend real GDP growth is driven by the slow fading of positive contributions from past monetary policy accommodation. For inflation, the EDO model interprets the weakness in inflation over the past few years as driven by negative wage markup shocks and expects them to dissipate gradually over the projection horizon.

The output gap is estimated to be -1.2 percent in 2017 Q3, and is projected to close very slowly and remain slightly negative at the end of 2020. The real natural rate of interest is projected to increase from 0.6 percent in the third quarter of 2017 to 1.9 percent at the end of 2020, 0.2 percentage points below its steady-state value of 2.1 percent. According to the EDO model, capital-specific risk premium shocks—inferred from weak investment over the past several years—have been holding down the output gap and the real natural rate. As these shocks slowly dissipate, the output gap closes and the real natural rate rises.

Consistent with the gradual return of inflation and the output gap to their long-run values, the federal funds rate is projected to increase gradually over the forecast horizon, reaching 3.8 percent by the end of 2020. At the end of the projection horizon, the federal funds rate is still somewhat below its long-run value of 4.1 percent, reflecting the inertia in the policy rule and the persistently negative output gap even at the end of the projection horizon.

The EDO model's projection of real GDP growth is slightly faster for the next two years than it was in June 2017. The upward revision in the real GDP growth projection is driven by more negative markup shocks inferred from weaker-than-expected wage growth as well as downward revisions in the historical real wage series associated with the BEA's annual data revisions. Core PCE inflation is, on average, 30 basis points lower over the forecast horizon than in June, also due to these more negative markup shocks. In the near term, the output gap has revised down slightly since June, but it is higher in the medium term. The projection of the real natural rate of

interest is essentially unchanged from June. Consistent with the lower inflation path, the path of the federal funds rate is lower this round than in June.

### **The NY Fed Model**

The New York Fed model forecasts are obtained using data released through 2017Q2, augmented for 2017Q3 with the New York Fed staff forecasts (as of August 30) for real GDP growth and core PCE inflation, and with values of the federal funds rate, the 10-year Treasury yield and the spread between Baa corporate bonds and 10-year Treasury yields based on 2017Q3 averages up to August 30.

The model projects real GDP growth of 2.3 percent in 2017, which is higher than the June forecast of 2.0 percent growth for 2017. Growth falls back to 2.0 percent in 2018 and 2019, in line with the previous quarter's forecast. The projections of inflation have been revised upwards slightly at all horizons, sitting about 0.1 percentage point higher than the model's projection in June. Inflation is projected to be 1.4 percent in 2017, dipping slightly to 1.3 percent in 2018, and increasing slightly thereafter to 1.5 percent in 2019 and 1.7 percent in 2020, still below the committee's target. These projections are slightly higher than the June forecasts, which indicated 1.3, 1.3, 1.4 and 1.6 percent for 2017, 2018, 2019 and 2020 respectively.

The current output gap is estimated to be -0.9 percent and is projected to slowly shrink to minus 0.6 percent by the end of 2020. Compared to June, both the near-term and long-term forecasts have been revised upwards with the longer-term forecasts seeing larger improvements. While the 2017 forecast was revised up only 0.1 percentage points from June, the forecasts for 2018, 2019 and 2020 saw a larger revision, increasing from a June forecast of -1.1 percent for all three years to the current forecast of -0.8 percent for 2018 and -0.6 percent for 2019 and 2020. The natural rate of interest is projected to be 0.5 percent at the end of 2017, the same as in June. In fact, the projected path of the natural rate remains unchanged from the June forecast.

The projections for all the variables are surrounded by notable uncertainty. For instance, the range of 68 percent probability interval for GDP growth is as large as 1.9 percentage points in 2017, from 1.3 to 3.2 percent, and widens over the forecast horizon, reaching 5.6 percentage points in 2020, from -0.8 to 4.8 percent. Similarly, the 68 percent probability intervals for inflation range from 1.2 to 1.6 percent in 2017 and from 0.4 to 2.9 percent in 2020.

The model attributes the temporarily higher level of real GDP growth in 2017 to continued favorable financial conditions (measured by the financial and marginal efficiency of investment shocks) and to a positive aggregate demand shock, although these were hampered by low TFP growth. The model attributes the below target path for inflation partly to persistently low wage and price markups. Although the forecast for the natural rate of interest did not change since June, the model continues to project that improving financial conditions will gradually return the natural rate to its long run level and contribute to reducing the output gap. A somewhat more accommodative monetary policy than anticipated in June also contributes to reducing the output gap.

Finally, the federal funds rate is projected to increase gradually over the forecast horizon, reaching 2.9 percent by the end of 2020. The federal funds rate remains below its long run level of 4 percent throughout the forecast horizon owing to persistence in the interest rate rule, persistently low inflation and a lingering output gap. The projected path is shallower than the September Tealbook forecast.

### **The PRISM Model**

The Philadelphia Research Intertemporal Stochastic Model (PRISM) forecast is constructed using data through 2017Q2 that are then supplemented with a 2017Q3 nowcast based on the most recent Macroeconomic Advisors model forecast.

PRISM forecasts that output growth will accelerate from a 2.7 percent pace in 2017 to 3.1 percent in 2020. The nowcast pins down real output growth in 2017Q3 at 3 percent. Growth gradually accelerates to a peak of 3.4 percent in 2018. Core inflation rises from 1 percent in 2017Q3 to 1.9 percent in 2020. The PRISM projection has the funds rate following an estimated policy rule through the forecast horizon: the federal funds rate rises to 1.4 percent in 2017Q4 and then advances steadily to reach 3.5 percent in 2020Q4.

PRISM also forecasts the natural rate of interest and the output gap as determined from the model. The natural rate of interest – the rate of interest that would prevail if wages and prices were fully flexible – is estimated at -0.8 percent in 2017Q3. As output growth strengthens and the economy normalizes to trend, the natural rate rises over the forecast horizon to reach 1.8 percent at the end of 2020. Our estimates of the output gap are derived from the log deviation of

real output from its flexible-price counterfactual level. The estimated output gap is at -1.7 percent in 2017Q3 and shrinks slowly over the next three years to reach -0.7 percent at the end of 2020.

According to PRISM, the rebound in output growth in 2017Q2 was due to positive shocks to government spending, investment and hours worked offsetting negative shocks to TFP, the discount rate (financial shocks), and monetary policy. Going forward, TFP shocks exert a drag on output growth over the next two years, as do monetary policy and financial shocks. Output growth is projected to run at an above-trend pace through the forecast horizon. Investment shocks, government spending shocks, and labor supply shocks continue to make a positive contribution to output growth over the next three years. Consumption growth ran at an above-trend pace in 2016 driven by strong contributions from financial shocks. In the model, financial shocks account for the discrepancy between consumption growth and investment growth. Going forward, consumption growth accelerates toward its trend pace as negative contributions from shocks to TFP, investment, and monetary policy are offset by labor supply and financial shocks. Consumption growth is back to trend in 2020. Shocks to the marginal efficiency of investment lead to an investment growth rebound in 2017Q2. As these shocks wane, investment growth settles to a 4.5 percent pace over the next few quarters and then gradually eases to about 2.5 percent in 2020. On balance, the model continues to imply a de-trended level of output that is below its steady state and an important factor in accounting for this 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 2017Q3 nowcast for core PCE inflation is 1 percent. The model predicts that inflation rises gradually to 1.9 percent by early 2020. With inflation edging up to trend over the forecast horizon, PRISM has upward pressure on prices from investment growth and the renormalization of the labor market being largely offset by the slow unwinding of past financial shocks, and a rising funds rate.

The forecast is implemented with a rule-based federal funds rate path. By 2017Q4 the funds rate averages 1.4 percent, rising to 2.3 percent in 2018Q4 and 3.1 percent in 2019Q4 -- a somewhat slower pace of normalization compared to the June forecast. 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.