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To: Federal Open Market Committee
From: Brian F. Madigan
Subject: DSGE Models Update

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 FRBNY 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 2017Q1 and conditioning assumptions or “nowcasts” for 2017Q2 where the sources of the nowcasts vary slightly across the models. (EDO, the New York Fed model, and PRISM use forecasts from the Board staff, the New York Fed staff and Macroeconomic Advisers, respectively.) For all the models, the federal funds rate path is determined by the respective estimated policy reaction function. For the sake of comparison, the tables include the April Tealbook forecast (the most recent Tealbook forecast available to us at the time of writing), as well as the DSGE model forecasts prepared for the March FOMC meeting. 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.

Turning first to GDP growth, the median forecast is largely unchanged from March and has steady growth at 2.5 percent in 2017, 2.7 percent in 2018, and 2.6 percent in 2019. Disagreement across the forecasts, defined as the difference between the highest and lowest forecast, remains modest. On the low end, the New York Fed model has output growth at 2 percent over 2017-2019. On the high end, PRISM has output growth rising to about 3.2 percent in 2018 and 2019. The Tealbook forecast is on balance weaker than the PRISM and EDO forecasts and somewhat stronger than the New York Fed forecast. The Tealbook projects a growth path that decelerates from 2.4 percent in 2017 to 1.8 percent in 2019.

Turning to inflation, the median projection has core PCE inflation rising from 1.5 percent in 2017 to 2 percent in 2019, and the disagreement in projections is similar to that in March. The New York Fed model continues to project the weakest inflation path at about 1.3 percent through the forecast horizon. PRISM predicts that inflation will be at about 2 percent in 2017 and remain there through 2019. EDO has inflation slightly overshoot the mandate-consistent target in 2018 and 2019. The PRISM, EDO, and Tealbook inflation paths are similar and somewhat stronger than the New York Fed forecast.

The three models show similar assessments of the current level and the future expected evolution of both r^* and the output gap. Looking at the medians across the three models' point forecasts, the real natural rate is projected to be slightly positive at the end of 2017 and to rise gradually to 1.3 percent in 2019, with a fairly narrow range of 1.1 to 1.7 percent. As for the output gap, the three models estimate it to be negative at present and to remain so throughout the forecast horizon. The estimates are, on balance, slightly more optimistic on the output gap than they were in March. As has been the case for some time, the models' assessment of economic slack is markedly different from the Tealbook, whose output gap estimate takes more signal from unemployment and is both positive and growing steadily over the 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 and, in particular, investment. Negative productivity shocks have also contributed to depress economic activity over the course of the recovery, except in its very early phase. The restraint due to tight financial conditions 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. Over time, the models project that these headwinds will continue to abate, contributing to lifting the natural rate and economic activity more broadly.

The expected speed of normalization in the federal funds rate varies across models and is consistent with their assessments of the speed at which economic activity and especially inflation rebound. The PRISM and EDO forecasts are similar, with the funds rate reaching 1.9 and 1.7 percent respectively at the end of 2017, and then climbing to about 3.6 percent by the end of 2019. The New York Fed continues to expect a more gradual pace of tightening with the federal

funds rate at 1.4 percent at the end of 2017 and 2.6 percent at the end of 2019. The June Tealbook forecasts the federal funds rates to be 1.5 percent at the end of 2017, close to the New York Fed model projection. However, its pace of normalization is steeper afterwards, with the federal funds rate reaching 3.7 percent in 2019 and so slightly above the projections from EDO and PRISM.

Forecasts

Model	Real GDP Growth (Q4/Q4)					
	2017		2018		2019	
	Jun	Mar	Jun	Mar	Jun	Mar
EDO - Board of Governors	2.8 (1.6,3.8)	2.6 (1.1,4.2)	2.7 (0.7,4.7)	2.3 (0.3,4.5)	2.6 (0.5,4.8)	2.6 (0.4,4.6)
FRBNY - New York Fed	2.0 (0.4,3.4)	1.9 (-0.2,3.7)	2.0 (-0.9,4.5)	2.2 (-0.6,4.7)	2.0 (-0.8,4.8)	2.5 (-0.3,5.2)
PRISM - Philadelphia Fed	2.5 (1.2,4.0)	2.5 (0.4,4.8)	3.2 (-0.1,6.5)	3.1 (-0.2,6.7)	3.3 (-0.1,6.9)	3.3 (-0.2,7.0)
Median*	2.5	2.5	2.7	2.3	2.6	2.6
June Tealbook	2.4		2.2		1.8	

Model	Core PCE Inflation (Q4/Q4)					
	2017		2018		2019	
	Jun	Mar	Jun	Mar	Jun	Mar
EDO - Board of Governors	1.5 (1.2,1.8)	2.3 (1.8,2.8)	2.1 (1.3,2.8)	2.3 (1.5,3.2)	2.2 (1.3,3.2)	2.3 (1.4,3.3)
FRBNY - New York Fed	1.3 (0.9,1.6)	1.6 (1.0,2.1)	1.3 (0.3,2.2)	1.5 (0.5,2.4)	1.4 (0.3,2.6)	1.6 (0.4,2.7)
PRISM - Philadelphia Fed	1.9 (1.4,2.4)	1.9 (1.1,2.8)	1.9 (0.5,3.4)	2.0 (0.5,3.6)	2.0 (0.4,3.7)	2.1 (0.4,3.7)
Median*	1.5	1.9	1.9	2.0	2.0	2.1
June Tealbook	1.6		1.9		2.0	

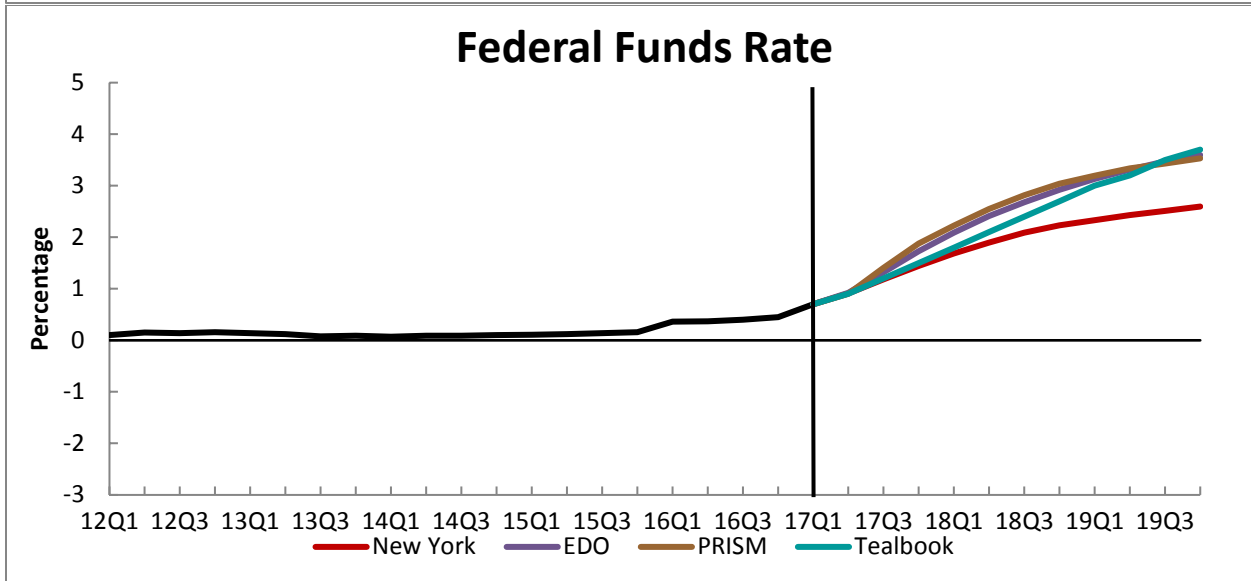
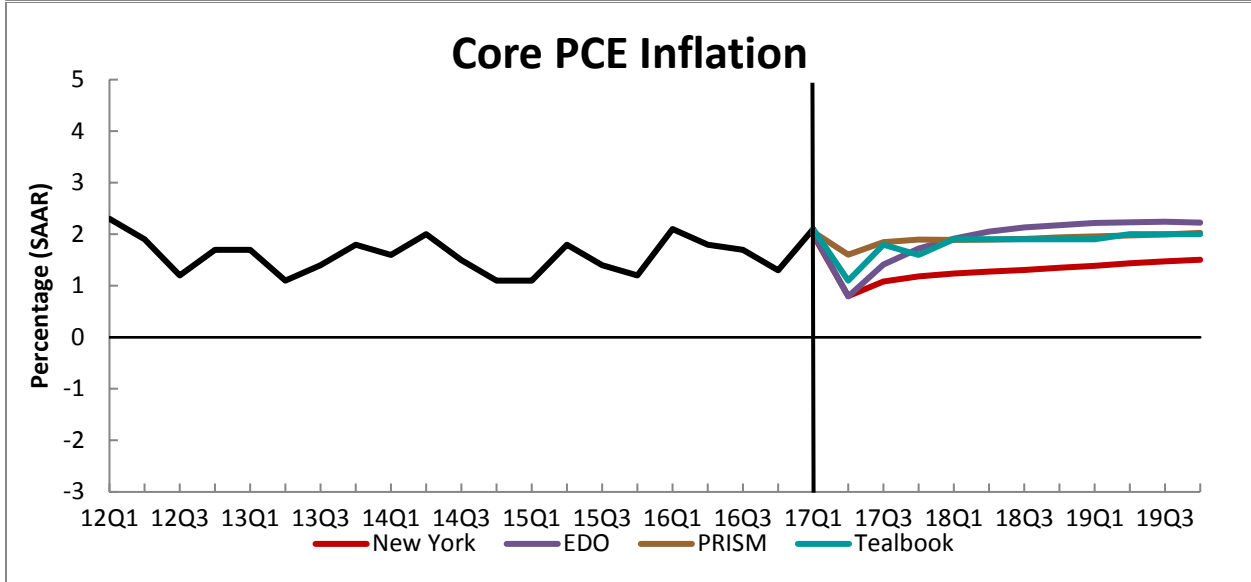
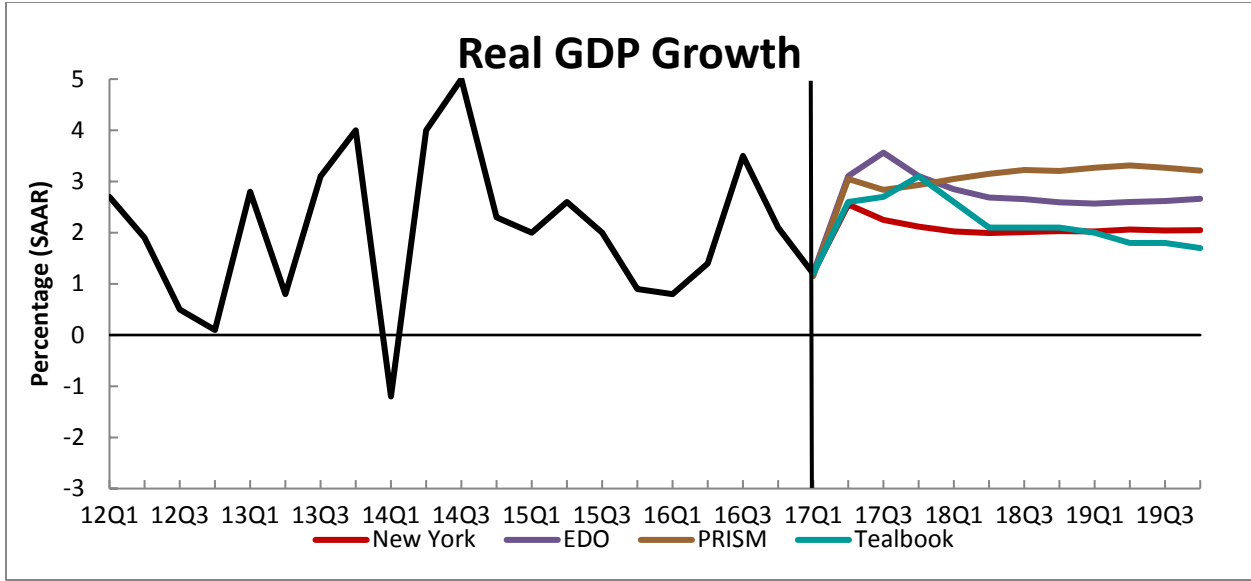
Model	Federal Funds Rate (Q4)					
	2017		2018		2019	
	Jun	Mar	Jun	Mar	Jun	Mar
EDO - Board of Governors	1.7 (0.9,2.5)	2.1 (1.1,3.1)	2.9 (1.5,4.4)	3.1 (1.5,4.8)	3.6 (1.8,5.4)	3.7 (1.8,5.6)
New York Fed	1.4 (0.3,2.6)	1.6 (0.5,2.9)	2.2 (0.7,3.9)	2.4 (0.9,4.1)	2.6 (0.9,4.5)	2.8 (1.0,4.7)
PRISM - Philadelphia Fed	1.9 (1.0,2.8)	2.0 (0.9,3.3)	3.0 (1.0,4.8)	3.2 (0.8,5.1)	3.5 (0.9,6.0)	3.7 (1.2,6.5)
Median*	1.7	2.0	2.9	3.1	3.5	3.7
June Tealbook	1.5		2.7		3.7	

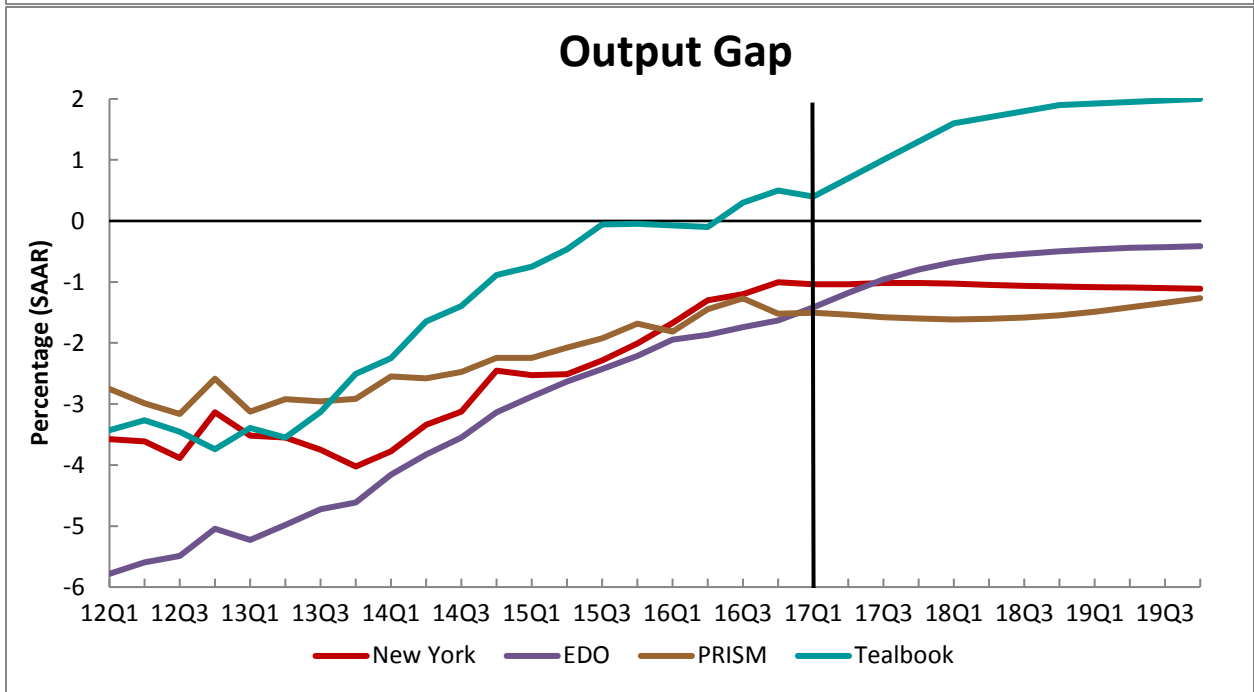
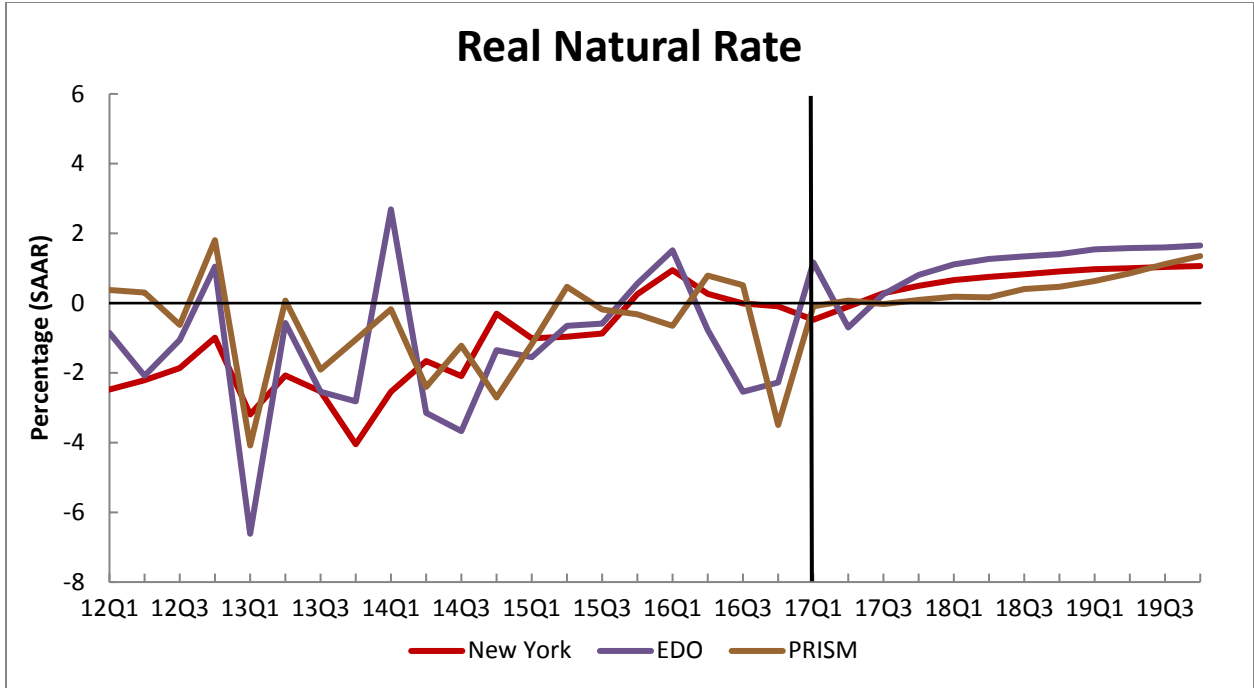
Model	Real Natural Rate of Interest r* (Q4)					
	2017		2018		2019	
	Jun	Mar	Jun	Mar	Jun	Mar
EDO - Board of Governors	0.8 (-3.8,5.3)	0.8 (-4.1,5.6)	1.5 (-3.5,6.3)	1.4 (-3.6,6.5)	1.7 (-3.4,6.7)	1.6 (-3.4,6.8)
New York Fed	0.5 (-1.0,2.0)	0.4 (-1.2,2.0)	0.9 (-0.8,2.7)	0.8 (-1.0,2.5)	1.1 (-0.8,3.0)	1.1 (-0.8,2.9)
PRISM - Philadelphia Fed	0.1 (-2.7,3.0)	0.0 (-2.8,3.2)	0.5 (-3.0,3.2)	1.0 (-2.3,4.2)	1.3 (-1.7,4.7)	1.4 (-1.8,4.4)
Median*	0.5	0.4	0.9	1.0	1.3	1.4
June Tealbook	-		-		-	

Model	Output Gap (Q4)					
	2017		2018		2019	
	Jun	Mar	Jun	Mar	Jun	Mar
EDO - Board of Governors	-0.8 (-1.6,0.0)	-1.0 (-2.1,0.0)	-0.5 (-2.1,1.1)	-0.9 (-2.6,0.8)	-0.4 (-2.3,1.6)	-0.7 (-2.8,1.3)
New York Fed	-1.0 (-2.7,0.6)	-1.5 (-3.3,0.0)	-1.1 (-3.8,1.3)	-1.5 (-4.4,0.8)	-1.1 (-4.6,1.9)	-1.3 (-4.9,1.6)
PRISM - Philadelphia Fed	-1.6 (-2.8,-0.5)	-1.4 (-2.4,0.1)	-1.5 (-2.9,-0.1)	-1.4 (-2.4,0.2)	-1.3 (-2.8,0.2)	-1.2 (-2.4,0.6)
Median*	-1.0	-1.4	-1.1	-1.4	-1.1	-1.2
June Tealbook	1.3		1.9		2.0	

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 first quarter of 2017 and on a preliminary Tealbook forecast for the second quarter of 2017. Average real GDP growth is 2.8 percent over the forecast horizon (2017:Q3 to 2019:Q4), which is slightly below the estimated trend growth rate of 3 percent. Inflation reaches the Committee's 2 percent objective in the second quarter of 2018 and then slightly overshoots the target, reaching almost 2.3 percent at the end of 2019. The path for the federal funds rate slopes upward over the forecast horizon, reaching 3.6 percent by the end of 2019.

Recent data, including the nowcast for the second quarter of 2017, portray an economy in which unemployment is somewhat below the model's steady-state value of 5¼ percent, while consumption growth over the past few quarters has been mostly to the upside of the model's expectations. Despite several years of what the model perceives as unusually accommodative monetary policy, both investment and inflation have been generally disappointing, although investment has rebounded in the past few quarters.

In reaction to these data, the model interprets the path of unemployment and consumption growth as signaling that its main cyclical driver, the aggregate risk premium, is just below its steady state. An elevated risk premium on physical capital has held down investment until recently, but the negative effect has started to fade since the beginning of 2017. Inflation continues to surprise to the downside because of negative markup shocks.

Consistent with this interpretation of the data, the EDO model's near-term (2017:Q3 to 2017:Q4) forecast is boosted by the positive effects of negative aggregate risk premium shocks. However, these effects diminish rather quickly. Over the medium-term horizon, growth is restrained by the waning effects of unusually accommodative monetary policy and by the extremely persistent adverse movements in the capital-specific risk premium. As these headwinds gradually fade, GDP growth picks up again, reaching 2.7 percent at the end of 2019.

Largely responding to the still-low levels of the employment-to-population ratio, the model estimates an output gap of negative 1.2 percent in the second quarter of 2017.² The output gap closes very slowly and remains at negative 0.4 percent by the end of 2019. The real natural rate of interest is projected to increase from negative 0.7 percent in the second quarter of 2017 to 1.7 percent at the end of 2019, 0.4 percentage point below its steady-state value of 2.1 percent. The natural rate is held down mainly by the capital risk-premium shock.

The nowcast for GDP growth in the second quarter of 2017 is a touch weaker than the model expected in March, but the model attributes most of this unexpected weakness to transient factors that reverse rapidly in the forecast.³ Consequently, growth in 2017 is slightly higher than in the previous round, and it is 0.4 percent higher in 2018, mainly as a result of more negative markup shocks and higher capital-specific productivity. The nowcast for core inflation in the second quarter of 2017 is substantially below model expectations, with the discrepancy explained almost entirely by markup shocks in the current quarter. Although the same innovation to markups also lowers the near-term forecast for inflation, the overall forecast contour for the inflation rate over the forecast horizon remains similar to the previous round.

The New York Fed DSGE Model

The New York Fed model forecasts are obtained using data released through 2017Q1, augmented for 2017Q2 with the New York Fed staff forecasts (as of May 26) 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 2017Q2 averages up to May 26.

The model projects real GDP growth of 2.0 percent (Q4/Q4) in all 2017, 2018, and 2019. Relative to March, the projection for 2017 is slightly higher (it was 1.9 percent in March), but those for the medium and longer run are weaker, with the 2019 projection 0.5 percentage point lower than in March. The projections of inflation are revised downward throughout the horizon,

² The output gap is defined as actual output minus the level of output prevailing in the absence of nominal rigidities and inefficient markup shocks.

³ Note that the nowcast used for the March EDO forecast was a preliminary version of the March Tealbook projection.

reversing the uptick the model projected in March. These forecasts are 1.3 percent for both 2017 and 2018, and 1.4 percent in 2019, down from March projections of 1.6, 1.5 and 1.6 percent for 2017, 2018 and 2019, respectively. The projections are surrounded by notable uncertainty. The range of 68 percent probability interval for GDP growth is as large as 3.0 percentage points in 2017, from 0.4 to 3.4 percent, and widens over the forecast horizon, reaching 5.6 percentage points in 2019, from -0.8 to 4.8 percent. The 68 percent probability intervals for inflation range from 0.9 to 1.6 percent in 2017 and from 0.3 to 2.6 percent in 2019.

The slight upward revision in the near-term growth forecast reflects to a large extent the New York Fed staff forecasts for 2017Q2 which is larger than the model projected in March. For the medium and longer-term, the downward revisions of the model GDP growth projections result primarily from the model projection of weaker productivity growth throughout the forecast horizon. The decline in productivity depresses also the assessment of potential output, leading to a less negative output gap, relative to the March projections. Inflation projections are revised downward, despite the decline in productivity, due to negative mark-up shocks early in 2017. The projected path of the natural rate of interest is about 10 basis points higher than in March for 2017 and 2018, due to the persistent effects of the decline in corporate spreads that took place at the end of 2016.

Finally, the projected path for the federal funds rate is slightly flatter than in March, following the more subdued path of inflation, and it is shallower than the path of the April Tealbook, especially at the longer end.

The PRISM Model

The Philadelphia Research Intertemporal Stochastic Model (PRISM) forecast is constructed using data through 2017Q1 that are then supplemented with a 2017Q2 nowcast based on the most recent Macroeconomic Advisors model forecast.

PRISM forecasts that output growth will accelerate from a 1.9 percent pace in 2016 to 3.3 percent in 2019. The nowcast pins down real output growth in 2017Q2 at 3.1 percent. Growth gradually accelerates to a peak of about 3.3 percent in 2019Q2. Core inflation rises from 1.6 percent in 2017Q2 to 2 percent in early 2019. The PRISM projection has the funds rate following

an estimated policy rule through the forecast horizon: the federal funds rate rises to 1.9 percent in 2017Q4 and then advances steadily to reach 3.5 percent in 2019Q4.

We also forecast 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 0.1 percent in 2017Q2. As output growth strengthens and the economy normalizes to trend, the natural rate rises to reach about 1.3 percent at the end of 2019. Our estimates of the output gap are derived as the log deviation of real output from its flexible-price counterfactual level. The estimated output gap is at -1.5 percent in 2017Q2 and shrinks slowly over the next three years to reach -1.3 percent at the end of 2019.

According to PRISM, below trend output growth in 2017Q1 was largely due to negative shocks to TFP, the discount rate (financial shocks), and monetary policy. These shocks continue to act as a drag on output growth in the second quarter, but are offset by positive contributions from government spending shocks, investment shocks, and labor supply shocks. Going forward, the unwinding of TFP shocks exerts a small drag on output growth as do monetary policy and financial shocks. By mid- 2018, output growth is projected to rise above the model-estimated trend rate. The unwinding of past shocks to investment, government spending, and labor supply makes a positive contribution to output growth over the forecast horizon. Consumption growth ran at a healthy pace in 2016 driven by strong contributions from financial shocks. Going forward, consumption growth accelerates back to trend by 2019. Shocks to the marginal efficiency of investment led to above-trend investment growth over the last few quarters. As these shocks wane, investment growth settles at its trend pace of 3 percent by year's end. 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 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 2017Q2 nowcast for core PCE inflation is 1.6 percent. The model predicts that inflation rises gradually to 2 percent by early 2019. With inflation running close to trend over the next three years, 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 1.9 percent, rising to 3 percent in 2018Q4 and 3.5 percent in 2019Q4 -- a slightly slower pace of normalization compared to the March 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.