BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM

DIVISION OF MONETARY AFFAIRS

FOMC SECRETARIAT

Date: December 3, 2019

To: Federal Open Market Committee

From: Matthew M. Luecke

Subject: DSGE Models Update

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

System DSGE Project

Forecasts December 3, 2019

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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), New York Fed, Philadelphia Fed, and Chicago 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. The DSGE model forecasts were obtained using actual data through 2019Q3 and nowcasts for 2019Q4. EDO, the New York Fed model and the Philadelphia Fed model use their estimated policy rules to determine the federal funds rate path. In contrast, the Chicago Fed model uses the federal funds rate from the September Survey of Market Participants (adjusted for the developments in OIS markets since the SMP survey date) to pin down the funds rate for the next ten quarters. Thereafter, the model's estimated interest rate rule governs its policy forecasts. For the sake of comparison, the tables include the December Tealbook forecasts, as well as the DSGE model forecasts prepared for the September FOMC meeting. The tables and figures also present 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. Finally, they report 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 defined as the level of output that would prevail if prices and wages were fully flexible.

Turning first to GDP growth, the median forecast has growth equal to 2.1 percent in 2019, gliding down to 2 percent in 2020 and to 1.9 percent in 2021, with a modest rebound to 2.2 percent in 2022. The Tealbook forecasts are quite similar to the median DSGE forecasts; in particular, output growth equals 2.1 percent in 2019 and 2020 and 1.9 percent in 2021. At the end of the forecasting horizon, the Tealbook forecast is more pessimistic with growth settling at 1.7 percent. Compared to the September projections, the median DSGE forecasts declined 20 basis points for 2019 and 10 basis points for 2020 and 2021. All individual forecasts for 2019 have been adjusted downward inducing a downward revision of the median forecast for 2019. The latter is mostly due to the assumptions about a weak outlook for the fourth quarter of 2019. The Philadelphia Fed model predicts that output growth will be hovering around 2.3 percent throughout the forecast horizon. The New York Fed sees real output growth slowing down from 2 percent this year to 1.7

percent in 2020, and bouncing back to 2 percent and above in the following two years. EDO also predicts a slowdown for next year, from 2.1 percent in 2019 to 1.6 percent in 2020. However, contrary to the more optimistic scenario of the New York Fed model, EDO sees subdued output growth also in 2021 (1.8 percent). According to EDO, growth will be above potential only at the end of the forecasting horizon, reaching 2.2 percent in 2022. The Chicago Fed forecast is more favorable than other forecasts in the near term, but over the medium term it decreases sharply from 2.4 percent in 2020 to 1.4 percent in 2021 and to 0.8 percent in 2022.

Turning to inflation, the median forecast is 1.7 percent in 2019, which is unchanged from the September projection. The median forecast for inflation picks up to 2.2 percent in 2020 and settles 20 basis points above the FOMC target for the following years. Regarding the individual model forecasts, all of the forecasts have core PCE inflation below 2 percent in 2019. The Philadelphia Fed model forecasts inflation rising steadily from 1.8 percent in 2019 to 2.2 and 2.4 percent in 2021 and 2022 respectively. The EDO forecast is remarkably similar to the Philadelphia model forecast over the same forecast horizon. At the low end, the New York Fed model has inflation at 1.6 percent in 2019 sliding down to 1.3 percent in 2021 and 2022. The Chicago Fed model forecasts inflation essentially around the FOMC target over the medium term. The Tealbook forecast for inflation is at 1.6 percent for 2019. Going forward, inflation is just below the 2 percent target.

While all of the models expect the federal funds rate to be near 1.7 percent by the end of the year, the trajectories going forward vary substantially. EDO predicts that the federal funds rate will be at 2.9 percent at the end of 2020, followed by additional rate hikes that will nudge the federal funds rate close to 4 percent by the end of 2022. The Philadelphia Fed forecasts are slightly weaker; the federal funds rate is expected to reach 2.1 percent by the end of 2020 and the tightening cycle for 2021 and 2022 proceeds at a more moderate pace than in the EDO model. In particular, the forecasts for the federal funds rate are 2.9 and 3.2 percent for end of 2021 and 2022. The New York Fed forecast of the federal funds rate for the end of 2020 is close to the Philadelphia Fed one. However, going forward, the federal funds rate is expected to be lower, reaching 2.4 percent and 2.6 percent at the end of 2021 and 2022 respectively. The Chicago Fed instead sees a flat federal funds rate path until the end of 2021, largely reflecting the SMP and OIS data rather than rule-based monetary policy. The forecasted path of federal funds rate rises markedly to 2.7 percent by the end of 2022, when the rule base policy starts to govern the forecast. Of the four models' forecasts, that from New York resembles those from the Tealbook most closely.

The four models' estimates of the real natural rate of interest differ substantially from one another. For 2019, the estimates range from a low of negative 1.2 percent in the Chicago Fed model to a high of 1.5 percent in EDO model. All the models predict an upward path for the real neutral rate of interest. The Chicago Fed forecast increases to 0.3 percent in 2021 and to 0.5 percent in 2022. The Philadelphia forecast shows a full percent rise by the end of 2022. Similarly, the EDO model forecasts the real natural rate moving up from 1.5 percent to 1.9 percent by the end of the forecast horizon. The New York Fed model has the real natural rate forecast rising only modestly from 0.9 percent in 2019 to 1.2 percent in 2022. Note that the range of uncertainty surrounding estimates of the natural rate is large.

Estimates of the output gap also show substantial dispersion across the models and the forecasts differ on whether they see the output gap widening or shrinking over the next three years. As with the natural rate estimates, the uncertainty surrounding gap estimates is high. At the end of 2019, estimates range from the zero gap for the New York Fed to a high of 2.8 percent for the Chicago Fed model. Both the New York Fed and EDO models expect negative gaps until the end of the forecasting horizon. The Chicago Fed and Philadelphia Fed models, by contrast, expect positive output gaps which will be about to close at the end of 2022. The Tealbook forecast estimates the output gap at 1.5 percent at the end of 2019, edging up to 1.8 percent by the end of 2021, and settling at 1.7 percent by the end of 2022.

Model	Output Growth (Q4/Q4)						
	2019		2020		2021		2022
	December	*September*	**December**	*September*	**December**	*September*	**December**
EDO - Board of Governors	**2.1** **(2.1, 2.1)**	2.3 (1.7, 3.0)	**1.6** **(-0.2, 3.5)**	1.7 (-0.2, 3.7)	**1.8** **(-0.3, 3.8)**	2.0 (-0.1, 4.1)	**2.2** **(0.1, 4.4)**
New York Fed	**2** **(2.0, 2.0)**	2.4 (1.4, 3.3)	**1.7** **(-0.7, 4.1)**	2.0 (-0.9, 4.4)	**2** **(-0.6, 4.7)**	2.0 (-1.0, 4.5)	**2.2** **(-0.6, 4.9)**
PRISM - Philadelphia Fed	**2.1** **(2.1, 2.1)**	2.3 (1.4, 3.1)	**2.3** **(-0.1, 4.6)**	2.2 (-0.3, 4.7)	**2.4** **(-0.2, 5.0)**	2.3 (-0.5, 5.0)	**2.3** **(-0.3, 4.9)**
Chicago Fed	**2.1** **(2.1, 2.1)**	2.5 (1.6, 3.5)	**2.4** **(-1.9, 6.6)**	2.6 (-1.9, 7.1)	**1.4** **(-3.3, 6.1)**	1.6 (-3.1, 6.3)	**0.8** **(-4.0, 5.6)**
Median Forecast*	**2.1**	2.3	**2.0**	2.1	**1.9**	2.0	**2.2**
December Tealbook	**2.1**		**2.1**		**1.9**		**1.7**

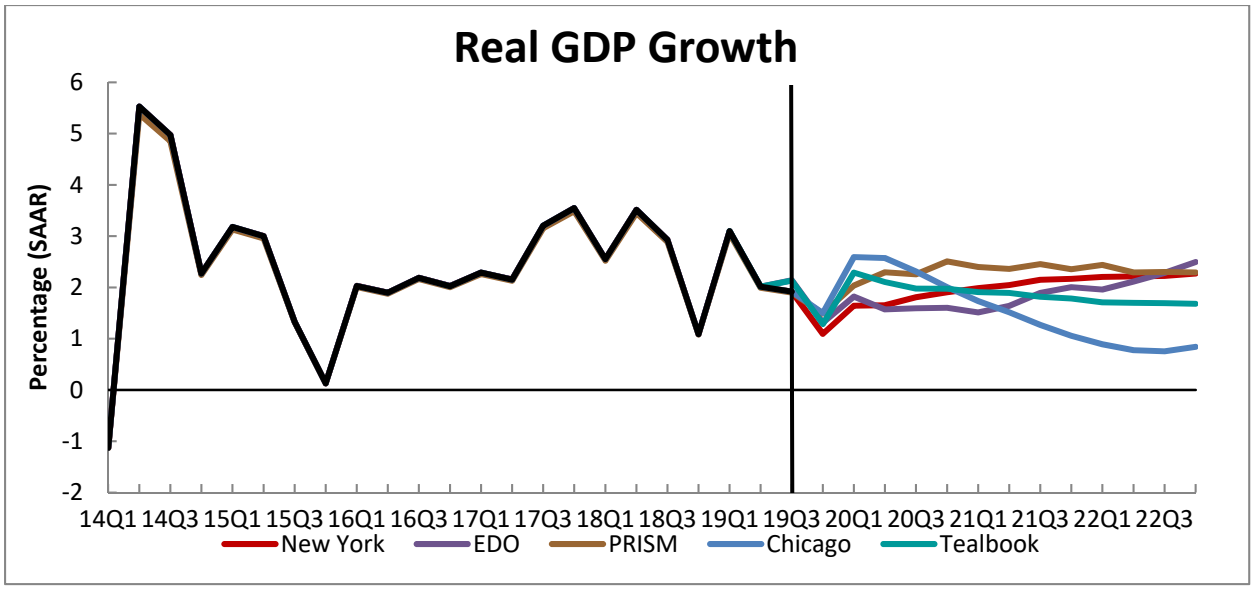
Model	Core PCE Inflation (Q4/Q4)						
	2019		2020		2021		2022
	December	*September*	**December**	*September*	**December**	*September*	**December**
EDO - Board of Governors	**1.6** **(1.6, 1.6)**	1.8 (1.6, 1.9)	**2.2** **(1.6, 2.8)**	2.3 (1.6, 3.0)	**2.4** **(1.6, 3.3)**	2.4 (1.5, 3.3)	**2.4** **(1.4, 3.3)**
New York Fed	**1.6** **(1.6, 1.6)**	1.6 (1.4, 1.8)	**1.3** **(0.6, 2.1)**	1.3 (0.4, 2.2)	**1.3** **(0.3, 2.4)**	1.3 (0.2, 2.4)	**1.4** **(0.2, 2.6)**
PRISM - Philadelphia Fed	**1.8** **(1.8, 1.8)**	1.9 (1.7, 2.2)	**2.2** **(1.1, 3.3)**	2.5 (1.2, 3.8)	**2.4** **(0.8, 3.9)**	2.5 (0.9, 4.1)	**2.4** **(0.7, 4.1)**
Chicago Fed	**1.7** **(1.7, 1.7)**	1.7 (1.3, 2.0)	**2.2** **(1.1, 3.4)**	2.1 (1.0, 3.3)	**2.1** **(0.9, 3.2)**	2.0 (0.8, 3.2)	**2** **(0.8, 3.2)**
Median Forecast*	**1.7**	1.7	**2.2**	2.2	**2.2**	2.2	**2.2**
December Tealbook	**1.6**		**1.9**		**1.9**		**1.9**

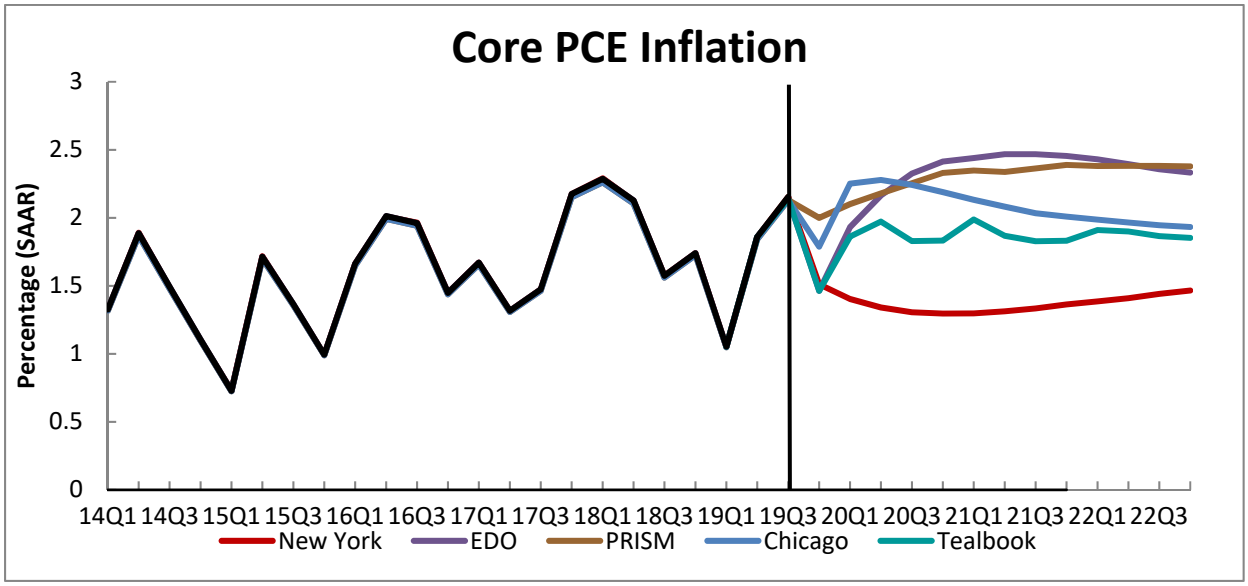
Model	Federal Funds Rate (Q4)						
	2019		2020		2021		2022
	December	*September*	**December**	*September*	**December**	*September*	**December**
EDO - Board of Governors	**1.6** **(1.6, 1.6)**	2.6 (2.1, 3.1)	**2.9** **(1.7,4.2)**	3.4 (2.0, 4.8)	**3.6** **(1.9, 5.3)**	3.8 (2.0, 5.6)	**3.9** **(2.0, 5.8)**
New York Fed	**1.7** **(1.7, 1.7)**	2.2 (1.2, 3.3)	**2.0** **(0.3,3.7)**	2.2 (0.7, 3.9)	**2.4** **(0.5, 4.2)**	2.4 (0.7, 4.2)	**2.6** **(0.6, 4.5)**
PRISM - Philadelphia Fed	**1.8** **(1.8, 1.8)**	2.4 (1.4, 3.4)	**2.1** **(-0.5,4.6)**	3.1 (0.0, 6.1)	**2.9** **(-0.9, 6.7)**	3.4 (-0.5, 7.5)	**3.2** **(-1, 7.6)**
Chicago Fed	**1.6** **(1.6, 1.6)**	1.8 (1.7, 1.9)	**1.7** **(0.9,2.5)**	1.5 (0.4, 2.5)	**1.8** **(0.1, 3.4)**	1.4 (-0.5, 3.2)	**2.7** **(0.5, 4.9)**
Median Forecast*	**1.7**	2.3	**2.0**	2.6	**2.6**	2.9	**3.0**
December Tealbook	**1.6**		**2.0**		**2.3**		**2.5**

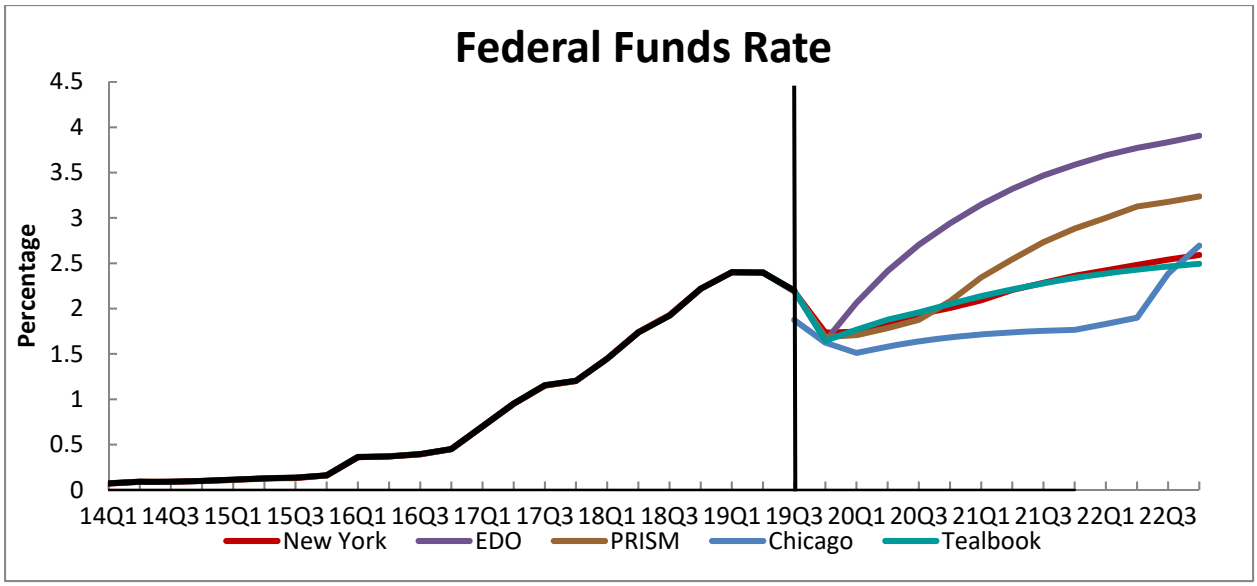
Model	Real Natural Rate of Interest r* (Q4)						
	2019		2020		2021		2022
	December	*September*	**December**	*September*	**December**	*September*	**December**
EDO - Board of Governors	**1.5** **(-0.3, 3.4)**	1.5 (-2.7, 5.7)	**1.7** **(-3.1, 6.8)**	2.1 (-2.9, 7.0)	**1.8** **(-3.2, 7)**	1.9 (-3.2, 6.8)	**1.9** **(-3.2, 6.8)**
New York Fed	**0.9** **(-0.2, 2.1)**	0.9 (-0.7, 2.6)	**0.9** **(-0.6, 2.4)**	1.1 (-0.8, 2.9)	**1** **(-0.5, 2.6)**	1.2 (-0.8, 3.1)	**1.2** **(-0.5, 2.8)**
PRISM - Philadelphia Fed	**1** **(0.7, 1.4)**	1.6 (-0.9, 4.1)	**0.9** **(-2.6, 4.3)**	1.8 (-2.1, 5.5)	**1.7** **(-2.7, 6.1)**	2.0 (-2.5, 6.6)	**2.1** **(-2.6, 6.6)**
Chicago Fed	**-1.2** **(-1.2, -1.2)**	-0.7 (-2.4, 1.1)	**-0.1** **(-2.9, 2.7)**	-0.3 (-3.3, 2.7)	**0.3** **(-2.9, 3.6)**	0.2 (-3.1, 3.5)	**0.5** **(-2.8, 3.9)**
Median Forecast*	**1.0**	1.0	**0.9**	1.3	**1.4**	1.7	**1.5**

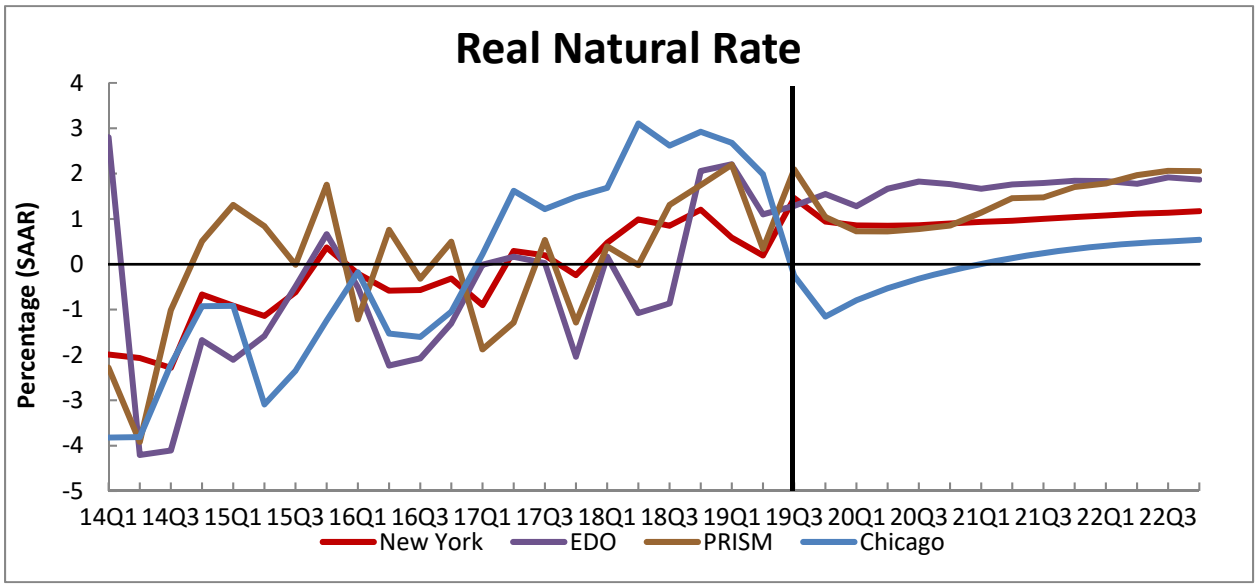
Model	Output Gap (Q4)						
	2019		2020		2021		2022
	December	*September*	**December**	*September*	**December**	*September*	**December**
EDO - Board of Governors	**0.2 (-0.3, 0.7)**	0.1 (-0.5, 0.8)	**-0.1 (-1.3, 1.2)**	-0.1 (-1.6, 1.3)	**-0.4 (-2.2, 1.4)**	-0.4 (-2.3, 1.4)	**-0.5 (-2.6, 1.5)**
New York Fed	**0.0 (-1.3, 1.3)**	0.3 (-1.4, 1.9)	**-0.3 (-2.4, 1.8)**	0.4 (-2.5, 2.8)	**-0.3 (-3.1, 2.4)**	0.5 (-3.3, 3.4)	**-0.2 (-3.5, 3.0)**
PRISM - Philadelphia Fed	**0.7 (0.6, 0.7)**	0.8 (0.6, 1.0)	**0.5 (0.0, 1.0)**	0.6 (0.0, 1.2)	**0.3 (-0.6, 1.2)**	0.3 (-0.6, 1.3)	**0.2 (-0.9, 1.2)**
Chicago Fed	**2.8 (2.8, 2.8)**	2.6 (2.2, 3.1)	**2.4 (0.9, 3.9)**	2.5 (0.7, 4.3)	**1.5 (-1.0, 4.0)**	1.7 (-1.1, 4.4)	**0.3 (-2.6, 3.3)**
Median Forecast*	**0.4**	0.5	**0.2**	0.5	**0.0**	0.4	**0.0**
December Tealbook	**1.5**		**1.8**		**1.8**		**1.7**

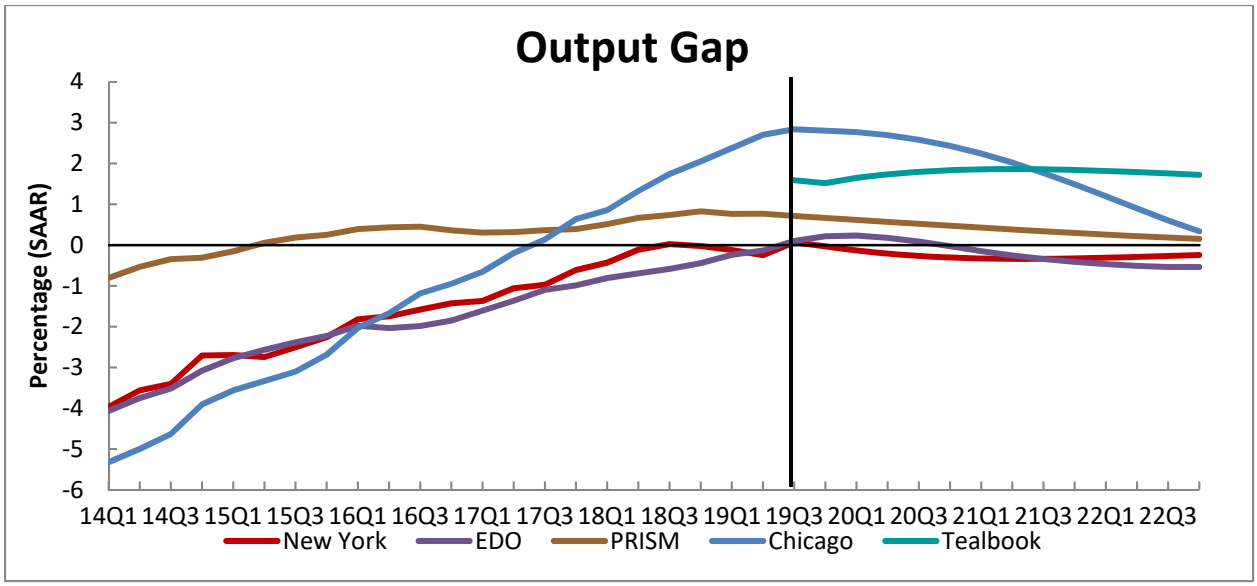
For each individual forecast, the numbers in parentheses represent 68% confidence bands.
*The median forecast is calculated as the median of the Q4/Q4 projections from the forecasters.


Real GDP Growth
Percentage (SAAR)
6
5
4
3
2
1
0
-1
-2
14Q1 14Q3 15Q1 15Q3 16Q1 16Q3 17Q1 17Q3 18Q1 18Q3 19Q1 19Q3 20Q1 20Q3 21Q1 21Q3 22Q1 22Q3
New York
EDO
PRISM
Chicago
Tealbook


Core PCE Inflation
Percentage (SAAR)
3
2.5
2
1.5
1
0.5
0
14Q1 14Q3 15Q1 15Q3 16Q1 16Q3 17Q1 17Q3 18Q1 18Q3 19Q1 19Q3 20Q1 20Q3 21Q1 21Q3 22Q1 22Q3
New York
EDO
PRISM
Chicago
Tealbook


Federal Funds Rate
Percentage
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
14Q1 14Q3 15Q1 15Q3 16Q1 16Q3 17Q1 17Q3 18Q1 18Q3 19Q1 19Q3 20Q1 20Q3 21Q1 21Q3 22Q1 22Q3
New York
EDO
PRISM
Chicago
Tealbook


Real Natural Rate
Percentage (SAAR)
4
3
2
1
0
-1
-2
-3
-4
-5
14Q1 14Q3 15Q1 15Q3 16Q1 16Q3 17Q1 17Q3 18Q1 18Q3 19Q1 19Q3 20Q1 20Q3 21Q1 21Q3 22Q1 22Q3
New York
EDO
PRISM
Chicago


Output Gap
Percentage (SAAR)
4
3
2
1
0
-1
-2
-3
-4
-5
-6
14Q1 14Q3 15Q1 15Q3 16Q1 16Q3 17Q1 17Q3 18Q1 18Q3 19Q1 19Q3 20Q1 20Q3 21Q1 21Q3 22Q1 22Q3
New York
EDO
PRISM
Chicago
Tealbook

Detailed Descriptions of Individual Model Forecasts

The EDO Model

The EDO model's forecast is conditional on data through the third quarter of 2019 and on a preliminary Tealbook forecast for the fourth quarter of 2019.

Real GDP growth is 1.9 percent on average, over the projection horizon, a touch below the average growth rate of potential output. The four-quarter inflation rate rises from 1.6 percent in the current quarter and reaches 2.4 percent in 2021 and 2022.

Potential GDP growth is about 1.9 percent over the projection horizon, held down below trend by the slow fading of adverse investment shocks. The output gap is currently estimated to be positive 0.2 percent, is projected to close at the end of 2020, and is expected to reach negative 0.5 percent at the end of the forecast period. The real natural rate of interest—estimated to be 1.5 percent in the fourth quarter of 2019—increases to 1.8 percent in 2021 and stays close to this value until the end of 2022, diverging from its long-run value of 2.2 percent. Both the output gap and natural rate of interest remain slightly, but stubbornly, below their long-run values as a result of persistent adverse shocks to investment over the past few years. Those shocks have depressed the current capital stock below the level that would have prevailed in the absence of nominal rigidities and are expected to restrain investment spending for quite a while in the forecast.

From the perspective of the model, inflation has been held down by persistently low wage growth, which has been surprisingly weak given the strength of aggregate demand. As wage markup shocks progressively fade, and because of the aforementioned adverse investment shocks and the accommodative stance of monetary policy, inflation is expected to rise and overshoot its target from 2020 to 2022. As the positive inflation gap and negative output gap offset, the federal funds rate increases toward its long-run value of 4.1 percent. The pace of the increase is gradual, reflecting the inertia in the Taylor rule. The federal funds rate reaches 3.6 percent by the end of 2021 and approaches 4 percent in 2022.

The employment and labor force participation data were stronger in 2019:Q3 than the EDO model had projected in September, and the model accounts for this surprise with persistent favorable labor supply shocks. The staff has, however, revised down its real GDP growth forecast for 2019. The downward revision to growth is attributable to a worse outlook for

investment due to adverse shocks to economy-wide total-factor productivity growth and capital-specific risk premiums. Recent data on PCE inflation in the third quarter of 2019, and the staff's forecast for the fourth quarter, were also weaker than the EDO model had projected in September. The model interprets these surprises as arising from price-markup shocks and carries some of that weakness into 2020. The output gap has revised up, particularly at the beginning of the forecast horizon. The natural rate of interest has also revised up in 2019, but is lower than the EDO model had projected in September in subsequent years. The path for the federal funds rate revised down considerably, following the two rate cuts in September and October.

The NY Fed Model

The New York Fed model forecasts are obtained using data released through 2019Q3, augmented for 2019Q4 with the New York Fed staff forecasts (as of November 19) for real GDP growth and core PCE inflation, and with values of the federal funds rate, and the yields on 10-year Treasuries and Baa corporate bonds based on 2019Q4 averages up to November 19.

The real economic outlook as seen through the lens of the New York Fed DSGE model has gotten somewhat worse than projected in September. Real GDP growth in 2019Q3 and the limited data available so far for the fourth quarter, as captured in our staff forecast, have been weaker than expected, leading to a fairly sizable downward revision to the forecast for GDP growth through 2021. These negative revisions—of 0.4 and 1 full percentage point in Q3 and Q4 respectively—led to a downgrade of expected growth in 2019 from 2.4 to 2 percent. This weakness further propagates to 2020, with growth estimated at 1.7 percent, but later recovering to 2 and 2.2 percent in 2021 and 2022. The inflation projection is the same as in September and remains extremely weak through the forecast horizon.

The model implied output gap, which was estimated to be positive in 2019 and to remain so through 2022, is now zero in 2019 and slightly negative in the next three years. The real natural rate is unchanged at 0.9 percent in 2019, rising to 1.2 percent in 2022, along an even shallower path than the one projected in September.

The Federal Funds Rate is expected to close the year at 1.7 percent, 50 basis points below the September projection, and to move only very gradually higher in the subsequent years, with roughly one and two 25 basis point hikes in 2020 and 2021 respectively. This shallower path

than the one projected in September reflects the model's weaker assessment of the economy, as well as the effects of recent accommodative monetary policy shocks.

The projections for all variables are surrounded by significant uncertainty. For instance, the 68 percent posterior probability interval for GDP growth includes negative readings for 2020, 2021 and 2022. In comparison, the posterior probability intervals for inflation are tighter, with their upper bound well below 3 percent throughout the forecast horizon.

The model attributes much of the recent unexpected weakness in GDP growth to negative shocks to the level of total factor productivity (TFP). The effect of these shocks would have been more significant in the absence of the recent policy accommodation. On its own, the combination of negative productivity shocks and accommodative monetary policy shocks would lift inflation. However, this positive effect is counterbalanced by negative markup shocks, which leave the inflation forecast unchanged.

The Philadelphia Model

The Philadelphia forecast is constructed using data through 2019Q3 that are then supplemented with a 2019Q4 current-quarter forecast based on staff judgement. For 2019Q4, real GDP growth is pegged at 1.5 percent, core inflation is at 2 percent, and the federal funds rate is at 1.7 percent. With this nowcast and the historical data in hand, the Philadelphia model estimates the current output gap at 0.7 percent and the natural real rate of interest at 1 percent.

Looking ahead, real GDP is expected to grow at 2.3 percent in 2020, and then edge up to 2.4 percent in 2021. Output growth is expected to be very close to our estimate of trend (2.4 percent) over the forecast horizon. Inflation rises from 1.75 percent in 2019 to an average pace of about 2.2 percent in 2020 and 2.4 percent in 2021 and 2022. Responding to above-target inflation, the federal funds rate rises from 1.7 percent in 2019Q4 to 3.2 percent in 2022Q4.

The natural rate of interest – the rate of interest that would prevail if wages and prices were full flexible – is expected to rise from 1 percent in 2019Q4 to 2.1 percent at the end of 2022. Our estimate of the output gap is derived from the log deviation of real output from its flexible-price counterfactual level. The gap stands at 0.7 percent in 2019Q4, and falls modestly over the forecast horizon – to 0.2 percent by 2022Q4.

According to the Philadelphia model, trend output growth over the forecast horizon is driven by positive contributions from investment specific technology shocks, government spending shocks, and matching efficiency shocks that are counterbalanced by negative

contributions from TFP shocks and discount factor shocks. Weak output growth in 2019Q4 is attributed to investment shocks, TFP shocks, and discount factor shocks. TFP shocks have acted as a drag on growth over the last several years and are expected to continue doing so over the next three years. The model sees consumption growth (nondurables and services) as running below trend over the next three years. After a particularly weak 2019Q4, consumption growth rebounds in 2020Q1 to about 1.5 percent growth, and then moves up slowly to just below 2 percent by the end of 2022. Investment growth quickly rebounds from a weak 2019Q4 and runs at an above-trend pace over the next three years, driven largely by contributions from investment shocks that offset downward pressure from TFP and discount factor shocks.

Core inflation is expected to run at a pace somewhat above the FOMC target over the forecast horizon reaching a peak of 2.4 percent in 2021Q4. Positive contributions to inflation come from TFP, markup, and discount factor shocks and are only partly offset by negative contributions from investment and government spending shocks.

The forecast is implemented with a rule-based federal funds rate path that sets the funds rate based on the lagged interest rate, inflation, and output growth. The funds rate moves up gradually over the forecast horizon, reaching 2.1 percent in 2020Q4, 2.9 percent in 2021Q4, and 3.2 percent in 2022Q4. The model currently has the steady state federal funds calibrated to 3.75 percent. Over the medium term, negative contribution from investment shocks, government spending shocks, and trend interest rate shocks pull the funds rate below its longer-run value. As these shocks wane, the funds rate rises and so moderates the rise in inflation over the medium term.

The Chicago Fed Model

The FRB Chicago DSGE model forecast is constructed using data through 2019Q3 supplemented by judgmental Macro Advisers assumptions for 2019Q4 GDP, consumption and investment. We included 2019Q4 expected inflation, both one-quarter ahead and over the next 10 years, taken from the fourth quarter SPF survey. We used data on expected future funds rates from the September 19 Survey of Market Participants augmented with OIS rate changes since then to determine the federal funds rate path for the next 10 quarters. The model rationalizes these expectations with forward guidance shocks. Beginning in 2022Q3, the model's estimated policy rule takes over. Market participant expectations do not smoothly transition into the federal funds rate path implied

by the rule. This suggests that the FOMC is communicating a relatively accommodative monetary policy stance.

The model sees mild growth in 2019 and 2020. The strong real activity data in the first semester of 2019 is somehow offset by a lower than expected Q3 number and by our assumptions about weak GDP growth in Q4, e.g. 1.5 percent. This results in an annual Q4/Q4 GDP growth rate slightly above potential in 2019 and in a GDP growth forecast of 2.4 percent for 2020. Relative to our previous round forecasts, the projections are revised downward for both 2019 and 2020, by 30 and 20 basis points respectively. Starting in 2021 the real economy will run below potential; and the slowdown is mostly attributable to the removal of monetary policy accommodation which acts as a drag for the economy until the end of our forecasting sample.

Our forecast for Q4/Q4 core PCE inflation is below target in 2019 (e.g. 30 bps). This is mostly due to the weak inflation numbers of the first semester of 2019. The model continues to interpret this deviation from target as temporary, e.g. mostly driven by markup shocks and by measurement errors, which have little persistence out of sample. As a consequence, inflation is forecasted to revert back to target relatively quickly and we do not foresee subdued inflation dynamics for the coming years. In particular, inflation equals 2.2 percent in 2020, 2.1 percent in 2021 and 2.0 percent in 2022. Overall, the model suggests that inflation will be close to the FOMC's target in the medium term.

We also forecast the natural rate of interest and the output gap. The natural rate is the contemporaneous spot rate on 3-month government bonds that would prevail if wages and prices were fully flexible and if markup shocks were absent. We measure the output gap as the log deviation of output from its flexible wage and price and markup free counterfactual. The model forecasts end-of-year output gaps for 2019 through 2022 of 2.8 percent, 2.4 percent, 1.5 percent and 0.3 percent. These gaps have been revised slightly downward relative to the analogous forecasts we reported in the previous DSGE memo. We forecast the (real) natural rate of interest at the end of the year for 2019 through 2022 to equal -1.2 percent, -0.1 percent, 0.3 percent and 0.5 percent.