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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

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Ozge Akinci[1]

Federal Reserve Bank of New York

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 2019Q2 and nowcasts for 2019Q3. 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 July 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 September Tealbook forecasts, as well as the DSGE model forecasts prepared for the June 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 2.3 percent in 2019, edging down to 2.1 percent in 2020 and to 2 percent in 2021 with a modest increase to 2.1 percent in 2022. Compared to the June projections, the median forecasts for 2019 and 2020 declined 0.2 percentage points, while the median forecast for 2021 remained unchanged. The revision of the median forecast for 2019 reflects slight downward revisions of the EDO, Philadelphia and Chicago forecasts, which were only partially offset by significant upward revisions to the New York Fed forecast. The latter were due to stronger than expected growth in the second quarter of 2019. The Tealbook forecasts for 2019 and 2020, at 2.1 percent and 2.0 percent, respectively, are 0.2 and 0.1 percentage points lower than the median forecasts. The Tealbook has output growth declining from 2.0 percent in 2020 to 1.8 percent in 2021 and to 1.7 percent in 2022, somewhat below the median. The Philadelphia Fed model predicts that output growth will be hovering around 2.2

percent throughout the forecast horizon. The New York Fed sees real output growth slowing down from 2.4 percent this year to 2 percent in 2020, and to around 1.9 percent in the following two years. EDO also predicts a slowdown from 2.3 percent this year to 1.7 percent next year. However, contrary to the New York Fed model forecasts, EDO has output growth increasing in the longer run from 2 percent in 2021 to 2.4 percent in 2022. The Chicago Fed forecast is more optimistic than other forecasts in the near term, but over the medium term it decreases sharply from 2.6 percent in 2020 to 1.6 percent in 2021 and to 0.9 percent in 2022.

Turning to inflation, the median forecast is 1.7 percent in 2019, which is unchanged from the June projection. The median forecast for 2020 shows inflation rising to 2.2 percent, and then hovering around that rate for the next two years. Regarding individual model forecasts, all of the forecasts have core PCE inflation below 2 percent in 2019. The Philadelphia Fed model forecasts inflation rising from 1.9 percent in 2019 to 2.4 percent in 2022. The EDO forecast is a tad lower than the Philadelphia model forecast over the forecast horizon, increasing from 1.8 percent in 2019 to 2.3 percent in 2022. At the low end, the New York Fed model has inflation at 1.6 percent in 2019, edging down to 1.4 percent in 2022. The Chicago Fed model forecasts inflation essentially at around the FOMC target over the medium term. The Tealbook forecast for inflation is just below the 2 percent target for all years over the forecast horizon.

While all of the models but the Chicago Fed model predict a rising path for the federal funds rate, their slopes vary substantially. EDO predicts that the federal funds rate will be at 2.6 percent at the end of 2019. The Philadelphia Fed forecast is slightly weaker at 2.4 percent, followed by the New York Fed at 2.2 percent, and the Chicago Fed at 1.8 percent. EDO predicts substantial further tightening in the following three years, with the federal funds rate reaching 4 percent by the end of 2022. Tightening proceeds less rapidly in the Philadelphia Fed model, whose forecasts for the federal funds rate are 3.1, 3.4 and 3.5 percent for end 2020, 2021 and 2022. On the low end, the New York Fed model predicts one 25 basis point hike sometime over the forecast horizon. The Chicago Fed model has a downward revision to its forecasted funds rate path – starting from 1.8 percent in 2019 and easing to 1.5 percent in 2020 and to 1.4 percent in 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 -0.7 percent in the Chicago Fed model to a high of 1.6 percent in Philadelphia model. All the models predict an upward path for the real neutral rate of interest. The Chicago Fed forecast increases to 0.2 percent in 2021 and to 0.5 percent in 2022. The Philadelphia forecast shows a 70 basis points 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 of the gap range from a low of 0.1 for EDO to a high of 2.6 percent for the Chicago Fed model. EDO predicts a small negative output gap, at -0.1 percent by the end of 2020, which edges further down to -0.4 percent by the end of the forecast horizon. All other models, by contrast, expect a slightly positive output gap at the end of 2022. The Tealbook forecast estimates the output gap at 1.5 percent at the end of 2019, edging up to 1.7 percent by the end of 2020 before gradually decreasing to 1.4 percent by the end of 2022.

Forecasts

Model	Output Growth (Q4/Q4)						
	2019		2020		2021		2022
	September	*June*	September	*June*	September	*June*	September
EDO - Board of Governors	**2.32** (1.69, 2.97)	2.4 (1.4, 3.5)	**1.68** (−0.24, 3.71)	2.2 (0.1, 4.2)	**1.97** (−0.09, 4.13)	2.3 (0.2, 4.4)	**2.44** (0.32, 4.54)
New York Fed	**2.37** (1.41, 3.30)	1.8 (0.3, 3.2)	**1.97** (−0.94, 4.42)	1.7 (-1.1, 4.2)	**1.95** (−0.99, 4.51)	1.7 (-1.1, 4.4)	**1.86** (−1.01, 4.57)
PRISM - Philadelphia Fed	**2.28** (1.44, 3.12)	2.5 (1.0, 4.0)	**2.21** (−0.27, 4.71)	2.7 (0.0, 5.6)	**2.27** (−0.46, 4.94)	2.8 (-0.1, 5.8)	**2.24** (−0.45, 4.94)
Chicago Fed	**2.50** (1.55, 3.46)	2.8 (0.7, 4.9)	**2.62** (−1.88, 7.12)	2.4 (-2.3, 7.0)	**1.56** (−3.13, 6.25)	1.4 (-3.4, 6.1)	**0.87** (−3.94, 5.67)
Median Forecast*	**2.3**	2.5	**2.1**	2.3	**2.0**	2.0	**2.1**
September Tealbook	**2.1**		**2.0**		**1.8**		**1.7**

Model	Core PCE Inflation (Q4/Q4)						
	2019		2020		2021		2022
	September	*June*	September	*June*	September	*June*	September
EDO - Board of Governors	**1.8** (1.63, 1.94)	1.7 (1.4, 2.0)	**2.3** (1.60, 3.04)	2 (1.2, 2.8)	**2.4** (1.48, 3.29)	2.1 (1.2, 3.1)	**2.3** (1.33, 3.28)
New York Fed	**1.6** (1.40, 1.81)	1.4 (1.0, 1.8)	**1.3** (0.43, 2.15)	1.4 (0.5, 2.3)	**1.3** (0.20, 2.35)	1.5 (0.4, 2.6)	**1.4** (0.20, 2.62)
PRISM - Philadelphia Fed	**1.9** (1.67, 2.19)	1.7 (1.1, 2.3)	**2.5** (1.23, 3.84)	2.3 (0.6, 3.9)	**2.5** (0.87, 4.08)	2.4 (0.5, 4.3)	**2.4** (0.67, 4.13)
Chicago Fed	**1.7** (1.27, 2.01)	1.9 (1.2, 2.4)	**2.1** (0.97, 3.28)	2.1 (1.2, 3.0)	**2.0** (0.80, 3.17)	2 (1.0, 2.9)	**1.9** (0.71, 3.12)
Median Forecast*	**1.7**	1.7	**2.2**	2.1	**2.2**	2.1	**2.1**
September Tealbook	**1.8**		**1.8**		**1.8**		**1.8**

Model	Federal Funds Rate (Q4)						
	2019		2020		2021		2022
	September	*June*	September	*June*	September	*June*	September
EDO - Board of Governors	**2.6**	2.9	**3.4**	3.4	**3.8**	3.8	**4.0**
	(2.10, 3.11)	(2.1, 3.7)	**(2.04, 4.79)**	(1.9, 5.0)	**(2.03, 5.55)**	(2.0, 5.6)	**(2.03, 5.96)**
New York Fed	**2.2**	2.4	**2.2**	2.5	**2.4**	2.7	**2.5**
	(1.15, 3.31)	(0.9, 3.9)	**(0.66, 3.93)**	(0.9, 4.3)	**(0.74, 4.23)**	(1.0, 4.5)	**(0.83, 4.58)**
PRISM - Philadelphia Fed	**2.4**	2.6	**3.1**	3.6	**3.4**	4.6	**3.5**
	(1.38, 3.38)	(1.2, 4.1)	**(0.04, 6.09)**	(0.1, 7.0)	**(−0.54, 7.49)**	(0.0, 9.1)	**(−0.82, 7.94)**
Chicago Fed	**1.8**	2.1	**1.5**	1.9	**1.4**	1.9	**2.7**
	(1.65, 1.92)	(1.8, 2.4)	**(0.43, 2.48)**	(0.6, 3.2)	**(−0.47, 3.18)**	(−0.1, 4.0)	**(0.42, 4.89)**
Median Forecast*	**2.3**	2.5	**2.6**	3.0	**2.9**	3.3	**3.1**
September Tealbook	**2.23**		**2.40**		**2.46**		**2.50**

Model	Real Natural Rate of Interest r* (Q4)						
	2019		2020		2021		2022
	September	*June*	September	*June*	September	*June*	September
EDO - Board of Governors	**1.5**	2.1	**2.1**	1.9	**1.9**	2	**1.9**
	(−2.66, 5.65)	(−2.6, 6.7)	**(−2.87, 6.98)**	(−3.1, 6.7)	**(−3.19, 6.83)**	(−3.2, 6.9)	**(−3.24, 6.78)**
New York Fed	**0.9**	1.2	**1.1**	1.3	**1.2**	1.3	**1.2**
	(−0.65, 2.56)	(−0.4, 2.8)	**(−0.76, 2.92)**	(−0.5, 3.1)	**(−0.79, 3.12)**	(−0.5, 3.2)	**(−0.78, 3.23)**
PRISM - Philadelphia Fed	**1.6**	0.8	**1.8**	1.3	**2.0**	2.2	**2.3**
	(−0.85, 4.07)	(−2.3, 3.8)	**(−2.05, 5.52)**	(−3.1, 5.7)	**(−2.47, 6.58)**	(−3.1, 7.4)	**(−2.31, 6.94)**
Chicago Fed	**−0.7**	0.1	**−0.3**	0.3	**0.2**	0.6	**0.5**
	(−2.38, 1.07)	(−2.1, 2.4)	**(−3.25, 2.65)**	(−2.8, 3.3)	**(−3.10, 3.47)**	(−2.7, 3.9)	**(−2.89, 3.87)**
Median Forecast*	**1.2**	1.0	**1.4**	1.3	**1.5**	1.7	**1.6**

| Model	Output Gap (Q4)						
	2019		2020		2021		2022
	September	*June*	September	*June*	September	*June*	September
EDO - Board of Governors	0.1	0	-0.1	-0.1	-0.4	-0.2	-0.4
	(–0.49, 0.76)	(–0.8, 0.8)	**(–1.59, 1.27)**	(–1.7, 1.4)	**(–2.30, 1.43)**	(–2.1, 1.7)	**(–2.60, 1.62)**
New York Fed	0.3	-0.4	0.4	-0.5	0.5	-0.6	0.5
	(–1.37, 1.88)	(–2.1, 1.2)	**(–2.48, 2.75)**	(–3.2, 1.8)	**(–3.25, 3.39)**	(–3.9, 2.3)	**(–3.74, 3.76)**
PRISM - Philadelphia Fed	0.8	0.9	0.6	0.8	0.3	0.6	0.1
	(0.63, 1.01)	(0.6, 1.2)	**(–0.02, 1.21)**	(0.0, 1.5)	**(–0.64, 1.27)**	(–0.4, 1.6)	**(–1.00, 1.23)**
Chicago Fed	2.6	2.9	2.5	2.4	1.7	1.3	0.5
	(2.24, 3.05)	(2.1, 3.7)	**(0.65, 4.33)**	(0.2, 4.6)	**(–1.06, 4.37)**	(–1.6, 4.3)	**(–2.54, 3.53)**
Median Forecast*	0.5	0.5	0.5	0.4	0.4	0.2	0.3
September Tealbook	1.5		1.7		1.6		1.4

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

Core PCE Inflation

Federal Funds Rate

Real Natural Rate

Output Gap
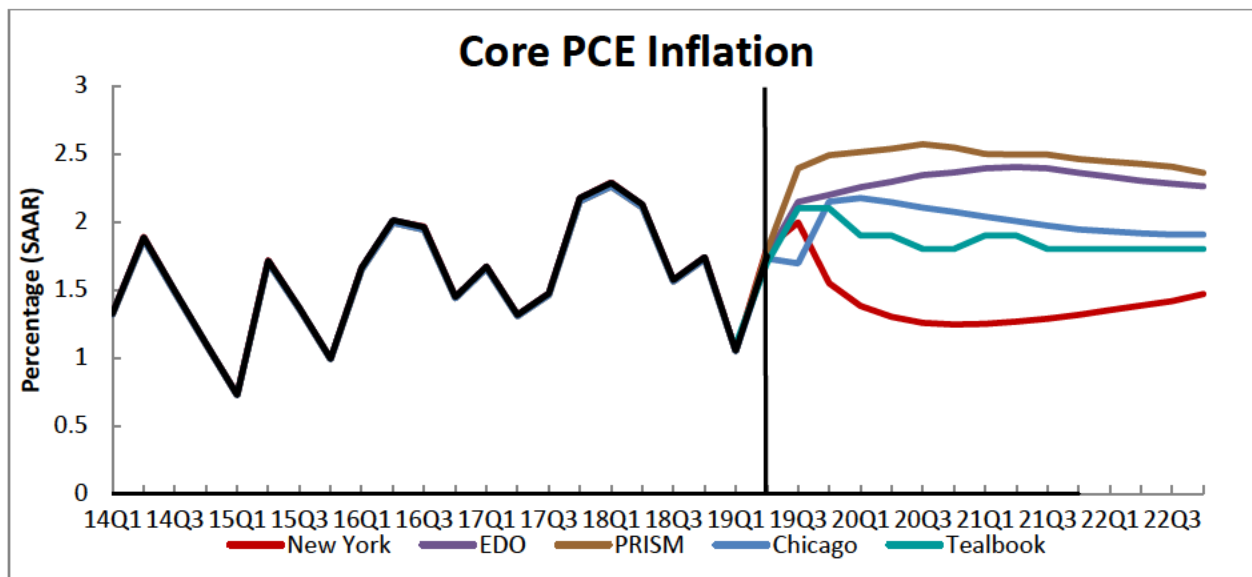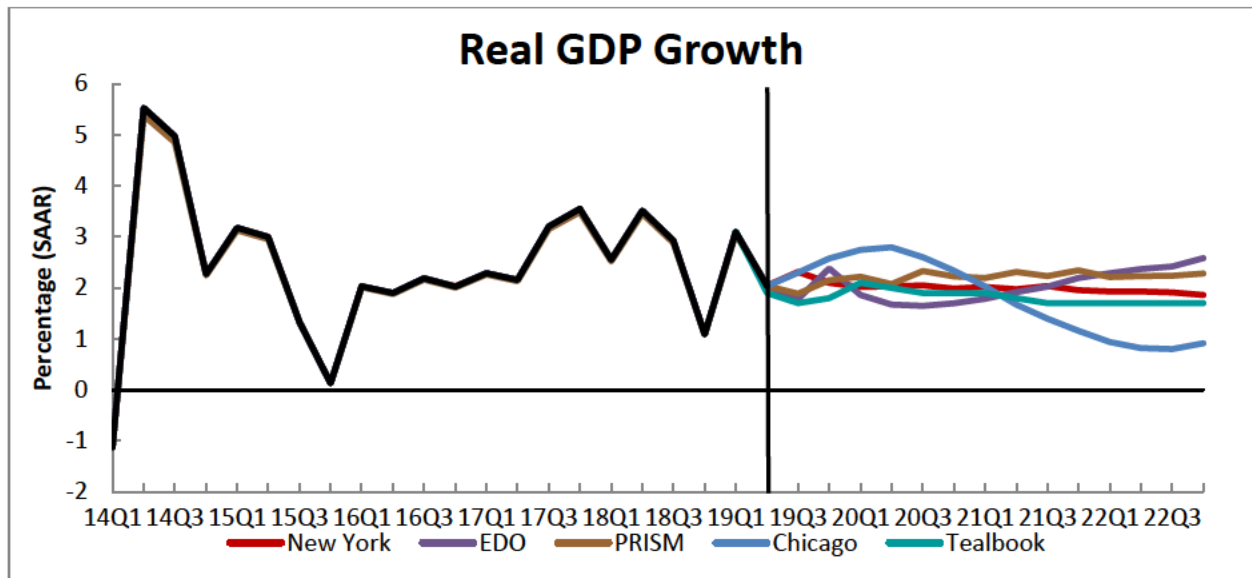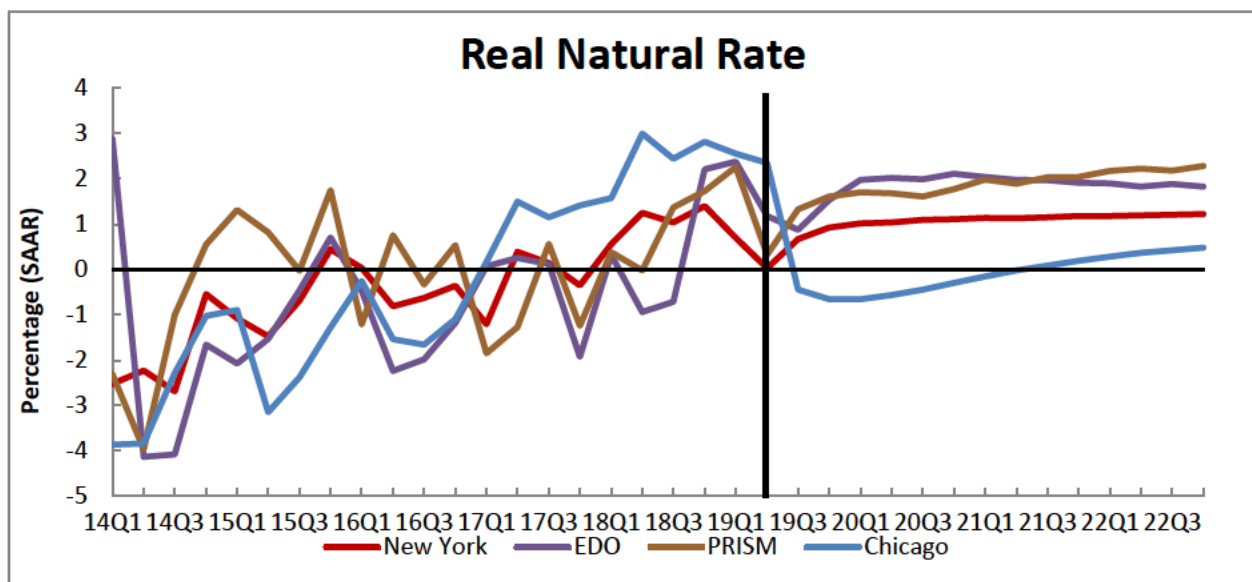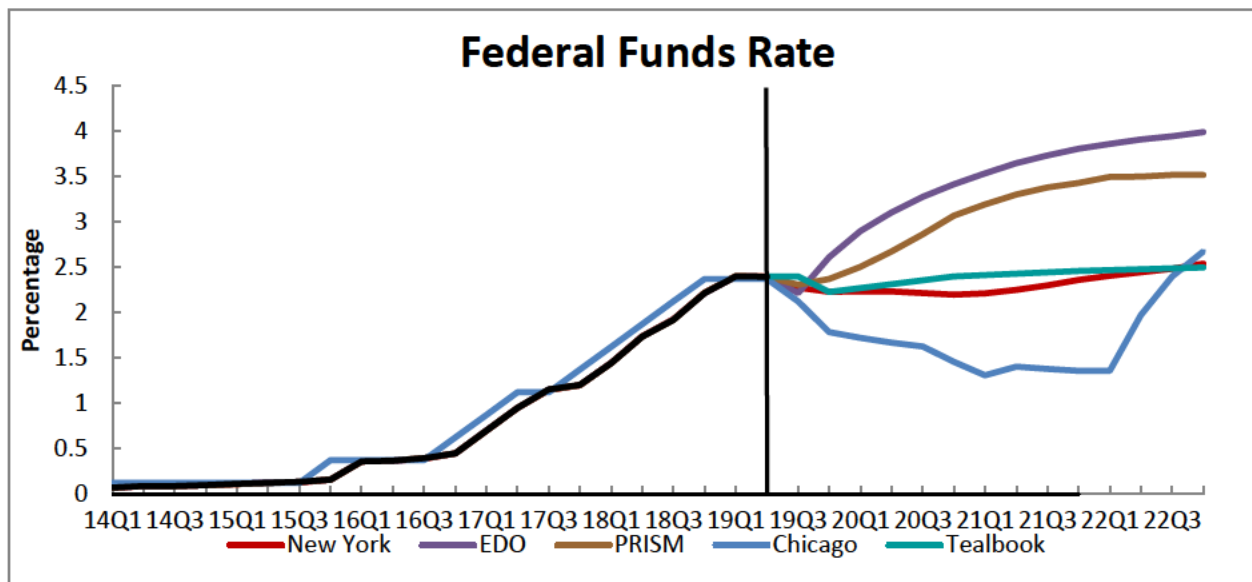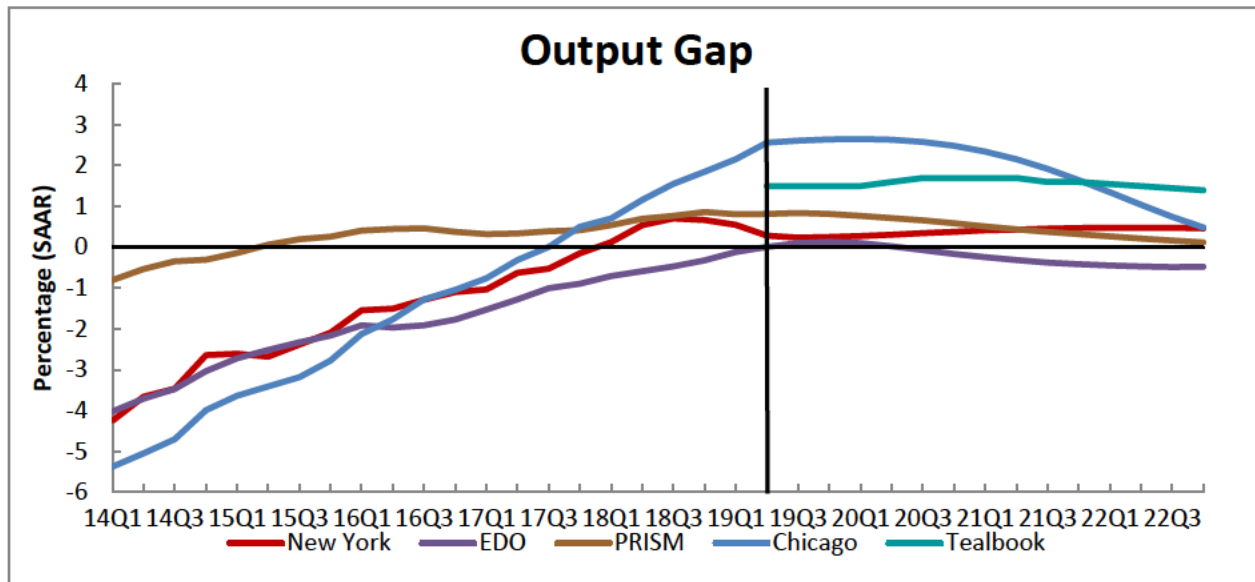
Detailed Descriptions of Individual Model Forecasts

The EDO Model

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

Real GDP growth is 2 percent, on average, over the projection horizon, slightly below the average growth rate of potential output. The inflation rate starts near 2 percent from the current quarter and reaches 2.4 percent until the end of 2021, before gradually falling towards the target by the end of forecast period.

Potential GDP growth is about 2¼ percent over the projection horizon, held down below trend by the slow fading of adverse risk premium shocks. The output gap is currently estimated to be positive 0.1 percent and is projected to turn negative in 2020, reaching negative 0.5 percent by the end of 2022. The real natural rate of interest—estimated to be 0.9 percent in the third quarter of 2019—approaches 2 percent in 2020 before it gradually declines to 1.8 percent by 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.

Due to positive wage markup shocks, the inflation rate is expected to overshoot the target on average during the forecast horizon. As the positive inflation gap and negative output gap offset each other out, the federal funds rate increases toward the long-run value of 4.1 percent as in the June round. The pace of the increase is gradual, reflecting the inertia in the Taylor rule. The federal funds rate reaches 3¾ percent by the end of 2021, a bit below its long-run value.

The data on 2019:Q2 GDP growth were stronger than the EDO model had projected in June, and the model accounts for about half of the surprise with a temporary boost to total factor productivity and, for about another half, with a decline in the aggregate risk premium. After 2019Q2, however, real GDP growth is revised down throughout the forecast period. The downward revision to growth is attributable to a worse outlook for investment as a result of adverse shocks to capital-specific technology and capital-specific risk premiums. In addition, real wage growth in the first quarter of 2019 was also much stronger than the model had

anticipated, leading it to infer much higher wage markups and further depressing the GDP growth forecast over the next few years.

By contrast, recent data on PCE inflation in the first quarter of 2019 were much weaker than the EDO model had projected in June. However, the previously mentioned positive wage markup shocks dominate the inflation forecast revisions, raising the core inflation rate over the projection horizon. As a result of the drag on real activity, both the output gap and the natural rate of interest have also revised down, particularly toward the end of the forecast horizon. The forecast for the federal funds rate in 2019 has revised down 0.3 percentage point, as the contribution to the funds rate from higher inflation in that year outweighs the effects of the negative revisions to the output gap. By 2021, however, the current forecast of the federal funds rate is close to the June projection, as the upward revision in inflation is perfectly offset by the downward revision in output gap, leaving the federal funds rate unchanged from the June projection.

The NY Fed Model

The New York Fed model forecasts are obtained using data released through 2019Q2, augmented for 2019Q3 with the New York Fed staff forecasts (as of August 29) 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 2019Q3 averages up to August 29.

Real GDP growth in 2019Q2 turned out to be higher than the model expected, leading to an upward revision of the projections for real activity, especially in the short run. The model projects growth of 2.4 percent in 2019 on a Q4/Q4 basis, somewhat above the June forecasts of 1.8 percent. Growth is projected to slow down to 2 percent in 2020 and to 1.9 percent in 2021 and 2022. For comparison, in the June projections GDP growth was anticipated to be 1.6 percent in 2020, and 1.8 percent in both 2021 and 2022. The model predicts a slightly stronger inflation outlook in 2019, at 1.6 percent (Q4/Q4) relative to 1.4 percent in the June projection. This projection reflects the current New York Fed staff judgmental forecast, which is somewhat more optimistic than the model's unconditional assessment of a 1.3 percent inflation rate for this year. Inflation is projected to ease to 1.3 percent in 2020, and remain steady at that rate in 2021 with a modest increase to 1.4 percent in 2022, a path slightly weaker than the medium run inflation outlook projected in June.

The model implied output gap is estimated to be modestly positive in 2019 while June projections had predicted a small negative gap, 0.3 percent compared with -0.4 percent. The gap is expected to tick up to 0.4 percent in 2020 and to 0.5 percent in both 2021 and 2022. Compared to the June estimate the natural rate of interest is projected to be slightly lower at 0.9 percent in 2019. The natural rate is expected to move up gradually to 1.1 percent in 2020, and to 1.2 percent in both 2021 and 2022. The Federal Funds Rate is forecast to have a shallower path than anticipated in June, increasing gradually from 2.2 percent in 2019 to 2.5 percent in 2022 (down from the corresponding June forecast of 2.4 percent in 2019 and 2.8 percent in 2022).

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 stronger than expected real GDP growth in the second quarter of 2019 to a positive and persistent productivity growth shock that increases the real GDP projections throughout the forecast horizon and lowers inflation over the medium run. As the effect of this favorable productivity shock diminishes, growth is projected to slow down gradually from the above average growth in 2019 towards potential in the following years. The tightening of financial conditions that took place in late 2018 and early 2019 along with a gradual withdrawal of monetary accommodation throughout the forecast horizon also act as a drag on growth over the medium term. The model projects inflation to be persistently below the FOMC's long run goal, driven primarily by negative shocks to wage and price markups, but also by the still lingering effects of the financial headwinds that hampered the recovery. The Federal Funds Rate path is projected to remain below its long-run level of 4 percent throughout the forecast horizon owing to persistence in the interest rate rule and a weak inflation projection.

The Philadelphia Model

The Philadelphia forecast is constructed using data through 2019Q2 that are then supplemented with a 2019Q3 current-quarter forecast based on staff judgement. For 2019Q3, real GDP growth is pegged at 1.9 percent, core inflation is at 2.4 percent, and the federal funds rate is at 2.3 percent. With this nowcast and the historical data in hand, the Philadelphia model estimates the output gap at 0.9 percent and the natural real rate of interest at 1.3 percent in 2019Q3.

Looking ahead, real GDP is expected to grow at 2.3 percent in 2019, and then at about the same pace over the span 2020-2022. Output growth is expected to be slightly below our estimate of trend (2.4 percent) over the forecast horizon. With output growing at a slightly below-trend pace, inflation rises from 1.9 percent in 2019 to an average pace of about 2.5 percent over the next three years. Responding to above-target inflation, the federal funds rate rises from 2.4 percent in 2019Q4 to 3.5 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 1.3 percent in 2019Q3 to 2.3 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 0.8 percent in 2019Q3, and falls modestly over the forecast horizon – to 0.12 percent by 2022Q4.

According to the Philadelphia model, below-trend output growth over the forecast horizon is driven by positive contributions from investment specific technology shocks and government spending shocks that are partially offset by negative contributions from TFP shocks and discount factor shocks. Over the past few quarters, markup shocks made a significant contribution to output growth, but their relevance recedes quickly and so do not meaningfully contribute to future growth. 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 anticipates that output growth edges up to about 2.3 percent in mid-2021 and then stays near that pace through the end of 2022. The model sees consumption growth (nondurables and services) as running below trend, on average, over the next two years. But consumption growth rises gradually over the forecast horizon to reach a 2 percent pace by the end of 2022. Investment growth, however, is expected to be 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 2.6 percent in 2020Q3. 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. By 2019Q4 the funds rate averages 2.4 percent and rises steadily to 3.5 percent at the end of 2022. This represents less acceleration in the funds rate compared to our June forecast. However, this is due not to a

change in the forecast per se, but rather to a change in the way we model the longer term trend in the funds rate. The model currently has the equilibrium federal funds calibrated to 3.75 percent. Over the medium term, negative contribution from investment shocks, government spending shocks, and the 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 2019Q2 supplemented by judgmental Macro Advisers assumptions for 2019Q3 GDP, consumption and investment. We included 2019Q3 expected inflation, both one-quarter ahead and over the next 10 years, taken from the third quarter SPF survey. We used data on expected future funds rates from the July 22 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 2022Q2, the model's estimated policy rule takes over. Market participant expectations do not smoothly transitions 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 positive growth for 2019 and 2020. This mostly embodies strong real activity data in the first semester of the year and solid growth projections for the coming year, which generates an annual Q4/Q4 GDP growth rate of 2.6 percent. Relative to our previous round forecasts, the projections are revised slightly downward for 2019 and upward for 2020, by 20 and 10 basis points respectively. The model interprets this as the results of positive technology shocks, improvements in the marginal efficiency of investment and an accommodative monetary policy stance. These favorable conditions are not going to last after 2020 and the removal of monetary policy accommodation will act as a drag for the real economy in 2021.

Our forecast for Q4/Q4 core PCE inflation is below target in 2019 (e.g. 35 bps). This is mostly due to the weak inflation data in the first semester of 2019. The model interprets 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 2.1 percent in 2020, 2 percent in 2021 and 1.9 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. We measure the output gap as the log deviation of output from its flexible wage and price counterfactual. The model forecasts end-of-year output gaps for 2019 through 2022 of 2.6 percent, 2.5 percent, 1.7 percent and 0.5 percent. These gaps have not changed much from 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 -0.7 percent, -0.3 percent, 0.2 percent and 0.5 percent.