

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

**DIVISION OF MONETARY AFFAIRS**

**FOMC SECRETARIAT**

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**Date:** March 13, 2019  
**To:** Federal Open Market Committee  
**From:** Matthew M. Luecke  
**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**

March 12, 2019

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<sup>1</sup>We thank Keshav Dogra, Michael Siemer and Keith Sill for their contributions.

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), Philadelphia Fed, New York 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 2018Q4 and nowcasts for 2019Q1. The New York Fed, Philadelphia Fed and EDO models 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 January Survey of Market Participants (augmented using developments in OIS markets since the SMP survey date) to pin down the funds rate for the next ten quarters. Thereafter, that model's estimated interest rate rule governs its policy forecasts. For the sake of comparison, the tables include the March Tealbook forecasts, as well as the DSGE model forecasts prepared for the December FOMC meeting. The Philadelphia Fed has substantially altered its forecasting methodology, so its forecasts from December are not comparable to its current forecasts. 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 for 2019 has dropped six tenths to 1.6 percent. This reflects substantial downward revisions for EDO, the New York Fed, and the Chicago Fed. The median forecasts for 2020 and 2021 are each down one tenth. The Tealbook forecasts for 2019 and 2020, at 1.8 percent and 2 percent, respectively, are close to the median forecasts. However the Tealbook has output growth stepping down to 1.5 percent in 2021 from 2 percent in 2020 while our median forecast has it holding steady at 2 percent. EDO, the New York Fed, and the Philadelphia Fed all predict constant or increasing output growth from 2020 to 2021.

However, the Chicago Fed forecasts qualitatively share the Tealbook's pessimism about developments from 2020 to 2021.

Turning to inflation, our median forecasts for 2020, 2021 and 2022 are all very close to the committee's 2 percent target. Both EDO and the Philadelphia Fed model have core PCE inflation exceeding the 2 percent target by two tenths in 2019. In contrast, the New York Fed and Chicago Fed models forecast 2019 core PCE inflation at 1.5 percent and 1.8 percent respectively. New York's weak forecasts for inflation persist through 2021. EDO predicts inflation to be two tenths over target in 2020 and 2021, Philadelphia predicts it to be four tenths over target for 2020 and 2021, and the Chicago Fed predicts inflation at target over those years. The Tealbook forecast for inflation equals the 2 percent target for all years over the forecast horizon.

While all of the models predict a rising path for the federal funds rate, their slopes vary substantially. On the high end, EDO and Philadelphia Fed model predict that the federal funds rate will equal 3.1 percent and 2.9 percent, respectively, at the end of 2019. EDO predicts modest further tightening in 2020 and 2021, with the federal funds rate ending those years at 3.5 percent and 3.7 percent. In contrast, tightening proceeds rapidly in the Philadelphia Fed model. Its forecasts for the federal funds rate equal 4.0 and 4.8 percent for the end of 2020 and 2021. On the low end, the New York Fed model predicts one 25 basis point hike sometime over the forecast horizon. The Chicago Fed model's predictions lie between these extremes, but they reflect the SMP and OIS data rather than rule-based monetary policy. Of the four models' forecasts, that from EDO resembles those from the Tealbook most closely

The four models' estimates of the real natural rate of interest differ substantially from one another. Their backcasts for 2018 range from 0.7 percent (Philadelphia) to 2.3 percent (Chicago). For 2019, the New York Fed and Philadelphia Fed models both predict the natural rate to approximately equal 1.25 percent. New York Fed's real natural rate forecast stays relatively unchanged over the forecast horizon, while Philadelphia's increases substantially. EDO and the Chicago Fed model also predict relatively constant paths for the real natural rate of interest, but their initial values differ dramatically. Their predictions for 2019 equal 1.8 percent and 0.6 percent, respectively.

Estimates of the output gap as of the end of 2018 also show substantial dispersion across the models. Both EDO and the New York Fed model estimate it at -0.2 percent, while both the

Philadelphia Fed and the Chicago Fed models estimate it at 1.0 percent. All of these estimates lie well below the Tealbook backcast of 1.9 percent. EDO and the New York Fed Models predict that the output gap will deteriorate over the course of the forecast horizon. The Philadelphia Fed model predicts that the output gap will evolve slowly towards its neutral rate of zero over the forecast horizon, while the Chicago Fed model forecasts that the same evolution will occur much more quickly and overshoot slightly into negative territory in 2021. None of the models share the Tealbook's forecast of a persistently high output gap.

## Forecasts

Model	Output Growth (Q4/Q4)							
	2018		2019		2020		2021	
	March	December	March	December	March	December	March	December
EDO - Board of Governors	3.1 (3.1,3.1)	3.0 (3.0,3.0)	1.5 (0.1,3.0)	2.1 (0.3,4.0)	1.9 (-0.1,4.0)	2.1 (0.1,4.1)	2.3 (0.1,4.4)	2.4 (0.2,4.6)
New York Fed	3.1 (3.1,3.1)	3.1 (3.1,3.1)	1.6 (-0.4,3.5)	2.0 (-0.6,4.3)	1.7 (-1.2,4.2)	1.9 (-1.0,4.5)	1.7 (-1.1,4.4)	1.9 (-1.0,4.6)
Philadelphia Fed	3.1 (3.1,3.1)	3.1 (3.1,3.1)	2.2 (0.1,4.3)	3.3 (0.5,6.4)	2.7 (-0.1,5.5)	3.3 (0.0,6.7)	2.7 (-0.2,5.7)	3.1 (-0.2,6.7)
Chicago Fed	3.1 (3.1,3.1)	3.3 (3.3,3.3)	1.3 (-1.9,4.4)	2.2 (-2.1,6.5)	2.1 (-2.6,6.7)	2.1 (-2.6,6.8)	1.8 (-2.9,6.6)	1.8 (-3.0,6.6)
Median Forecast*	3.1	3.1	1.6	2.2	2.0	2.1	2.0	2.1
March Tealbook	3.1		1.8		2.0		1.5	

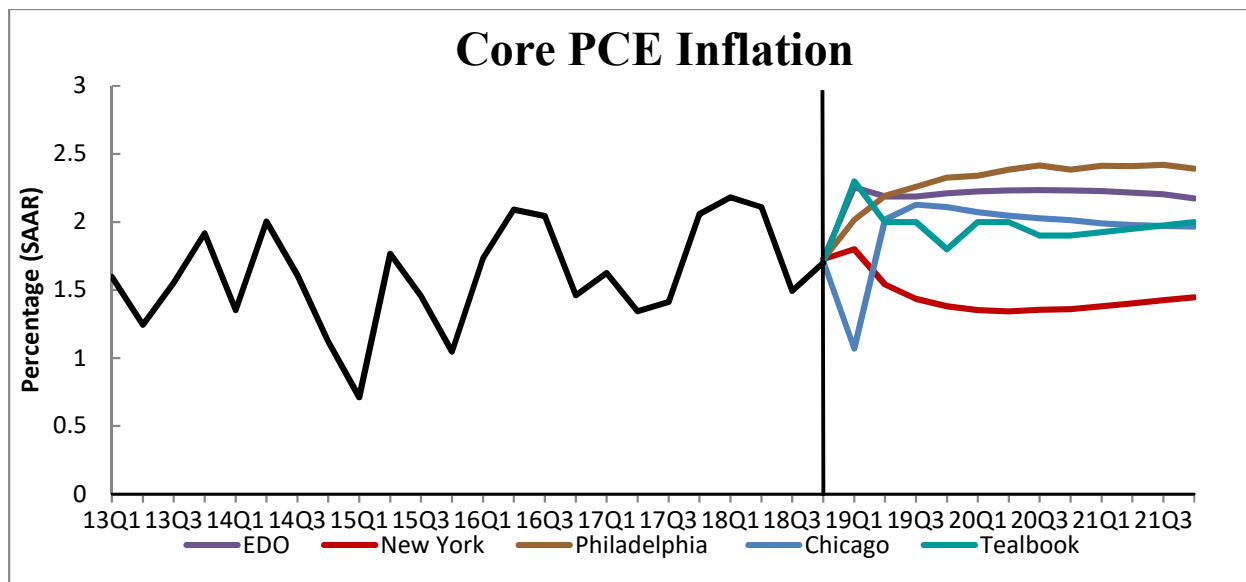
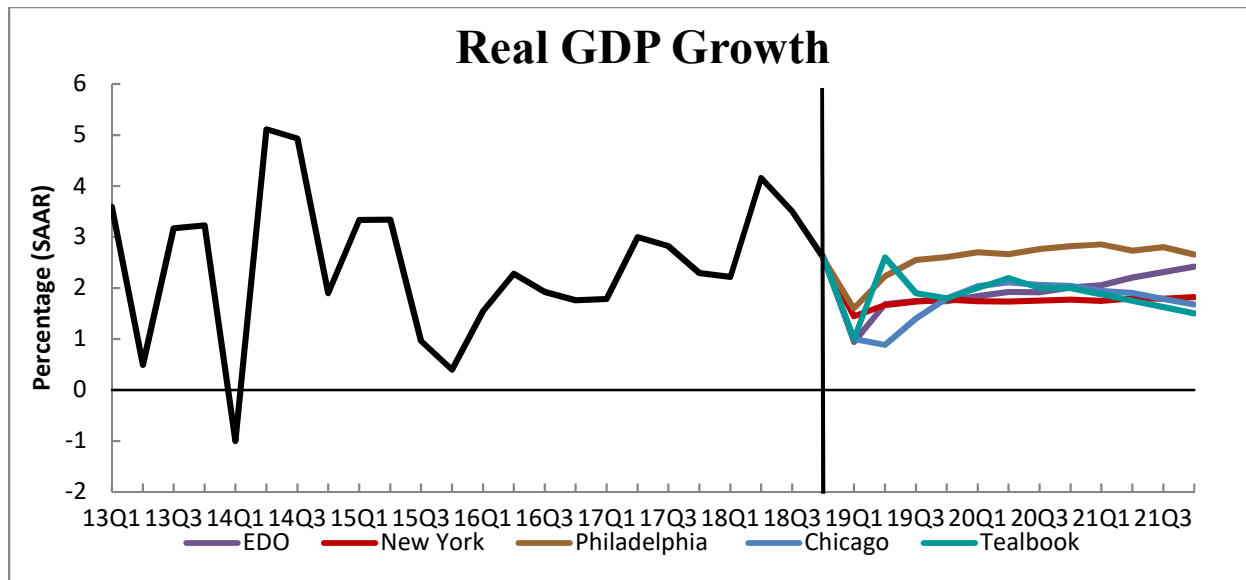
Model	Core PCE Inflation (Q4/Q4)							
	2018		2019		2020		2021	
	March	December	March	December	March	December	March	December
EDO - Board of Governors	1.9 (1.9,1.9)	1.9 (1.9,1.9)	2.2 (1.7,2.7)	1.9 (1.3,2.5)	2.2 (1.4,3.1)	2.2 (1.3,3.0)	2.2 (1.4,3.1)	2.2 (1.3,3.0)
New York Fed	1.9 (1.9,1.9)	1.8 (1.9,1.9)	1.5 (1.0,2.1)	1.4 (1.3,2.5)	1.4 (0.3,2.3)	1.4 (1.3,3.0)	1.4 (0.3,2.6)	1.5 (1.3,3.0)
Philadelphia Fed	1.9 (1.9,1.9)	2.0 (2.0,2.0)	2.2 (1.2,3.1)	2.1 (0.9,3.2)	2.4 (0.6,4.1)	2.2 (0.7,3.7)	2.4 (0.4,4.4)	2.2 (0.7,3.8)
Chicago Fed	1.9 (1.9,1.9)	2.0 (2.0,2.0)	1.8 (1.3,2.9)	2.1 (1.3,2.9)	2.0 (1.2,2.9)	2.0 (1.1,2.9)	2.0 (1.1,2.9)	2.0 (1.1,2.9)
Median Forecast*	1.9	1.9	2.0	2.0	2.1	2.1	2.1	2.1
March Tealbook	1.9		2.0		2.0		2.0	

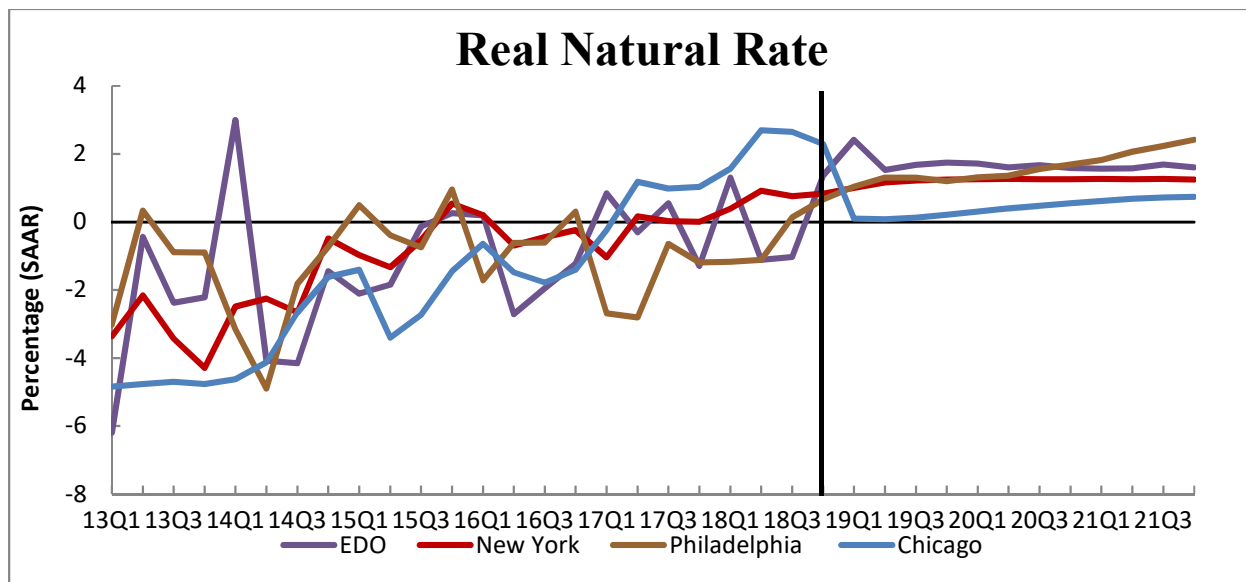
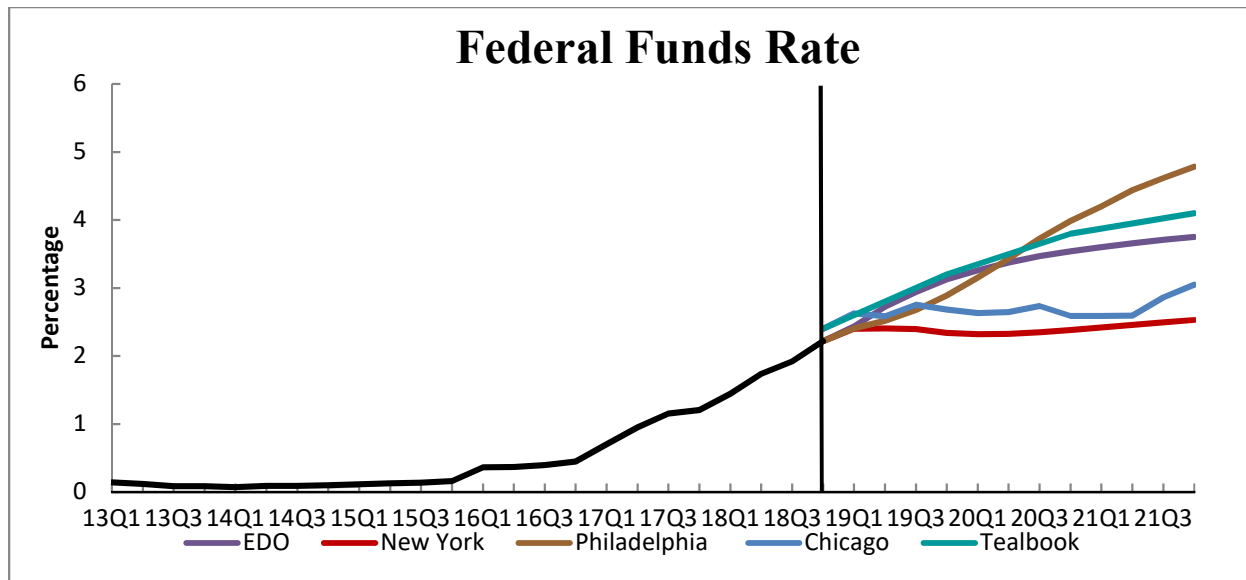
Model	Federal Funds Rate (Q4)							
	2018		2019		2020		2021	
	March	December	March	December	March	December	March	December
EDO - Board of Governors	2.2 (2.2,2.2)	2.2 (2.2,2.2)	3.1 (2.1,4.2)	3.2 (2.0,4.4)	3.5 (1.9,5.2)	3.7 (1.9,5.4)	3.7 (1.9,5.6)	3.9 (2.0,5.8)
New York Fed	2.2 (2.2,2.2)	2.2 (2.2,2.2)	2.3 (0.7,3.9)	2.4 (0.9,4.1)	2.4 (0.7,4.2)	2.6 (0.9,4.4)	2.5 (0.8,4.5)	2.8 (0.9,4.8)
Philadelphia Fed	2.2 (2.2,2.2)	2.2 (2.2,2.2)	2.9 (0.9,4.8)	3.0 (1.6,4.5)	4.0 (0.1,8.0)	3.5 (1.1,5.7)	4.8 (0.1,9.5)	4.0 (1.2,6.4)
Chicago Fed	2.4 (2.4,2.4)	2.4 (2.4,2.4)	2.8 (2.3,3.4)	3.1 (2.3,3.9)	2.9 (1.4,4.4)	3.1 (1.4,4.8)	3.0 (0.8,5.2)	3.2 (0.9,5.5)
Median Forecast*	2.2	2.2	2.9	3.0	3.2	3.3	3.4	3.5
March Tealbook	2.4		3.2		3.8		4.1	

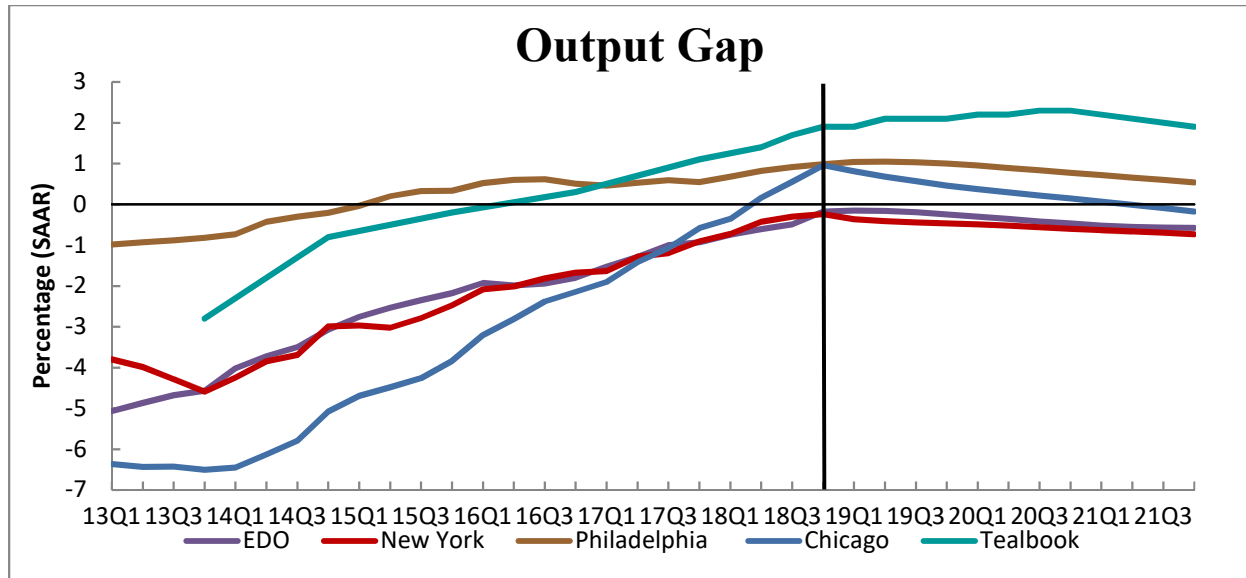
Model	Real Natural Rate of Interest r* (Q4)							
	2018		2019		2020		2021	
	March	December	March	December	March	December	March	December
EDO - Board of Governors	1.4 (-0.4,3.2)	2.2 (0.5,4.0)	1.8 (-3.1,6.5)	1.9 (-2.9,6.9)	1.6 (-3.4,6.5)	1.8 (-3.3,6.8)	1.6 (-3.5,6.4)	1.9 (-3.1,7.0)
New York Fed	0.8 (0,1.7)	1.2 (-0.1,2.5)	1.3 (-0.5,2.9)	1.3 (-0.4,3.0)	1.3 (-0.6,3.1)	1.3 (-0.5,3.2)	1.2 (-0.7,3.2)	1.3 (-0.6,3.2)
Philadelphia Fed	0.7 (0.7,0.7)	-0.5 (-3.3,2.0)	1.2 (-2.2,4.6)	0.3 (-2.7,3.4)	1.7 (-3.0,6.5)	1.1 (-2.2,4.0)	2.4 (-2.9,7.8)	1.6 (-1.7,4.7)
Chicago Fed	2.3 (2.3,2.3)	1.6 (1.6,1.6)	0.2 (-2.4,2.8)	0.8 (-2.0,3.7)	0.6 (-2.6,3.7)	0.8 (-2.4,4.1)	0.7 (-2.7,4.1)	0.9 (-2.6,4.2)
Median Forecast*	1.1	1.4	1.2	1.1	1.4	1.2	1.4	1.5

Model	Output Gap (Q4)							
	2018		2019		2020		2021	
	March	December	March	December	March	December	March	December
EDO - Board of Governors	-0.2 (-0.7,0.3)	-0.2 (-0.7,0.3)	-0.2 (-1.3,0.8)	0.0 (-1.3,1.2)	-0.5 (-2.2,1.2)	-0.2 (-1.9,1.6)	-0.6 (-2.6,1.4)	-0.3 (-2.3,1.8)
New York Fed	-0.2 (-1.4,0.9)	-0.2 (-1.5,1.0)	-0.5 (-2.5,1.4)	-0.2 (-2.4,1.8)	-0.6 (-3.5,1.9)	-0.3 (-3.3,2.4)	-0.7 (-4.4,2.2)	-0.4 (-4.0,2.8)
Philadelphia Fed	1.0 (1.0,1.0)	-2.5 (-3.4,-0.9)	1.0 (0.6,1.5)	-2.0 (-3.4,-0.5)	0.8 (0.0,1.6)	-1.6 (-3.2,-0.1)	0.5 (-0.5,1.6)	-1.3 (-2.6,0.7)
Chicago Fed	1.0 (1.0,1.0)	0.6 (0.6,0.6)	0.5 (-0.8,1.7)	0.5 (-1.0,2.1)	0.1 (-2.3,2.6)	0.3 (-2.4,2.9)	-0.2 (-3.2,2.9)	0.0 (-3.1,3.1)
Median Forecast*	0.4	-0.2	0.1	-0.1	-0.2	-0.2	-0.4	-0.3
March Tealbook	1.9		2.1		2.3		1.9	









## Detailed Descriptions of Individual Model Forecasts

### The EDO Model

The EDO model's forecast is conditional on data through the fourth quarter of 2018 and on a preliminary Tealbook forecast for the first quarter of 2019.

Real GDP growth is 2 percent, on average, over the projection horizon, slightly below the growth rate of potential output. Inflation rises above the Committee's 2 percent objective in the first quarter of 2019 and hovers around a level slightly below  $2\frac{1}{4}$  percent thereafter. Potential GDP growth is about  $2\frac{1}{4}$  percent over the projection horizon, about  $\frac{1}{2}$  percent below trend, held down by the slow fading of unfavorable risk premium shocks. The level of actual output is currently supported by accommodative monetary policy and favorable shocks to aggregate demand. The waning stimulus from these shocks is largely responsible for holding GDP growth below potential. On the nominal side, the inflation projection is persistently above target following the sharp increase in the first quarter of 2019, as the boost from strong aggregate demand gradually dissipates.

The output gap, currently estimated to be negative 0.2 percent, is projected to fall further to negative  $\frac{1}{2}$  percent by 2021. The real natural rate of interest—estimated to be 2.4 percent in the first quarter of 2019—is projected to fall slightly to 1.6 percent in the final quarter of 2021,  $\frac{1}{2}$  percent below its steady-state value of 2.1 percent. The trajectories of the natural rate of interest and the output gap are heavily driven by the model's view that capital stocks are currently below those that would have prevailed in the absence of nominal rigidities and the view that the investment-related shocks responsible for this condition are likely to dissipate slowly.

With inflation near the Committee's objective, the output gap reasonably close to zero, and the current federal funds rate still low, the federal funds rate increases toward the long-run value of 4.1 percent over the forecast horizon. The pace of the increase is gradual, reflecting the inertia in the Taylor rule. The federal funds rate reaches  $3\frac{3}{4}$  percent by the end of 2021, a bit below its long-run value.

The data on recent GDP growth have been weaker than the EDO model had projected in December, and the model interprets much of the surprise as due to slower total factor productivity (TFP) growth and adverse risk premium shocks. Accordingly, the EDO model's forecast of real GDP growth in this round is modestly lower over the forecast horizon—about 20 basis points, on

average—as the temporary deceleration in TFP growth gradually fades. Recent data on core PCE inflation have been slightly stronger than the EDO model had projected in December. As a consequence, core PCE inflation has been revised up 15 basis points over the forecast horizon. The output gap has been revised down about  $\frac{1}{4}$  percent over the forecast horizon relative to the December round. The estimated path of the real natural rate of interest has been revised down appreciably since December. The path of the federal funds rate has been revised down about one-tenth since December, as the effects of the downward revision to the output gap over the forecast horizon outweigh the effects of the upward revisions to core PCE inflation.

### **The New York Fed Model**

The New York Fed model forecasts are obtained using data released through 2018Q4, augmented for 2019Q1 with the New York Fed staff forecasts (as of March 5) 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 2019Q1 averages up to March 5.

The model projects real GDP growth of 1.6 percent in 2019 on a Q4/Q4 basis, which is somewhat below the December forecast of 2 percent growth for 2019. This revision largely reflects the fact that the March New York Fed staff forecast for 2019Q1 real GDP growth is much lower than the model's projection as of December. GDP growth is anticipated to increase slightly to 1.7 percent in both 2020 and 2021, below the December projection of 1.9 percent growth in both 2020 and 2021. The model's projections for inflation remain broadly similar to its projections in December. Inflation is forecast to be 1.5 percent in 2019, 0.1 percentage points higher than the forecast in December. The model projects that inflation will decline to 1.4 percent in both 2020 and 2021.

The output gap is estimated to be larger in 2019 than projected in December: -0.5 percent compared with -0.2 percent. The gap is forecast to widen further to -0.6 percent in 2020 and -0.7 percent in 2021, compared to December forecasts of -0.3 percent and -0.4 percent respectively. The natural rate of interest is projected to remain at 1.3 percent in 2019 and 2020, in line with the December forecast, before dipping slightly to 1.2 percent in 2021. The federal funds rate is forecast to rise gradually, but at a slower pace than anticipated in December, reaching 2.5 percent in 2021

(down from the December forecast of 2.8 percent) from the current level of 2.3 percent. This shallower path translates into approximately one more hike throughout the forecast horizon, rather than the two more hikes forecast in December.

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 all the years between 2019 and 2021. 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 the slowdown in real GDP growth, relative to the above average growth in 2018, to the abatement of the favorable financial conditions experienced in 2018 and to a decline in productivity. Over the medium term, weaker productivity and the gradual withdrawal of monetary accommodation act as a drag on growth. The model projects a persistent decline in inflation driven primarily by negative shocks to wage and price markups, but also by 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, a weak inflation projection, and a persistently negative output gap.

### **The Philadelphia Fed Model**

Philadelphia is implementing a new forecasting model beginning this round. The major change from the previous forecasting model (PRISM) is the addition of a labor market based on search and matching frictions to an otherwise standard NKDSGE framework. We estimated the new set of structural equations and report the forecast based on the updated framework. Consequently, for this round, the Philadelphia forecast is not directly comparable to the PRISM forecast we presented in December. Details of the new model and its estimation are available upon request.

The Philadelphia forecast is constructed using data through 2018Q4 that are then supplemented with a 2019Q1 current-quarter forecast based on staff judgement. For 2019Q1, real GDP growth is pegged at 1.6 percent, core inflation is at 2 percent, and the federal funds rate is at 2.4 percent. With this nowcast and the historical data in hand, the Philadelphia model estimates the output gap at 1 percent and the natural real rate of interest at 1 percent in 2019Q1.

Looking ahead, real GDP growth is expected at 2.2 percent in 2019, rising to 2.7 percent over 2020-2021. Thus, output growth is expected to be largely above our estimate of trend (2.4 percent) over the forecast horizon. With output growing at an above-trend pace, inflation rises from 2.2 percent in 2019 to 2.4 percent in 2021. Responding to above-target inflation, the federal funds rate rises from 2.9 percent in 2019Q4 to 4.8 percent in 2021Q4.

The forecast of the natural rate of interest and the output gap are different under the new model formulation compared to the PRISM model that we used in December. 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 2019Q1 to 1.7 percent at the end of 2020 and 2.4 percent at the end of 2021. 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 1 percent in 2019Q1, and falls modestly over the forecast horizon – to 0.5 percent by 2021Q4.

According to the Philadelphia model, below-trend output growth in 2019Q1 is due to negative contributions from shocks to TFP, the labor market, and preferences (discount factor shocks). Growth rebounds to 2.2 percent in the second quarter, and rises to about 2.9 percent in early 2021 as TFP shocks and discount factor shocks wane. Government spending shocks make a small positive contribution to growth over the forecast horizon. The model sees consumption growth (nondurables and services) as significantly below trend in 2019Q1, but then rising gradually over the forecast horizon to reach a 2 percent pace by the end of 2021. Investment growth, however, is expected to be at an above-trend pace over the next four years driven largely by contributions from investment shocks and, over the near term, markup shocks.

Core inflation is expected to run at a pace above the FOMC target over the forecast horizon. Positive contributions to inflation from TFP, markup, and discount factor shocks are only partly offset by negative contributions from investment, government spending, and labor shocks. However, inflation peaks at a bit over 2.4 percent in 2021Q3 and then begins to edge down.

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 2.9 percent and rises steadily to 4.8 percent at the end of 2021. The model currently has the equilibrium federal funds calibrated to 3.75 percent. Over the medium term, negative contribution from investment and government spending shocks pull the funds rate well 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 Chicago Fed's DSGE model forecast is constructed using data until 2018Q4 augmented with a nowcast for 2019Q1. For 2018Q4 we use the 'first' BEA release for GDP, consumption and investment<sup>2</sup>. Our dataset also includes two measures of wage inflation, core PCE inflation and core CPI inflation and their expectations, 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 January 22 Survey of Market Participants augmented with OIS rate changes between then and March 5 to determine the federal funds rate path for the next 10 quarters. The model rationalizes these expectations with both the endogenous response of the rule to the future expected macroeconomic conditions and with forward guidance shocks. Beginning in 2021Q3, the model's estimated policy rule alone determines interest rates.

The model projects annual GDP growth of 1.3 percent for 2019, seven tenths below its potential. This large markdown from our forecast in the December DSGE memo (2 percent) arises entirely from our weak nowcast for 2019Q1, which leads us to predict below potential growth for all of 2019. As before, we forecast GDP growth is predicted to be at 2.1 percent in 2020 and 1.8 percent in 2021. In the model, the deceleration of output from 2020 to 2021 comes from the gradual removal of monetary accommodation and tightening of financial conditions.

Our forecast for Q4/Q4 core PCE inflation is two tenths below target in 2019, which is a substantial reduction from our forecast in the previous DSGE memo. This difference arises entirely from our weak nowcast for 2019Q1. Just as before, our inflation forecast equals 2 percent for 2020 and 2021. Overall, the model supports the idea that inflation will be close to the FOMC's target in the short and 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

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<sup>2</sup> Due to the recent partial government shutdown, this 'first' report for the fourth quarter and annual GDP for 2018 replaces the release of the "advance" estimate originally scheduled for January 30th and the "second" estimate originally scheduled for February 28th.



wage and price counterfactual. The model forecasts end-of-year output gaps for 2018 through 2021 of 1.0 percent, 0.5 percent, 0.1 percent, and -0.2 percent. We backcast the natural rate of interest at the end of the year for 2018 at 2.3 percent, and we forecast it for 2019 through 2021 at 0.2 percent, 0.6 percent, and 0.7 percent. Difficult-to-forecast transitory factors, which are large in our model, cause the substantial difference between our 2018 backcast and our forecasts. Nevertheless, our forecasts suggest that the neutral federal funds rate consistent with the committee's two percent inflation target is somewhat less than 3 percent over the forecast horizon.