

**BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM**  
**DIVISION OF MONETARY AFFAIRS**  
**FOMC SECRETARIAT**

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**Date:** September 4, 2015  
**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**

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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 give a summary of the model forecasts and then describe each model's forecasts in greater detail.

## **Summary of Model Forecasts**

The current forecasts for real GDP growth, core PCE inflation, and the federal funds rate, as well as those prepared for the June FOMC meeting, are displayed in the table and figures at the end of this summary section. These forecasts were obtained using actual data through 2015Q2 and conditioning assumptions or 'nowcasts' for 2015Q3, where the sources of the nowcast vary slightly across the models (EDO, the FRBNY model, and PRISM use forecasts from the Board staff, the FRBNY staff and Macroeconomic Advisors, respectively.) Federal funds rate expectations are assumed to be consistent with market expectations through 2015Q2 for FRBNY, through 2015Q3 for PRISM, and through 2018Q1 for EDO. For the sake of comparison, the tables and figures also include the July Tealbook forecast (the most recent Tealbook forecast available to us).

The GDP growth forecasts for 2015 were revised up in all models, reflecting stronger-than-expected 2015Q2 GDP data. Output growth for 2015 (Q4/Q4) is now projected in a range of 2.0 to 2.5 percent, relative to the 1.1 to 1.5 percent range reported in June. Afterwards, the projections for all models are largely in line with those of June. EDO and FRBNY forecasts for output growth are 2.1 percent in 2016, and 2.6 and 2.3 percent, respectively, for 2017. Both models forecast a pick-up in GDP growth at the end of the forecast period, and EDO projects an above trend growth of 3.1 percent. PRISM is as usual more optimistic, projecting output growth between 3.5 and 3.8 percent over the 2016-2018 period. The DSGE models forecast higher output growth than the July Tealbook projections in 2015, but the latter do not incorporate the comprehensive NIPA revision nor the revised GDP data for 2015Q2. The medium term projections of the July Tealbook are similar to those of FRBNY and EDO.

Turning to the inflation projections, the median of the DSGE models' inflation forecast is 1.4 percent for 2015, unchanged relative to June, and slightly above the July Tealbook. Beyond 2015, the inflation paths are flatter than in June. Despite that, EDO and PRISM project inflation accelerating and reaching the FOMC target of 2 percent in 2018. The July Tealbook projections for inflation are largely in line with those of EDO and PRISM. By contrast, FRBNY projects a significantly weaker inflation path: core PCE inflation declines to 1.1 percent in 2016, and rises to only 1.3 percent by the end of 2018.

The broad picture of the forecast is similar across the different models: steady, moderate growth will progressively absorb the slack in economy, in an environment of subdued inflation. The models generally agree on the reason why gaps are still open: past shocks to financial conditions – so-called headwinds – have a lasting effect on the economy by continuing to restrain demand and, in particular, investment. More recently, negative productivity shocks have also held down the level of economic activity. Where the models differ is in the projected speed at which gaps will close. FRBNY is particularly pessimistic in this regard, attributing the projected further delay in the return of output to potential and inflation to mandate consistent levels to the most recent turbulence in financial markets and the associated widening of credit spreads.

The expected speed of renormalization in the federal funds rate varies across models, consistent with their different assessments regarding the speed of the recovery in economic activity and inflation. In PRISM, the pace of renormalization, unchanged relative to June, is even more rapid than in the other forecasts, with the federal funds rate projected to be above 3 percent by mid-2017. By contrast, the pace in the EDO model, constrained through 2018Q1, reflects the subdued path of market expectations, and remains below 2.0 percent through the end of the forecast horizon. The FRBNY projections fall in between those of the other two models, and are very close to the July Tealbook path. Consistent with the weaker projections for inflation, the FRBNY path is shallower than in June, with the FFR rising to 1.2 percent by the end of 2016 and 2.4 percent by the end of 2018.

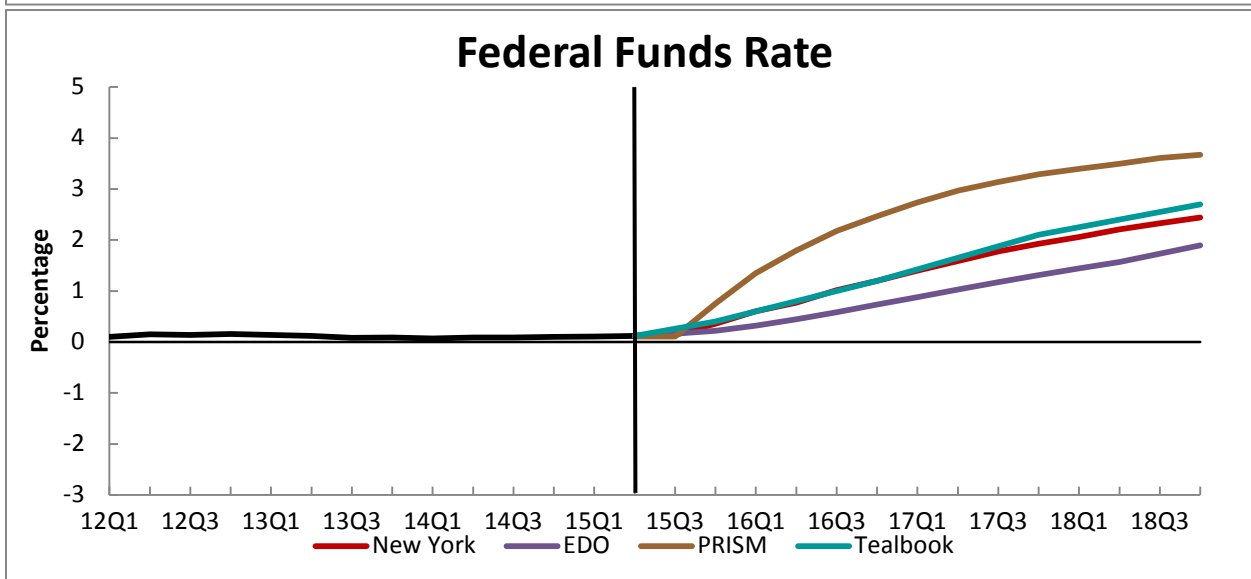
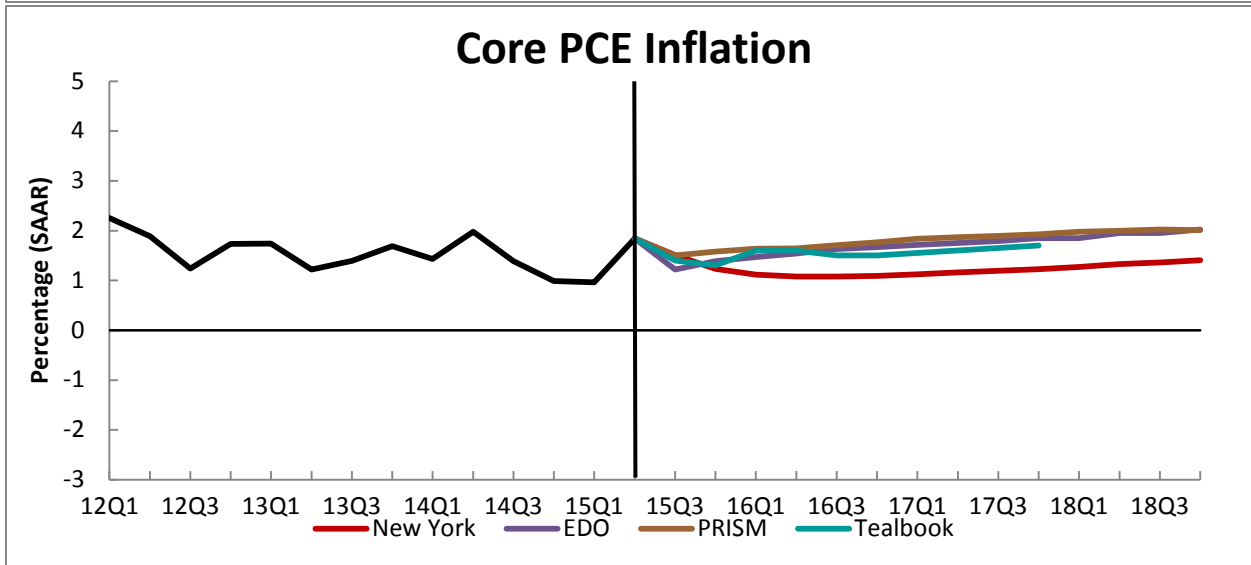
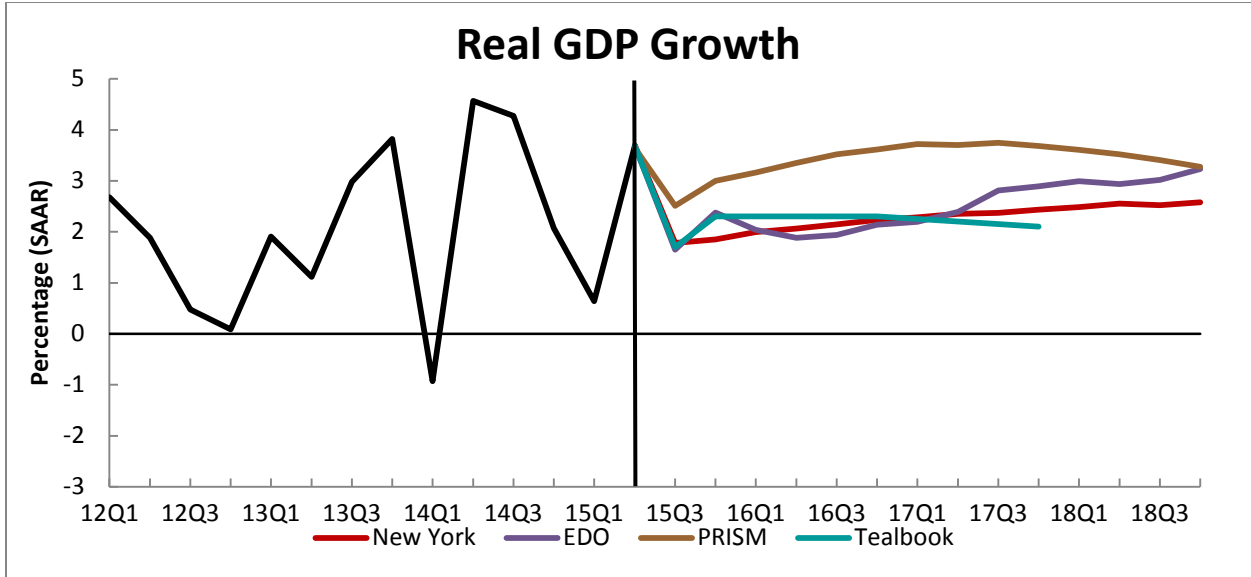
## Forecasts

Model	Real GDP Growth (Q4/Q4)						
	2015		2016		2017		2018
	September	June	September	June	September	June	September
EDO - Board of Governors	2.1 (0.5, 3.8)	1.5 (-0.8, 3.7)	2.1 (-0.3, 4.4)	2.0 (-0.3, 3.9)	2.6 (0.6, 4.6)	2.6 (0.6, 4.5)	3.1 (1.2, 5)
New York Fed	2.0 (1.0, 2.7)	1.1 (-0.5, 2.2)	2.1 (-1.0, 4.1)	2.0 (-0.8, 4.2)	2.3 (-0.5, 4.8)	2.3 (-0.4, 4.8)	2.5 (-0.2, 5.2)
PRISM - Philadelphia Fed	2.5 (1.8, 3.2)	1.5 (0.1, 3.0)	3.5 (0.3, 7.1)	3.2 (-0.1, 6.8)	3.8 (0.2, 7.4)	3.7 (0.1, 7.4)	3.5 (0.0, 7.3)
Median	2.1	1.5	2.1	2.0	2.6	2.6	3.1
July Tealbook	1.5 (0.5, 3.1)		2.3 (0.5, 4.0)		2.1 (-0.1, 4.0)		2.0 --

Model	Core PCE Inflation (Q4/Q4)						
	2015		2016		2017		2018
	September	June	September	June	September	June	September
EDO - Board of Governors	1.3 (1.3, 1.5)	1.5 (1.3, 1.8)	1.6 (1.1, 2.2)	1.8 (1.2, 2.4)	1.7 (1.1, 2.4)	1.9 (1.3, 2.6)	1.9 (1.3, 2.6)
New York Fed	1.4 (1.2, 1.6)	1.2 (0.9, 1.6)	1.1 (0.4, 1.8)	1.2 (0.4, 1.9)	1.2 (0.3, 2)	1.3 (0.5, 2.2)	1.3 (0.4, 2.2)
PRISM - Philadelphia Fed	1.5 (1.2, 1.7)	1.4 (0.9, 2.0)	1.7 (0.4, 3.2)	1.8 (0.3, 3.3)	1.9 (0.3, 3.6)	1.9 (0.2, 3.6)	2.0 (0.2, 3.8)
Median	1.4	1.4	1.6	1.8	1.7	1.9	1.9
July Tealbook	1.3 (1.0, 1.5)		1.5 (0.9, 2.3)		1.7 --		1.8 --

Model	Federal Funds Rate (Q4)						
	2015		2016		2017		2018
	September	June	September	June	September	June	September
EDO - Board of Governors	0.3 (0.0, 0.7)	0.4 (0.0, 1.1)	0.8 (0.0, 2.4)	1.0 (0.0, 2.5)	1.2 (0.0, 3.4)	1.5 (0.0, 3.5)	1.8 (0.4, 3.8)
New York Fed	0.4 (0.1, 1.2)	0.6 (0.1, 1.9)	1.2 (0.1, 3)	1.6 (0.3, 3.4)	1.9 (0.5, 4)	2.3 (0.8, 4.4)	2.4 (0.8, 4.7)
PRISM - Philadelphia Fed	0.8 (0.3, 1.4)	0.8 (-0.2, 1.6)	2.5 (0.8, 4.3)	2.5 (0.5, 4.5)	3.3 (0.9, 6)	3.3 (0.7, 6.0)	3.7 (0.7, 6.5)
Median	0.4	0.6	1.2	1.6	1.9	2.3	2.4
July Tealbook	0.4 --		1.2 --		2.1 --		2.7 --

For each individual forecast, the numbers in parentheses represent 68% confidence bands except for Tealbook which uses 70%.  
 \*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 forecast conditions on data through 2015Q2 and a preliminary Tealbook forecast for the third quarter of 2015. The model forecast for the federal funds rate path is constrained to be consistent with futures prices through 2018Q1.<sup>2</sup>

For 2015 and 2016, the EDO model projects real GDP growth around 2 percent,  $\frac{3}{4}$  of a percent below its trend of 2.7 percent, but higher than the June projections. Subsequently, real GDP growth picks up, rising above trend in 2018. Inflation increases gradually over the next two years from the current 1.3 percent, reaching the Committee's 2 percent objective by the end of 2018. Based on futures data, the model assumes that private agents anticipate the federal funds rate to lift above its effective lower bound in the first quarter of 2016.

Output growth is held down by two factors. First, while the model regards the market-expected federal funds rate path as accommodative relative to the estimated rule, the waning of this unusual accommodation restrains growth in the forecast. Second, the model attributes the slow-down in economic activity in the first quarter of 2015 to a sharp decline in total factor productivity. However, this shock affects only the level of total factor productivity, not its expected growth rate; its effect on output growth beyond 2015 is thus small. The gradual increase in projected inflation over the forecast horizon is due to the gradual increase in wages, which is driven by the slowly dissipating negative wage markup shock.

Despite a sizeable upward revision in 2015, output growth in 2016 and afterward is little changed from June. Much of the surprise in growth for 2015 is accounted for by positive revisions to the trend levels of aggregate hours and total factor productivity and, as discussed above, such shocks to trend levels have only modest effects on growth after a few quarters. The projection for inflation is noticeably weaker, largely as a result of wage and price markup shocks to which the model attributes the low inflation readings in 2015Q3. The key drivers behind the forecast are relatively unchanged relative to June.

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<sup>2</sup> Observations of the market-expected funds rate path are incorporated in the model starting in 2008Q4.

## **The FRBNY Model**

The FRBNY model forecasts are obtained using data released through 2015Q2, augmented for 2015Q3 with the FRBNY staff forecasts (as of August 27) for real GDP growth and core PCE inflation, and with values of the federal funds rate and the spread between Baa corporate bonds and 10-year Treasury yields based on 2015Q3 averages up to August 27. We constrain the expected federal funds rate to be equal to market expectations, as measured by OIS rates, through 2015Q2, and use the estimated interest feedback rule in the projections. The projections in this memo are obtained with a version of the FRBNY which differs from the one used in June in that it is estimated using two measures of output, GDP and GDI (Gross Domestic Income), broadly following the work of Aruoba et al. (2013).<sup>3</sup>

The model projects real GDP to grow 2.0 percent in 2015(Q4/Q4), up sharply from 1.1 percent in June. For 2016 and 2017, by contrast, the current growth forecasts are 2.1 and 2.3 percent, respectively, essentially the same as in June. Growth is expected to pick up again at the end of the forecast horizon: the Q4/Q4 forecast for GDP growth in 2018, reported for the first time, is 2.5 percent. Similarly to the growth forecast, inflation projections are slightly higher in the near term; they are however lower in the medium-run. Projections for core PCE inflation are 1.4 percent for 2015, up from 1.2 percent in June. For 2016 and 2017, they are 1.1 and 1.2 percent, respectively, 10 basis points below the June forecasts. The model predicts inflation to remain depressed at 1.3 percent at the end of 2018.

The changes in the FRBNY DSGE forecasts relative to June are driven by two opposing factors. On the one hand, GDP growth was revised upward for both 2015Q1 and 2015Q2, and in the second quarter growth turned out to be stronger, and inflation higher, than expected. This change boosted the near term forecasts of both output and inflation. On the other hand, financial conditions deteriorated in the current quarter, offsetting the positive impact of the data revisions: as a consequence, the medium term projections remain largely unchanged relative to June.

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<sup>3</sup> S. Boragan Aruoba, Francis X. Diebold, Jeremy Nalewaik, Frank Schorfheide and Dongho Song (2013). *Improving GDP measurement: A measurement-error perspective*, [NBER WP No. 18954](#).



Overall, the broad picture of the forecasts is still consistent with the narrative we have been developing so far this year. The headwinds that slowed down the economy in the aftermath of the financial crisis are finally abating; the natural rate of interest is slowly moving towards positive ranges; the output gap – the difference between output and natural output – is closing, although very gradually. However, the recent turbulence in financial markets and the associated widening of credit spreads represent a partial set-back to this normalization process. Although the model at this stage interprets the tightening of financial conditions as temporary, relative to the June projections the natural rate of interest now remains negative for an extra quarter, and the output gap is projected to be slightly larger over the forecast horizon. In addition, inflation is projected to move even more slowly towards the FOMC longer-term objective.

Consistent with these forecasts, the projected path for the federal funds rate is shallower relative to June. In the current projections the federal funds rate remains below 2 percent through the end of 2017, five quarters longer than forecasted in June. This path reflects in part the endogenous response of policy to weak inflation, according to the historical reaction function estimated by the model. Moreover, the FFR is held down by the effect of past forward guidance, which maintained expected future federal funds rates at a lower level than implied by the historical reaction function. Despite this subdued path, the projected FFR implies a path for the ex-ante real interest rate that is close to the estimated natural rate of interest until mid-2016, and then moves slightly above it for the remainder of the forecast horizon. This path indicates that low levels of the FFR do not imply a particularly accommodative monetary policy.

Uncertainty around the forecasts is significant, particularly for GDP growth. The width of the 68 percent probability interval for GDP growth is 1.7 percentage points in 2015, ranging from 1.0 to 2.7 percent, and widens to 5.4 percentage points in 2018, from -0.2 to 5.2 percent. The 68 percent probability intervals for inflation range from 1.2 to 1.6 percent in 2015 and from 0.4 to 2.2 percent in 2018.

## **The PRISM Model**

The Philadelphia Research Intertemporal Stochastic Model (PRISM) forecast is constructed using data through 2015Q2 that are then supplemented with a 2015Q3 nowcast based on the most recent Macroeconomic Advisors model forecast.

PRISM forecasts that output growth will accelerate from a 2.5 percent pace in 2015 to near 3.8 percent in 2017, and then edge down to 3.5 percent in 2018. The nowcast pins down real output growth in 2015Q3 at 2.5 percent, but growth then accelerates to 3 percent in 2015Q4 and reaches a peak of about 3.7 percent in early 2017. Core inflation remains contained and edges up gradually to reach 2 percent in early 2018. The federal funds rate in the PRISM projections follows the estimated policy rule: it rises to 0.75 percent in 2015Q4 and then advances steadily to reach 3.7 percent at the end of 2018.

According to PRISM, negative shocks to TFP growth have been a key factor dampening real output growth over the past four quarters. Positive and offsetting contributions come from the rebound in hours worked and investment spending. As TFP shocks wane, output growth rises above steady state growth by the end of 2015. Investment shocks and labor supply shocks make a positive contribution to output growth over the forecast horizon, while the rise in the federal funds rate dampens growth through 2016. Consumption growth remains below its steady state level until the beginning of 2017, held down by TFP shocks, investment shocks, and monetary policy shocks. On balance, the model continues to imply a de-trended level of output that is below its steady state; an important factor in accounting for this negative output gap is the level of aggregate hours worked, which remains low due to a combination of labor supply shocks and government spending shocks.

The 2015Q3 nowcast for core PCE inflation is 1.5 percent. The model predicts a steady but very gradual rise in inflation over the next 3 years to reach 2 percent in early 2018. The main factors accounting for below-trend core inflation over the forecast horizon are the slow unwinding of the effects of past financial shocks, and monetary policy shocks that had kept the federal funds rate near zero. These factors are only partially offset by a rebound in hours worked and aggregate demand (which put upward pressure on inflation).

According to the estimated policy rule, the funds rate begins to rise fairly quickly in 2015Q4, jumping by about 65 basis points on average over the quarter. By the end of 2016, the funds rate is projected to be at about 2.5 percent, and then rise to 3.7 percent by the end of 2018. Since the model puts relatively little weight on the output gap in the estimated policy rule, 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.