BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM
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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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This memo describes the economic forecasts for three of the four 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 presented at the December FOMC meeting, are displayed in the table and figures at the end of this summary section. These forecasts were obtained using actual data through 2014Q4 and conditioning assumptions or "nowcasts" for 2015Q1, where the nowcast assumptions vary slightly across the models depending on their source (EDO, the FRBNY model, and PRISM use forecasts from, respectively, Board staff, FRBNY staff, and Macroeconomic Advisors). Federal funds rate expectations are assumed to be consistent with market expectations through 2015Q2 for FRBNY and PRISM, and throughout the forecast horizon (2017Q4) for EDO. For the sake of comparison, the tables and figures also provide the January Tealbook forecast (the March Tealbook forecast not being yet available to us).We should also stress that the FRBNY projections are based on a new model, where the set of observables is much larger than in the previous model. The FRBNY model summary section, below, and the Research Directors Draft, describe this model in more detail.

The GDP growth forecasts of two of the three models are broadly similar to those in the January Tealbook. EDO and FRBNY project output growth between 2 and 3 percent throughout the forecast horizon (except for 2015Q2, for which EDO projects 3.6 percent growth). PRISM is more optimistic, as it forecasts output to grow between 3.5 and 4 percent from 2015H2 through 2017. The inflation forecasts mirror the projections for economic activity, in that models that are more upbeat tend to have inflation converging faster to the FOMC long run objective. The pace of convergence differs substantially across models, however, with PRISM and EDO (and the January Tealbook) projecting inflation to be near 2 percent by the end of the forecast horizon, while FRBNY has core PCE inflation still a half percentage point away from the objective by the end of 2017. The projections for both output growth and inflation are a bit weaker than they were

in December for both EDO and PRISM. For FRBNY, the differences partly reflect the new model.

The economic interpretation behind all three forecasts is broadly similar: gaps in economic activity have not yet closed, which implies that inflation is projected to remain below mandate consistent levels throughout the forecast horizon. The models also 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. Where the models differ is in the projected speed at which gaps will close. This difference is reflected in the inflation projections.

The expected speed of the renormalization in the federal funds rate varies across models, consistent with the different assessments regarding the speed of the recovery in economic activity and inflation. In PRISM, the pace of renormalization is somewhat more rapid than in the January Tealbook, with the federal funds rate projected to be above 3 percent by the end of 2017. This pace is slower in FRBNY and EDO: for these models the 2017Q4 federal funds rate forecast is 2.4 and 1.8 percent, respectively. We should note that EDO constrains federal funds rate expectations for the entire forecast horizon, however.

Forecasts

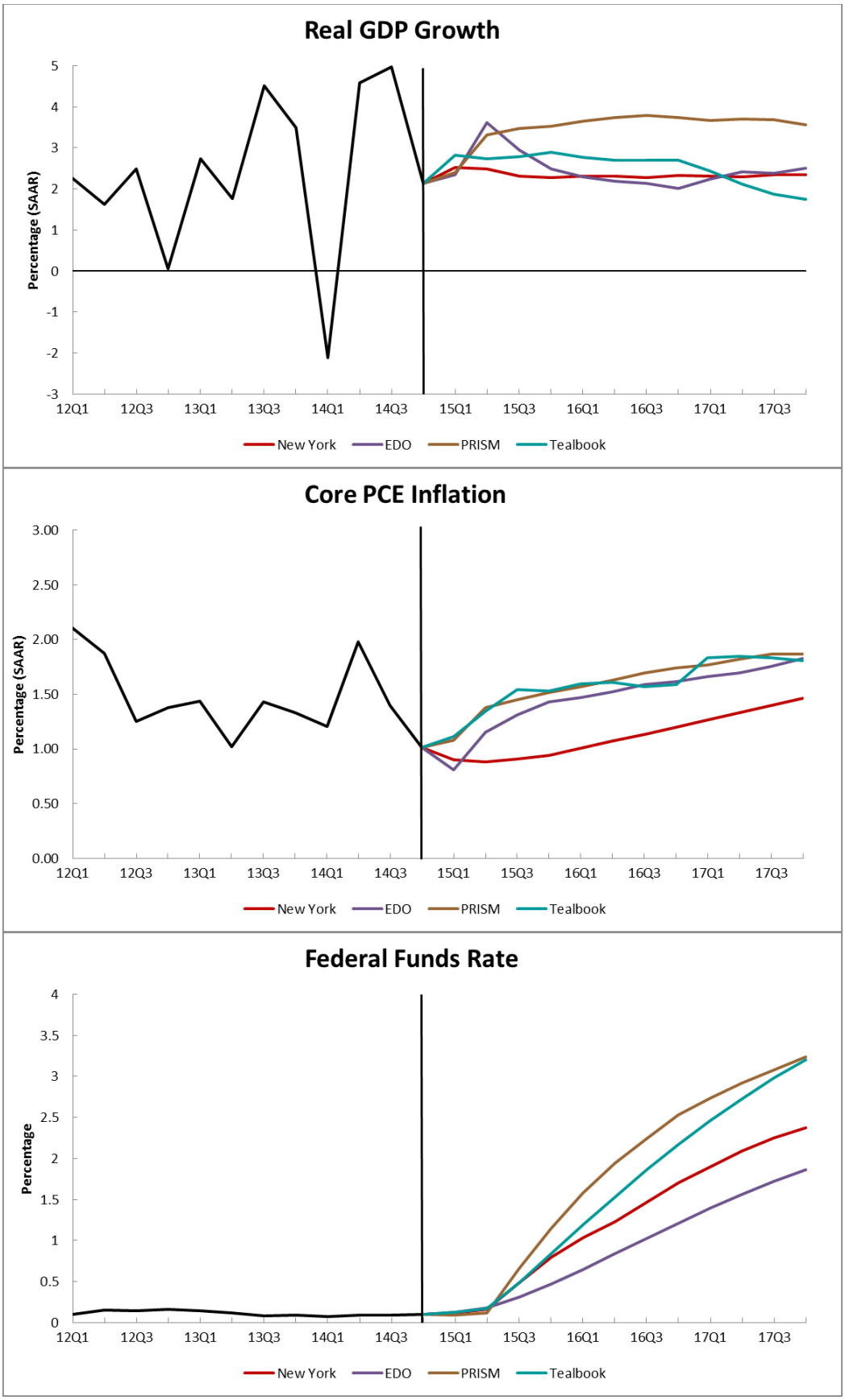
Model	Output Growth (Q4/Q4)					
	2015		2016		2017	
	Mar	*Dec*	Mar	*Dec*	Mar	*Dec*
EDO - Board of Governors	**2.9** **(0.3,5.5)**	3.0 (-0.3,6.4)	**2.2** **(0.5,4)**	2.6 (1.0,4.3)	**2.4** **(0.5,4.4)**	2.6 (0.8,4.6)
New York Fed	**2.4** **(-0.1,3.7)**	2.0 (-0.9,4.1)	**2.3** **(-0.6,4.6)**	1.9 (-1.4,4.9)	**2.3** **(-0.3,4.9)**	1.9 (-1.4,5.2)
PRISM - Philadelphia Fed	**3.2** **(1.1,5.7)**	4.0 (0.8,7.2)	**3.8** **(0.3,7.4)**	4.0 (0.5,7.7)	**3.7** **(0.1,7.5)**	3.8 (0.1,7.6)
Median Forecast*	**2.9**	3.0	**2.3**	2.6	**2.4**	2.6
Januray Tealbook	2.8 (1.3,4.3)		2.7 (1.0,4.5)		2.0 --	

Model	Inflation (Q4/Q4)					
	2015		2016		2017	
	Mar	*Dec*	Mar	*Dec*	Mar	*Dec*
EDO - Board of Governors	**1.2** **(0.8,1.5)**	1.5 (1.0,2.0)	**1.5** **(0.9,2.2)**	1.6 (1.0,2.3)	**1.8** **(1.1,2.4)**	1.8 (1.2,2.5)
New York Fed	**0.9** **(0.4,1.4)**	1.2 (0.6,1.8)	**1.1** **(0.3,1.9)**	1.5 (0.8,2.2)	**1.4** **(0.5,2.2)**	1.8 (1.0,2.6)
PRISM - Philadelphia Fed	**1.4** **(0.4,2.2)**	1.5 (0.2,2.8)	**1.7** **(0.1,3.3)**	1.8 (0.2,3.5)	**1.8** **(0,3.5)**	1.9 (0.2,3.7)
Median Forecast*	**1.2**	1.5	**1.5**	1.6	**1.8**	1.8
January Tealbook	1.4 (0.8,1.9)		1.4 (0.9,2.3)		1.6 --	

Model	Federal Funds Rate (Q4)					
	2015		2016		2017	
	Mar	*Dec*	Mar	*Dec*	Mar	*Dec*
EDO - Board of Governors	**0.6** **(0,1.6)**	0.7 (0.0,1.9)	**1.2** **(0,3.2)**	1.5 (0.1,3.2)	**1.8** **(0.3,3.7)**	2.0 (0.4,3.9)
New York Fed	**0.8** **(0.1,2.3)**	0.8 (0.2,1.7)	**1.7** **(0.4,3.7)**	1.5 (0.5,2.8)	**2.4** **(0.8,4.5)**	2.3 (0.9,3.7)
PRISM - Philadelphia Fed	**1.1** **(-0.1,2.3)**	1.3 (-0.2,2.8)	**2.5** **(0.4,4.9)**	2.6 (0.3,5.0)	**3.2** **(0.4,6)**	3.3 (0.4,6.1)
Median Forecast*	**0.8**	0.8	**1.7**	1.5	**2.4**	2.3
January Tealbook	0.8 --		2.2 --		3.2 --	

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)
5
4
3
2
1
0
-1
-2
-3
12Q1
12Q3
13Q1
13Q3
14Q1
14Q3
15Q1
15Q3
16Q1
16Q3
17Q1
17Q3
New York
EDO
PRISM
Tealbook
Core PCE Inflation
Percentage (SAAR)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
12Q1
12Q3
13Q1
13Q3
14Q1
14Q3
15Q1
15Q3
16Q1
16Q3
17Q1
17Q3
New York
EDO
PRISM
Tealbook
Federal Funds Rate
Percentage
4
3.5
3
2.5
2
1.5
1
0.5
0
12Q1
12Q3
13Q1
13Q3
14Q1
14Q3
15Q1
15Q3
16Q1
16Q3
17Q1
17Q3
New York
EDO
PRISM
Tealbook

Detailed Descriptions of Individual Model Forecasts

The EDO Model

The EDO model forecast uses data up to 2014Q4 and is conditional on a preliminary Tealbook forecast for the first quarter of 2015. The forecast assumes that the funds rate path through 2017Q4 is consistent with market expectations, which indicate that private agents anticipate the federal funds rate to lift above its effective lower bound in the third quarter of 2015, and to increase slowly after that.

For 2015, the EDO model projects real GDP growth slightly higher on average than its trend of 2.7 percent. Subsequently, real GDP growth declines to an average 2¼ percent through the end of the forecast period. The unemployment rate rises to 5¾ percent by the end of 2015 and continues rising to reach 6¼ percent by the end of 2017. Inflation runs below the Committee's 2 percent objective, averaging around 1½ percent over the next three years.

The lackluster growth of GDP and the increase in unemployment in 2016 and 2017 is the product of two offsetting forces. On the one hand, GDP grows rapidly toward potential as the risk premium, which is the model's main cyclical driver and which is currently estimated to be high, converges to its historical average. The high premium estimates are due to the combination of weak growth in consumption along with relatively high real short-term interest rates. On the other hand, the model also interprets the market-expected path of the federal funds rate as unusually accommodative, given the expected state of the economy and the estimated monetary policy reaction function. Although these lower-than-expected interest rates boost the current level of real GDP, these effects vanish over the medium term, lowering GDP growth. These two forces are balanced in EDO's forecast, leading to roughly trend GDP growth. In the near-term, the model has interpreted the decline in oil prices as a short-lived price markup shock, boosting GDP growth over the second and third quarters of 2015 and lowering the near-term inflation projections. The gradual increase in projected inflation over the forecast horizon is driven by the rebound of wages, which are currently kept low by shocks capturing labor market frictions. All told, GDP growth both in 2015 and over the medium term is ¼ percentage point lower on

average compared to December, while the inflation rate has also been revised down ¼ percentage point on average over the forecast horizon.

The FRBNY Model

The FRBNY model forecasts are obtained using a new version of the FRBNY DSGE model, which builds on the New Keynesian model with financial frictions used in Del Negro, Giannoni, and Schorfheide (2015).[2] This model has been shown to provide a reasonable explanation for the behavior of inflation in the aftermath of the Great Recession, and relatively accurate forecasts of output growth and inflation throughout recent history.[3] Relative to the previous FRBNY model, the set of observable indicators is augmented with data on consumption and investment growth, survey-based long-run inflation expectations, which provide information on the public's perception of the central bank's inflation objective, and the 10-year Treasury yield, in order to incorporate information about long-term rates. In addition, the model is estimated using two distinct measures of inflation – the GDP deflator and core PCE inflation. Finally, the model allows for persistent shocks to both the level and the growth rate of productivity, in an attempt to allow for the possibility of secular stagnation, and uses John Fernald's estimate of the growth rate of productivity as an observable. In describing the model's forecasts, we rely on estimates of the so-called natural level of output and rate of interest – which we define as output and interest rate obtained in the absence of nominal rigidities, markup shocks, and financial frictions. These quantities, which are not directly observable, inform us about the stance of monetary policy. The Research Directors Draft provides more details on the model.

The FRBNY model forecasts are obtained using data released through 2014Q4, augmented for 2015Q1 with the FRBNY staff forecasts for real GDP growth, core PCE inflation, and growth in total hours, and with values of the federal funds rate and the spread between Baa

[2] Del Negro, Giannoni, and Schorfheide, 2015, "Inflation in the Great Recession and New Keynesian Models," *American Economic Journal: Macroeconomics* 7(1): 168-196.

[3] See Del Negro, Hasegawa, and Schorfheide, 2014, "Dynamic Prediction Pools: An Investigation of Financial Frictions and Forecasting Performance," NBER Working Paper 20575, and Del Negro and Schorfheide, 2013, "DSGE-Model Based Forecasting," Handbook of Economic Forecasting Vol. 2, Elsevier.

corporate bonds and 10-year Treasury yields based on 2015Q1 observations. The expected federal funds rate is constrained to equal market expectations, as measured by OIS rates, through 2015Q2. This constraint is implemented via anticipated policy shocks. The 2015Q1 staff projections, OIS rates and spreads are those that were available on February 27.

The FRBNY DSGE forecast for output growth is slightly stronger than it was in December. The model projects the economy to grow 2.4 percent in 2015 and 2.3 percent in 2016 and 2017. The headwinds that slowed down the economy in the aftermath of the financial crisis are finally abating, resulting in an increase of the natural rate of interest toward positive ranges and a gradual closing of the output gap – the difference between output and natural output. The gap is closing only slowly, however. Moreover, the model's estimate of firms' marginal costs suggests that these have not recovered much over the last few years, due to the weakness in real wage growth. As a consequence, inflation projections are weak: core PCE inflation is expected to remain below 1.5 percent until the end of 2017. Note that increases in future real wages and marginal costs, far from being a warning sign of impending inflationary pressures, are actually a necessary condition for this (albeit slow) convergence of inflation towards the FOMC long-run objective. In the absence of accelerating wages, inflation projections would be even weaker.

The change in inflation forecasts relative to December reflects both weak inflation data since December and the switch to the new version of the model. In terms of inflation forecasts, the new model differs from the old one in two dimensions. First, it features more persistence in inflation, which is largely endogenous and due to the fact that the output gap closes very gradually. Second, it features more persistent mark-up shocks. This is because mark-up shocks no longer have to capture the substantial high frequency noise in quarterly core inflation, given that inflation is measured as the common factor between core PCE inflation and the GDP deflator. In terms of the current forecast, this implies that mark-up shocks, which capture declines in oil prices and have recently been large, have a relatively prolonged effect on inflation.

The model projects the federal funds rate to reach 2.4 percent by the end of 2017, well below its steady state value. This relatively shallow path after lift-off is mostly driven by the

endogenous response of policy to weak inflation, according to the historical reaction function estimated by the model. However, past forward guidance on interest rates, which is estimated to have provided consistent support to GDP growth and inflation over the last several years, also contributes to maintaining a lower expected future federal funds rates than is implied by the historical reaction function. The estimated natural real rate of interest has been well below the actual real rate during and after the crisis, indicating that the zero lower bound imposed a constraint on interest-rate policy. Currently, the natural rate is close to, but still below, the actual real rate, suggesting that policy is still not particularly accommodative.

Uncertainty around the forecasts is significant, particularly for GDP growth. The width of the 68 percent probability interval for GDP growth is 3.8 percentage points in 2015, ranging from -0.1 to 3.7 percent, and widens to 5.2 percentage points in 2017 – from -0.3 to 4.9 percent. The 68 percent probability intervals for inflation remain relatively tight, ranging from 0.4 to 1.4 percent in 2015 and from 0.5 to 2.2 percent in 2017.

The PRISM Model

The Philadelphia Research Intertemporal Stochastic Model (PRISM) forecast is constructed using data through 2014Q4 that are then supplemented with a 2015Q1 nowcast based on the most recent Macroeconomic Advisors model forecast. In addition, the forecasted path for the federal funds rate is constrained through 2015Q2 using market expectations implied by futures market data.

PRISM forecasts that growth will accelerate from a 2.4 percent pace in 2014 to about 3.2 percent in 2015 and 3.8 percent 2016. While 2015Q1 real output growth is pinned down at 2.4 percent by the nowcast, the forecast calls for output growth to rise to 3.3 percent in the second quarter of 2015, and then gradually edge up to 3.8 percent in the second half of 2016. While output growth is projected to be fairly robust, core inflation remains contained at below 2 percent through the forecast horizon. The forecast has the funds rate following the financial market expectation through 2015Q2 and then rising to 1.1 percent by the end of 2015 and 3.2 percent by the end of 2017.

According to PRISM, an ongoing rebound in the labor market and investment demand will drive above-trend growth over the next 3 years. The model continues to imply a de-trended level of output that is below its steady state and an important factor in accounting for this output gap is the low level of aggregate hours worked, which the model generates through a combination of labor supply shocks, investment shocks, and government spending shocks. The model attributes somewhat weak output growth in 2014Q4 and 2015Q1 to negative shocks to technology and government spending. Looking ahead though, the model anticipates that above-trend real GDP growth will be driven by a rebound in hours worked, investment, and government spending that are partly offset by an unwinding of technology and monetary policy shocks.

The 2015Q1 nowcast for core PCE inflation is 1.1 percent. The model predicts a steady but gradual rise in inflation over the next 3 years, reaching about 1.9 percent at the end of 2017. The principal factor accounting for below-trend core inflation over the forecast horizon is the very slow unwinding of the effects of past financial shocks, and a rising funds rate. The factors are only partially offset by a rebound in hours worked and aggregate demand (which put upward pressure on inflation).

The forecast is implemented with a path for the federal funds rate that is constrained by financial market expectations through 2015Q2. When that constraint is lifted in 2015Q3, the funds rate begins to rise quickly, jumping by about 55 basis points in 2015Q3. By the end of 2017, the funds rate is projected to be at about 3.2 percent. The model puts relatively little weight on the output gap in the estimated policy rule. Consequently, the shocks that account for the dynamics of the federal funds rate are largely the same as those that account for the dynamics of inflation.