Board of Governors of the Federal Reserve System
Division of Monetary Affairs
FOMC Secretariat

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To: Federal Open Market Committee

From: Deborah J. Danker

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 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), FRBNY and Chicago models. We first give a summary of the model forecasts and then provide 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 March FOMC meeting, are displayed in the table and figure at the end of this summary section. These forecasts were obtained using actual data through 2013Q1, conditioning assumptions for 2013Q2, and expectations of future federal funds rates implied by market prices of interest rate swaps. The conditioning assumptions of each model are explained in further detail in the individual summaries below.

The models' projections for real GDP growth in 2013, 2014, and 2015 (Q4/Q4) are only slightly different than in the March round. The median forecast across models is for growth of 2.6 percent in 2013 (down from 2.8 percent in March) rising to 2.8 percent in 2014 (up from 2.6 percent in March) and 3.1 percent in 2015 (down from 3.2 percent in March). The Chicago and PRISM models continue to project output growth in 2013 and 2014 in excess of 3 percent, while growth is expected to be closer to 2 percent in the EDO and FRBNY models. The FRBNY model carries this weakness forward into 2015, while the remaining models project above-trend growth by then.

Both the Chicago and PRISM models interpret the exceptionally low federal funds rate path as providing unusually high accommodation, which lifts their forecasts for 2013 and 2014. In contrast, the EDO and FRBNY models both rationalize the low path by inferring more underlying economic weakness that which makes near-zero interest rates more in line with the estimated policy rule. In the FRBNY model, this weakness comes from the lagged effects of financial headwinds, while in EDO it comes from expected increases in future risk premia. These different interpretations of current interest rate expectations are the primary source of the models' different GDP forecasts.

Each of the models constrains future interest rates to equal market expectations only over the next two to three years. Thereafter, they use their estimated interest-rate rules to forecast policy. All of the models predict an immediate increase of the federal funds rate when this transition occurs. The projections for the fed funds rate at the end of 2015 range from 0.7 to 1.6 percent, with the median forecast unchanged from March at 1.1 percent. Large projected output gaps and low projected inflation both contribute to the measured pace of the subsequent rise of the funds rate. All four models project inflation (Q4/Q4) to remain below 2 percent over the forecast horizon, with the median forecast across models gradually rising from 1 percent in 2013 to 1.5 percent in 2015.

Forecast Summary

Model	Output Growth (Q4/Q4)					
	2013		2014		2015	
	June	Mar	June	Mar	June	Mar
EDO - Board of Governors	**1.9** (-0.5,4.3)	1.9 (-1.0,4.7)	**1.8** (-0.4,3.9)	2.0 (-0.1, 3.9)	**2.9** (0.9,5.0)	3.3 (1.2, 5.3)
New York Fed	**2.3** (0.9,3.2)	2.3 (0.1, 3.7)	**2.1** (-1.2,4.4)	1.9 (-1.7,4.5)	**1.5** (-1.8,4.4)	1.4 (-2.1,4.3)
PRISM - Philadelphia Fed	**2.9** (1.3,4.4)	3.7 (1.2,6.1)	**4.2** (0.6,8.1)	4.5 (0.8,8.6)	**3.9** (0.1,8.0)	3.9 (0.0,8.0)
Chicago Fed	**3.1**	3.4	**3.5**	3.3	**3.3**	3.1
Median Forecast*	**2.6**	2.8	**2.8**	2.6	**3.1**	3.2

Model	Inflation (Q4/Q4)					
	2013		2014		2015	
	June	Mar	June	Mar	June	Mar
EDO - Board of Governors	**0.9** (0.7,1.2)	1.2 (0.8, 1.6)	**1.1** (0.5,1.8)	1.3 (0.6, 2.0)	**1.4** (0.7,2.2)	1.6 (0.8, 2.3)
New York Fed	**1.0** (0.7,1.3)	1.1 (0.6, 1.5)	**1.2** (0.4,1.8)	1.3 (0.4,1.9)	**1.5** (0.6,2.2)	1.5 (0.5, 2.2)
PRISM - Philadelphia Fed	**1.4** (0.9,2.0)	1.5 (0.6, 2.4)	**1.7** (0.3,3.2)	1.8 (0.2, 3.3)	**1.7** (0.2,3.5)	1.8 (0.1, 3.5)
Chicago Fed	**0.9**	0.8	**0.4**	0.6	**0.7**	1.0
Median Forecast*	**1.0**	1.1	**1.2**	1.3	**1.5**	1.6

Model	Federal Funds Rate (Q4)					
	2013		2014		2015	
	June	Mar	June	Mar	June	Mar
EDO - Board of Governors	**0.2** (0.0,1.0)	0.3 (0.0, 1.2)	**0.5** (0.0,2.1)	0.5 (0.0, 2.0)	**1.0** (0.0,2.8)	0.9 (0.0, 2.5)
New York Fed	**0.1** (0.3,0.7)	0.1 (0.3,1.1)	**0.3** (0.3,1.5)	0.2 (0.3, 1.5)	**1.1** (0.3,2.5)	1.1 (0.3, 2.6)
PRISM - Philadelphia Fed	**0.1** (-0.7,1.1)	0.1 (-1.0,1.4)	**0.4** (-1.5,2.6)	0.3 (-2.0, 2.5)	**1.6** (-1.1,4.4)	1.6 (-1.4, 4.3)
Chicago Fed	**0.1**	0.1	**0.3**	0.2	**0.7**	1.0
Median Forecast*	**0.1**	0.1	**0.4**	0.3	**1.1**	1.1

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
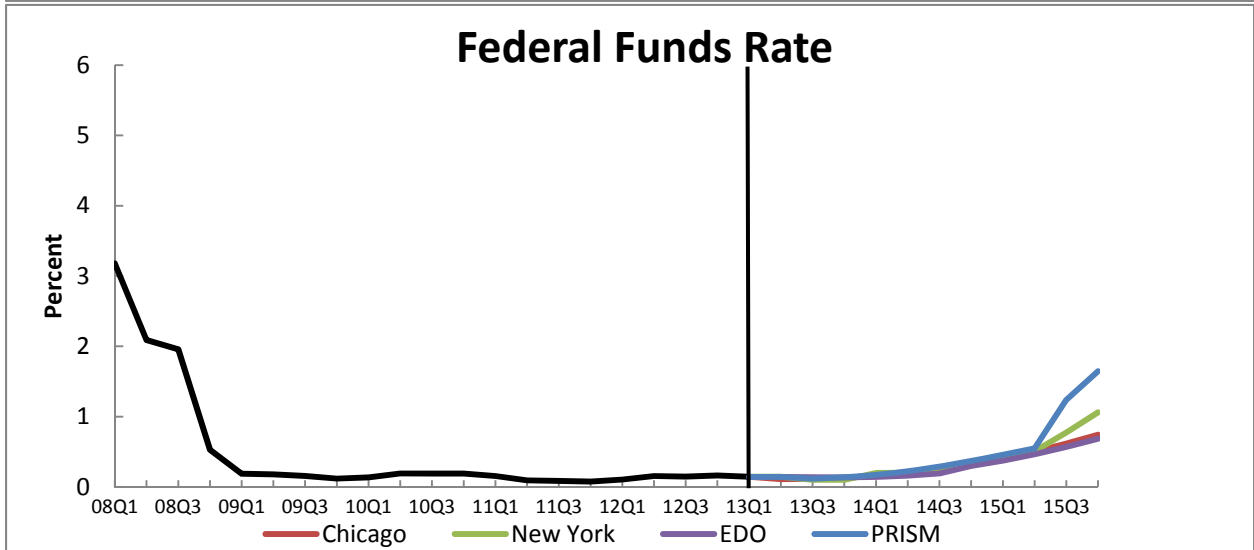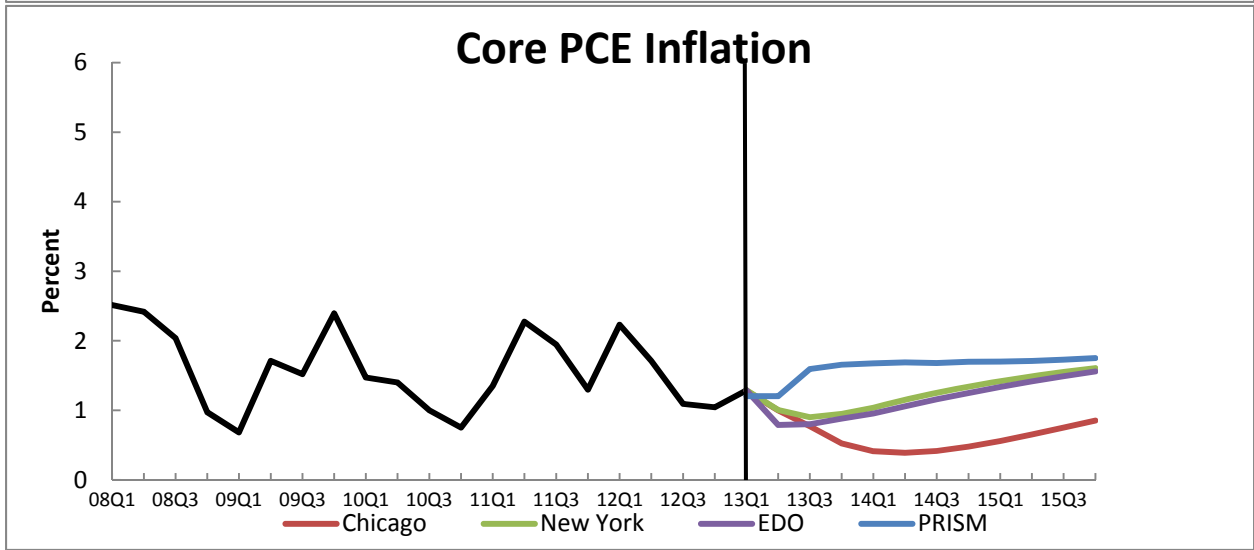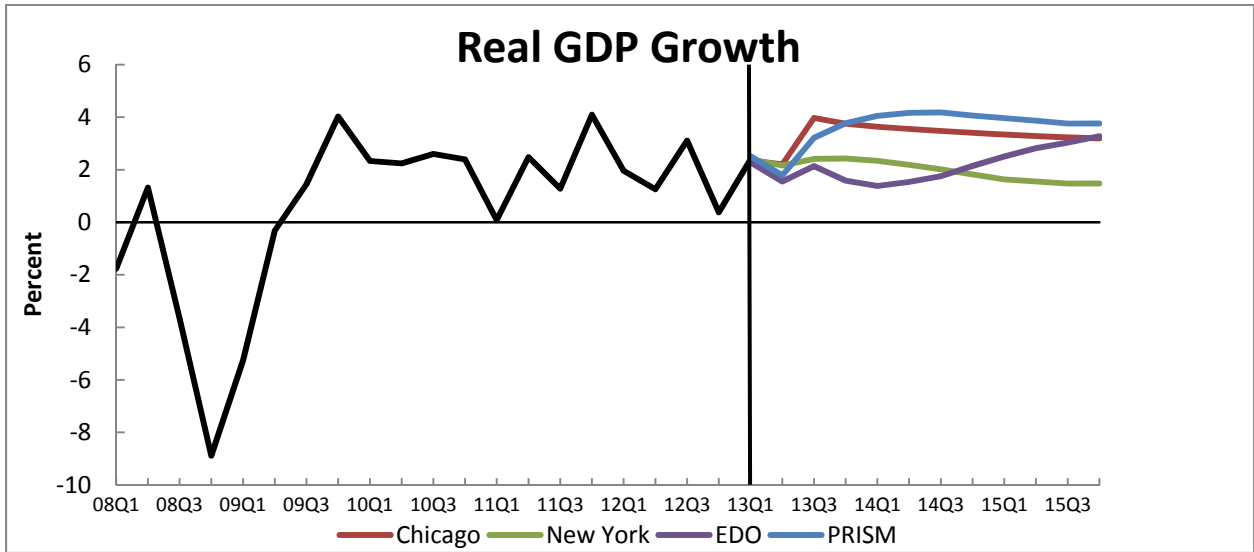
Detailed Descriptions of Individual Model Forecasts

The EDO Model

The EDO model projects average real GDP growth below its trend of 2.7 percent until mid-2015 and unemployment around 8 percent until the end of 2015. This subdued pace of real activity is accompanied by inflation gradually accelerating from a low of 0.8 percent in the middle of 2013 to about 1 ¾ percent by the end of 2016. Private agents do not expect the federal funds rate to rise appreciably above its effective lower bound until the final quarter of 2014.

The weak economic forecast is heavily shaped by the model's interpretation of the anticipated path of the federal funds rate inferred from interest rate swaps, which is considerably lower than the model would have anticipated in the absence of data on market expectations. In part, the model accounts for this lower path by attributing to private agents the expectation of relatively adverse financial conditions over the forecast horizon. The aggregate risk premium remains in the neighborhood of its early 2012 levels, lowering GDP growth and boosting unemployment well above its steady-state. In addition, repeatedly lower-than-expected labor productivity and surprisingly high inflation have led the model to infer a steady deterioration of aggregate supply conditions since the beginning of 2011.

Given the weakness of aggregate demand in the forecast, the federal funds rate remains only modestly below the level consistent with the model's estimated policy rule. Accordingly, exceptionally accommodative policy provides only a small boost to the level of economic activity, with the contribution declining rapidly after mid-2013. Inflation is held below target, muting pressure on wages in the labor market.

The unemployment rate rises slowly through the beginning of 2015, reaching a peak of 8.2 percent, before declining to 8.0 percent by the end of 2015. The initial rise in unemployment reflects the above-mentioned high risk premiums and adverse supply conditions. By the end of the forecast, however, a substantial portion of the elevated unemployment rate is accounted for

by a highly persistent shift in household labor supply. Given the nominal rigidities in the model, labor supply shocks affect household willingness to work much more strongly than firms' willingness to hire, and thus unemployment responds by more than other measures of economic activity. The model, therefore, naturally attributes a large share of low-frequency variation in unemployment to this source.

The PRISM Model

The Philadelphia Research Intertemporal Stochastic Model (PRISM) forecast is constructed using data through 2013Q1 that are then supplemented with a 2013Q2 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 futures market data – implied expectations.

PRISM forecasts a fairly strong acceleration in growth from the average pace posted in 2012. While 2013Q2 real output growth is pinned down at 1.8 percent by the nowcast, the forecast calls for output growth to rebound to 3.2 percent in the third quarter and then increase gradually to a peak of a bit over 4 percent in the second half of 2014. Output growth then runs at a near 4 percent pace in 2015 and 3.7 percent in 2016. While output growth is projected to be fairly robust, inflation remains contained at 1.7 percent through the forecast horizon. The forecast has the funds rate following the market expectation through 2015Q2 and then rising to 1.6 percent by the end of 2015 and 2.5 percent by the end of 2016.

According to PRISM, the primary factors that account for weak real GDP growth in 2013Q2 are negative shocks to TFP, to the efficiency with which investment is turned into capital, and to monetary policy. The model continues to see the de-trended level of output well 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 labor supply shocks, investment shocks, and government spending shocks. Looking ahead, the model anticipates that above-trend real GDP growth will be driven by a rebound in hours worked and a waning of investment and financial shocks. Real GDP growth peaks at 4.2 percent in 2014Q2 and then gradually tapers down to 3.6 percent in 2016Q4.

Over the last few quarters, markup shocks have helped to keep core inflation below trend. However, the model does not estimate these shocks as being very persistent and so inflation accelerates a bit in 2013Q3 (by about 0.4 percentage points at an annual rate). Looking ahead, as hours worked rebound and aggregate demand picks up inflation edges up modestly from a 1.4 percent average pace in 2014 to a 1.8 percent average pace in 2016.

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 about 70 basis points in 2015Q3. By the end of 2016, the funds rate is projected to be at 2.5 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.

The FRBNY Model

The FRBNY model forecasts are obtained using data released through 2013Q1, augmented for 2013Q2 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 corporate bonds and 10-year Treasury yields based on 2013Q2 observations. The expected future federal funds rates are constrained to equal market expectations, as measured by the OIS rates, through 2015Q2, using anticipated policy shocks. The standard deviations of these shocks are estimated using federal funds rate expectations since 2008Q4, the beginning of the zero bound period. The 2013Q2 staff projections and OIS rates are those available on May 30, 2013.

Output growth in 2013Q1 and 2013Q2 (as projected by the FRBNY staff) was in line with the DSGE model forecasts produced in March, hence our output projections are essentially the same as in the last DSGE System memo. The model continues to project a lackluster recovery in economic activity, with output growth in the neighborhood of 2 percent throughout the forecast horizon. Growth forecasts for 2013, 2014 and 2015 (Q4/Q4) are 2.3, 2.1 and 1.5 percent, respectively, compared to the rates of 2.3, 1.9 and 1.4 percent, respectively, that we reported in

March. Core PCE inflation in 2013Q1 (again, as projected by the staff) turned out in line with the March DSGE projections, and inflation forecasts are also virtually the same as in March. Mean core PCE inflation projections for 2013, 2014 and 2015 (Q4/Q4) are below the FOMC long-run goal of 2 percent throughout the forecast horizon. Specifically, these are 1.0, 1.2 and 1.5 percent, respectively, compared to 1.1, 1.3 and 1.5 percent, respectively, in March.

There is significant uncertainty around real GDP forecasts, with 68 percent bands covering the interval 0.9 to 3.2 percent in 2013 (Q4/Q4), -1.2 to 4.4 percent in 2014 (Q4/Q4), and -1.8 to 4.4 percent in 2015 (Q4/Q4). The forecast distribution for inflation remained virtually unchanged relative to March, with the 68 percent probability bands within the 0.4 to 2.2 percent interval throughout 2015.

The FRBNY forecast is driven by two main factors. On the one hand, the headwinds from the financial crisis, as captured by the effect of shocks to credit spreads and to the marginal efficiency of investment (MEI), result in a low real activity, real marginal costs, and consequently low inflation. The economy experienced large spread shocks during the Great Recession and a sequence of adverse MEI shocks afterwards. Given that these shocks have persistent effects on output growth and inflation, financial headwinds continue to negatively affect the forecasts for real activity and inflation throughout the end of the forecast horizon. On the other hand, accommodative monetary policy, particularly forward-guidance, has played an important role in counteracting these headwinds, and lifting output and inflation. However, the impact of past forward guidance announcements on the *level* of output has begun to wane according to the model. This implies that the effect of policy on *growth* forecasts is actually negative, particularly toward the end of the forecasting horizon. This largely explains why output growth is still below trend by the end of 2015.

The model views the federal funds rate at the zero lower bound as mostly driven by the endogenous response of policy to the weak economy. In fact, throughout 2013 the historical rule would imply a rate at about 25 basis points. However, by early 2015 the policy accommodation provided by the forward guidance becomes more noticeable, implying a federal funds rate path below the historical rule by about 75 basis points.

The Chicago model

The Chicago model forecast incorporates data through 2013Q1 and uses staff projections to plug in the necessary inputs for 2013Q2. Of these inputs, the most important are the annual growth rate of real GDP, growth in the consumption of nondurables and services, and residential and nonresidential investment growth excluding inventory investment. The staff projections for Q2 are for real GDP growth to rise 2.2 percent as real consumption decreases and real investment increases slightly from their Q1 values.

In addition, we use forward guidance shocks to help shape the model's expected federal funds rates through the end of 2015 based on their implied values from futures markets prices. The model also includes a slowly drifting inflation anchor (currently 2.3 percent) which dominates changes in long-run expected inflation and is identified by equating the 10-year average of model-based expected consumer price inflation with 10-year-ahead CPI forecasts from the Survey of Professional Forecasters.

The Chicago forecasts for real GDP growth are lower in the near term than they were in March. Real GDP growth in 2013 on a Q4/Q4 basis is projected to be 3.1 percent, down from 3.4 percent in March reflecting slower growth in the first half of the year. The economy is then projected to pick up a bit more in the second half of 2013 than it was in March and continues to grow aboveat the model's potential growth rate, 2.7 percent, throughout the remainder of the forecast horizon. Accordingly, the measure of the output gap that enters our Taylor-type policy rule decreases from -5.1 percent in 2012 to 0.3 percent by the fourth quarter of 2016.

Transitory adverse demand shocks largely explain the recent weakness in economic activity. In particular, a residual shock to the national income and product accounting identity, embodying a change in the valuation of inventories, net exports, and government expenditures in the model, accounts for much of the weakness in GDP growth in the first half of this year. Negative serial correlation in this shock then results in a slight boost to GDP growth in the second half of 2013 and 2014. Continued declines in government expenditures as a result of sequestration are likely

to diminish such a response. Furthermore, the recent slow-down in net exports as economies around the world have slowed could be seen as a risk to the model's forecast in this regard.

Recent favorable monetary policy shocks, primarily reflecting forward guidance on the funds rate, boost GDP growth in 2013 and 2014. Market expectations hold the funds rate near or below 0.5 percent through mid-2015; after that it gradually rises ending 2015 at about 0.75 percent, down slightly from 1.0 percent in March. Subsequent increases in the funds rate average a bit more than 25 bps per quarter, ending 2016 at about 2 percent.

A decrease in spreads, beyond what is warranted by firms' balance sheets according to the model, also boosts GDP growth in 2013 and 2014. Its effect and that of forward guidance shocks are partially offset, however, by recent adverse technology shocks. Both the forward guidance and spread shocks each added roughly 0.1 percentage point to the four quarter average of GDP growth in the second quarter of 2013, while an adverse neutral technology shock subtracted nearly 0.15 percentage points.

The forecasted path for Q4/Q4 core PCE inflation remains largely unchanged from March. Inflation declines from the 1.5 percent observed in 2012 to 0.9 percent in 2013 and 0.4 percent in 2014 before gradually increasing to 1.1 percent in 2016. Small, positive price mark-up shocks inferred from incoming data account for the slightly higher inflation in 2013 than was projected in March. However, their effect on the forecast is short-lived.