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DIVISION OF MONETARY AFFAIRS
FOMC SECRETARIAT

Date: March 11, 2013
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 present a summary of the forecasts and then provide details about each model's projections.

Forecasts Summary

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 figure at the end of this summary section. These forecasts are obtained using actual data through 2012Q4. All models except Chicago also use current projections for 2013Q1, and treat them as if they were data. The forecasts are conditioned on the anticipation that the federal funds rate will remain exceptionally low through at least mid-2015. This constraint is imposed by anchoring the expected path of the federal funds rate to market expectations until 2015Q2; the specific measures of market expectations differ slightly across models and are discussed in detail below. Note that by conditioning on the market's expected path for the federal funds rate, the forecasts implicitly incorporate the market's interpretation of the "threshold" language announced in December.

Growth projections are generally a bit weaker than in December. Since none of the models explicitly incorporates the recent changes in fiscal policy, this weakness mainly reflects the fact that GDP growth was less than expected in 2012Q4, and that its projection for the current quarter is lower than forecasted in December. As was the case in December, growth forecasts differ substantially across models: PRISM, Chicago, and FRBNY project growth to be in the neighborhood of 4, 3, and 2 percent, respectively, throughout the forecast horizon. EDO's forecasts are close to those from the FRBNY model in 2013 and 2014, but closer to Chicago's in 2015. The differences in forecasts are in large part attributable to the different speed in the unwinding of the financial headwinds that were responsible for both the severity of the recession and the lackluster recovery. In PRISM, the unwinding is relatively fast, leading to robust growth. At the other end of the spectrum, headwinds still play a prominent role in the FRBNY and EDO projections, leading to growth below steady state in 2013 and 2014. The presence of these headwinds affects the projections also indirectly, by leading the various models to interpret the recent macroeconomic data differently. For FRBNY and Chicago, and to a lesser degree for EDO, growth in 2012 would have been even weaker had it not been for accommodative

monetary policy. However, as the monetary accommodation on the *level* of output wanes going forward, the unwinding of the support from monetary policy acts as a drag on output *growth* in 2014 and 2015. PRISM interprets the same data quite differently. This model largely attributes the recent lackluster performance of the economy to temporary factors, as opposed to the continuing impact of headwinds from the financial crisis. The waning of these temporary factors produces further impetus to growth in PRISM. A similar mechanism is at play in EDO, except that the recovery is much delayed relative to PRISM, and occurs only toward the end of the forecast horizon.

Inflation projections are very close to those reported in December, with all models forecasting inflation below the Fed's long run mandate throughout the forecast horizon. Inflation forecasts are largely consistent with the output growth forecasts, with PRISM for instance forecasting higher inflation than FRBNY and Chicago, but the inflation forecasts are not as different across models. This is for two reasons. First, marginal costs are below steady state in all models. Second, the Phillips curve is generally estimated to be quite flat, so that differences in economic activity map into smaller differences in inflation.

In terms of interest rates, by construction all four models project extremely low interest rates over the forecast horizon, since projected rates are anchored by market expectations until mid-2015. As soon as this anchoring is lifted and policy is expected to be conducted according to each model's estimated policy rule, the projections imply an increase of the federal funds rate. This increase reflects inflation and output forecasts toward the end of the horizon, as well as the degree of inertia in the policy rule. The increase in rates is very rapid in PRISM, with the federal funds rate reaching 1.5 percent by the end of 2015, while it is much more moderate in EDO because of the high degree of inertia.

Forecast Summary

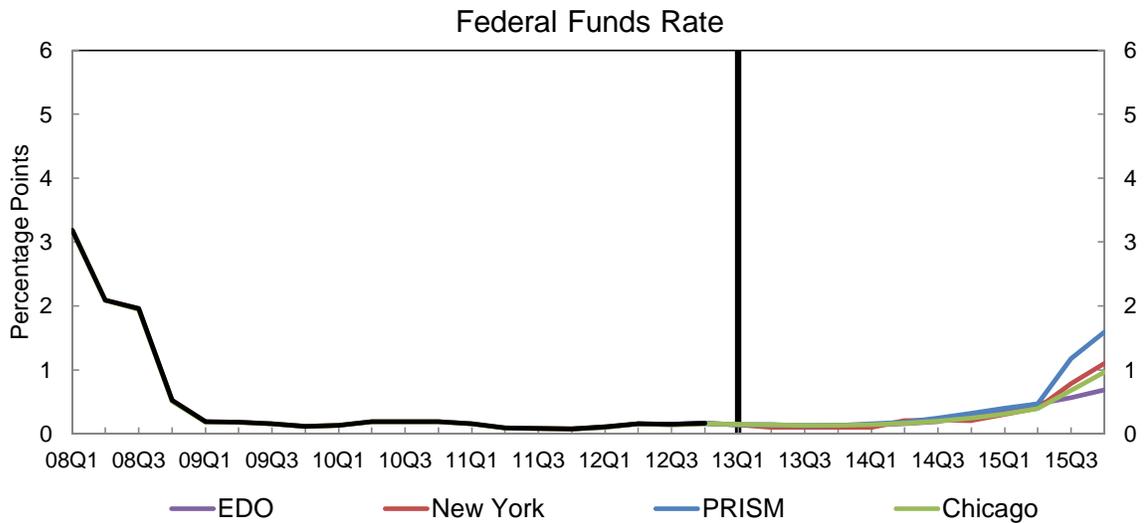
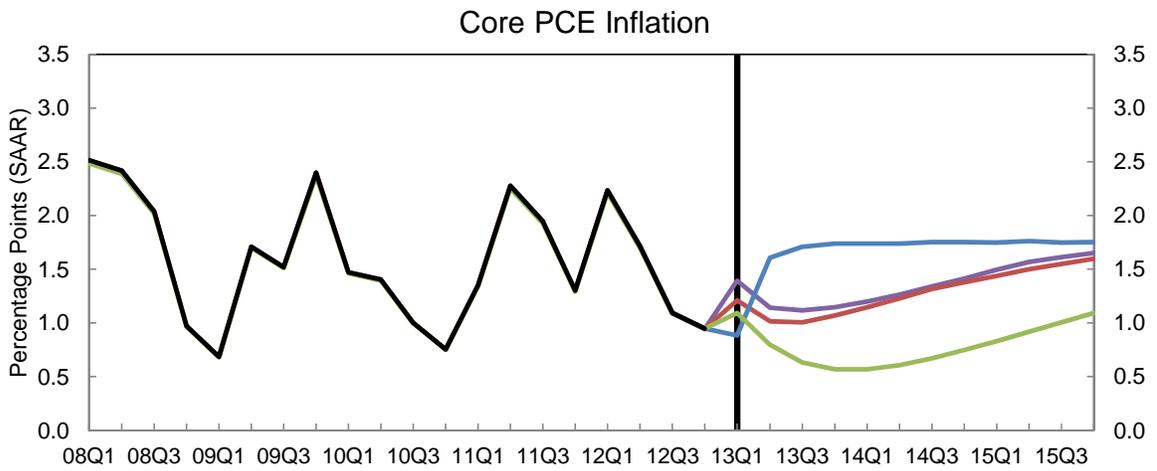
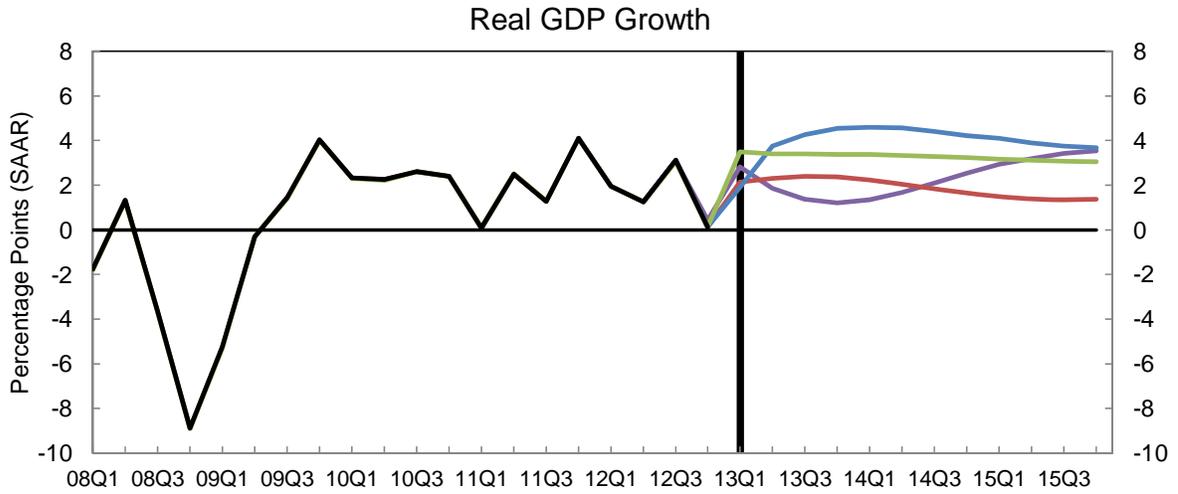
| Model | Output Growth (Q4/Q4) | | | | | |
|--------------------------|--------------------------|-------------------|--------------------------|-------------------|--------------------------|-------------------|
| | 2013 | | 2014 | | 2015 | |
| | Mar | Dec | Mar | Dec | Mar | Dec |
| EDO - Board of Governors | 1.9 (-1.0,4.7) | 1.6 (-1.7,4.9) | 2.0 (-0.1,3.9) | 2.2 (0.2,4.2) | 3.3 (1.2,5.3) | 3.5 (1.4,5.6) |
| New York Fed | 2.3 (0.1,3.7) | 2.7 (-0.3,4.6) | 1.9 (-1.7,4.5) | 2.3 (-1.4,4.9) | 1.4 (-2.1,4.3) | 1.6 (-1.9,4.5) |
| PRISM - Philadelphia Fed | 3.7 (1.2,6.1) | 4.3 (1.0,7.9) | 4.5 (0.8,8.6) | 4.7 (0.9,8.7) | 3.9 (0.0,8.0) | 3.9 (0.1,8.0) |
| Chicago Fed | 3.4 | 3.2 | 3.3 | 3.3 | 3.1 | 3.2 |
| Median Forecast* | 2.8 | 2.9 | 2.6 | 2.8 | 3.2 | 3.3 |

| Model | Inflation (Q4/Q4) | | | | | |
|--------------------------|-------------------------|------------------|-------------------------|------------------|-------------------------|------------------|
| | 2013 | | 2014 | | 2015 | |
| | Mar | Dec | Mar | Dec | Mar | Dec |
| EDO - Board of Governors | 1.2 (0.8,1.6) | 1.2 (0.6,1.8) | 1.3 (0.6,2.0) | 1.4 (0.7,2.1) | 1.6 (0.8,2.3) | 1.6 (0.9,2.4) |
| New York Fed | 1.1 (0.6,1.5) | 0.9 (0.2,1.4) | 1.3 (0.4,1.9) | 1.2 (0.3,1.8) | 1.5 (0.5,2.2) | 1.5 (0.5,2.2) |
| PRISM - Philadelphia Fed | 1.5 (0.6,2.4) | 1.7 (0.5,2.9) | 1.8 (0.2,3.3) | 1.7 (0.2,3.4) | 1.8 (0.1,3.5) | 1.7 (0.0,3.5) |
| Chicago Fed | 0.8 | 0.9 | 0.6 | 0.6 | 1.0 | 0.9 |
| Median Forecast* | 1.1 | 1.0 | 1.3 | 1.3 | 1.6 | 1.6 |

| Model | Federal Funds Rate (Q4) | | | | | |
|--------------------------|--------------------------|-------------------|--------------------------|-------------------|--------------------------|-------------------|
| | 2013 | | 2014 | | 2015 | |
| | Mar | Dec | Mar | Dec | Mar | Dec |
| EDO - Board of Governors | 0.3 (0.0,1.2) | 0.3 (0.0,1.5) | 0.5 (0.0,2.0) | 0.5 (0.0,2.0) | 0.9 (0.0,2.5) | 1.0 (0.0,2.5) |
| New York Fed | 0.1 (0.3,1.1) | 0.1 (0.1,1.2) | 0.2 (0.3,1.5) | 0.2 (0.2,1.5) | 1.1 (0.3,2.6) | 1.2 (0.3,2.7) |
| PRISM - Philadelphia Fed | 0.1 (-1.0,1.4) | 0.1 (-1.5,1.6) | 0.3 (-2.0,2.5) | 0.2 (-2.3,2.6) | 1.6 (-1.4,4.3) | 1.5 (-1.5,4.5) |
| Chicago Fed | 0.1 | 0.1 | 0.2 | 0.3 | 1.0 | 0.8 |
| Median Forecast* | 0.1 | 0.1 | 0.3 | 0.2 | 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.



— EDO
 — New York
 — PRISM
 — Chicago

Detailed Descriptions of Individual Model Forecasts

The EDO Model

The EDO model projects real GDP growth below trend until the end of 2014 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 1.1 percent in the middle of 2013 to about 1 $\frac{3}{4}$ percent by the end of 2015. Anticipated future federal funds rates are constrained to equal market expectations, as inferred from OIS rates. EDO forecasts are furthermore conditional on Board staff estimates for 2013Q1.

The weak activity forecast is heavily shaped by the model's interpretation of the low level of interest rates through 2015. Low interest rates over the projection mainly reflect the weakness in activity and disinflation associated with continued adverse financial conditions. Fluctuations in risk premiums are indeed the dominant factor in accounting for fluctuations in interest rates over history and remain important over the projection period. The aggregate risk premium is projected to remain in the neighborhood of its early 2012 levels, lowering GDP growth and boosting unemployment well above its long-run level. In addition, lower than expected labor productivity and higher than expected inflation have led the model to infer a deterioration of aggregate supply conditions since the beginning of 2011.

The unemployment rate rises slowly through mid 2014, reaching a peak of 8.7 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 adverse labor market conditions associated with wage and price rigidities. In particular, EDO estimates that households would be willing to work for notably lower real wages—but the stickiness in nominal wages and prices in the model implies that this incipient downward pressure on real wages is not realized. This process evolves slowly, and is the primary factor accounting for elevated unemployment late in the projection.

Given that the model attributes the low expected federal funds rate path largely to persistently restrictive financial conditions, the amount of policy accommodation is estimated to be modest. This additional stimulus from monetary policy boosts growth noticeably through the

end of 2012, but has little effect over the forecast period. Inflation is held below target, muting pressure on wages in the labor market.

The FRBNY Model

The FRBNY model forecasts are obtained using data released through 2012Q4, augmented for 2013Q1 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 2013Q1 observations. The expected future federal funds rates are constrained to equal market expectations, as measured by the OIS rates, through 2015Q2. The 2013Q1 staff projections and OIS rates are those available on March 4, 2013.

Output growth in 2012Q4 and 2013Q1 (as projected by the staff) was in line with the DSGE model forecasts produced in December, hence our output projections are essentially the same as in the last DSGE System memo. The model still projects 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, 1.9 and 1.4 percent, respectively, marginally below the rates of 2.7, 2.3 and 1.6 percent, respectively, reported in December. Core PCE inflation in 2013Q1 (again, as projected by the staff) turned out a bit higher than in the December DSGE projections, lifting up the near-term inflation projections slightly, but leaving the medium and long run projections unchanged. The model predicts core PCE inflation to remain below the FOMC long-run goal of 2 percent throughout the forecast horizon. Specifically, core PCE inflation projections for 2013, 2014 and 2015 (Q4/Q4) are 1.1, 1.3 and 1.5 percent, respectively, compared to 0.9, 1.2 and 1.5 percent, respectively, in December.

There is significant uncertainty around real GDP forecasts, with 68 percent bands covering the interval 0.1 to 3.7 percent in 2013 (Q4/Q4), -1.7 to 4.5 percent in 2014 (Q4/Q4), and -2.1 to 4.3 percent in 2015 (Q4/Q4). The forecast distribution for inflation moved up slightly relative to December, and the 68 percent probability bands are 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 subdued recovery, low real marginal costs, and

consequently low inflation. The impact of these shocks on the recovery is long-lasting and starts to wane only in mid-2013. On the other hand, accommodative monetary policy, particularly the forward-guidance, has played an important role in counteracting the financial headwinds, which has lifted up output and inflation. However, the impact of policy on the *level* of output starts to wane by the end of 2012, which implies that the effect of policy on *growth* is actually negative after that. 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, by the end of 2012 the historical rule would imply a rate that is slightly below 25 basis points. However, by early 2015 the policy accommodation provided by forward guidance becomes noticeable, implying a federal funds rate path below the historical rule by about one percentage point.

The PRISM Model

The Philadelphia Research Intertemporal Stochastic Model (PRISM) forecast is constructed using data through 2012Q4 that are then supplemented with a 2013Q1 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 expectations implied by futures market data.

PRISM forecasts a fairly strong acceleration in growth from the average pace posted in 2012. Note that there is no explicit adjustment for the budget sequestration that went into effect on March 1. The PRISM forecast for 2013Q2 real output growth is 3.7 percent, rising to about 4.5 percent in 2013Q4. Output growth then runs at about a 4.5 percent pace in 2014 and at a 3.9 percent pace in 2015 (both Q4/Q4). While output growth is projected to be fairly robust, inflation remains contained at a bit below 2 percent through the forecast horizon. The forecast has the funds rate following the market expectations through 2015Q2 and then rising to 1.6 percent by the end of 2015.

According to PRISM, the primary factors that accounted for weak real GDP growth in 2012Q4 were negative shocks to government spending, total factor productivity (TFP), and the efficiency with which investment is turned into capital. For the current quarter, below-trend growth is accounted for by shocks to TFP and the marginal efficiency of investment. The model continues to see the de-trended *level* of output well below its steady state. An important factor in

accounting for this output gap is the low level of aggregate hours worked, which the model accounts for through a combination of adverse labor supply shocks, financial shocks, and investment shocks. Over the last few quarters, markup shocks have been important in accounting for below-trend core inflation. These shocks are not persistent in the model and so inflation quickly rebounds in 2013Q2. Looking ahead, the unwinding of the labor supply shocks (rebound in hours worked), financial shocks, and marginal efficiency of investment shocks (rebound in investment) are key factors in accounting for strong output growth over the next three years. Inflation, however, remains contained both because the gradual increase in labor supply puts downward pressure on wages and marginal costs, and because of lingering effects of financial shocks. Going forward, the model predicts core PCE inflation will average a bit above 1.75 percent in 2014 and 2015.

The forecast for PRISM obtained without using federal funds rate expectations as conditioning information projects a significantly stronger path for the federal funds rate. In that scenario, the federal funds rate rises to 2.6 percent by the end of 2014 and 3.4 percent by the end of 2015. The path for real output growth is similar to that obtained under the forecast that uses federal funds rate expectations, while the path for inflation is a bit higher, averaging 2.1 percent in 2014 and 2.2 percent in 2015.

The Chicago model

The Chicago model forecast incorporates data through 2012Q4. We use forward guidance shocks to help shape the model's expected federal funds rates through mid-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 (SPF).

The Chicago forecasts for real GDP growth and inflation have not changed substantially from December. Real GDP growth in 2013 on a Q4/Q4 basis is projected to be 3.4 percent, up from 3.2 percent in December. The economy is then projected to continue to grow slightly above potential (2.7 percent in our model) throughout the remainder of the forecast horizon. Accordingly, the measure of the output gap that enters our Taylor-type policy rule decreases from -5.4 to -0.6 percent over the forecast horizon.

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 fourth quarter. Negative serial correlation in this shock then results in a slight boost to GDP growth in 2013 and 2014. This could be seen as a risk to the model's forecast if in fact the weakness in government expenditures continues as a result of sequestration.

Recent favorable monetary policy and spread shocks, the latter embodying movements in the external finance premium beyond what is warranted by firms' balance sheets, also boost GDP growth in 2013 and 2014. These 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 fourth quarter of 2012, while an adverse neutral technology shock subtracted nearly 0.3 percentage point.

The forecasted path for Q4/Q4 core PCE inflation remains largely unchanged from December. Inflation declines from the 1.5 percent observed in 2012 to 0.8 percent in 2013 and 0.6 percent in 2014 before edging back up to 1.0 percent in 2015. Positive price mark-up shocks account for the higher inflation in 2012. Lower subsequent inflation stems from a moderately lower Q4 SPF forecast for 10-year CPI inflation and transitory residual price and demand shocks in the model.

Market expectations hold the funds rate just below 0.5 percent through mid-2015. The funds rate then rises on average a bit more than 25 bps per quarter, ending 2015 at 1.0 percent, up slightly from 0.8 percent in December. This change reflects the effects of a slightly less negative output gap and marginally lower inflation target in the model's policy rule.