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To: Federal Open Market Committee
From: Deborah J. Danker
Subject: DSGE Models Update

The attached memo provides a quarterly 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 detail 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 April FOMC meeting, are displayed in the table and figure at the end of this summary section. These forecasts are obtained using actual data through 2012Q1 and current projections for 2012Q2, which are treated by the models as if they were data. The forecasts are also conditioned on the anticipation that the federal funds rate will remain exceptionally low through at least mid-2014. This constraint is imposed by anchoring the expected path of the federal funds rate to market expectations at least until 2014Q2; the specific measure of market expectations adopted by each model is explained in the detailed forecasts below. Most models project a federal funds rate path somewhat weaker than the one incorporated in the April forecasts.

The growth projections for 2012 and 2013 (Q4/Q4) are fairly similar across the models, except for PRISM, which continues to project a significant strengthening in economic activity. Relative to April, all models project more moderate growth (EDO's projections are higher than those reported in April due to changes in the structure of the model; however, current four-quarter GDP growth forecasts are about $\frac{1}{4}$ of a percent lower in 2012 and 2013 than those obtained using the current model with data available at the time of the April FOMC).

The EDO, FRBNY and Chicago models anticipate below trend economic activity, explained in large part by the continued persistent effects of the financial headwinds that were responsible for both the severity of the recession and the lackluster recovery. Additionally, a combination of transitory shocks contributes in the near-term to economic weakness in the Chicago forecast. By contrast, PRISM foresees a strong rebound of economic activity as the economy reverts to trend much faster than in the other models. In particular, the unwinding of labor supply shocks that previously kept employment weak and the attenuation of marginal efficiency of investment shocks that were restraining investment contribute to a robust recovery.

In 2014 the EDO model sees the pace of economic activity picking up, while the FRBNY and Chicago project weak growth throughout the forecast horizon. In the FRBNY model this is

explained by the negative effect of monetary policy on the growth rate of output after 2012, as the impact of accommodative policy on the level of output fades over time.

EDO has been modified to explicitly model unemployment. The model projects unemployment to edge down only very slowly, reaching 7 $\frac{3}{4}$ percent by the end of 2014. The slow decline principally reflects both the inertial behavior of unemployment following shocks to the aggregate risk premium, as well as the elevated level of that shock over the forecast horizon. In addition, adverse labor supply shocks contribute moderately to the high rate of unemployment.

All models forecast a decline in inflation in the first half of 2012, with a slow return to values around 2 percent by the end of the forecast horizon. The depth of the decline differs across the models, with a trough in the Chicago and FRBNY models between 0.5 and 1.1 percent while in PRISM and EDO inflation remains between 1.5 and 2 percent. All models attribute the inflation pick-up in 2011 and the first part of 2012 largely to temporary factors. In the EDO and FRBNY models, the same forces that are at the origin of the sluggish recovery also contribute to a subdued inflation outlook for the whole forecast period. Negative price mark-up shocks inferred from incoming data are instead the primary driver of the inflation forecast in the Chicago model. PRISM's inflation outlook remains contained, despite its robust growth forecast, both because the increase in labor supply puts downward pressure on wages and marginal costs, and because of the lingering effects of discount factor shocks. Accommodative monetary policy has little impact on the inflation forecasts, as in most models current policy is interpreted as reflecting depressed economic conditions.

In terms of interest rates, by construction all four models project extremely low interest rates over the forecast horizon and slightly lower rates than were anticipated in April. The lower projected path results from the flattening of the market expectations that anchor the forward guidance at least until mid-2014. As soon as this conditioning is lifted and policy is expected to be conducted according to each model's estimated policy rule, the projections imply an immediate increase of the federal funds rate, with some differences across models. In EDO the federal funds rate remains below 1 percent by the end of 2014, while in the FRBNY and PRISM models it increases to 1-1.5 percent. The Chicago model constrains the rate through the end of 2014.

Forecast Summary

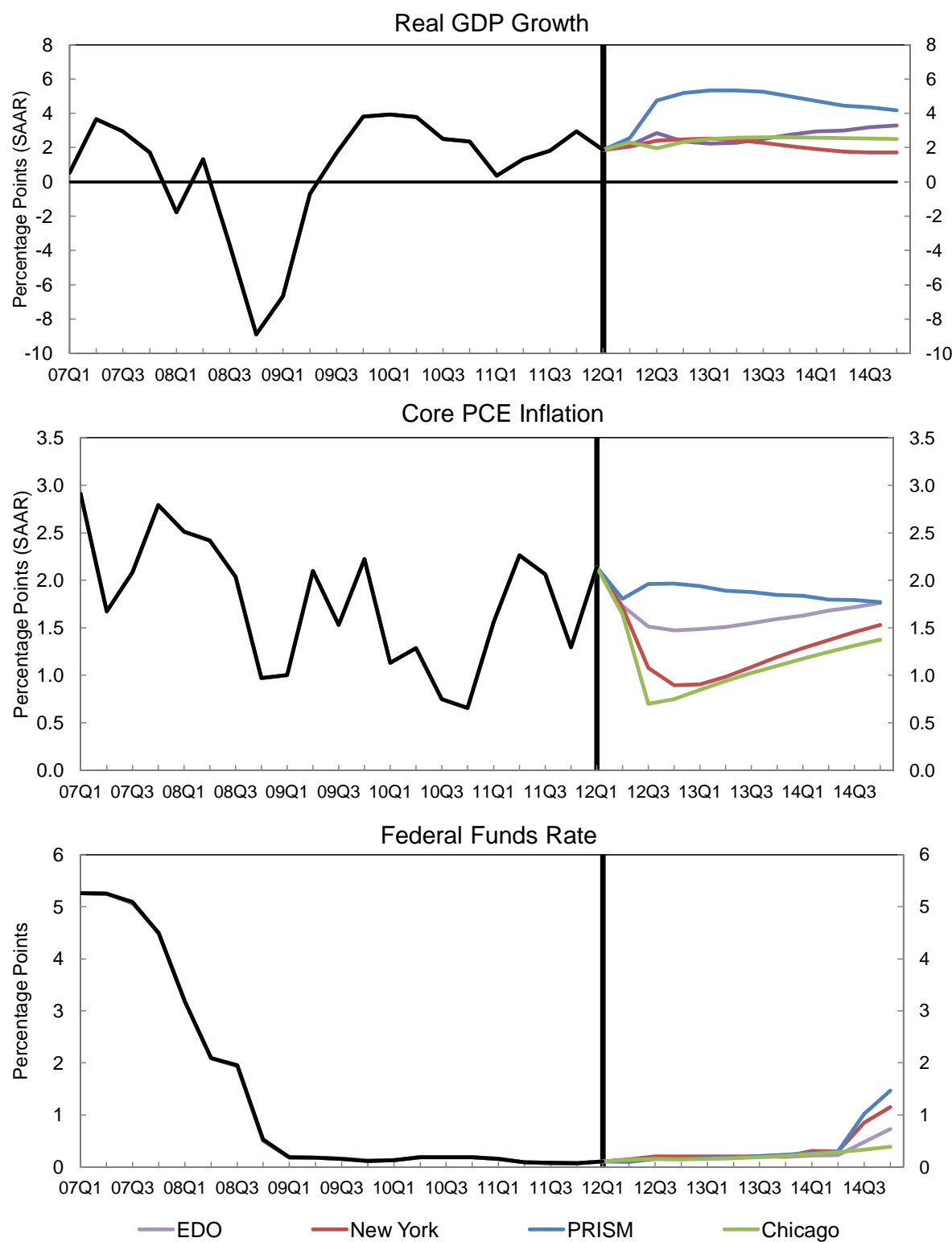
Model	Output Growth (Q4/Q4)					
	2012		2013		2014	
	June	Apr	June	Apr	June	Apr
EDO - Board of Governors	2.3 (0.0,4.7)	1.4 (-1.0,3.8)	2.6 (0.4,4.6)	1.7 (0.0,3.4)	3.2 (1.1,5.2)	2.6 (1.0,4.3)
New York Fed	2.2 (0.8,3.2)	2.3 (0.0,3.8)	2.3 (-1.3,4.8)	1.9 (-1.7,4.6)	1.8 (-1.9,4.7)	1.4 (-1.9,4.6)
PRISM - Philadelphia Fed	3.6 (2.0,5.4)	5.2 (1.6,8.8)	5.3 (1.1,9.5)	4.9 (0.8,9.0)	4.5 (0.1,8.6)	3.7 (-0.5,7.8)
Chicago Fed	2.1 (,,)	3.4 (,,)	2.6 (,,)	3.1 (,,)	2.5 (,,)	2.7 (,,)
Median Forecast*	2.2	2.9	2.6	2.5	2.9	2.7

Model	Inflation (Q4/Q4)					
	2012		2013		2014	
	June	Apr	June	Apr	June	Apr
EDO - Board of Governors	1.7 (1.4,2.0)	1.7 (1.3,2.2)	1.5 (0.9,2.2)	1.4 (0.8,2.1)	1.7 (1.0,2.4)	1.4 (0.7,2.0)
New York Fed	1.4 (1.1,1.7)	1.5 (1.0,1.9)	1.0 (0.2,1.7)	1.4 (0.5,2.0)	1.4 (0.5,2.1)	1.6 (0.6,2.3)
PRISM - Philadelphia Fed	2.0 (1.5,2.4)	2.0 (0.7,3.2)	1.9 (0.8,3.1)	1.8 (0.2,3.4)	1.8 (0.6,3.1)	1.7 (0.1,3.4)
Chicago Fed	1.3 (,,)	0.7 (,,)	1.0 (,,)	1.2 (,,)	1.3 (,,)	1.4 (,,)
Median Forecast*	1.6	1.6	1.3	1.4	1.5	1.5

Model	Federal Funds Rate (Q4)					
	2012		2013		2014	
	June	Apr	June	Apr	June	Apr
EDO - Board of Governors	0.3 (0.0,1.0)	0.2 (0.0,1.5)	0.4 (0.0,1.8)	0.3 (0.0,2.1)	1.0 (0.0,2.5)	1.4 (0.4,3.1)
New York Fed	0.2 (0.3,1.0)	0.2 (0.3,1.2)	0.2 (0.3,1.4)	0.5 (0.3,1.7)	1.2 (0.3,2.6)	1.3 (0.3,2.7)
PRISM - Philadelphia Fed	0.2 (-0.7,1.0)	0.1 (-1.2,1.2)	0.2 (-1.8,2.1)	0.1 (-2.0,2.2)	1.5 (-1.1,3.8)	1.2 (-1.5,3.6)
Chicago Fed	0.2 (,,)	0.1 (,,)	0.2 (,,)	0.3 (,,)	0.4 (,,)	1.0 (,,)
Median Forecast*	0.2	0.2	0.2	0.3	1.1	1.3

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.



Detailed Descriptions of Individual Model Forecasts

The EDO Model

The EDO model projects real GDP growth below trend on average until the end of 2013 and unemployment around 8 percent until the beginning of 2014. This subdued pace of real activity is accompanied by inflation gradually accelerating from a low of 1.5 percent in the second half of 2012 to around 1 $\frac{3}{4}$ percent at the end of 2014 -- still below the target of 2 percent. Accordingly, the federal funds rate is not expected to increase appreciably above its effective lower bound until the second half of 2014.

The weak activity forecast is heavily shaped by the model's interpretation of the anticipated path of the federal funds rate obtained from the futures market, which is considerably lower than the model would have otherwise anticipated. 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, recent data on labor productivity have led the model to infer a deterioration of aggregate supply conditions since the beginning of 2011. The stimulus from monetary policy boosts growth noticeably through the end of 2012, while inflation is held below target by a combination of weak aggregate demand and muted pressure on wages in the labor market.

Since April, EDO has been modified to incorporate a structural model of unemployment. In the labor market framework adopted in the model, unemployment reflects a gap between the level of employment demanded by firms, at a given wage, and the desire of households to work at that wage—a gap supported by imperfect competition in the labor market. As was true in the previous version of EDO, business cycle variation in labor inputs is largely driven by movements in the aggregate risk premium, the same shock primarily responsible for business cycle variation in the other observables in the model.

The unemployment rate is projected to edge down only very slowly, on balance, over the projection period, as unemployment reaches 8 $\frac{1}{4}$ percent in 2013Q4 and 7 $\frac{3}{4}$ percent in 2014Q4. The slow decline principally reflects both the inertial behavior of unemployment following shocks to the aggregate risk premium, as well as the elevated level of the premium over the forecast horizon. 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 move unemployment much more than other measures of activity. The model therefore naturally attributes a large share of low-frequency variation in unemployment to this source.

In addition, the model's treatment of the trend in aggregate hours has been altered to diminish the variability of end-of-sample estimates. With the current model specification, four-quarter GDP growth is around $\frac{1}{4}$ percent lower in 2012 and 2013 than would have been anticipated using April's data. This downward revision in growth rates can be traced back to the model's heightened pessimism about the medium-term prospects for improvements in financial conditions, as a result of the decline in the expected path of the funds rate in the second half of 2014. Note, however, that the current projection for GDP growth from EDO is actually faster than that reported in the April memo to the Committee because of the revised model specification, especially the more robust outlook for trend hours growth associated with the new specification, which results in a higher estimate of trend GDP growth going forward.

The FRBNY Model

The FRBNY model forecast is obtained using data released through 2012Q1, augmented for 2012Q2 with the FRBNY staff forecast for real GDP growth, core PCE inflation and growth in total hours, and with the values of the federal funds rate and the spread between Baa corporate bonds and 10-year Treasury yields based on April and May observations. The expected future federal funds rates are constrained to equal the OIS expected future funds rate through 2014Q2. The model is estimated using per-capita data, but the population measure has been filtered to avoid the large swings due to the fact that the series is not revised backwards.

These projections are broadly similar to those presented in April, as the data came in roughly in line with April's forecasts. The model still projects a lackluster recovery in economic activity, with output growth in the neighborhood of 2 percent throughout the forecast horizon. Output growth forecasts for 2012, 2013, and 2014 (Q4/Q4) are 2.2, 2.3, and 1.8 percent, respectively, compared to 2.3, 1.9, and 1.4, respectively, in April. The FRBNY staff forecast for 2012Q2 core PCE inflation is also in line with the April projections, showing some reduction in inflation relative to 2012Q1. As a result, inflation projections remain subdued throughout the forecast

horizon. Projections for 2012, 2013, and 2014 (Q4/Q4) are 1.4, 1.0, and 1.4 percent, respectively, compared to 1.5, 1.4, and 1.6 percent, respectively, in April.

There is significant uncertainty around real GDP forecasts, with 68 percent bands covering the interval 0.8 to 3.2 percent in 2012 (Q4/Q4), and -1.3 to 4.8 percent in 2013 (Q4/Q4). The forecast distribution for inflation moved down relative to April: the 68 percent probability bands are within the 0-2.1 percent interval throughout the forecast horizon, implying that the model places high probability on inflation realizations below the FOMC long run inflation goal, but the upper band is at 2 percent or above in 2013 and 2014 (Q4/Q4).

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 both spread and MEI (marginal efficiency of investment) shocks, 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, and particularly the forward guidance, plays an important role in counteracting the financial headwinds, and lifts up output and inflation. 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 explains in part why growth is still below trend by the end of 2014. The model attributes the pickup in core inflation in 2011 and in 2012Q1 to mark-up shocks, which capture temporary swings in inflation, such as those due to oil price fluctuations.

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. Policy shocks currently keep the federal funds rate 25 to 50 basis points lower than what would be implied by the historical rule. Moreover the near-zero policy rate through mid 2014 is seen by the model as 50 to 75 basis points more accommodative than what would be implied by the historical rule.

The PRISM Model

The Philadelphia Research Intertemporal Stochastic Model (PRISM) forecast is constructed using data through 2012Q1 that are then supplemented with 2012Q2 projections of output, consumption, investment, wages, and hours worked from the most recent Macroeconomic Advisors forecast (which forecasts 2012Q4 real GDP growth of about 2.2 percent). In addition,

the forecasted path for the federal funds rate is constrained through 2014Q2 using market expectations as implied by the CBT 30 day federal funds future contracts.

PRISM continues to forecast a fairly strong recovery with real GDP growth at about 5 percent in 2012H2 and 2013 (Q4/Q4), falling to about 4.2 percent by the end of the forecast horizon. While output growth is projected to be fairly robust, inflation remains contained at about 2 percent through the forecast horizon. The federal funds rate is constrained to remain in a range of 0 to 30 basis points through mid-2014 and is projected to increase to about 1.5 percent by the end of 2014.

According to PRISM, the primary factors that accounted for generally below-trend real output growth over the past four quarters were negative shocks to total factor productivity and to the efficiency with which investment is turned into capital. The model continues to see output well below its trend. An important factor in accounting for this output gap is the low level of aggregate hours worked, which the model captures through labor supply shocks. Looking ahead, the unwinding of labor supply shocks and of marginal efficiency of investment shocks (which result in a rebound in hours worked and investment, respectively) are key factors in accounting for strong output growth over the next three years. Inflation, however, remains contained both because the increase in labor supply puts downward pressure on wages and marginal costs, and because of the lingering effects of discount factor shocks.

The forecast for PRISM obtained without using federal funds rate expectations as conditioning information delivers a much higher interest-rate path over the next 3 years. With output projected to grow at an above-trend pace and inflation running above the target rate, this forecast has the funds rate rising immediately and then reaching about 3.2 percent by the end of 2014.

The Chicago model

The Chicago model forecast incorporates data through 2012Q1 augmented with estimates for 2012Q2 of, most importantly, real GDP, real Investment and Consumption, hours, and core PCE inflation, based on the incoming monthly data. We use forward guidance shocks to equate the model's expected federal funds rates through 2014 with their implied values from current futures markets prices. The model includes a slowly drifting inflation anchor (currently 2.5 percent) which dominates changes in long-run expected inflation and is disciplined 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.

Adverse demand shocks largely explain the weakness in the recovery of economic activity. Monetary policy partially offset their impact, adding roughly 0.4 percent to real GDP growth over the past year. Adverse supply shocks lifted core PCE inflation in the first half of this year.

The Chicago forecasts for both real GDP growth and inflation have changed substantially from April. The economy is now projected to grow just below potential throughout the forecast horizon. Real GDP growth in 2012 Q4/Q4 is projected to be 2.1 percent as opposed to 3.4 percent reported in April. This near-term downward revision is partly explained by transitory shocks, which dissipate within the year. Beyond 2012, the protracted weakness in the forecast is explained by the model's spread shock. This shock, which embodies movements in the external finance premium beyond what is warranted by firms' balance sheets, has particularly persistent effects on economic activity.

The forecasted path for Q4/Q4 core PCE inflation remains in the range of 1.0 to 1.3 percent throughout the forecast horizon. Momentum from a positive price mark-up shock raised the forecast for inflation in 2012 to 1.3 percent from 0.7 percent reported in April. Recent negative price mark-up shocks inferred from incoming Q2 data lowered the inflation forecasts for 2013 and 2014 by 0.2 and 0.1 percent, respectively, from those reported in April.