Date: September 6, 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 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 June FOMC meeting, are displayed in the table and figure at the end of this summary section. Please note that the forecasts now extend through 2016 and that, with the exception of the Chicago model, all the models have been estimated using the July 2013 comprehensive revision of the NIPA data. These forecasts were obtained using actual data through 2013Q2 and conditioning assumptions or "nowcasts" for 2013Q3. The nowcast assumptions for 2013Q3 vary across the models. For example, the Chicago model assumption is for output to rise by 1.8 percent in the current quarter, PRISM assumes a growth rate of 2.3 percent, FRBNY anticipates 2.1 percent, and EDO projects current quarter growth of 1.7 percent. Further, each model assumes that near-term expectations of the future federal funds rate are implied by market prices of interest rate swaps, with predicted funds rate behavior becoming model driven at somewhat different dates. Both PRISM and FRBNY assume that the funds rate is pinned down by market expectations until 2015Q2, while the Chicago model assumes they are market driven until 2016Q1, and EDO assumes that they are market driven through 2016Q2. Different conditioning assumptions can sometimes meaningfully affect forecasts, and each of the models' assumptions are explained in further detail in the individual summaries below.

With the exception of EDO, all the models have revised down their projections for real GDP growth in 2013. EDO has moved forward monetary policy lift off and that is interpreted as implying greater underlying economic strength. This greater strength is in large part responsible for the model's more upbeat prognosis for economic activity. For Chicago and PRISM, negative shocks to total factor productivity and transitory aggregate demand shocks, such as weakness in government spending, are the main contributors to the weaker near-term forecasts. Other than FRBNY, the models anticipate accelerating economic activity leading to above trend growth by

the end of the forecast horizon. Of the four models, only PRISM projects a robust recovery beginning next quarter. The median forecast across models is for growth of 2.0 percent in 2013 (down from 2.6 percent in June) rising to 2.6 percent in 2014 (down from 2.8 percent in June), 3.4 percent in 2015 (up from 3.1 percent in June), and 3.4 percent in 2016.

The Chicago model and EDO display very similar views regarding the forecast for real GDP from 2014 through 2016. Both forecasts are characterized by slow but steady improvement in the economy. Financial headwinds, which have very persistent effects in FRBNY, continue to weigh negatively on its forecast over the entire forecast horizon. Thus, the model anticipates below trend growth through 2016. In PRISM, the unwinding of adverse labor supply shocks and the model's inherent strong predilection for returning to trend contribute to its prediction of a rapid recovery.

Regarding inflation, all the models predict inflation rates below the FOMC's long-run target. The recent strength in inflation is viewed as totally transitory in PRISM. Financial shocks, which persistently and adversely affect inflation in the model, contribute to the muted view of inflation going forward. As in PRISM, financial shocks, along with shocks to investment restrain cost pressures and hence suppress inflation in FRBNY. The Chicago model is somewhat of an outlier projecting inflation rates well below one percent. The overall weakness in inflation is primarily due to weak aggregate demand, while the upward revision to the near-term inflation forecast is the result of the short lived markup shocks. In summary, the median forecasts of inflation from the four models is 1.3 percent in 2013 (up from 1.0 percent in June), 1.3 percent in 2014 (barely changed from 1.2 percent in June), 1.5 percent in 2015 (the same as in June), and 1.7 percent in 2016.

To varying degrees, EDO, PRISM, and FRBNY all interpret the federal funds rate path implied by market expectations as providing greater accommodation than would be indicated by each models interest rate rule. This feature is no longer true in the Chicago model, which now interprets the assumed policy path as a source of adverse forward guidance shocks. The slow policy lift off envisioned in their forecast is primarily due to the weakness in anticipated inflation. The weakness in the FRBNY forecast also implies a rather gradual increase in the

funds rate, once policy tightening commences. Alternatively, with inflation returning to near-targeted values at the end of the forecast horizon, PRISM anticipates, as it does with output, that the funds rate will return to a rate more consistent with its long-run steady state. Once each models estimated interest rule takes effect, by the end of 2016 the funds rate reaches 2.3 percent in EDO, 1.7 percent in the Chicago model, 2.1 percent in FRBNY, and 3.1 percent in PRISM.

Forecast Summary

Model	Output Growth (Q4/Q4)						
	2013		2014		2015		2016
	Sept	June	Sept	June	Sept	June	Sept
EDO - Board of Governors	1.8 (0.2,3.5)	1.9 (-0.5,4.3)	2.5 (-0.1,4.8)	1.8 (-0.4,3.9)	3.5 (1.6,5.2)	2.9 (0.9,5.0)	3.3 (1.4,5.2)
New York Fed	2.0 (1.3,2.4)	2.3 (0.9,3.2)	2.0 (-1.1,4.2)	2.1 (-1.2,4.4)	1.7 (-1.5,4.5)	1.5 (-1.8,4.4)	1.8 (-1.2,5.0)
PRISM - Philadelphia Fed	2.6 (2.0,3.4)	2.9 (1.3,4.4)	4.4 (1.1,8.0)	4.2 (0.6,8.1)	3.9 (0.3,7.6)	3.9 (0.1,8.0)	3.7 (0.2,7.6)
Chicago Fed	2.0	3.1	2.7	3.5	3.2	3.3	3.5
Median Forecast*	2.0	2.6	2.6	2.8	3.4	3.1	3.4

Model	Inflation (Q4/Q4)						
	2013		2014		2015		2016
	Sept	June	Sept	June	Sept	June	Sept
EDO - Board of Governors	1.2 (1.1,1.4)	0.9 (0.7,1.2)	1.3 (0.7,1.9)	1.1 (0.5,1.8)	1.5 (0.8,2.2)	1.4 (0.7,2.2)	1.7 (0.9,2.4)
New York Fed	1.3 (1.1,1.5)	1.0 (0.7,1.3)	1.2 (0.4,1.8)	1.2 (0.4,1.8)	1.5 (0.6,2.2)	1.5 (0.6,2.2)	1.7 (0.8,2.5)
PRISM - Philadelphia Fed	1.3 (1.1,1.6)	1.4 (0.9,2.0)	1.5 (0.2,2.9)	1.7 (0.3,3.2)	1.7 (0.1,3.3)	1.7 (0.2,3.5)	1.8 (0.0,3.5)
Chicago Fed	1.1	0.9	0.4	0.4	0.4	0.7	0.8
Median Forecast*	1.3	1.0	1.3	1.2	1.5	1.5	1.7

| Model	Federal Funds Rate (Q4)						
	2013		2014		2015		2016
	Sept	*June*	**Sept**	*June*	**Sept**	*June*	**Sept**
EDO - Board of Governors	**0.1** (0.0,0.6)	*0.2* (0.0,1.0)	**0.6** (0.0,2.1)	*0.5* (0.0,2.1)	**1.5** (0.1,3.4)	*1.0* (0.0,2.8)	**2.3** (0.6,4.1)
New York Fed	**0.1** (0.3,0.6)	*0.1* (0.3,0.7)	**0.4** (0.3,1.5)	*0.3* (0.3,1.5)	**1.3** (0.4,2.6)	*1.1* (0.3,2.5)	**2.1** (0.8,3.6)
PRISM - Philadelphia Fed	**0.1** (-0.5,0.6)	*0.1* (-0.7,1.1)	**0.4** (-1.4,2.1)	*0.4* (-1.5,2.6)	**2.0** (-0.5,4.5)	*1.6* (-1.1,4.4)	**3.1** (0.3,6.0)
Chicago Fed	**0.1**	*0.1*	**0.4**	*0.3*	**1.1**	*0.7*	**1.7**
Median Forecast*	**0.1**	*0.1*	**0.4**	*0.4*	**1.4**	*1.1*	**2.2**

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.

Forecasts

Core PCE Inflation

Federal Funds Rate
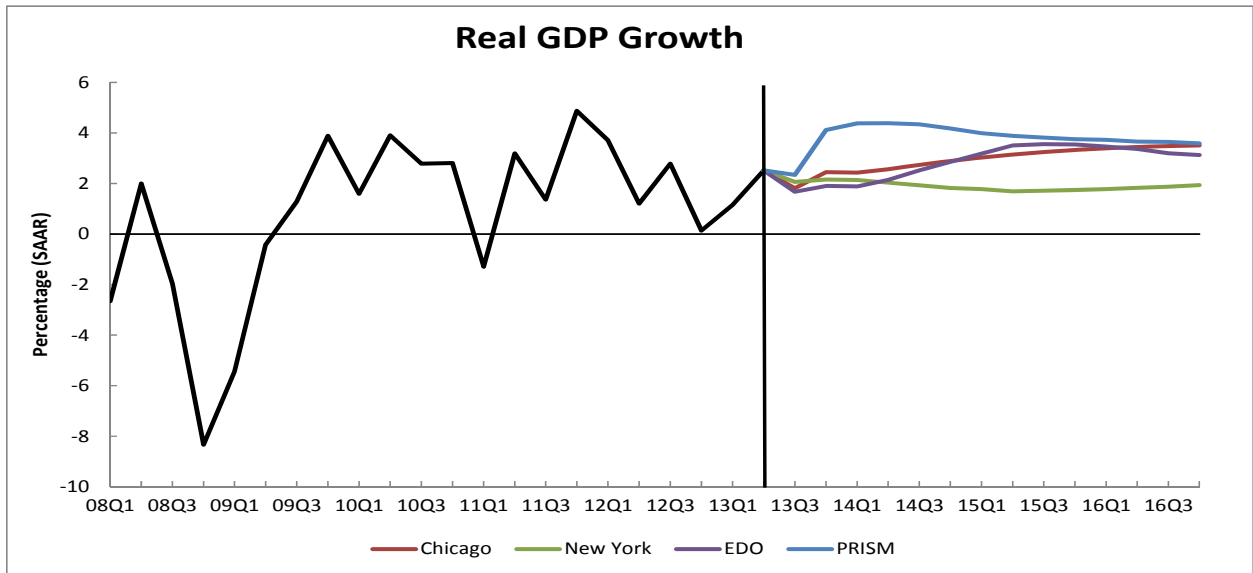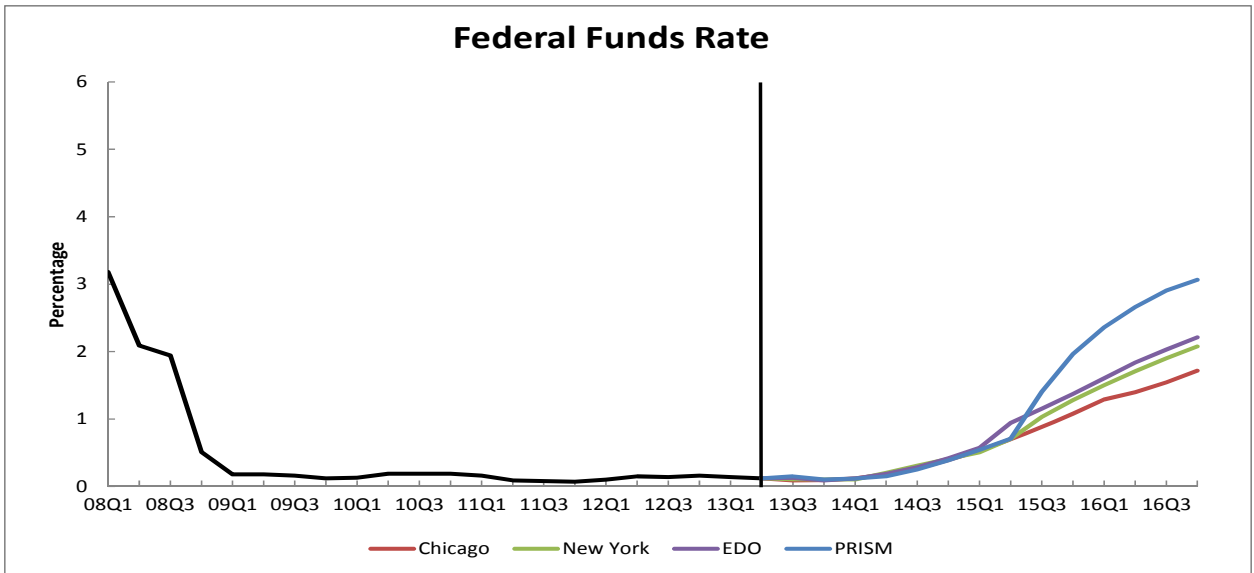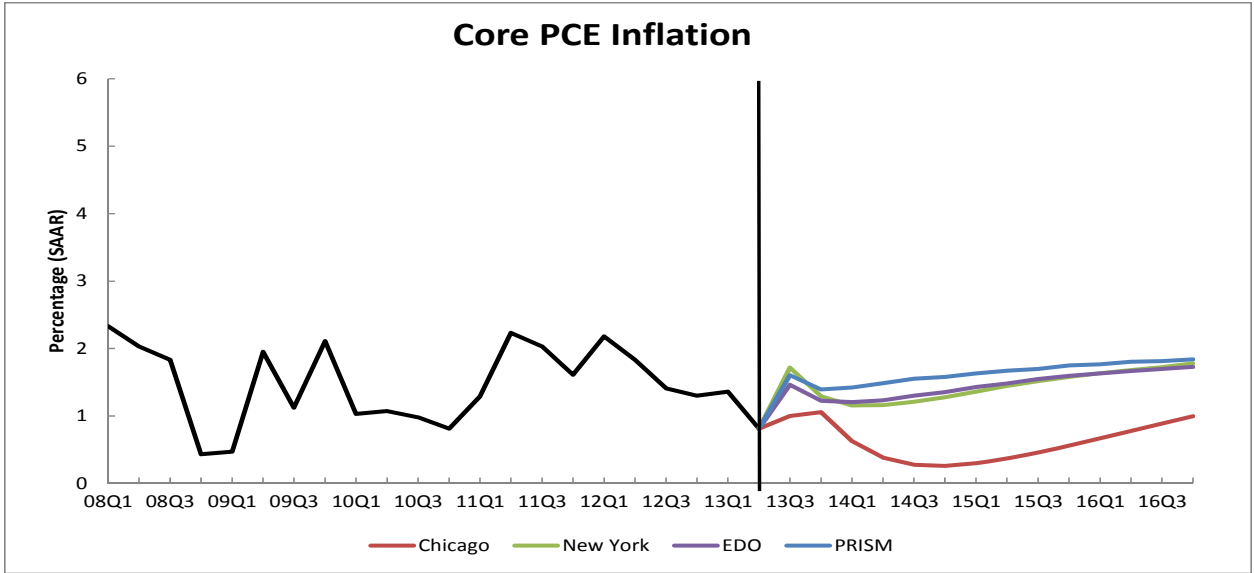
Detailed Descriptions of Individual Model Forecasts

The Chicago model
The Chicago model forecast incorporates data through 2013Q2 and uses staff projections to plug the necessary inputs for 2013Q3. The staff projections for Q3 are for real GDP growth to rise 1.8 percent as real consumption increases and real investment decreases from their Q2 values.

Additionally, we use forward guidance shocks to shape the model's expected federal funds rates through the first quarter of 2016 based on their implied values from futures market prices. The model also includes a slowly drifting inflation anchor (currently 2.2 percent) which dominates changes in long-run expected inflation and is identified by equating the 10-year average of model-based expected goods price inflation with the long-term annual average CPI inflation projection from the Survey of Professional Forecasters.

Several large shocks to aggregate demand during the recession continue to drag down our forecasts for growth and inflation. Counteracting the deflationary effect of these shocks are contemporaneous innovations to the model's highly persistent inflation anchor, reflecting the fact that inflation expectations remained well-anchored throughout this period.

The Chicago forecasts for real GDP growth are significantly lower than they were in June. Real GDP growth in 2013 and 2014 on a Q4/Q4 basis are now projected to be 2.0 and 2.7 percent, respectively, down from 3.1 and 3.5 percent in June. Consistent with our June projections, the growth forecast then rebounds to above 3 percent in 2015 and 2016. With growth below potential for a longer period of time, the measure of the output gap that enters our Taylor-type policy rule is slightly larger than in June, increasing from 0.3 percent in the fourth quarter of 2016 to -0.2 percent.

Transitory adverse demand shocks explain much of the near-term weakness in economic activity. In particular, a residual shock to the national income and product accounting identity -- embodying a change in expenditures on inventories, net exports, and government purchases in the model -- accounts for the majority of the weakness in GDP growth in the third quarter,

subtracting 1.0 percent from its four quarter average. However, negative serial correlation in this shock slightly boosts GDP growth in 2014.

In contrast, neutral technology and monetary policy shocks largely explain the persistence of weaker activity. The model interprets the weakening of consumption and investment concomitant with increasing hours worked over the last two quarters as adverse innovations to neutral technology. Additional weakness in the forecast stems from an adverse forward guidance shock. Market expectations now hold the path of the funds rate near or below 0.5 percent through the first quarter of 2015, implying lift-off one quarter earlier than in June. Both the forward guidance and technology shocks each subtracted 0.4 percent from the four quarter average of GDP growth in the third quarter of 2013.

The forecasted path for Q4/Q4 core PCE inflation declines from the 1.7 percent observed in 2012 to 1.1 percent in 2013 and 0.4 percent in 2014 (0.9 and 0.4 percent in June) before gradually increasing to 0.8 percent in 2016 (1.1 percent in June). Positive price mark-up shocks inferred from incoming data account for the slightly higher inflation in 2013 than was projected in June. However, their effect on the forecast is short-lived. At longer forecast horizons, innovations to the model's slowly drifting inflation anchor dominate our inflation forecast. The Q3 Survey of Professional Forecasters long-term annual average CPI projection decreased slightly from 2.3 to 2.2 percent and is largely responsible for our lower 2016 inflation forecast than in June.

After the projected lift-off of the funds rate in the first quarter of 2015, the interest rate forecasts increase less than 25 bps per quarter. Our forecasted interest rate ends 2016 at 1.7 percent, and this is 30 bps lower than the corresponding forecast in June. The decrease in our interest rate forecasts reflects weaker outlooks for both growth and inflation, and occurred despite an earlier projected lift-off date.

The EDO Model

The EDO model projects average real GDP growth below its trend of 2.7 percent until the end of 2014 and unemployment above 7 percent until the end of 2016.[2] This subdued pace of real activity is accompanied by inflation gradually accelerating from a low of 1.2 percent at the end of 2013 to about 1 ¾ percent by the end of 2016. Private agents do not expect the federal funds rate to lift appreciably above its effective lower bound until the final quarter of 2014. [3]

The weak activity forecast is heavily shaped by the model's interpretation of the anticipated path of the federal funds rate inferred from interest rate swaps. To a considerable extent, in recent quarters, the model accounts for this path by attributing to private agents the expectation of relatively adverse financial conditions over the forecast horizon, rather than to unusually accommodative policy. 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.

Thus restrained, GDP growth accelerates only modestly from 1.7 percent in 2013:Q3 to 2 percent through mid-2014. Chiefly as a result of the elevated risk premiums mentioned previously, the unemployment rate rises slowly through mid-2014, reaching a peak of 7.9 percent, before declining to 7.0 percent by the end of 2016. High risk premiums, along with a very persistent shift in household labor supply, also account for the low trajectory for inflation in the forecast.

As the model views the anticipated funds rate path as a reflection of demand conditions rather than unusual policy actions, the earlier expected departure of the funds rate from the ZLB in the current data, relative to market expectations in June, has been taken as a signal of more

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[2] Following the annual revision of NIPA data, the static parameters of the EDO model have been re-estimated using data through 2013:Q2. For estimation, the observable corresponding to the model's concept of investment excludes spending on intellectual property products. Data for 2013:Q3 are preliminary estimates by Board staff prepared for the Tealbook forecast process.

[3] Observations of the market-expected funds rate path through 11 quarters into the future are provided to the model starting in 2008:Q4. Thus, in the forecast, the funds rate path through 2016:Q2 is consistent with market expectations.

optimistic private sector expectations. Accordingly, the forecasts for both activity and inflation have revised up since June.

The FRBNY Model

The FRBNY model forecasts are obtained using data released through 2013Q2, augmented for 2013Q3 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 2013Q3 observations. The expected future federal funds rates are constrained to equal market expectations, as measured by the OIS rates, through 2015Q2. This constraint is implemented via 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 2013Q3 staff projections and OIS rates are those available on August 28, 2013.

The July comprehensive NIPA revision didn't have a notable effect on the forecast. However, 2013Q3 growth (as projected by the FRBNY staff) turned out to be below the June DSGE forecast. As a result, the current model projections for output growth are slightly below those obtained in June. Growth forecasts for 2013, 2014 and 2015 (Q4/Q4) are 2.0, 2.0 and 1.6 percent, respectively, compared to forecasted growth rates in June of 2.3, 2.1 and 1.5 percent, respectively. In general, the model continues to project a lackluster recovery in economic activity, with output growth in the neighborhood of 2 percent throughout the forecast horizon. Core PCE inflation for 2013Q3 (again, as projected by the staff) turned out to be higher than the June DSGE projection, and this contributed to move up the model inflation forecasts in the near term. Mean core PCE inflation for 2013 (Q4/Q4) is projected to be 1.3 percent, above the model's June forecast of 1.0 percent, while 2014 and 2015 (Q4/Q4) projections are unchanged relative to June, at 1.2 and 1.5 percent, respectively. That means that inflation is projected to remain below the FOMC long-run goal of 2 percent throughout the whole forecast horizon.

Uncertainty around real GDP forecasts narrowed somewhat relative to June, but remains large. The 68 percent bands cover the intervals 1.3 to 2.3 percent in 2013 (Q4/Q4), -1.1 to 4.2 percent in 2014 (Q4/Q4), and -1.5 to 4.5 percent in 2015 (Q4/Q4). The forecast distribution for inflation

was also marginally narrower relative to June, 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 low real activity, low real marginal costs, and consequently low inflation. The economy experienced large spreads 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 now 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 rather than by policy shocks. In fact, the current level of the policy rate is not too far from that implied by the estimated monetary policy rule. However, beyond 2013 the degree of policy accommodation provided by anticipated policy shocks (forward guidance) becomes more noticeable, implying a federal funds rate path below the historical rule by about 75 basis points.

The PRISM Model

The Philadelphia Research Intertemporal Stochastic Model (PRISM) forecast is constructed using data through 2013Q2 that are then supplemented with a 2013Q3 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 during the first half of 2013. While 2013Q3 real output growth is pinned down at 2.3 percent by the nowcast, the forecast calls for output growth to accelerate to 4.1 percent in the fourth quarter and then run at about a 4.4 percent pace over 2014. Real GDP growth then decelerates moderately to at 3.9 percent in 2015 and 3.7 percent in 2016. While output growth is projected to be fairly robust, 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 2 percent by the end of 2015 and 3.1 percent by the end of 2016.

According to PRISM, the primary factor that accounts for somewhat weak real GDP growth over the past few quarters is negative shocks to TFP. 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 4.4 percent in the first half of 2014 and then gradually tapers down to 3.6 percent in 2016Q4.

The principal factor accounting for below-trend core inflation over the forecast horizon is the slow unwinding of financial shocks that are being only partially offset by the rebound in hours worked and aggregate demand (which put upward pressure on inflation). The 2013Q3 inflation forecast of 1.6 percent is driven by a markup shock, which the model does not estimate as persistent. Consequently, core inflation then edges down to a 1.4 percent pace in 2013Q4 before then rising steadily to 1.8 percent in 2016Q4.

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 3 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.