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Division of Monetary Affairs

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Date: January 18, 2012

To: Research Directors

From: Deborah J. Danker

Subject: Supporting Documents for DSGE Models Update

The attached documents support the update on the projections of the DSGE models that was distributed in the January 13 memo, "DSGE Models Update."

Projections from EDO: Current Outlook January FOMC Meeting

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January 13, 2012

1 The Outlook for 2012 to 2015

The EDO model projects economic growth modestly below trend and low inflation while the policy rate is pegged to its effective lower bound until the beginning of 2014.

The normalization of the model's risk premia from their elevated levels immediately following the crisis has thus far been unusually slow and households and firms now anticipate that this pattern of slow normalization will persist for the near-term as well. Consequently, the current sizeable gap between actual production and its long-term trend closely only modestly over the projection. Inflation remains low as wage pressures are weak relative to labor productivity, reflecting the declines in household wealth over the past several years, low level of hours worked anticipated over the next few years, and the rapid increases in productivity seen in 2009.

This model forecast takes as data expectations for the federal funds rate path derived from the federal funds futures and eurodollar markets as of 2011:Q4. These expectations imply that the policy rate will remain at its effective lower bound until the beginning of 2014Q1, followed by a gradual rise thereafter. Conditional on these expectations and its usual observables, EDO projects that real GDP will advance at a pace somewhat below trend going forward– about 2.3 percent, on average, over

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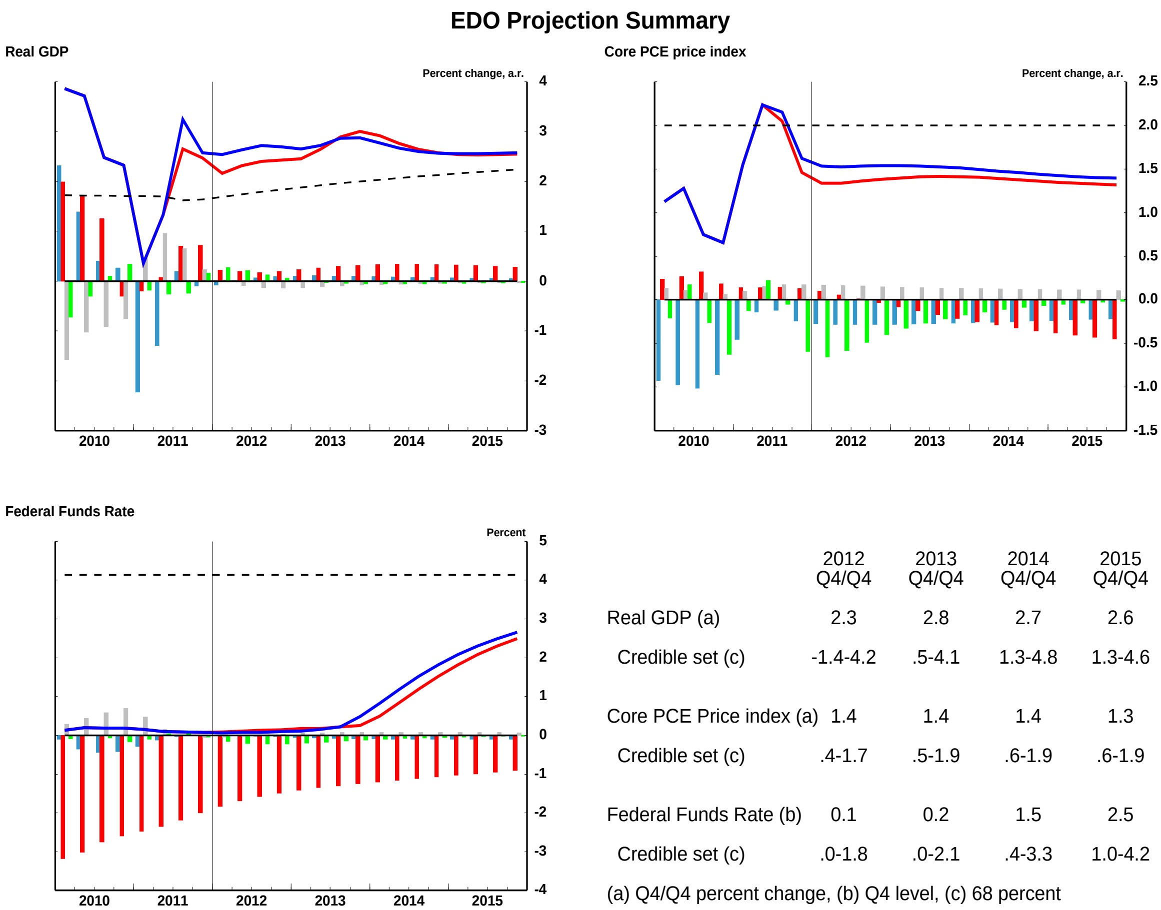
2012-2015, as shown in figure 1. The below-trend pace of growth is accompanied by inflation around 1.5 percent per year, noticeably below the target of 2 percent, as a consequence of labor market slack.[1]

Figure 1: Recent History and Forecasts



	2012 Q4/Q4	2013 Q4/Q4	2014 Q4/Q4	2015 Q4/Q4
Real GDP (a)	2.3	2.8	2.7	2.6
Credible set (c)	-1.4-4.2	.5-4.1	1.3-4.8	1.3-4.6
Core PCE Price index (a)	1.4	1.4	1.4	1.3
Credible set (c)	.4-1.7	.5-1.9	.6-1.9	.6-1.9
Federal Funds Rate (b)	0.1	0.2	1.5	2.5
Credible set (c)	.0-1.8	.0-2.1	.4-3.3	1.0-4.2

(a) Q4/Q4 percent change, (b) Q4 level, (c) 68 percent

Red, solid line -- Data (through 2011:Q4) and projections; Blue, solid line -- Previous projection (November, 2011, as of 2011:Q3); Black, dashed line -- Steady-state or trend values
Contributions (bars): Red -- Financial; Blue -- Technology; Silver -- Monetary policy; Green -- Other

The decomposition of the projections for these variables shown in figure 1 highlights the important role that the adverse shocks to financial conditions in 2008 and

[1]The EDO model has been shown to forecast as well as, or better than, alternatives in a number of papers (e.g., Edge, Kiley, and Laforte (2010) and Wieland and Wolters (2010); however, forecasting is very challenging, and models generally perform similar to, but not better than, simple time series alternatives, or consensus forecasts.

early 2009 play in shaping the recession in that period and the projected recovery, especially in the later years. Specifically, the figures decompose the movements in real GDP, the federal funds rate, and core inflation into the contributions from financial (risk premium) shocks, monetary policy shocks, productivity movements, and other disturbances (largely markup, or Phillips-curve, shocks); the first two are traditional "demand" shocks, and the latter two are traditional "supply" shocks.[2] As shown in the federal funds rate chart, the need to accommodate the adverse impact of the strain in the financial conditions (the red bars) is the most largest factor holding the federal funds rate at its affective lower bound throughout most of the projection. The recovery in real GDP projected for 2012-15 is essentially entirely the result of the projected gradual step-up in demand that should accompany lower risk premia, again illustrated by the contribution of the red bars in the GDP chart. The easing provided by forward guidance boosts real GDP growth in the early quarters of the projection.

Relative to the November forecast (the blue solid line in Figure 1), both real GDP growth and inflation have revised down in the current forecast. In part, these revisions reflect lower potential output estimates, occassioned by unexpectedly weak labor productivity and stronger-than-anticipated headline inflation. The effect of this small reduction in potential would, however, have led to very slight changes in the forecast. Rather, the downward revision apparent in the figure arises almost entirely from the model's reaction to market expectations about the level of the federal funds rate in 2013:Q4, now available to the model as data for the first time.

As mentioned previously, the forecast conditions on (rational) private-sector expectations of a policy rate path consistent with expectations derived from the federal funds and eurodollar futures markets (and with recent statements by the FOMC). This anticipated path is rationalized by augmenting the model's usual exogenous shock processes to include eight quarters of anticipated shocks to both the monetary policy reaction function and the household's Euler equation for nominal risk-free assets. This combination is natural because the two shocks affect private-sector decisions through identical channels. The model can thus account for the market-implied paths for the federal funds rate in three ways: by revising its estimates of the current state of the economy (taken to include the current state of the model's usual shocks,

[2]The contributions of the demand shocks now incorporate the effects of their anticipated counterparts.

such as technology), by infering an expected deviation from the model's estimated Taylor rule, or by modifying private-sector expectations regarding the normalization of the risk premium. In practice, the model exploits all three possibilities: on one hand, an unexpectedly low path for the federal funds rate signals unusually accomodative policy, relative to the historical pattern. However, model estimates of the strength of the activity and inflation are also moderated, in order to motivate the otherwise anomalous behavior of the policy rate.

The reaction of the model's estimates to a unit downward surprise in the federal funds rate eight quarters in advance shown in Figure 2. As can be seen in the lower left panel, in response to such a surprise, the model does indeed infer unusually accomodative policy. However, as shown in the lower right panel, the model infers that the expected risk premium also rises steeply over the same horizon. As a result, the model is required to make only very small adjustments to its estimates of the state over the period of time covered by data. Early in the forecast horizon, however, the output forecast is, on balance, weaker, as the period of elevated risk-premia is expected to be quite prolonged. This additional weakness in response to an unexpectedly low funds rate path explains the slight deterioration in the EDO forecast.

2 An Overview of Key Model Features

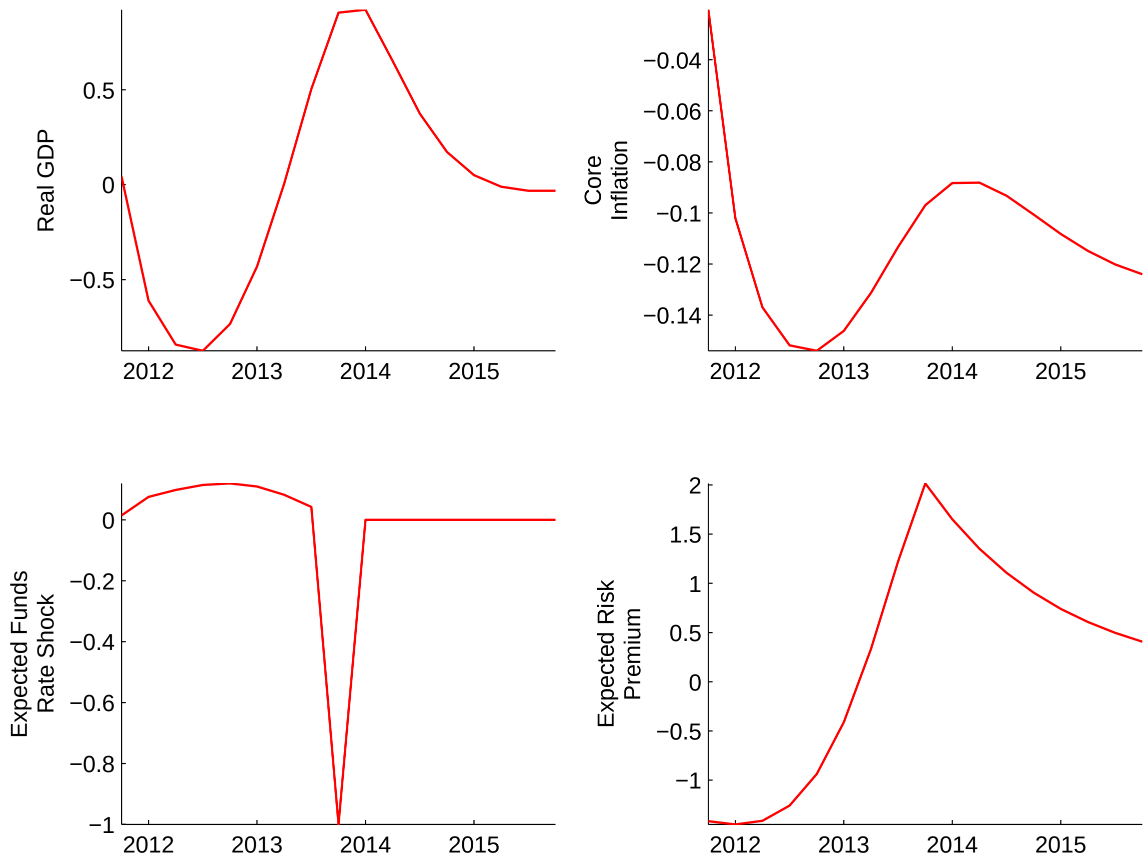
Figure 3 provides a graphical overview of the model. While similar to most related models, EDO has a more detailed description of production and expenditure than most other models.[3]

Specifically, the model possesses two final good sectors in order to capture key long-run growth facts and to differentiate between the cyclical properties of different categories of durable expenditure (e.g., housing, consumer durables, and nonresidential investment). For example, technological progress has been faster in the production of business capital and consumer durables (such as computers and electronics).

The disaggregation of production (aggregate supply) leads naturally to some disaggregation of expenditures (aggregate demand). We move beyond the typical model with just two categories of (private domestic) demand (consumption and investment) and distinguish between four categories of private demand: consumer non-durable

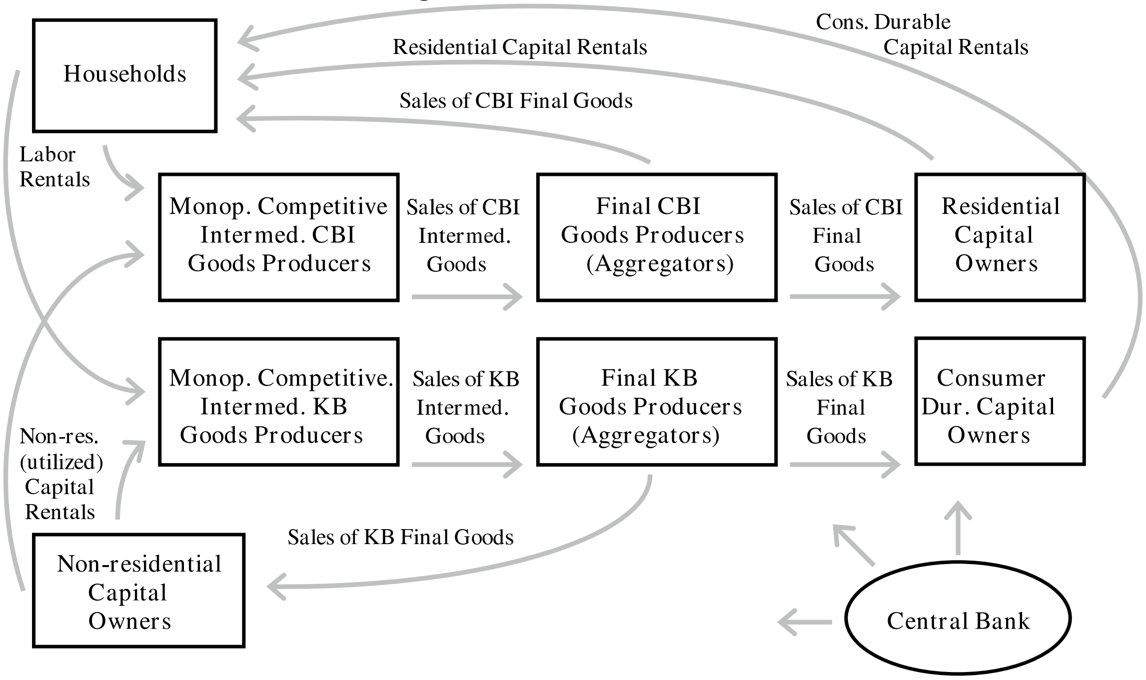
[3] Chung, Kiley, and Laforte (2011) provide much more detail regarding the model specification, estimated parameters, and model propeties.

Figure 2: The effect on EDO's estimates of real GDP (in levels), core inflation, the monetary policy shock and the expected risk premium following a downward surprise, as of 2011:Q4, in private-sector expectations regarding the path of the federal funds rate 8 quarters in the future.



goods and non-housing services, consumer durable goods, residential investment, and non-residential investment. The boxes surrounding the producers in the figure illustrate how we structure the sources of each demand category. Consumer non-durable goods and services are sold directly to households; consumer durable goods, residential capital goods, and non-residential capital goods are intermediated through capital-goods intermediaries (owned by the households), who then rent these capital stocks to households. Consumer non-durable goods and services and residential capital goods are purchased (by households and residential capital goods owners, respectively) from the first of economy's two final goods producing sectors, while consumer durable goods and non-residential capital goods are purchased (by consumer durable and residential capital goods owners, respectively) from the second sector.

Figure 3: Model Overview



In addition to consuming the non-durable goods and services that they purchase, households supply labor to the intermediate goods-producing firms in both sectors of the economy.

This remainder of this section provides an overview of the key properties of the model. In particular, the model has five key features:

- Production of goods and services occurs in two sectors, with differential rates of technological progress across sectors.
- A disaggregated specification of household preferences and firm production processes that leads to separate modeling of nondurables and services consumption, durables consumption, residential investment, and business investment.
- Risk premia associated with different investment decisions play a central role in the model. These include A) an aggregate risk-premium, or natural rate of interest, shock driving a wedge between the short-term policy rate and the interest rate facing private decisionmakers (as in Smets and Wouters (2007)) and B) fluctuations in the discount factor/risk premia facing the intermediaries financing household (residential and consumer durable) and business investment.

- A new-Keynesian structure for price and wage dynamics.
- A monetary policy that reacts to inflation and a measure of resource utilization.

2.1 Two-sector production structure

It is well known (e.g., Edge, Kiley, and Laforte (2010)) that real outlays for business investment and consumer durables have substantially outpaced those on other goods and services, while the prices of these goods (relative to others) has fallen. For example, real outlays on consumer durables have far outpaced those on other consumption, while prices for consumer durables have been flat and those for other consumption have risen substantially; as a result, the ratio of nominal outlays in the two categories has been much more stable, although consumer durable outlays plummeted in the Great Recession. Many models fail to account for this fact.

EDO accounts for this development by assuming that business investment and consumer durables are produced in one sector and other goods and services in another sector. Specifically, production by firm j in each sector s (where s equals kb for the sector producing business investment and consumer durables sector and cbi for the sector producing other goods and services) is governed by a Cobb-Douglas production function with sector-specific technologies:

$$X_t^s(j) \ = \left(Z_t^m Z_t^s L_t^s(j)\right)^{1-\alpha} \left(K_t^{u,nr,s}(j)\right)^{\alpha}, \text{ for } s = cbi, kb. \tag{1}$$

In 1, Z^m represents (labor-augmenting) aggregate technology, while Z^s represents (labor-augmenting) sector-specific technology; we assume that sector-specific technological change affects the business investment and consumer durables sector only; L^s is labor input and $K^{u,nr,s}$ is capital input (that is, utilized *non-residential business* capital (and hence the nr and u terms in the superscript). Growth in this sector-specific technology accounts for the long-run trends, while high-frequency fluctuations allow the possibility that investment-specific technological change is an important source of business cycle fluctuations.

2.2 The structure of demand

EDO differentiates between several categories of expenditure. Specifically, business investment spending determines non-residential capital used in production, and households value consumer nondurables goods and services, consumer durable goods, and residential capital (e.g., housing). Differentiation across these categories is important, as fluctuations in these categories of expenditure can differ notably, with the cycles in housing and business investment, for example, occurring at different points over the last three decades.

Valuations of these goods and services, in terms of household utility, is given by the following utility function:

$$\mathcal{E}_0 \sum_{t=0}^{\infty} \beta^t \Big\{ \varsigma^{cnn} \ln(E_t^{cnn}(i) - hE_{t-1}^{cnn}(i)) + \varsigma^{cd} \ln(K_t^{cd}(i)) + \varsigma^{r} \ln(K_t^{r}(i)) - \varsigma^{l} \frac{(L_t^{cbi}(i) + L_t^{kb}(i))^{1+\nu}}{1+\nu} \Big\}, \tag{2}$$

where E^{cnn} represents expenditures on consumption of nondurable goods and services, K^{cd} and K^{r} represent the stocks of consumer durables and residential capital (housing), $L^{cbi} + L^{kb}$ represents the sum of labor supplied to each productive sector (with hours worked causing disutility), and the remaining terms represent parameters (such as the discount factor, relative value in utility of each service flow, and the elasticity of labor supply).

By modeling preferences over these disaggregated categories of expenditure, EDO attempts to account for the disparate forces driving consumption of nondurables and durables, residential investment, and business investment – thereby speaking to issues such as the surge in business investment in the second half of the 1990s or the housing cycle the early 2000s recession and the most recent downturn. Many other models do not distinguish between developments across these categories of spending.

2.3 Risk premia, financial shocks, and economic fluctuations

The structure of the EDO model implies that households value durable stocks according to their expected returns, including any expected service flows, and according to their risk characteristics, with a premium on assets which have high expected returns in adverse states of the world. However, the behaviour of models such as EDO is conventionally characterized under the assumption that this second component is negligible. In the absence of risk adjustment, the model would then imply that households adjust their portfolios until expected returns on all assets are equal.

Empirically, however, this risk adjustment may not be negligible and, moreover, there may be a variety of factors, not explicitly modelled in EDO, which limit the ability of households to arbitrage away expected return differentials across different assets. To account for this possibility, EDO features several exogenous shocks to the rates of return required by the household to hold the assets in question. Following such a shock – an increase in the premium on a given asset, for example– households will wish to alter their portfolio composition to favor the affected asset, leading to changes in the prices of all assets and, ultimately, to changes in the expected path of production underlying these claims.

The "sector-specific" risk shocks affect the composition of spending more than the path of GDP itself. This occurs because a shock to these premia leads to sizable substitution across residential, consumer durable, and business investment; for example, an increase in the risk premia on business investment leads households to shift away from business investment and towards residential investment and consumer durables. Consequently, it is intuitive that a large fraction of the non-cyclical, or idiosyncratic, component of investment flows to physical stocks will be accounted for by movements in the associated premia.

Shocks to the required rate of return on the nominal risk-free asset play an especially large role in EDO. Following an increase in the premium, in the absence of nominal rigidities, the households' desire for higher real holdings of the risk-free asset would be satisfied entirely by a fall in prices, i.e., the premium is a shock to the natural rate of interest. Given nominal rigidities, however, the desire for higher risk-free savings must be off-set, in part, through a fall in real income, a decline which is distributed across all spending components. Because this response is capable of generating comovement across spending categories, the model naturally exploits such shocks to explain the business cycle. Reflecting this role, we denote this shock as the "aggregate risk-premium".

2.4 New-Keynesian Price and Wage Phillips Curves

As in most of the related literature, nominal prices and wages are both "sticky" in EDO. This friction implies that nominal disturbances – that is, changes in monetary policy – have effects on real economic activity. In addition, the presence of both price and wage rigidities implies that stabilization of inflation is not, in general, the best possible policy objective (although a primary role for price stability in policy objectives remains).

Given the widespread use of the New-Keynesian Phillips curve, it is perhaps easiest to consider the form of the price and wage Phillips curves in EDO at the estimated parameters. The price Phillips curve (governing price adjustment in both productive sectors) has the form:

$$\pi_t^{p,s} = 0.22\pi_{t-1}^{p,s} + 0.76E_t\pi_{t+1}^{p,s} + .017mc_t^s + \theta_t^s \tag{3}$$

where mc is marginal cost and θ is a markup shock. As the parameters indicate, inflation is primarily forward-looking in EDO.

The wage (w) Phillips curve for each sector has the form:

$$\triangle w_t^s = 0.01\triangle w_{t-1}^s + 0.95E_t\triangle w_{t+1}^s + .012\left(mrs_t^{c,l} - w_t^s\right) + \theta_t^w + adj.\,costs. \tag{4}$$

where mrs represents the marginal rate of substitution between consumption and leisure. Wages are primarily forward looking and relatively insensitive to the gap between households' valuation of time spent working and the wage.

2.5 The Monetary Policy Rule

The estimated monetary policy rule has standard features – the policy interest rate responds inertially to inflation and a deviation of output from a trend level:

$$r_t = 0.76r_{t-1} + (1-0.76)\left(1.50\triangle P_t^{PCE} + 1.20\left(y_t - trend\right)\right) + \delta_t^{Rshock}. \tag{5}$$

$$\delta_t^{Rshock} = \rho^{Rshock}\delta_{t-1}^{Rshock} + \epsilon_t^R \tag{6}$$

The long-run responses to the output gap and inflation are very similar to those in the literature. The measure of trend output is based on a production-function concept – that is, trend output is the level of output consistent with labor input and the utilization of capital at long-run levels, given the current level of productive capital; this output concept is a Divisia aggregate of production in the two sectors discussed earlier.

2.6 Summary of Model Specification

To summarize, fluctuations in all economic variables are driven by eleven structural shocks. It is most convenient to summarize these shocks into four broad categories:

- Permanent technology shocks: This category consists of shocks to aggregate and investment-specific (or fast-growing sector) technology.
- Financial, or intertemporal, shocks: This category consists of shocks to risk premia. In EDO, variation in risk premia – both the premium households' receive relative to the federal funds rate on nominal bond holdings and the additional variation in discount rates applied to the investment decisions of capital intermediaries – are purely exogenous. Nonetheless, the specification captures aspects of related models with more explicit financial sectors (e.g., Bernanke, Gertler, and Gilchrist (1999)).
- Monetary policy shocks.
- Other shocks: This category is dominated by shocks to price and wage markups, or Phillips curve shock; it als includes the shock to autonomous demand, which is quantitatively not important in EDO.

3 Estimation: Data and Properties

3.1 Data

The empirical implementation of the model takes a log-linear approximation to the first-order conditions and constraints that describe the economy's equilibrium, casts this resulting system in its state-space representation for the set of (in our case 12) observable variables, uses the Kalman filter to evaluate the likelihood of the observed variables, and forms the posterior distribution of the parameters of interest by combining the likelihood function with a joint density characterizing some prior beliefs. Since we do not have a closed-form solution of the posterior, we rely on Markov-Chain Monte Carlo (MCMC) methods.

Because of the detailed modeling of demand, EDO can consider more data on expenditure than other related models to inform its parameter estimates and projections. The model is estimated using 12 data series over the sample period from 1984:Q4 to 2011:Q1. The series are:

1. The growth rate of real gross domestic product (ΔGDP);
2. The growth rate of real consumption expenditure on non-durables and services (ΔC);
3. The growth rate of real consumption expenditure on durables (ΔCD);
4. The growth rate of real residential investment expenditure (ΔRes);
5. The growth rate of real business investment expenditure (ΔI);
6. Consumer price inflation, as measured by the growth rate of the Personal Consumption Expenditure (PCE) price index ($\Delta P_{C,total}$);
7. Consumer price inflation, as measured by the growth rate of the PCE price index excluding food and energy prices ($\Delta P_{C,core}$);
8. Inflation for consumer durable goods, as measured by the growth rate of the PCE price index for durable goods (ΔP_{cd});
9. Hours, which equals hours of all persons in the non-farm business sector from the Bureau of Labor Statistics (H);[4]
10. The growth rate of real wages, as given by compensation per hour in the non-farm business sector from the Bureau of Labor Statistics divided by the GDP price index (ΔRW);
11. The federal funds rate (R).
12. The yield on the 2-yr. U.S. Treasury security (RL).

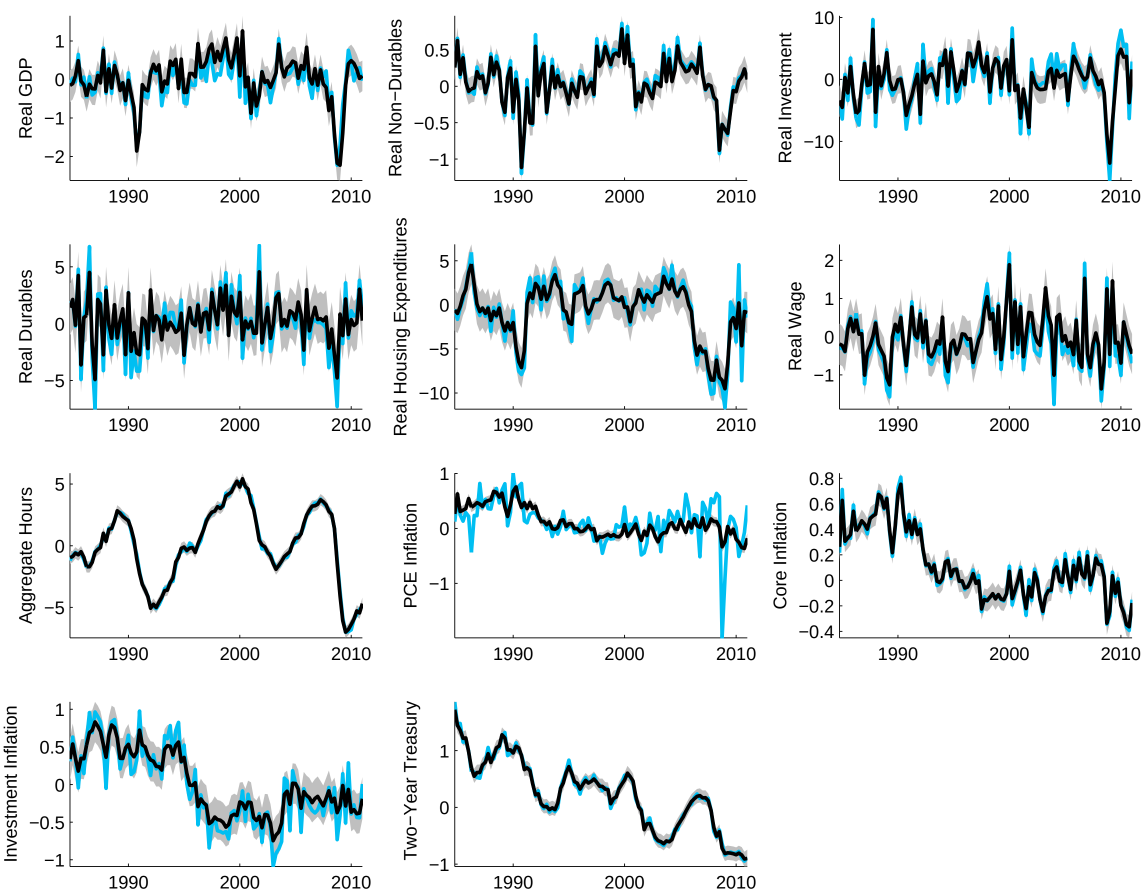
Our implementation adds measurement error processes to the likelihood implied by the model for all of the observed series used in estimation except the short-term nominal interest rate series.

Figure 4 presents the observed data (in blue) and the observable data net of the model's estimated measurement error (in black), along 95 percent confidence intervals. For series other than overall PCE price inflation, measurement error is a

[4] We remove a low-frequency trend from hours via the Hodrick-Prescott filter with a smoothing parameter of 128000; our model is not designed to capture low frequency trends in population growth or labor force participation.

moderate portion of movements in the series. The larger role for measurement error in accounting for the path of PCE price inflation reflects the absence of separate sectors for food and energy in the model.

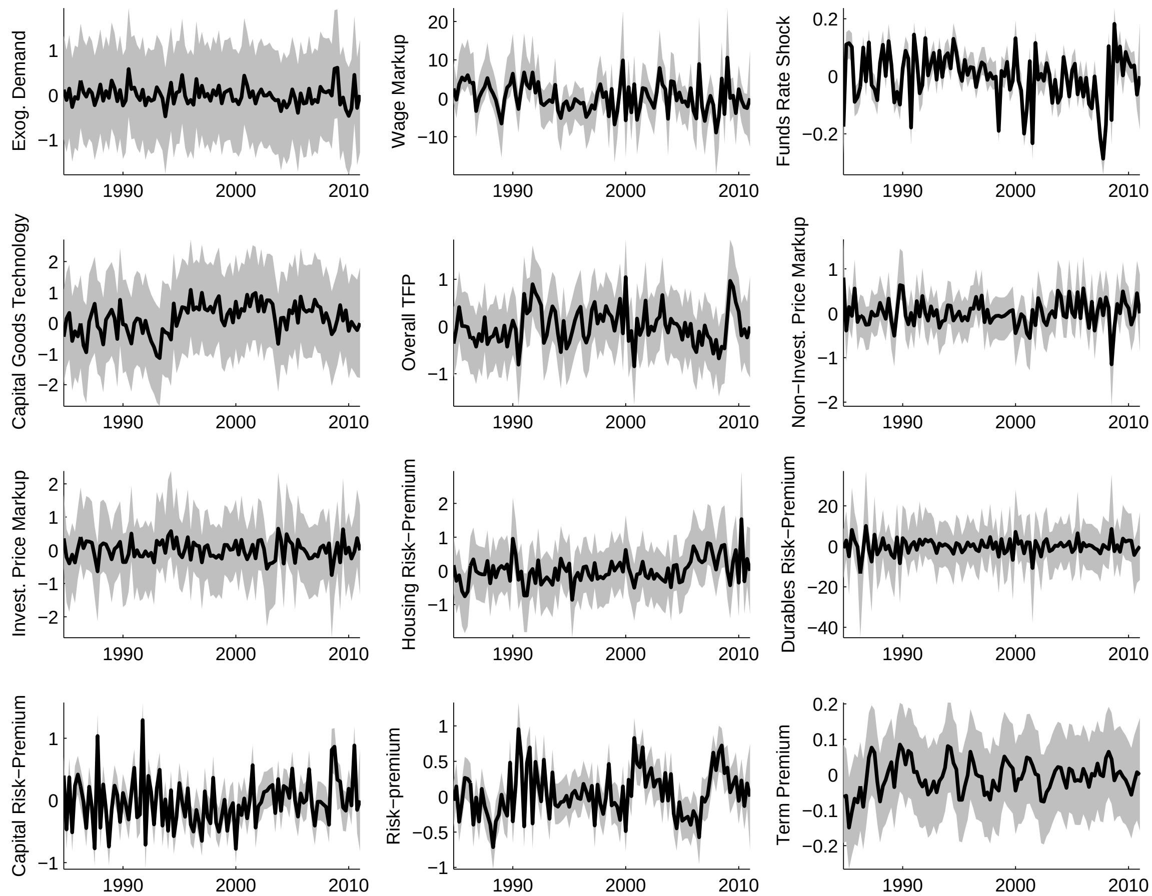
Figure 4: Smoothed Observables and Data



3.2 Estimates of shocks and exogenous fundamentals

Figures 5 and 6 report modal estimates of the model's structural shocks and the persistent exogenous fundamentals (i.e., risk premia and autonomous demand). These series have recognizable patterns for those familiar with U.S. economic fluctuations. For example, the risk premia jump at the end of the sample, reflecting the finan-

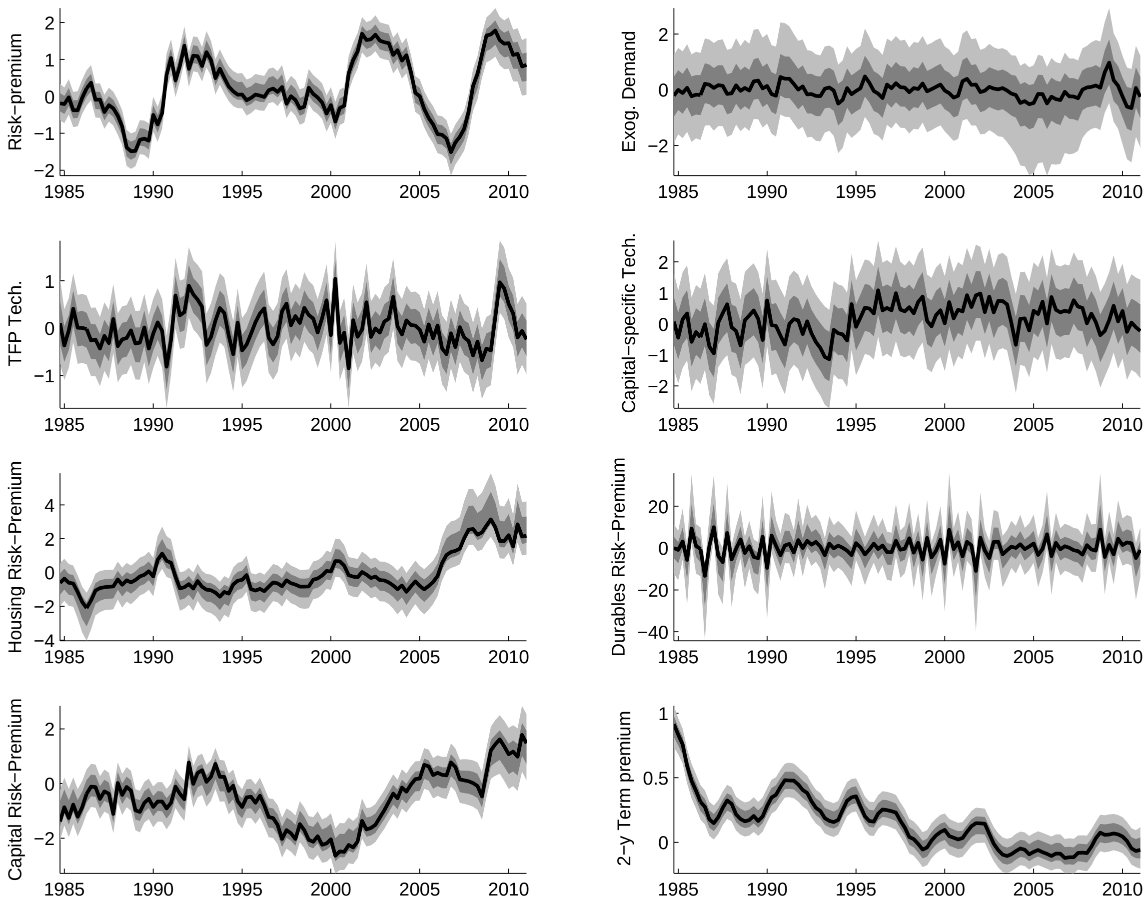
Figure 5: Innovations to Exogenous Processes



cial crisis and the model's identification of risk premia, both economy-wide and for housing, as key drivers.

Of course, these stories from a glance at the exogenous drivers yield applications for alternative versions of the EDO model and future model enhancements. For example, the exogenous risk premia can easily be made to have an endogenous component following the approach of Bernanke, Gertler, and Gilchrist (1999) (and indeed we have considered models of that type). At this point we view incorporation of such mechanisms in our baseline approach as premature, pending ongoing research on financial frictions, banking, and intermediation in dynamic general equilibrium models. Nonetheless, the EDO model captured the key financial disturbances during the last

Figure 6: Exogenous Drivers



several years in its current specification, and examining the endogenous factors that explain these developments will be a topic of further study.

3.3 Variance Decompositions and impulse responses

We provide detailed variance decompositions and impulse response in Chung, Kiley, and Laforte (2011), and only highlight the key results here.

Volatility in hours per capita is accounted for primarily by the economy-wide risk premium and business investment risk premium shocks at horizons between one and sixteen quarters. The large role for risk premia shocks in the forecast error decomposition at business cycle horizons illustrates the importance of this type of "demand" shock for volatility in the labor market. This result is notable, as hours per capita is the series most like a "gap" variable in the model – that is, house per capita shows persistent cyclical fluctuations about its trend value.

Volatility in aggregate GDP growth is accounted for primarily by the technology shocks in each sector, although the economy-wide risk premium shock contributes non-negligibly to the unconditional variance of GDP growth.

Volatility in core inflation is accounted for primarily by the markup shocks in the short run and technology shocks in the long run.

Volatility in the federal funds rate is accounted for primarily by the economywide risk premium.

Volatility in expenditures on consumer non-durables and non-housing services is, in the near horizon, accounted for predominantly by economy-wide and non-residential investment specific risk-premia shocks.

Volatilities in expenditures on consumer durables, residential investment, and non-residential investment are, in the near horizon, accounted for predominantly by their own sector specific risk-premium shocks.

With regard to impulse responses, we previously highlight the responses to the most important shock, the aggregate risk premium, in figure **??**. As we noted, this shock looks like a traditional demand shock, with an increase in the risk premium lowering real GDP, hours worked, and inflation; monetary policy offsets these negative effects somewhat by becoming more accommodative. As for responses to other disturbances, the impulse responses to a monetary policy innovation captures the conventional wisdom regarding the effects of such shocks. In particular, both household and business expenditures on durables (consumer durables, residential investment, and nonresidential investment) respond strongly (and with a hump-shape) to a contractionary policy shock, with more muted responses by nondurables and services consumption; each measure of inflation responds gradually, albeit more quickly than in some analyses based on vector autoregressions (VARs).[5]

Shocks to sectoral risk premia principally depress spending in the associated category of expenditure (e.g., an increase in the residential risk premium lowers residential investment), with offsetting positive effects on other spending (which is "crowded in").

[5]This difference between VAR-based and DSGE-model based impulse responses has been highlighted elsewhere – for example, in the survey of Boivin, Kiley, and Mishkin (2010).

Following an economy-wide technology shock, output rises gradually to its long-run level; hours respond relatively little to the shock (in comparison to, for example, output), reflecting both the influence of stick prices and wages and the offsetting income and substitution effects of such a shock on households willingness to supply labor.

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FRBNY DSGE Model: Research Directors Draft

January 9, 2012

Overview

The FRBNY DSGE model forecast is obtained using data released through 2011Q3 augmented, for 2011Q4, with observations on the federal funds rate and the Baa corporate bond spread, as well as the NY Fed staff forecast for real GDP growth, Core PCE inflation and hours. The projections are conditional on the federal funds rate being 25bp through 2013Q2, in line with the current FOMC statement.

The FRBNY DSGE projections for real activity are marginally more upbeat than in November. Nonetheless, the model still projects a lackluster recovery in economic activity over the next two years. Inflation projections for 2012 and 2013 shifted down relative to November. The main drivers of the subdued real GDP and inflation outlook are the same forces behind the Great Recession, namely the two shocks associated with frictions in the financial system: spread and MEI (marginal efficiency of investment) shocks, whose impact is long-lasting.

General Features of the Model

The FRBNY DSGE model is a medium-scale, one-sector, dynamic stochastic general equilibrium model. It builds on the neoclassical growth model by adding nominal wage and price rigidities, variable capital utilization, costs of adjusting investment, and habit formation in consumption. The model follows the work of Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007), but also includes credit frictions, as in the financial accelerator model developed by Bernanke, Gertler, and Gilchrist (1999). The actual implementation of the credit frictions closely follows Christiano, Motto, and Rostagno (2009).

In this section, we briefly describe the microfoundations of the model, including the optimization problem of the economic agents and the nature of the exogenous processes. The innovations to these processes, which we refer to as "shocks," are the drivers of macroeconomic fluctuations. The model identifies these shocks by matching the model dynamics with six quarterly data series: real GDP growth, core PCE inflation, the labor share, aggregate hours worked, the effective federal funds rate (FFR), and the spread between Baa corporate bonds and 10-year Treasury yields. Model parameters are estimated from 1984Q1 to the present using Bayesian methods. Details on the structure of the model, data sources, and results of the estimation procedure can be found in the accompanying "FRBNY DSGE Model Documentation" note.

The economic units in the model are households, firms, banks, entrepreneurs, and the government. (Figure 1 describes the interactions among the various agents, the frictions and the shocks that affect the dynamics of this economy.)

Households supply labor services to firms. The utility they derive from leisure is subject to a random disturbance, which we call "labor supply" shocks (this shock is sometimes also referred to as a "leisure" shock). Labor supply shocks capture exogenous movements in labor supply due to such factors as demographics and labor market imperfections. The labor market is also subject to frictions because of nominal wage rigidities. These frictions play an important role in the extent to which various shocks affect hours worked. Households also have to choose the amount to consume and save. Their savings take the form of deposits to banks and purchases of government bills. Household preferences take into account habit persistence, a characteristic that affects their consumption smoothing decisions.

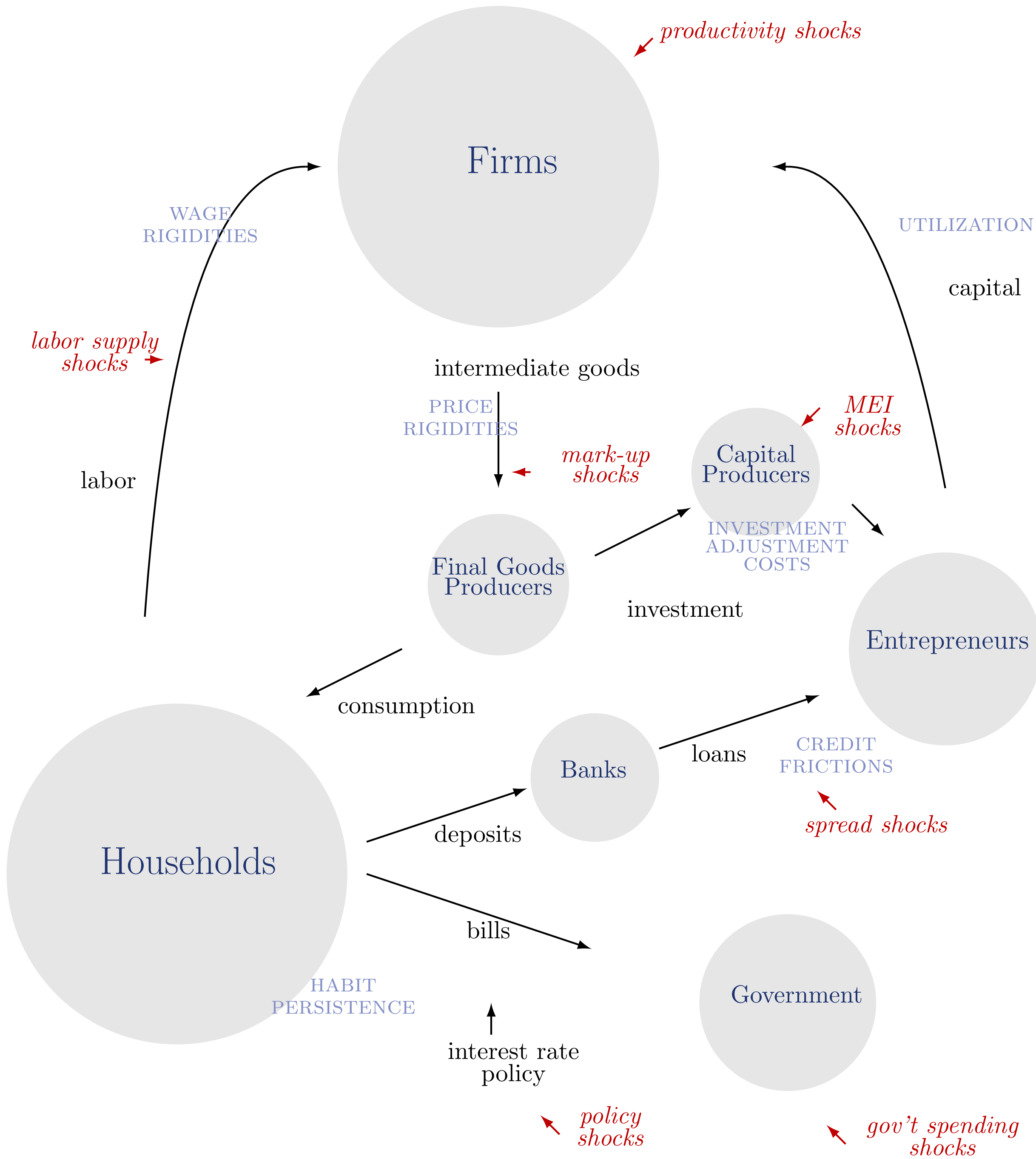
Monopolistically competitive firms produce intermediate goods, which a competitive firm aggregates into the single final good that is used for both consumption and investment. The production function of intermediate producers is subject to "total factor productivity" (TFP) shocks. Intermediate goods markets are subject to price rigidities. Together with wage rigidities, this friction is quite important in allowing demand shocks to be a source of business cycle fluctuations, as countercyclical mark-ups induce firms to produce less when demand is low. Inflation evolves in the model according to a standard, forward-looking New Keynesian Phillips curve, which determines inflation as a function of marginal costs, expected future inflation, and "mark-up" shocks. Mark-up shocks capture exogenous changes in the degree of competitiveness in the intermediate goods market. In practice, these shocks capture unmodeled inflation pressures, such as those arising from fluctuations in commodity prices.

Financial intermediation involves two actors, *banks* and *entrepreneurs*, whose interaction captures imperfections in financial markets. These actors should not be interpreted in a literal sense, but rather as a device for modeling credit frictions. Banks take deposits from households and lend them to entrepreneurs. Entrepreneurs use their own wealth and the loans from banks to acquire capital. They then choose the utilization level of capital and rent the capital to intermediate good producers. Entrepreneurs are subject to idiosyncratic disturbances in their ability to manage the capital. Consequently, entrepreneurs' revenue may not be enough to repay their loans, in which case they default. Banks protect against default risk by pooling loans to all entrepreneurs and charging a spread over the deposit rate. Such spreads vary endogenously as a function of the entrepreneurs' leverage, but also exogenously depending on the entrepreneurs' riskiness. Specifically, mean-preserving changes in the volatility of entrepreneurs' idiosyncratic shocks lead to variations in the spread (to compensate banks for changes in expected losses from individual defaults). We refer to these exogenous movements as "spread" shocks. Spread shocks capture financial intermediation disturbances that affect entrepreneurs' borrowing costs. Faced with higher borrowing costs, entrepreneurs reduce their demand for capital, and investment drops. With lower aggregate demand, there is a contraction in hours worked and real wages. Wage rigidities imply that hours worked fall even more (because nominal wages do not fall enough). Price rigidities mitigate price contraction, further depressing aggregate demand.

Capital producers transform general output into capital goods, which they sell to the entrepreneurs. Their production function is subject to investment adjustment costs: producing capital goods is more costly in periods of rapid investment growth. It is also subject to exogenous changes in the "marginal efficiency of investment" (MEI). These MEI shocks capture exogenous movements in the productivity of new investments in generating new capital. A positive MEI shock implies that fewer resources are needed to build new capital, leading to higher real activity and inflation, with an effect that persists over time. Such MEI shocks reflect both changes in the relative price of investment versus that of consumption goods (although the literature has shown the effect of these relative price changes to be small), and most importantly financial market imperfections that are not reflected in movements of the spread.

Finally, the *government* sector comprises a monetary authority that sets short-term interest rates according to a Taylor-type rule and a fiscal authority that sets public spending and collects lump-sum taxes to balance the budget. Exogenous changes in government spending are called "government" shocks (more generally, these shocks capture exogenous movements in aggregate demand). All exogenous processes are assumed to follow independent AR(1) processes with different degrees of persistence, except for i.i.d. "policy" shocks, which are exogenous disturbances to the monetary policy rule.

Figure 1: Model Structure



The Model's Transmission Mechanism

In this section, we illustrate some of the key economic mechanisms at work in the model's equilibrium. We do so with the aid of the impulse reponse functions to the main shocks hitting the economy, which we report in figures 8 to 14.

We start with the shock most closely associated with the Great Recession and the severe financial crisis that characterized it: the spread shock. As discussed above, this shock stems from an increase in the perceived riskiness of borrowers, which induces banks to charge higher interest rates for loans, thereby widening credit spreads. As a result of this increase in the expected cost of capital, entrepreneurs' borrowing falls, hindering their ability to channel resources to the productive sector via capital accumulation. The model identifies this shock by matching the behavior of the Baa corporate bond rate over 10-year Treasuries, and the spread's comovement with output growth, inflation, and the other observables. Figure 8 shows the impulse responses of the variables used in the estimation to a one-standard-deviation innovation in the spread shock. An innovation of this size increases the observed spread by roughly 35 basis points (bottom right panel). This leads to a reduction in investment and consequently to a reduction in output growth (top left panel) and hours worked (top right panel). The fall in the level of hours is fairly sharp in the first year and persists for many quarters afterwards, leaving the labor input not much higher than at the trough five years after the impulse. Of course, the effects of this same shock on GDP growth, which roughly mirrors the change in the level of hours, are much more short-lived. Output growth returns to its steady state level about two years after the shock hits, but it barely moves above it after that, implying no catch up of the level of GDP towards its previous trend. The persistent drop in the level of economic activity due to the spread shock also leads to a prolonged decline in real marginal costs - which in this model map one-to-one into the labor share (middle left panel)- and, via the New Keynesian Phillips curve, in inflation (middle right panel). Finally, policymakers endogenously respond to the change in the inflation and real activity outlook by cutting the federal funds rate (bottom left panel).

Very similar considerations hold for the MEI shock, which represents a direct hit to the "technological" ability of entrepreneurs to transform investment goods into productive capital, rather than an increase in their funding cost. Although the origins of these two shocks are different, the fact that they both affect the creation of new capital implies very similar effects on the observable variables, as shown by the impulse responses in figure 9. In particular, a positive MEI shock also implies a very persistent increase in investment, output and hours worked, as well as in the labor share and hence inflation. The key difference between the two impulses, which is also what allows us to tell them apart empirically, is that the MEI shock leaves spreads virtually unchanged (bottom right panel).

Another shock that plays an important role in the model, and whose estimated contribution to the Great Recession and its aftermath increased in light of the latest data revisions, is the TFP shock. As shown in figure 10, a positive TFP shock has a large and persistent effect on output growth, even if the reponse of hours is muted in the first few quarters (and slightly negative on impact). This muted response of hours is due to the presence of nominal rigidities, which prevent an expansion of aggregate demand sufficient to absorb the increased ability of the economy to supply output. With higher productivity, marginal costs and thus the labor share fall, leading to lower inflation. The policy rule specification implies that this negative correlation between inflation and real activity, which is typical of supply shocks, produces countervailing forces on the interest rate, which as a result moves little. These dynamics make the TFP shock particularly suitable to account for the first phase of the recovery, in which GDP growth was above trend, but hours and inflation remained weak. With the recent softening of the expansion, though, the role of TFP shocks is fading.

The last shock that plays a relevant role in the current economic environment is the mark-up shock, whose impulse response is depicted in figure 11. This shock is an exogenous source of inflationary pressures, stemming from changes in the market power of intermediate goods producers. As such, it leads to higher inflation and lower real activity, as producers reduce supply to increase their desired markup. Compared to those of the other prominent supply shock in the model, the TFP shock, the effects of markup-shocks feature significantly less persistence. GDP growth falls on impact after mark-ups increase, but returns above average after about one year. Inflation is sharply higher, but only for a couple of quarters, leading to a temporary spike in the nominal interest rate, as monetary policy tries to limit the pass-through of the shock to inflation. Unlike in the case of TFP shocks, however, hours fall immediately, mirroring the behavior of output.

Forecasts

Unconditional Forecast								
	2011 (Q4/Q4)		2012 (Q4/Q4)		2013 (Q4/Q4)		2014 (Q4/Q4)	
	Jan	Nov	Jan	Nov	Jan	Nov	Jan	Nov
Core PCE Inflation	1.7 (1.7,1.8)	1.5 (1.3,1.7)	0.8 (0.1,1.3)	1.0 (0.2,1.6)	1.2 (0.3,1.9)	1.3 (0.4,2.0)	1.5 (0.6,2.3)	1.6 (0.6,2.4)
Real GDP Growth	1.3 (1.2,1.4)	0.9 (0.2,1.5)	2.3 (-0.8,4.4)	1.7 (-1.6,4.2)	2.0 (-1.6,4.9)	1.6 (-2.1,4.5)	1.9 (-1.5,5.3)	1.8 (-1.6,5.1)

Conditional Forecast*								
	2011 (Q4/Q4)		2012 (Q4/Q4)		2013 (Q4/Q4)		2014 (Q4/Q4)	
	Jan	Nov	Jan	Nov	Jan	Nov	Jan	Nov
Core PCE Inflation	1.7 (1.7,1.7)	1.8 (1.6,2.0)	0.7 (0.1,1.3)	1.0 (0.3,1.7)	1.2 (0.3,1.9)	1.3 (0.4,2.0)	1.6 (0.6,2.3)	1.6 (0.7,2.4)
Real GDP Growth	1.7 (1.7,1.7)	1.8 (1.1,2.4)	3.2 (0.2,5.3)	2.6 (-0.8,5.0)	2.3 (-1.4,5.1)	1.8 (-1.8,4.8)	1.9 (-1.4,5.2)	1.8 (-1.5,5.1)

*The unconditional forecasts use data up to 2011Q3, the quarter for which we have the most recent GDP release, as well as the federal funds rate and spreads data for 2011Q4. In the conditional forecasts, we further include the 2011Q4 FRBNY staff projections for GDP growth, core PCE inflation, and hours worked as additional data points. Numbers in parentheses indicate 68 percent probability intervals.

We detail the forecast of three main variables over the horizon 2011-2014: real GDP growth, core PCE inflation and the federal funds rate. The federal funds rate expectations are constrained to be 25bp through 2013Q2. We capture policy anticipation by adding anticipated monetary policy shocks to the central bank's reaction function, following Laseen and Svensson (2009).

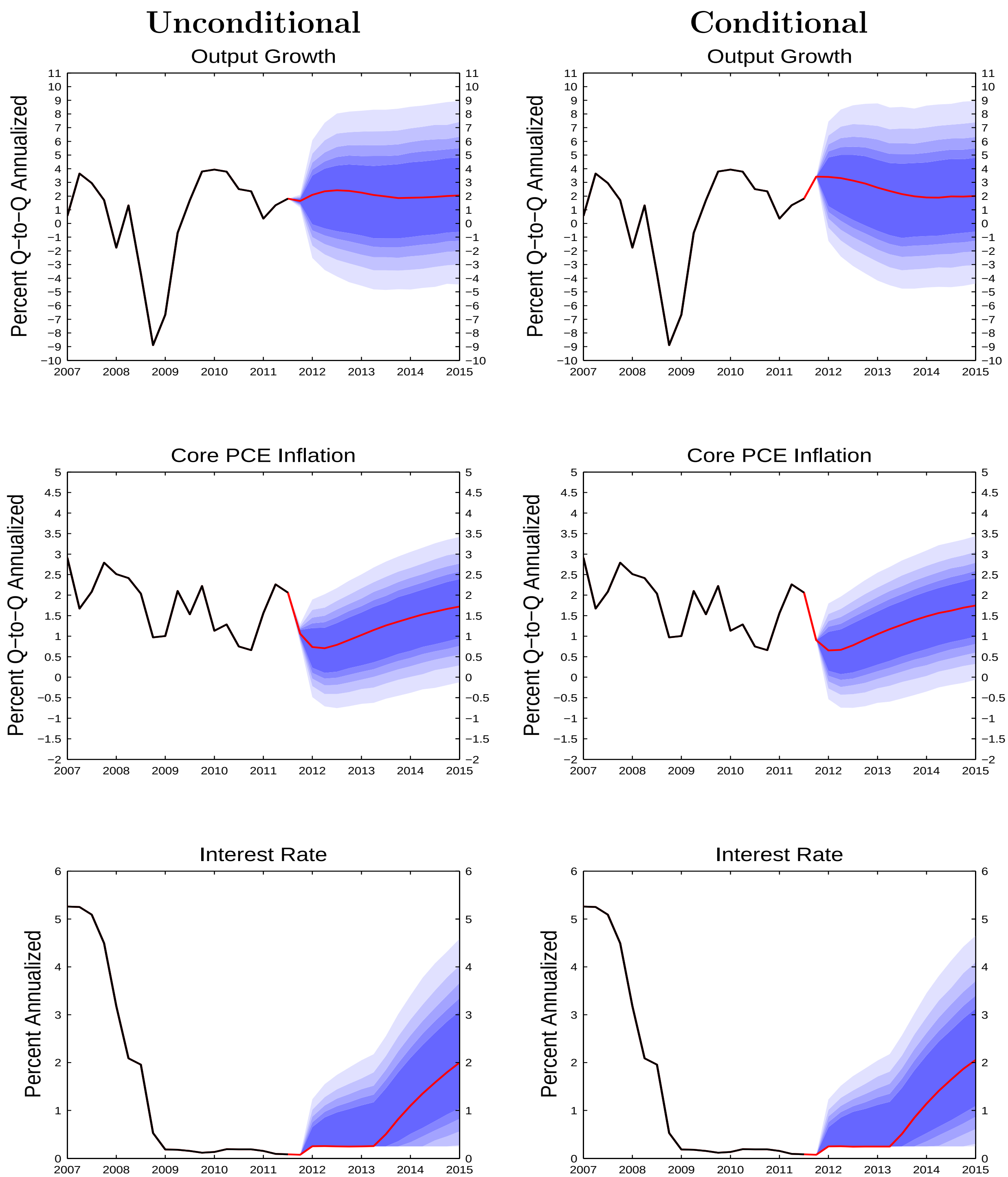
The table above presents Q4/Q4 forecasts for real GDP growth and inflation for 2011-2014, with 68 percent probability intervals. We include two sets of forecasts. The *unconditional* forecasts use data up to 2011Q3, the quarter for which we have the most recent GDP release, as well as the federal funds rate and spreads data for 2011Q4, which are currently available. In the *conditional* forecasts, we further include the 2011Q4 FRBNY staff projections for GDP growth, core PCE inflation, and hours worked as additional data points (as of January 9, the staff projections for 2011Q4 are 3.4% for output growth, 0.9% for core PCE inflation, and 1.7% growth for hours worked). Treating the staff forecasts as data allows us to incorporate into the DSGE forecasts information about the current quarter that is not yet available in the data. In addition to providing the current forecasts, for comparison we report the forecasts included in the DSGE memo circulated for the November FOMC meeting. Figure 2 presents quarterly forecasts, both unconditional (left panels) and conditional (right panels). In the graphs, the black line represents data, the red line indicates the mean forecast, and the shaded areas mark the uncertainty associated with our forecast as 50, 60, 70, 80 and 90 percent probability intervals. Output growth and inflation are expressed in terms of percent annualized rates, quarter to quarter. The interest rate is the annualized quarterly average. The bands reflect both parameter uncertainty and shock uncertainty. Figure 3 compares the current forecasts with those produced for the November FOMC meeting. Our discussion will mainly focused on the conditional forecasts, since these are the ones included in the memo for the FOMC.

In terms of inflation, the model had projected a substantial slowdown in core inflation relative to the first half of 2011. This slowdown has apparently taken place according to the most recent data, as incorporated in the FRBNY now-cast of 2011Q4 inflation, and may have even been a bit stronger than predicted. As a consequence, conditional inflation projections shifted down relative to November in the short and medium run, with 2012, 2013, and 2014 (Q4/Q4) forecasts at 0.7, 1.2, and 1.9 percent, respectively, from 1.0, 1.2, and 1.6, respectively. Unconditional inflation forecasts are very similar to the conditional ones. The 68 percent probability bands for inflation in 2012 and 2013 (Q4/Q4) are within the 0-2 percent interval for both conditional and unconditional forecasts, implying that the model places great probability on inflation realizations below the implicit FOMC target at least through 2013.

The FRBNY DSGE projections for real activity are marginally more upbeat than in November. Conditional output growth forecasts for 2012, 2013, and 2014 (Q4/Q4) moved up to 3.2, 2.3, and 1.9 percent, respectively, from 2.6, 1.8, and 1.8, respectively, in November. Nonetheless, the model still projects a lackluster recovery in economic activity over the next two years. There is significant uncertainty around the real GDP forecasts, with 68 percent bands covering the interval 0.2 to 5.4 percent in 2012 (Q4/Q4), and -1.4 to 5.1 percent in 2013 (Q4/Q4) for the conditional forecasts. Unconditional output forecasts are also more upbeat than in November, although they are still more pessimistic for 2012 and 2013 relative to the conditional ones.

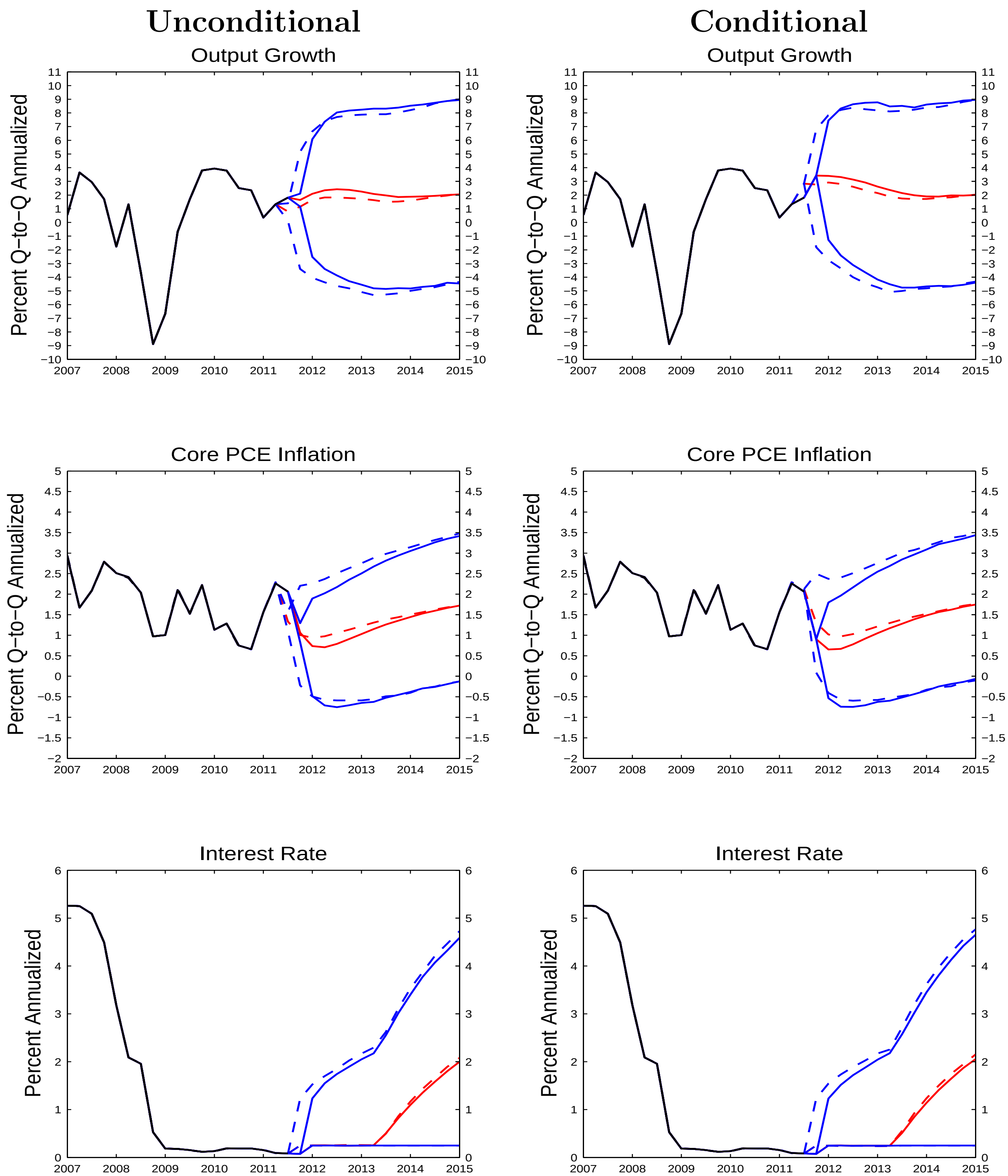
Finally, after liftoff in 2013Q3 the federal funds rate is assumed to raise gradually, and reach 2 percent by the beginning of 2014.

Figure 2: Forecasts



Black lines indicate data, red lines indicate mean forecasts, and shaded areas mark the uncertainty associated with our forecast as 50, 60, 70, 80, and 90 percent probability intervals.

Figure 3: Change in Forecasts



Solid and dashed red lines represent the mean for current and November's forecast, respectively. Solid and dashed blue lines represent 90 percent probability intervals.

Interpreting the Forecasts

We use the shock decomposition shown in Figure 4 to interpret the forecasts. This figure quantifies the importance of each shock for output growth, core PCE inflation, and the federal funds rate (FFR) from 2007 on, by showing the extent to which each of the disturbances contributes to keeping the variables from reaching their long-run values. Specifically, in each of the three panels the solid line (black for realized data, red for mean forecast) shows the variable in deviation from its steady state (for output, the numbers are per capita, as the model takes population growth as exogenous; for both output and inflation, the numbers are quarter-to-quarter annualized). The bars represent the contribution of each shock to the deviation of the variable from steady state, that is, the counterfactual values of output growth, inflation, and the federal funds rate (in deviations from the mean) obtained by setting all other shocks to zero. By construction, for each observation the bars sum to the value on the solid line.

The figure shows that all three variables of interest are currently below their steady-state values, and are forecast to stay so through the end of the forecast horizon. Two of the shocks most responsible for the Great Recession, the so-called "financial" shocks (Spread and MEI), are still the main drivers of the outlook a few years after the end of the recession. This is quite evident for inflation and interest rates, where it is clear that MEI and Spread shocks (azure and purple bars, respectively) play a key role in keeping these two variables below steady state.

This feature of the DSGE forecast is less evident for real output growth, as the contribution of MEI shocks seems small, particularly toward the end of the forecast horizon, and the contribution of Spread shocks is negligible (and positive). However, recall that a small, but still negative, effect on output *growth* implies that the effect of the MEI shocks on the *level* of output is getting *larger*, even several quarters after the occurrence of the shock. Similarly, the fact that the growth impact of Spread shock is positive but very small implies that the level of output is very slowly returning to trend. This is evident in the protracted effect of Spreads and MEI shocks on aggregate hours, shown in the impulse responses of Figures 8 and 9, respectively, and discussed above. In turn, the fact that economic activity is well below trend pushes inflation and consequently interest rates (given the Fed's reaction function) below steady state.

Some more insight about the interpretation of the "financial" shocks – MEI and Spread shocks – can be obtained from Figure 5. This figure shows the recent history of the shocks, expressed in standard deviation units. The panel labeled "Spread" shows that during the Great Recession there were two large Spread shocks, one in 2007 and one in concurrence with the Lehman Brothers default (recall from Figure 8 that positive Spread shocks raise spreads and have negative impact on economic activity). The panel labeled "MEI" shows that MEI shocks were mostly negative from 2009 onwards, that is, *after* the end of the recession (recall from Figure 9 that negative MEI shocks have negative impact on economic activity). These shocks therefore seem to capture the headwinds from the financial crisis. (The Spread shocks capture headwinds associated with a large spread while the MEI shocks capture financial headwinds that are not reflected necessarily in the spread.)

In discussing the weak outlook for real activity we emphasized so far the impact of shocks on deviations of the level of output from trend. But the trend may also shift, as pointed out by the literature on unit roots. The FRBNY DSGE model allows for a stochastic trend in total factor productivity, hence in output, and shifts in the trend can obviously have a significant impact on the outlook. Is there evidence of any such shifts? Figure 6 addresses this question. The figure shows the stochastic trend in TFP (solid lines) together with the deterministic component of that trend (dashed blue lines), both expressed in logarithms and normalized to zero at the beginning of 2007Q1. Deviations of the solid from the dashed line represent shifts in the trend. Because of the decline in productivity during the recession, by 2009 the trend had shifted down by about 6% relative to the deterministic drift. The pick-up in productivity in the second half of 2009 completely erased that gap, however. Hence we can find little evidence that shifts in the trend are responsible for the bleak outlook.

Other shocks, beside the "financial" shocks, play an important role in explaining the forecasts. For instance, the model attributes much of the rise in core inflation in the first half 2011 to price mark-up shocks. Increases in mark-ups in our monopolistically competitive setting push inflation above marginal costs and reduce output. Figure 11 shows that mark-up shocks capture large but transitory movements in inflation, such as those due to oil price fluctuations. As a result, the large positive mark-up shock behind the up-tick in inflation in recent quarters has almost no effect on the inflation forecasts. Since output is returning quickly to trend following mark-up shocks, these actually contribute positively to output growth through mid-2013.

Finally, according to the model, monetary policy shocks were largely expansionary in recent history, and especially in 2008. These shocks include both contemporaneous and anticipated deviations from the feedback rule, which we use to implement the lower bound through 2013Q2. The impact of policy shocks on the interest rate is currently very small, implying that the level of the interest rate is not too far from that implied by the estimated policy rule. In 2013 and 2014 the impact of these shocks becomes larger: the impact of the forward guidance, combined with the interest rates smoothing component of the policy which limits quarter-to-quarter adjustments, implies that the renormalization path is lower than that implied by the estimated rule. (Note however that this path is associated with a rather dim outlook for output and inflation, indicating that the estimated interest rate rule may be far from optimal under current circumstances.)

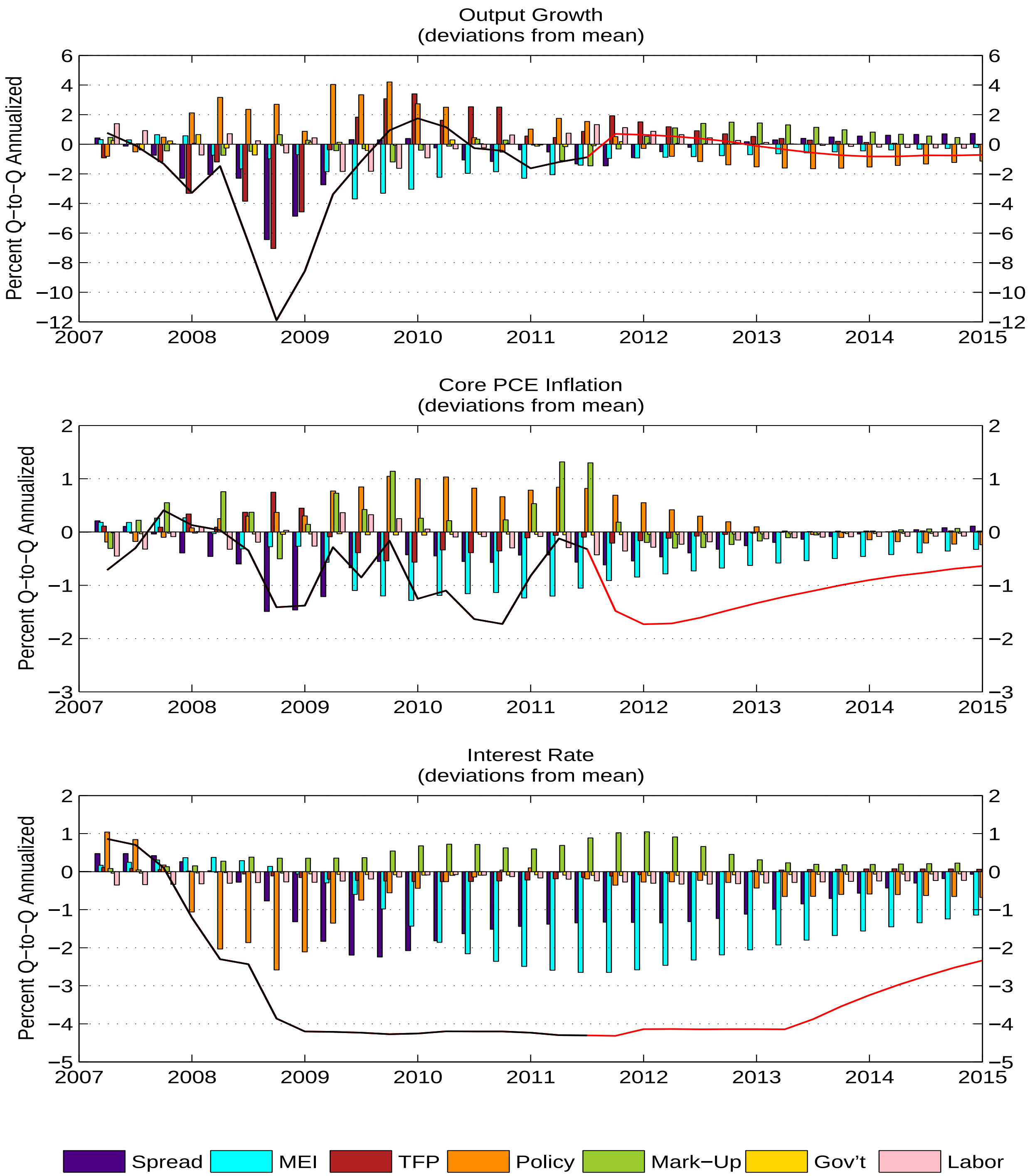
Policy shocks play an important role in pushing inflation upward in the aftermath of the recession. Interestingly, while policy shocks have a positive impact on current output growth, they have a negative impact on growth from 2012 onward. As much as this result may seem counter-intuitive at first, it is actually the natural consequence of the fact that the impact of expansionary monetary policy on the *level* of output, while still positive, is fading, implying that the effect on the *growth rate* is currently negative (as the level of output returns to its trend from below). This is partly because the stimulative effect of the "extended period" language is front-loaded, and hence had most impact when announced.

Forecasts without Incorporating Federal Funds Rate Expectations

As mentioned above, the federal funds rate expectations are constrained to be 25bp through 2013Q2. We do this by adding federal funds rate expectations through 2013Q2 to the usual set of observables, as described in more detlail in the FRBNY DSGE Model Documentation (we actually add federal funds rate expectations to the observables since the near-zero interest rate policy came into place in late 2008). We correspondigly change the model by adding anticipated monetary policy shocks to the central bank's reaction function, following Laseen and Svensson (2009). The model can therefore match the new information (the FFR expectations) in two different ways: (i) via the anticipated policy shocks, which capture pre-announced deviations from the estimated policy rule (that is, "we expect interest rates to be low because monetray policy is unsually accommodative") ; and (ii) by changing its assessment of the state of the economy (that is, "we expect interest rates to be low because the state of the economy is worse than previously estimated"). The two channels capture the exogenous and endogenous component of monetary policy, respectively.

We discussed the effect of anticipated shocks in the previous section. Figure 7 shows our baseline unconditional (left panels) and conditional (right panels) forecasts (solid lines) as well as the forecasts without incorporating federal funds rate expectations (dashed lines). This figure provides information as to how the model's assessment of the state of the economy changes following the additional information incorporated in FFR expectations. The figure shows that not imposing near-zero expectations for the federal funds rate through mid-2013 has only a modest impact on the forecasts for output and inflation through mid-2013. Output growth and inflation forecasts for 2014 are lower (by roughly 50 and 25 basis points, respectively) when we incorporate the policy rate expectations, indicating that the model partly interprets the near-zero federal funds rate as the endogenous response of monetary policy to a slow recovery. The interest rate rises to one percent as the 25bp FFR expectations are removed. This is in large part due to the fact that our estimated rule responds to the growth rate of output as opposed to the output gap, and may threrefore not approprioately capture current policy.

Figure 4: Shock Decomposition



The shock decomposition is presented for the conditional forecast. The solid lines (black for realized data, red for mean forecast) show each variable in deviation from its steady state. The bars represent the shock contributions; specifically, the bars for each shock represent the counterfactual values for the observables (in deviations from the mean) obtained by setting all other shocks to zero.

Figure 5: Shock Histories

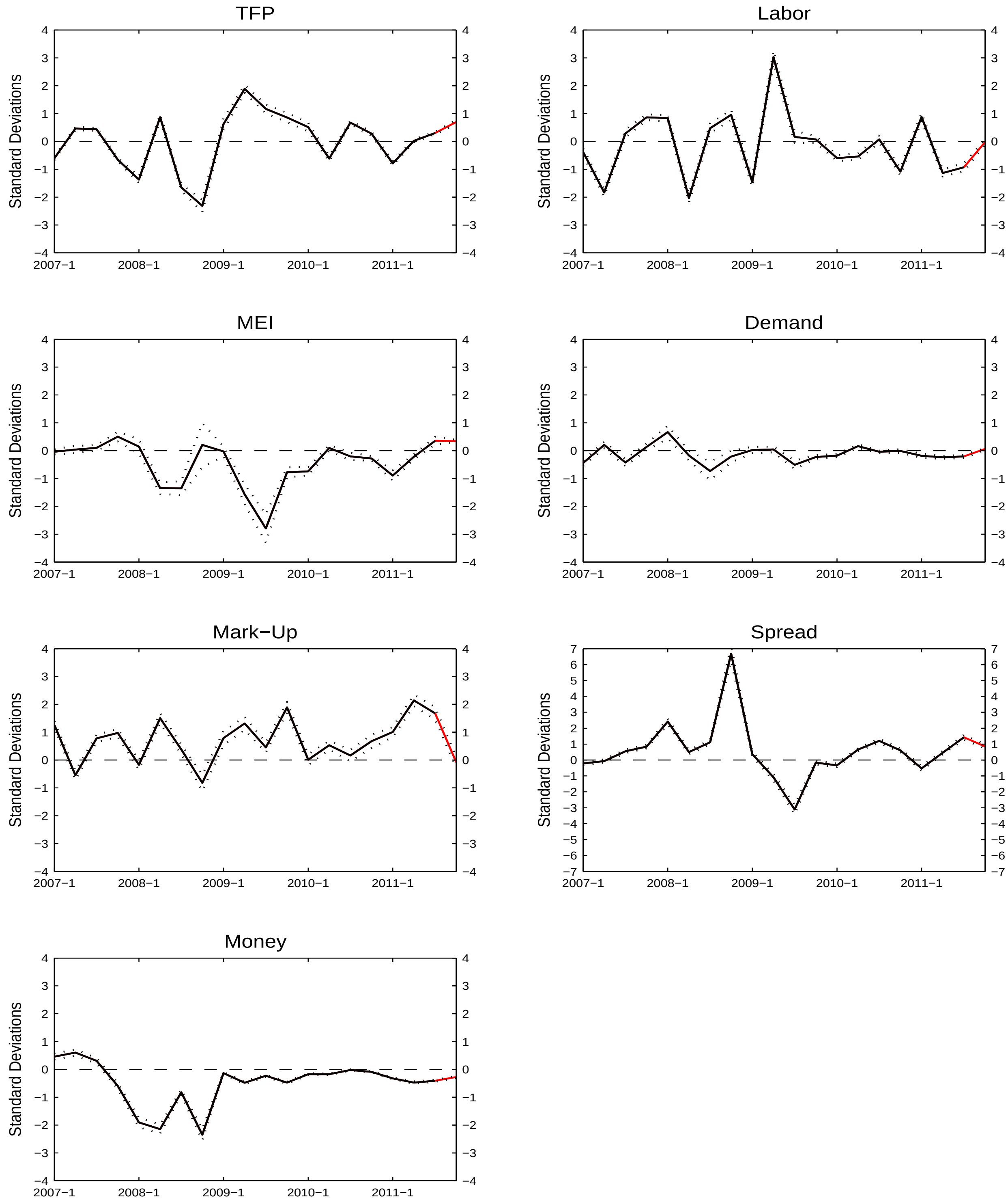
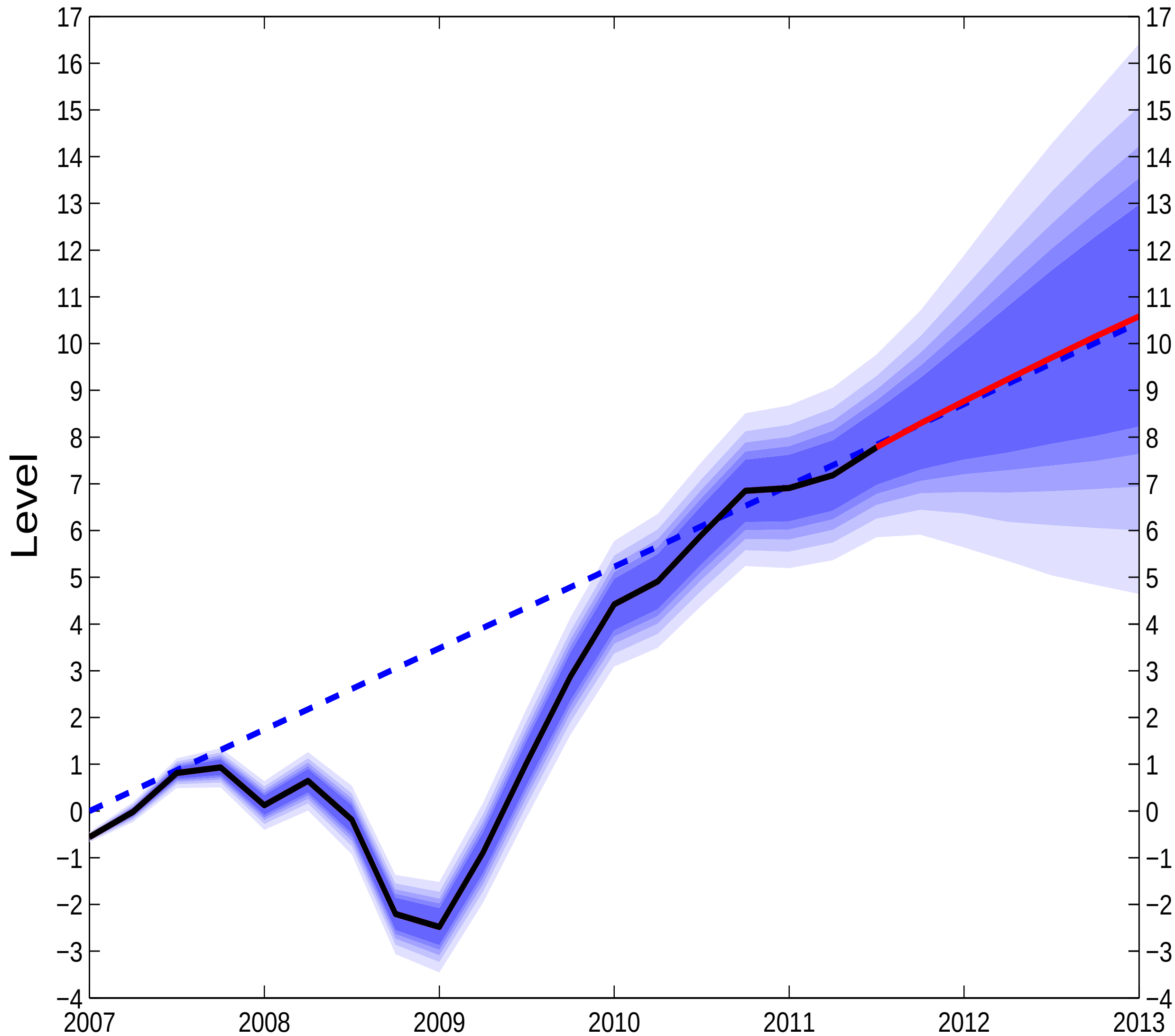
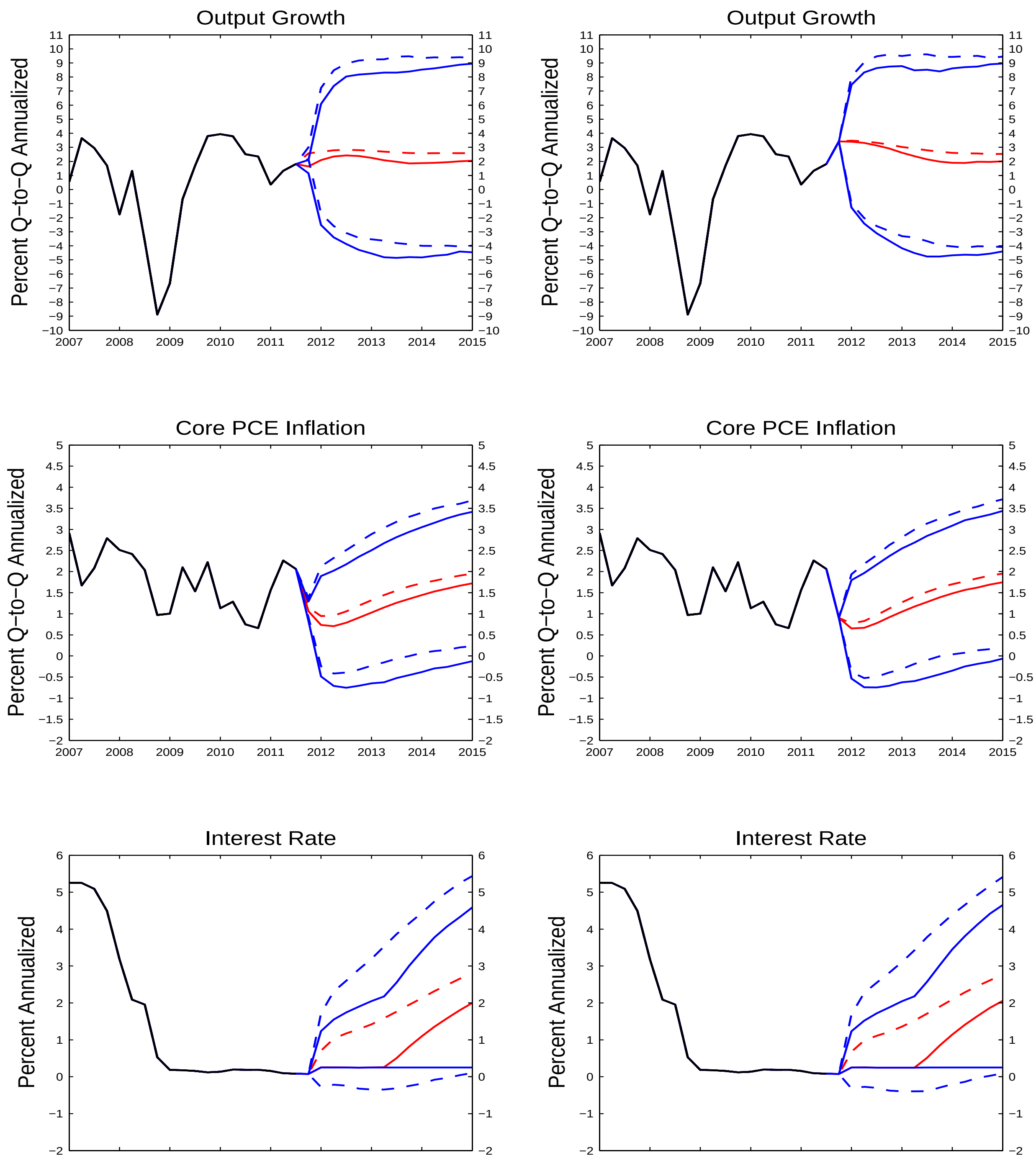


Figure 6: Trend Components of Productivity



The trend in productivity is decomposed as the sum of a deterministic component (dotted blue line) and a stochastic component (solid line; black for realized data and red for forecast). Shaded areas mark the uncertainty associated with our estimate as 50, 60, 70, 80, and 90 percent probability intervals.

Figure 7: Incorporating FFR Expectations



Solid and dashed red lines represent the mean for the forecast with and without incorporating FFR expectations, respectively. Solid and dashed blue lines represent 90 percent probability intervals.

Figure 8: Responses to a Spread Shock

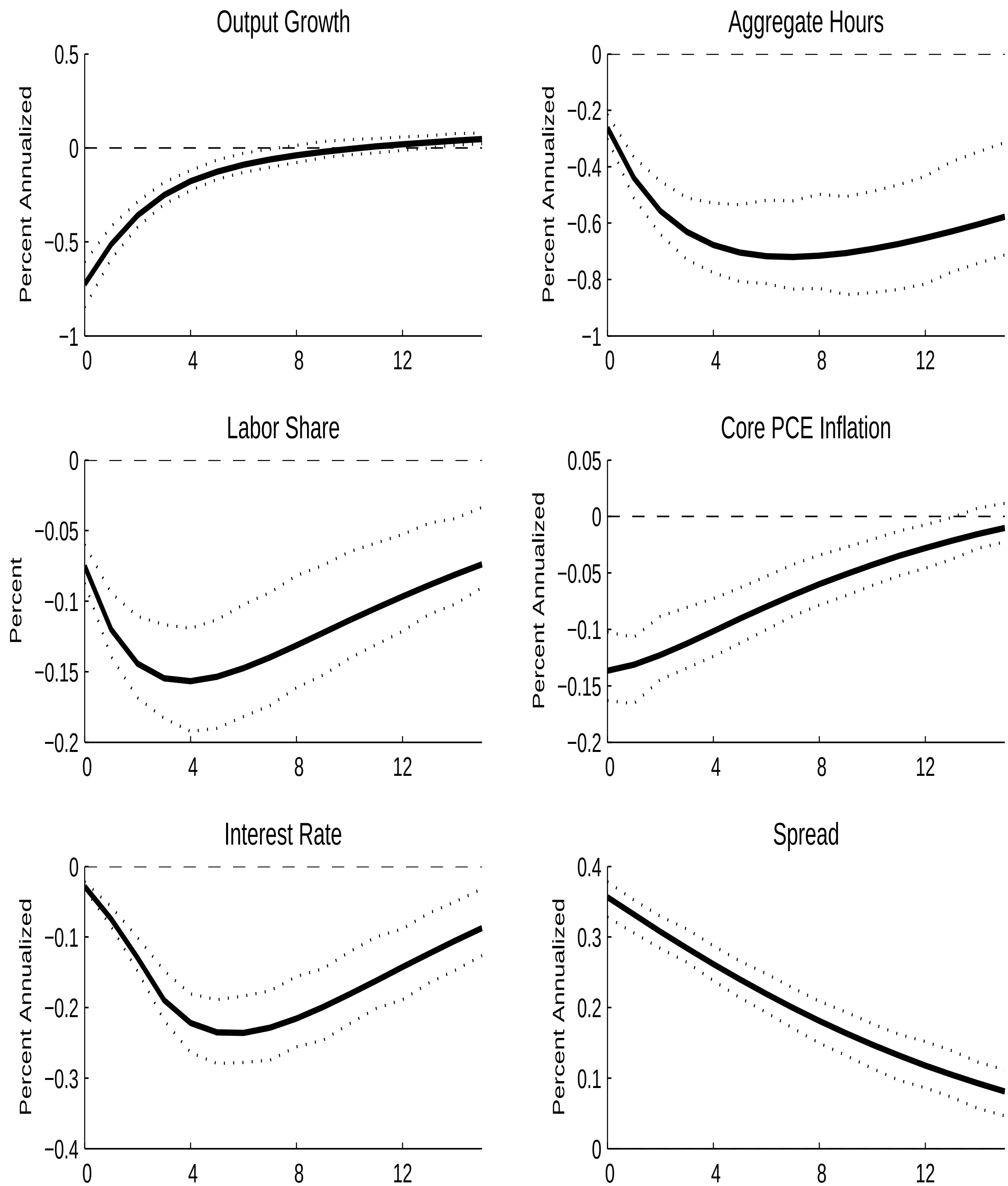


Figure 9: Responses to an MEI Shock

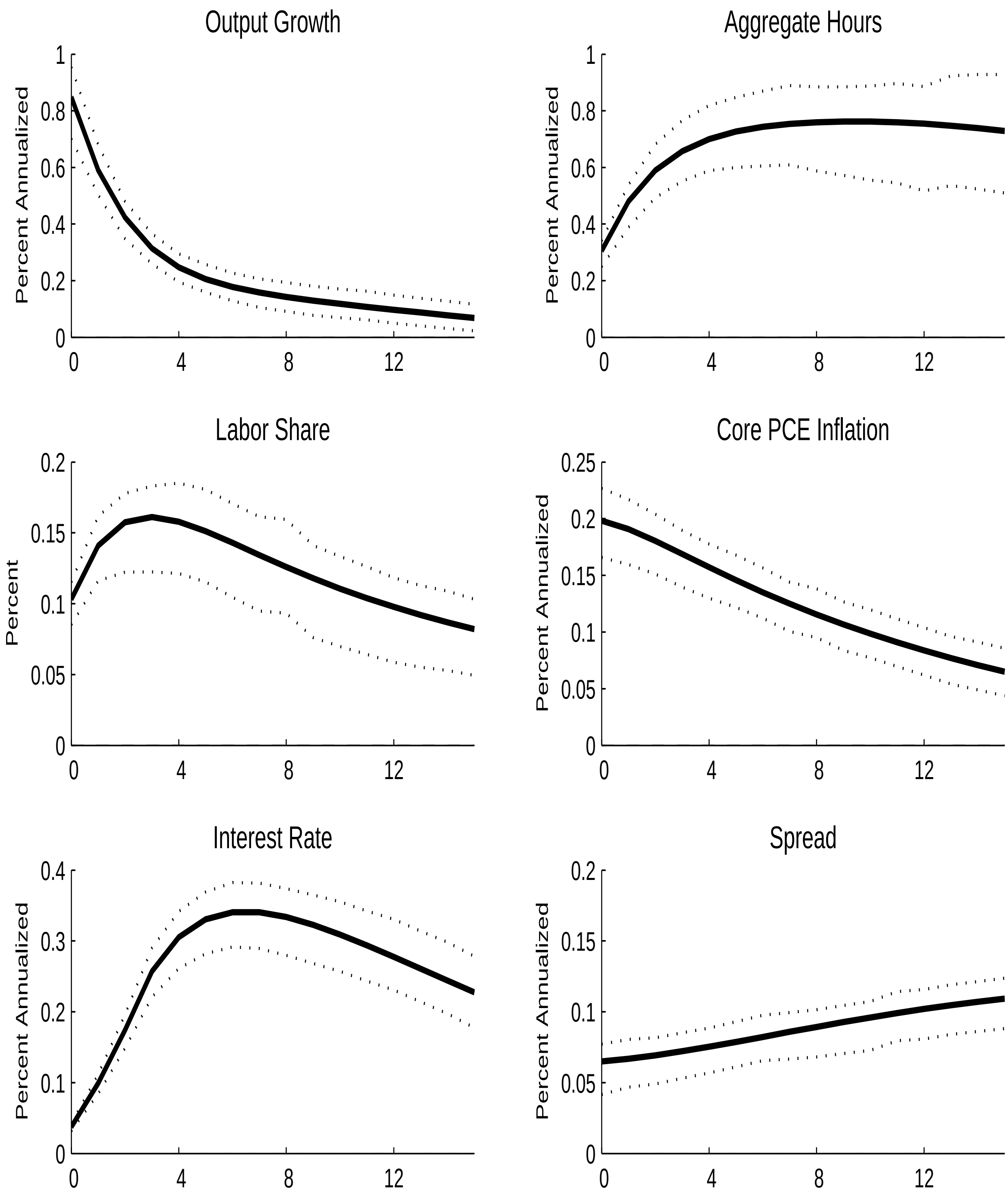


Figure 10: Responses to a TFP Shock

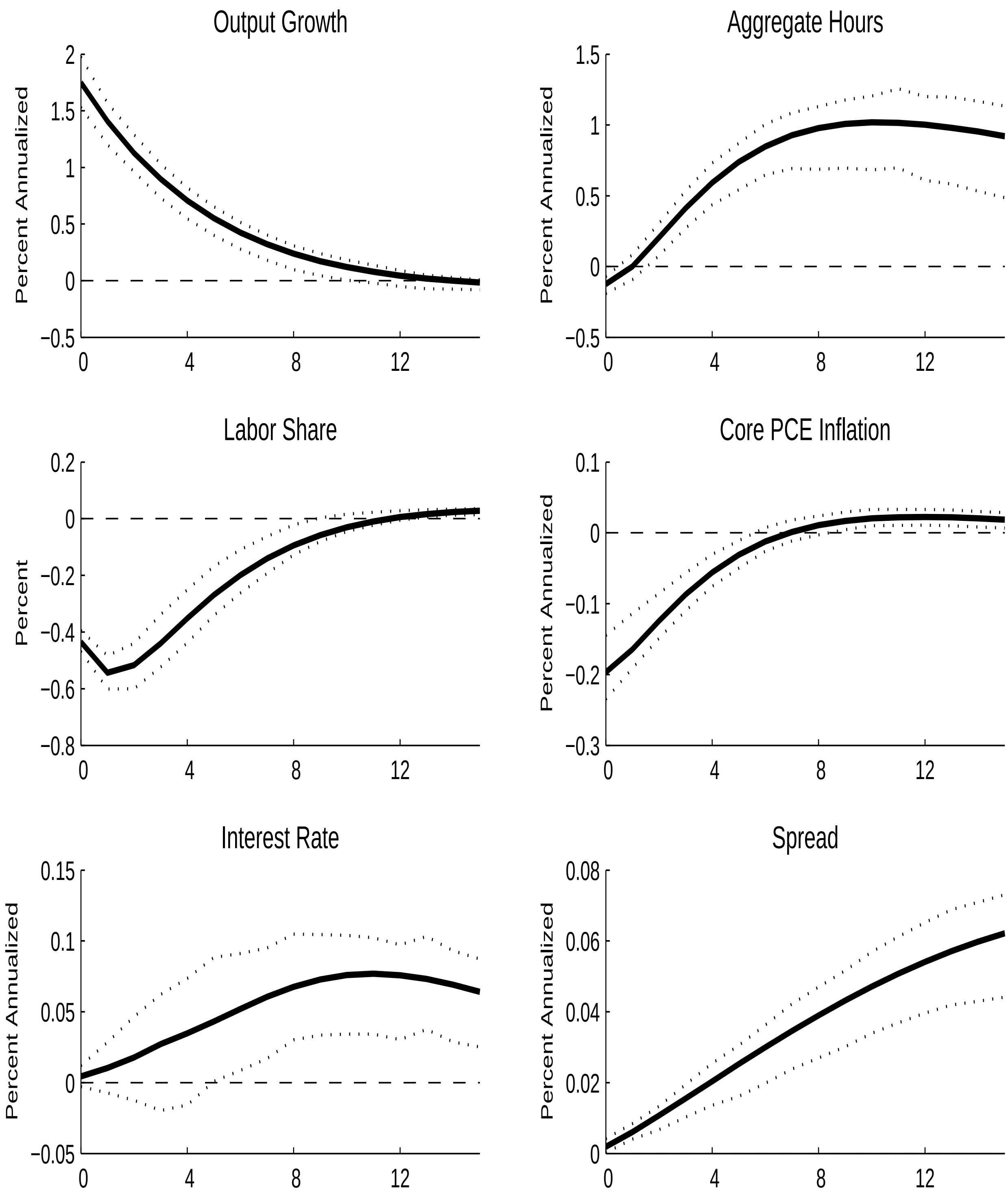


Figure 11: Responses to a Mark-up Shock

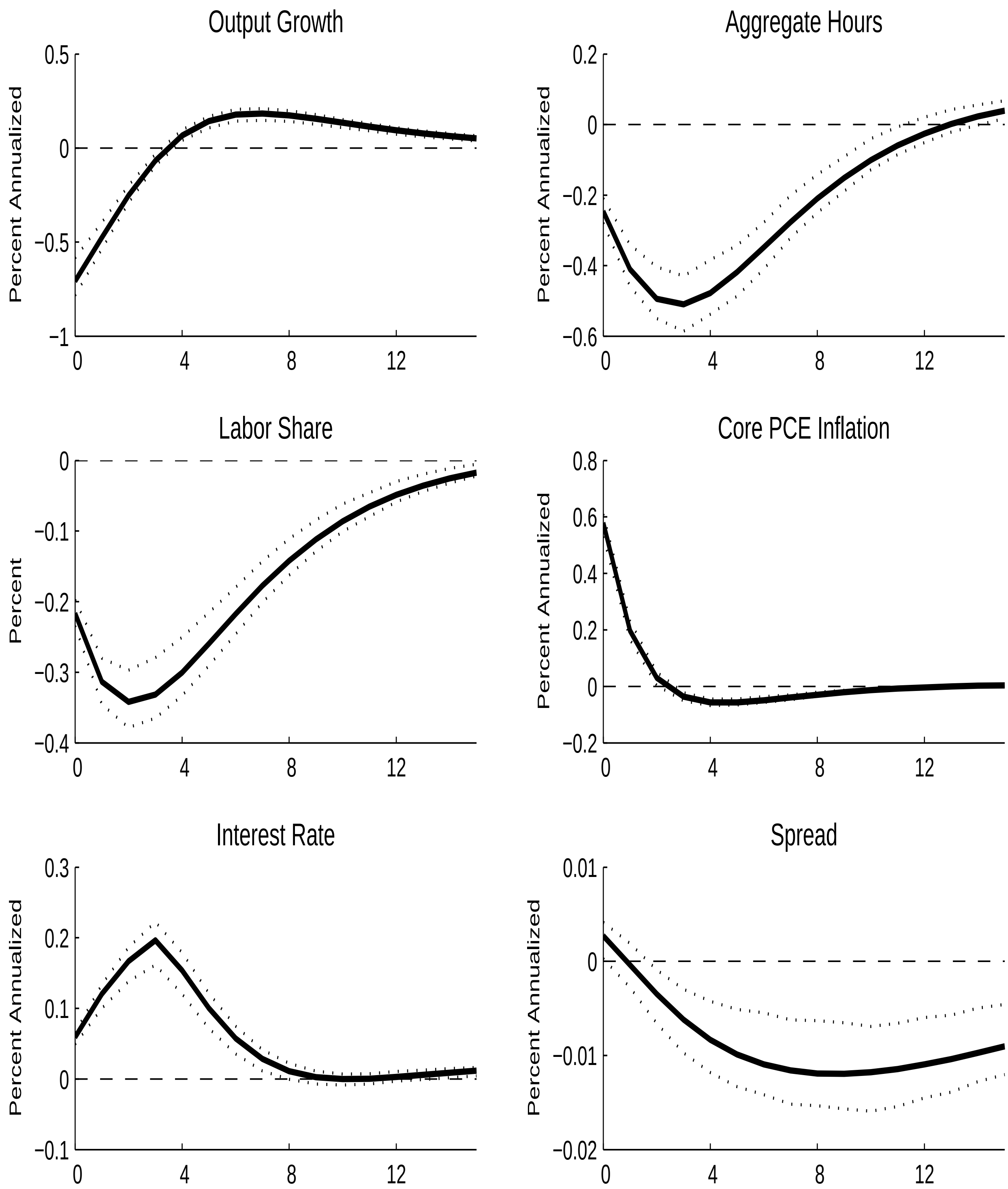


Figure 12: Responses to a Monetary Policy Shock

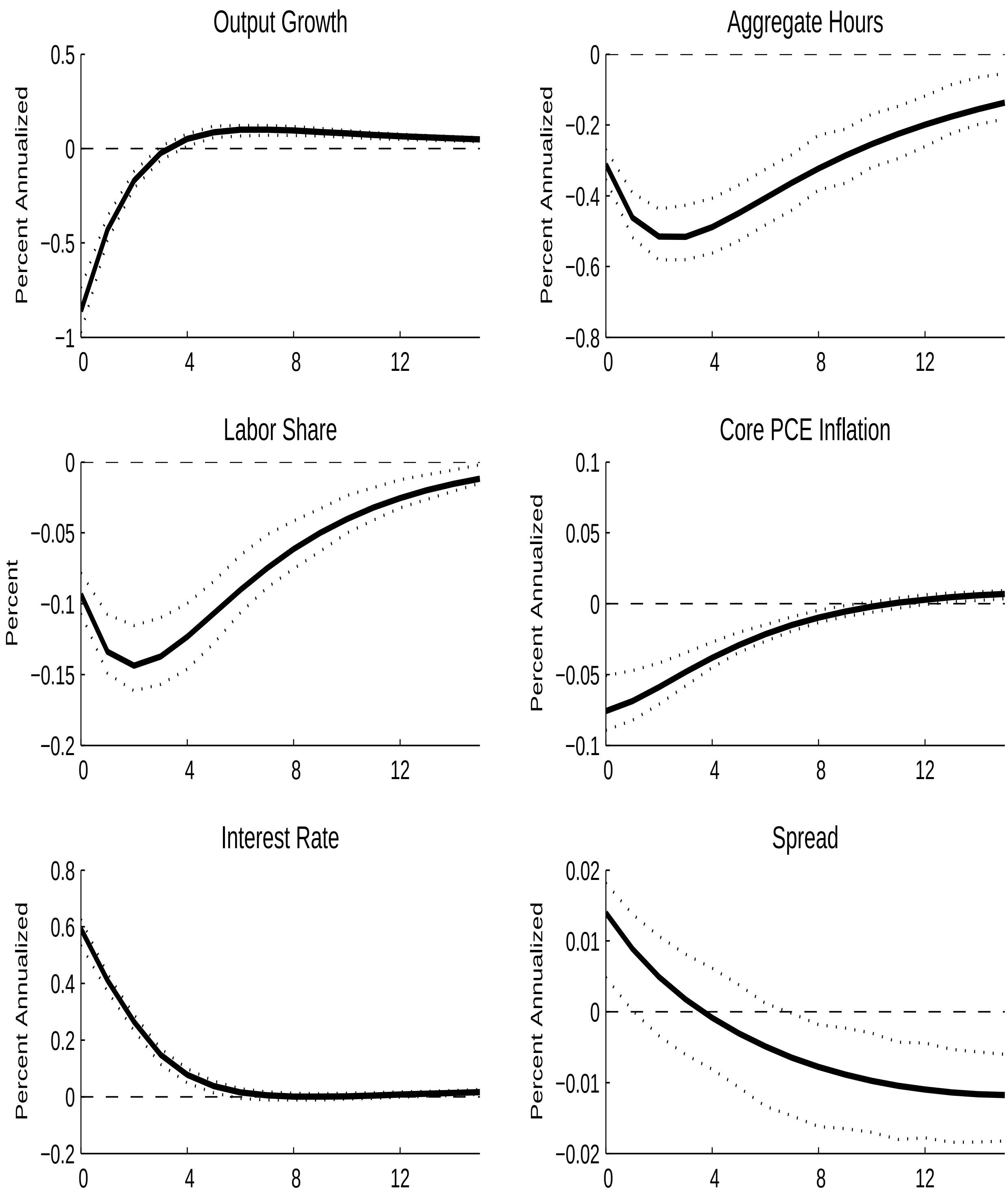


Figure 13: Responses to a Labor Supply Shock

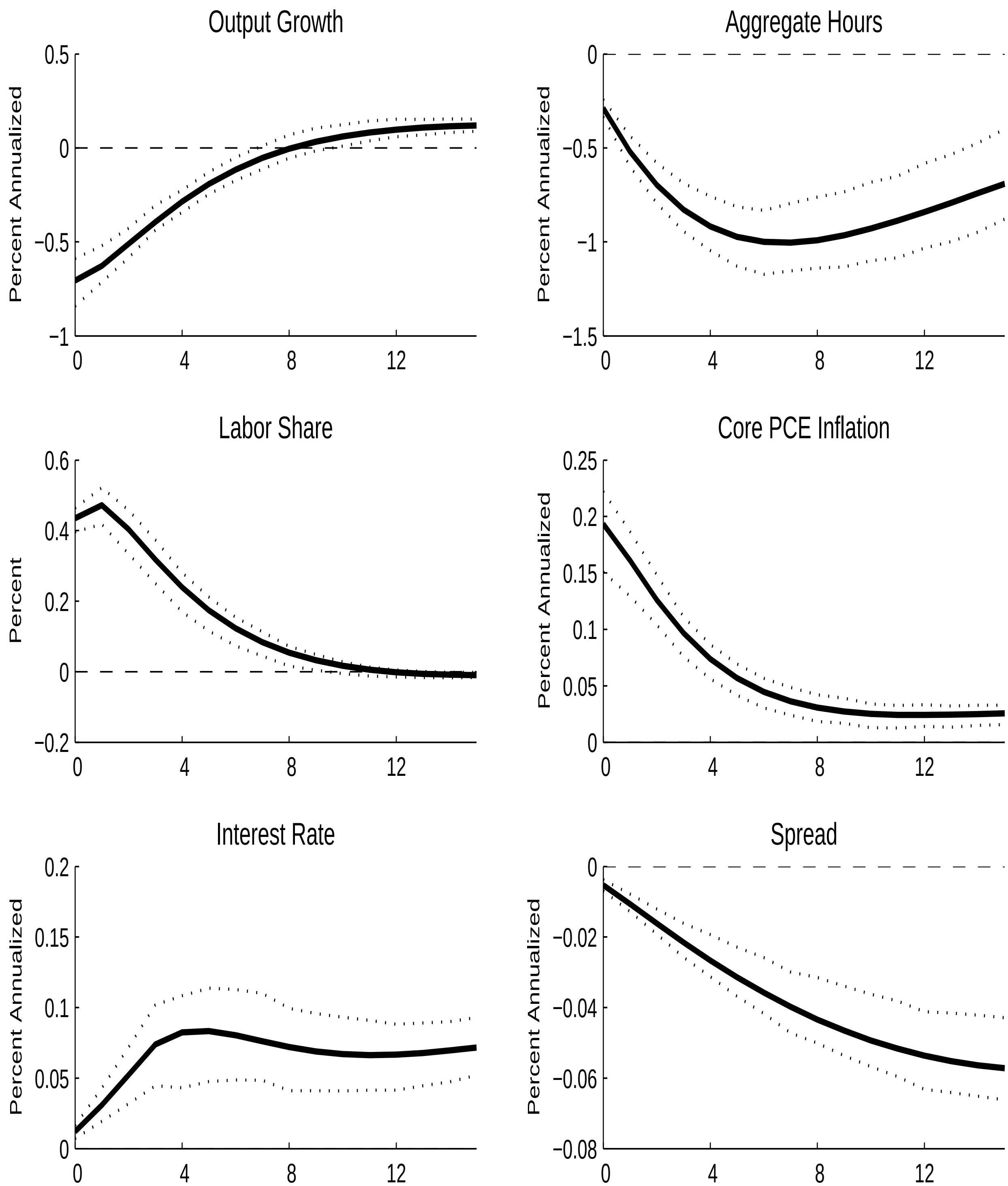
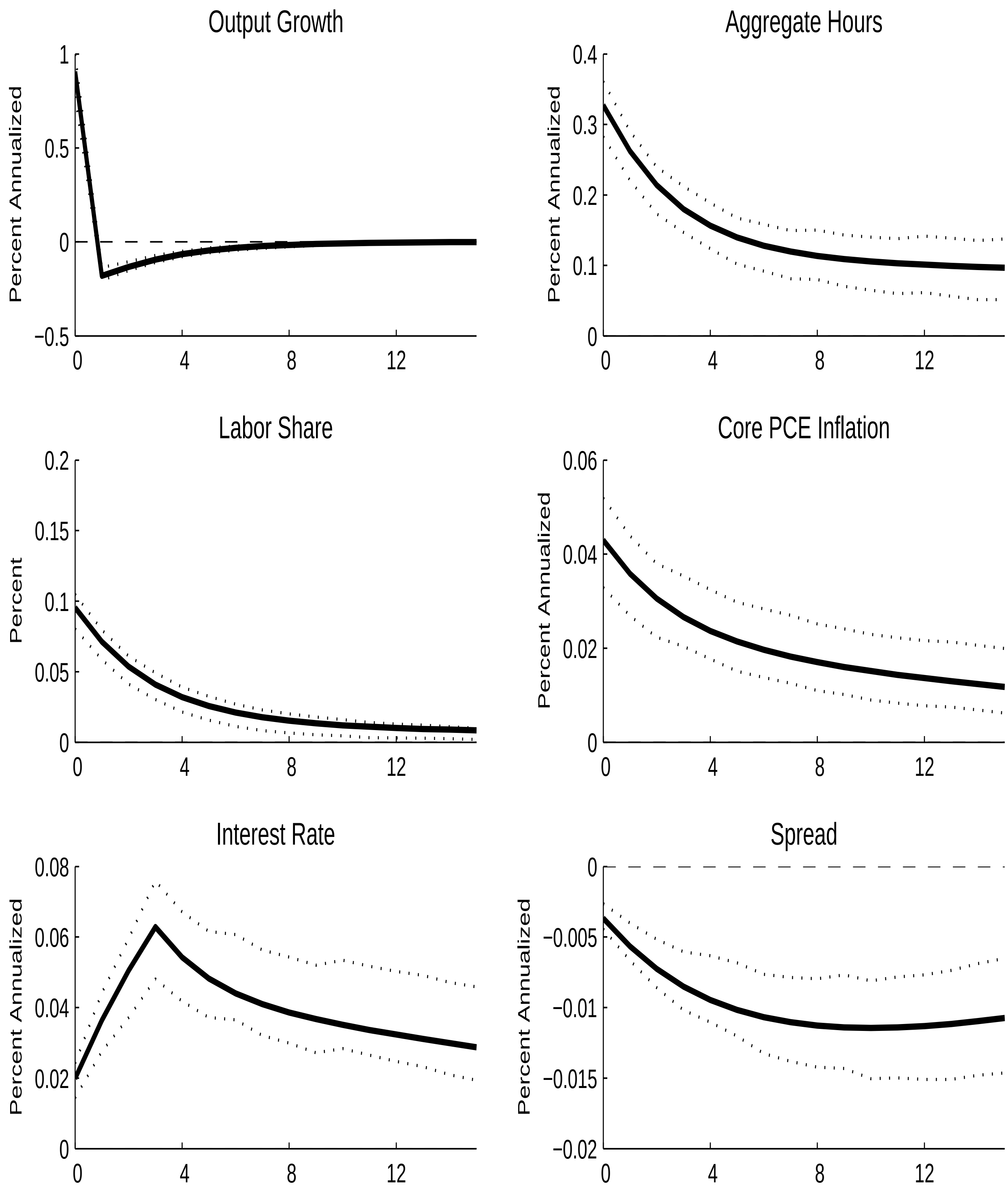


Figure 14: Responses to a Government Spending Shock



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Detailed Philadelphia (PRISM) Forecast Overview

January 2012

Keith Sill

Forecast Summary

The FRB Philadelphia DSGE model denoted PRISM, projects that real GDP growth will rebound fairly strongly over the forecast horizon with real output growth running a bit over 5 percent by mid 2012. Core PCE Inflation is projected to be well contained at 1.3 percent through 2014, even with significantly above-trend output growth. For this forecast round, we have implemented the assumption that the federal funds rate remains in a range of 0 to 0.25 percent through mid-2013. Monetary policy begins to tighten by the third quarter of 2013 in accord with the estimated monetary policy rule, and reaches a bit over 1.75 percent in 2014Q4. Currently, many of the model's variables are well below their steady-state values. In particular, consumption, investment, and the capital stock are low relative to steady state, and absent any shocks, the model would predict a rapid recovery. These state variables have been below steady state since the end of the recession. The relatively slow recovery to date and the low inflation that has recently characterized U.S. economic activity require the presence of shocks to offset the strength of the model's internal propagation channels.

The Current Forecast and Shock Identification

The PRISM model is an estimated New Keynesian DSGE model with sticky wages, sticky prices, investment adjustment costs, and habit persistence. The model is similar to the Smets & Wouters 2007 model and is described more fully in Schorfheide, Sill, and Kryshko 2010. Unlike in that paper though, we estimate PRISM directly on core PCE inflation rather than projecting core inflation as a non-modeled variable. Details on the model and its estimation are available in a Technical Appendix that was distributed for the June 2011 FOMC meeting or is available on request.

The current forecasts for real GDP growth, core PCE inflation, and the federal funds rate are shown in Figures 1a-1c along with the 68 percent probability coverage intervals. The forecast uses data through 2011Q3 supplemented by observations on 2011Q4 from the most recent Macroadvisers forecast. The model takes 2011Q4 output growth of 3.4 percent as given and the projection begins with 2012Q1. PRISM sees a strong rebound in real GDP growth, which rises to a bit above 5 percent by mid 2012. Output growth begins to taper off a bit in 2013, and falls to a 4 percent pace by 2014Q4. While output growth is fairly robust, core PCE inflation stays moderate, dropping from a bit over 2 percent in mid 2011 to 1.3 percent or below through the end of the forecast horizon. The federal funds rate is constrained at the zero bound through mid-2013. The zero bound constraint is implemented by adding fully anticipated monetary policy shocks to the model. Thereafter, the model dynamics take over and the funds rate rises to a bit under 2 percent in 2014Q4.

The key factors driving the projection are shown in the forecast shock decompositions (shown in Figures 2a-2e) and the smoothed estimates of the model's primary shocks (shown in Figure 3, where they are normalized by standard deviation). The primary shocks driving above-trend real output growth over the next 3 years are financial shocks in the form of discount factor shocks (labeled Fin), labor supply shocks (labeled Labor), and marginal efficiency of investment shocks (labeled MEI). PRISM estimates a long series of largely negative shocks to labor supply (in Figure 3 these are shown as positive shocks to a preference for leisure) since 2008. These shocks have a persistent negative effect on hours worked and so account for a large share of the decline in output in 2009 and 2010. These shocks have pushed hours worked well below steady state, and as they unwind over the projection period the labor market recovers and output growth is pushed above trend.

The model also estimates a sequence of largely negative discount factor shocks since 2008. All else equal, these shocks push down current consumption and push up investment, with the effect being very persistent. Consequently, consumption (nondurables + services) remains well below the model's estimated steady state at this point. As these shocks wane over the projection period, consumption growth picks up to an above-4 percent pace over most of the next three years (Figure 2d). The negative discount factor shocks worked to strengthen investment in 2010 and 2011, but these effects were in part offset by labor supply shocks and, more recently, adverse shocks to the marginal efficiency of investment (Figure 2e). A very strong sequence of negative MEI shocks in 2008 and 2009 pushed investment well below its steady state value. MEI shocks thus make a strong, positive contribution to investment growth over the next 3 years as investment rebounds to trend. Note though that the unwinding of the discount factor shocks that contributed positively to investment growth over 2009-2011 leads to a downward pull on investment growth over the next three years. On balance, investment growth runs at about a 10 percent pace in 2012, falling back to about 3 percent growth by the end of the forecast horizon.

The forecast for core PCE inflation is largely a story of unwinding of upward pressure from negative labor supply shocks being offset by downward pressure from the waning of discount factor shocks (Figure 2b). Negative discount factor shocks have a strong and persistent negative effect on marginal cost and inflation in the estimated model. Compared, for example, to a negative MEI shock that lowers real output growth by 1 percent, a negative discount factor shock that lowers real output growth by 1 percent leads to a 3 times larger drop in inflation that is more persistent. The negative discount factor shock leads to capital deepening and higher labor productivity. Consequently, marginal cost and inflation fall. The negative effect of discount factor shocks on inflation is estimated to have been quite significant since the end of 2008. As the effect of these shocks unwinds over the projection period there is a decreasing, but still substantial, downward effect on inflation over the next three years. Shocks to price markups also help explain the strength of core PCE inflation in 2011Q2-Q3, but their effects are not very persistent.

Partly offsetting the downward pressure on inflation from discount factor shocks is the upward pressure coming from labor supply shocks. Labor supply shocks that push down aggregate hours also serve to put upward pressure on the real wage and hence marginal cost. The effect is persistent, so as the labor supply shocks unwind over the forecast horizon they exert a waning upward push to inflation. On balance the effect of these opposing forces is to keep inflation below 1.5 percent through the forecast horizon.

The Unconditional Forecast

Pinning down the federal funds rate at the zero lower bound through mid-2013 (using fully anticipated monetary policy shocks that are added to the monetary policy rule) has a significant impact on the PRISM forecast. Figures 4a-c show the forecast and shock decompositions for the unconditional forecast (ie, a forecast that does not constrain the funds rate path). Without conditioning, the forecasted path for real GDP growth is about 1 percentage point higher over the next 3 years. The projection for core PCE inflation is at about 2 percent in 2013 and 2014, and the federal funds rate begins to rise immediately, reaching a bit over 3 percent by 2012Q4. Thus, the forecast is notably stronger if the funds rate is not constrained at the ZLB through mid-2013. As discussed further below, this occurs because the conditioning serves to re-estimate the current state of the economy.

The shock decompositions provide guidance on the difference between the conditional and unconditional forecasts. When the federal funds rate is constrained at the ZLB through mid-2013, it ultimately has an effect on expected inflation through the monetary policy reaction function (which puts little estimated weight on the output gap). Agents in the model fully anticipate that the funds rate will be low and with policy completely credible, put significant weight on future inflation being low, even though the anticipated shocks account for any deviation between the policy-rule-implied interest rate and the expectation of the interest rate. This feedback has an effect on the estimated current state of the economy and on how historical shocks get allocated by the Kalman filter.

For the unconditional real GDP forecast, discount factor shocks play a smaller role and MEI shocks play a larger role in the evolution of the forecast compared to the conditional forecast shock decomposition (see figure 2a and 4a). Similarly for the unconditional inflation forecast: discount factor shocks play a smaller role and MEI shocks play a larger role compared to the conditional forecast (see Figures 2b and 4b). Since discount factor shocks play a smaller role in keeping inflation low over the 2009-2011 period in the unconditional shock decomposition history, they exert less downward pull on inflation over the forecast period. Similarly, as the MEI shocks that helped pull down inflation over 2009-2011 unwind, they give an upward impetus to inflation over the forecast horizon. This is consistent with the impulse response function for inflation in response to a negative MEI shock, where there is eventual overshooting of the response rather than a monotonic return to steady state.

On balance, leaving the funds rate unconstrained in the forecast shifts the historical shock decomposition to give an expected path for output growth and inflation that is higher compared to the conditional forecast. With inflation running at about target and strong output growth, PRISM forecasts that the funds rate should begin rising immediately, reaching about 3 percent by the end of 2014 -- roughly 125 basis points above the constrained path federal funds rate at that point.

References

Schorfheide, Frank, Keith Sill, and Maxym Kryshko. 2010. “” *International Journal of Forecasting*, 26(2): 348-373.

Smets, Frank, and Rafael Wouters. 2007. “Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach.” *American Economic Review*, 97(3): 586-606.

Figure 1a

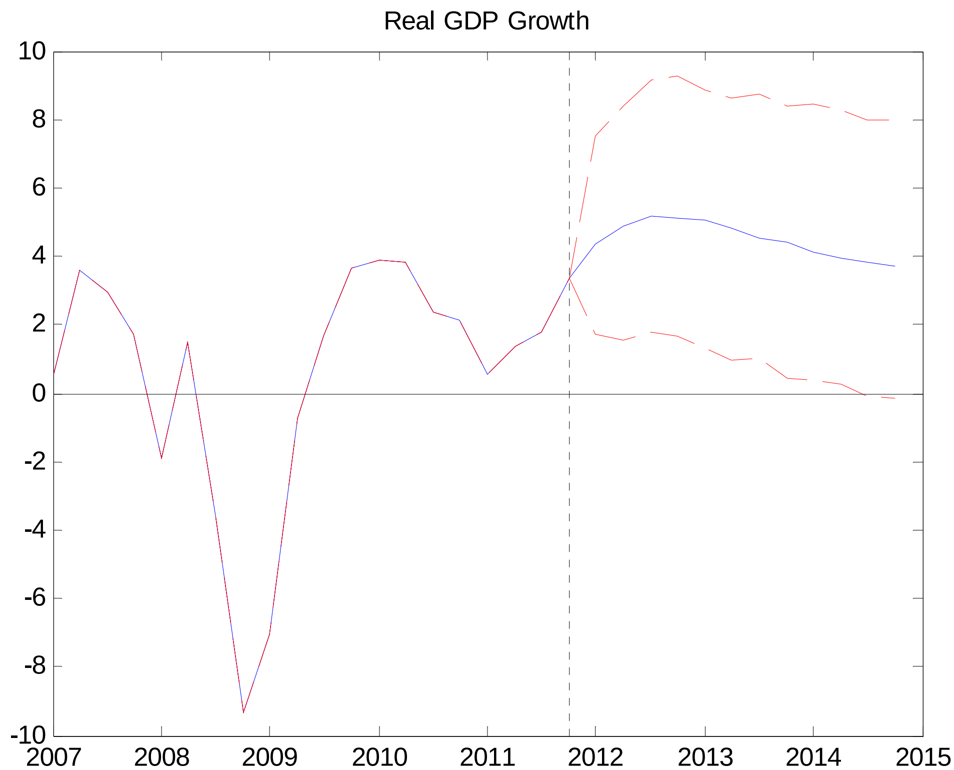

Real GDP Growth
10
8
6
4
2
0
-2
-4
-6
-8
-10
2007
2008
2009
2010
2011
2012
2013
2014
2015

Figure 1b

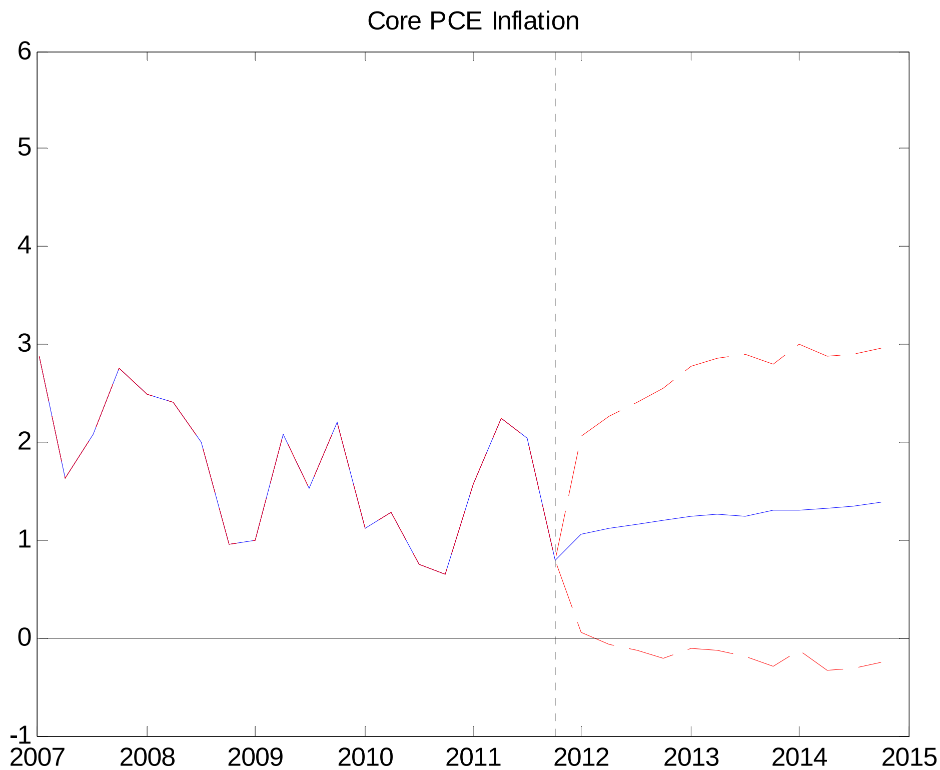

Core PCE Inflation
6
5
4
3
2
1
0
-1
2007
2008
2009
2010
2011
2012
2013
2014
2015

Figure 1c

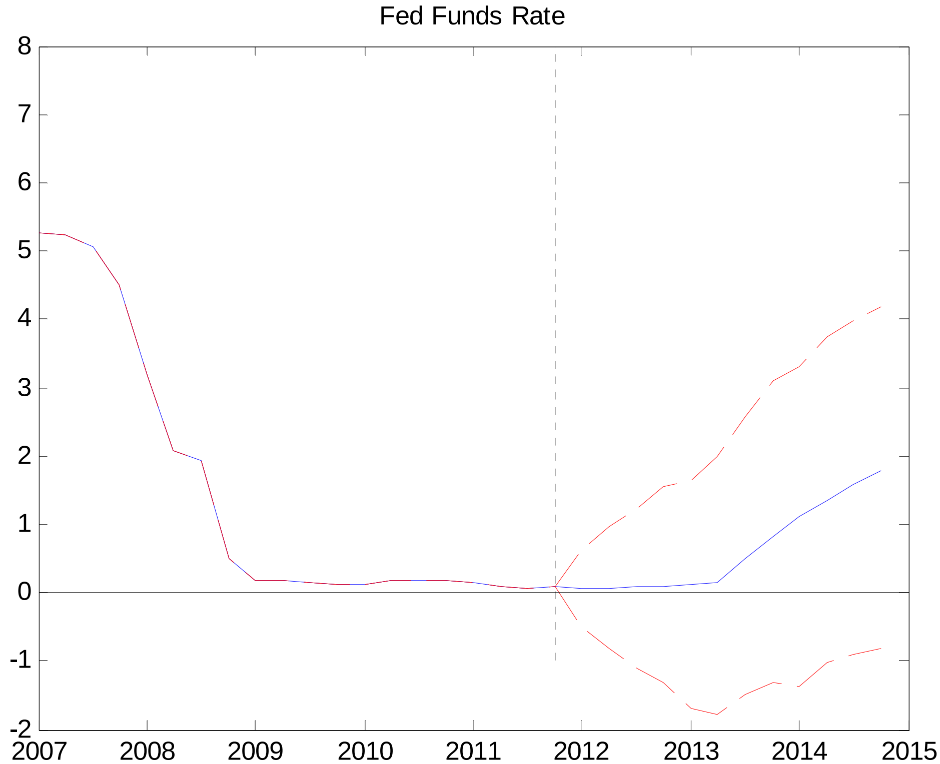
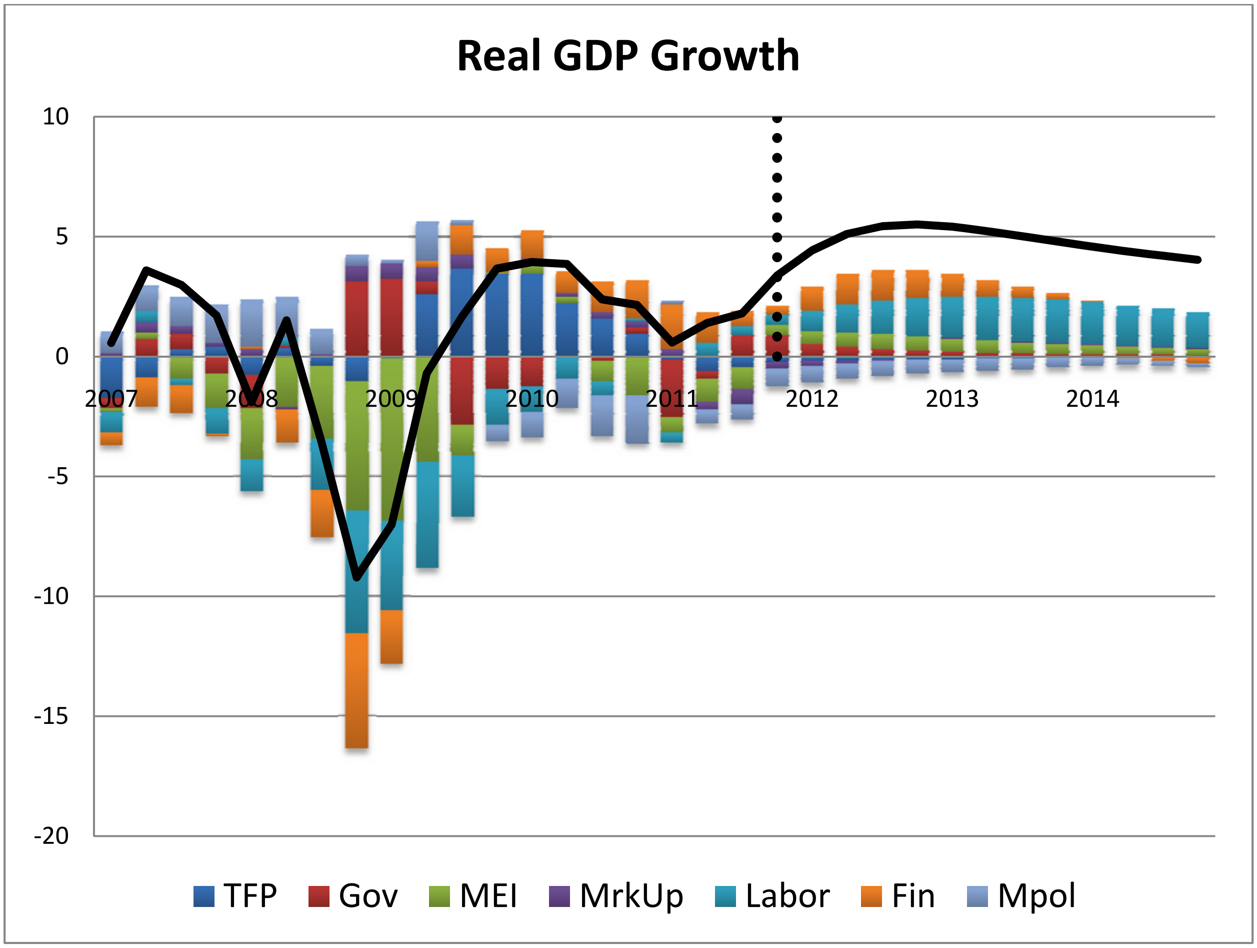

Fed Funds Rate
8
7
6
5
4
3
2
1
0
-1
-2
2007
2008
2009
2010
2011
2012
2013
2014
2015

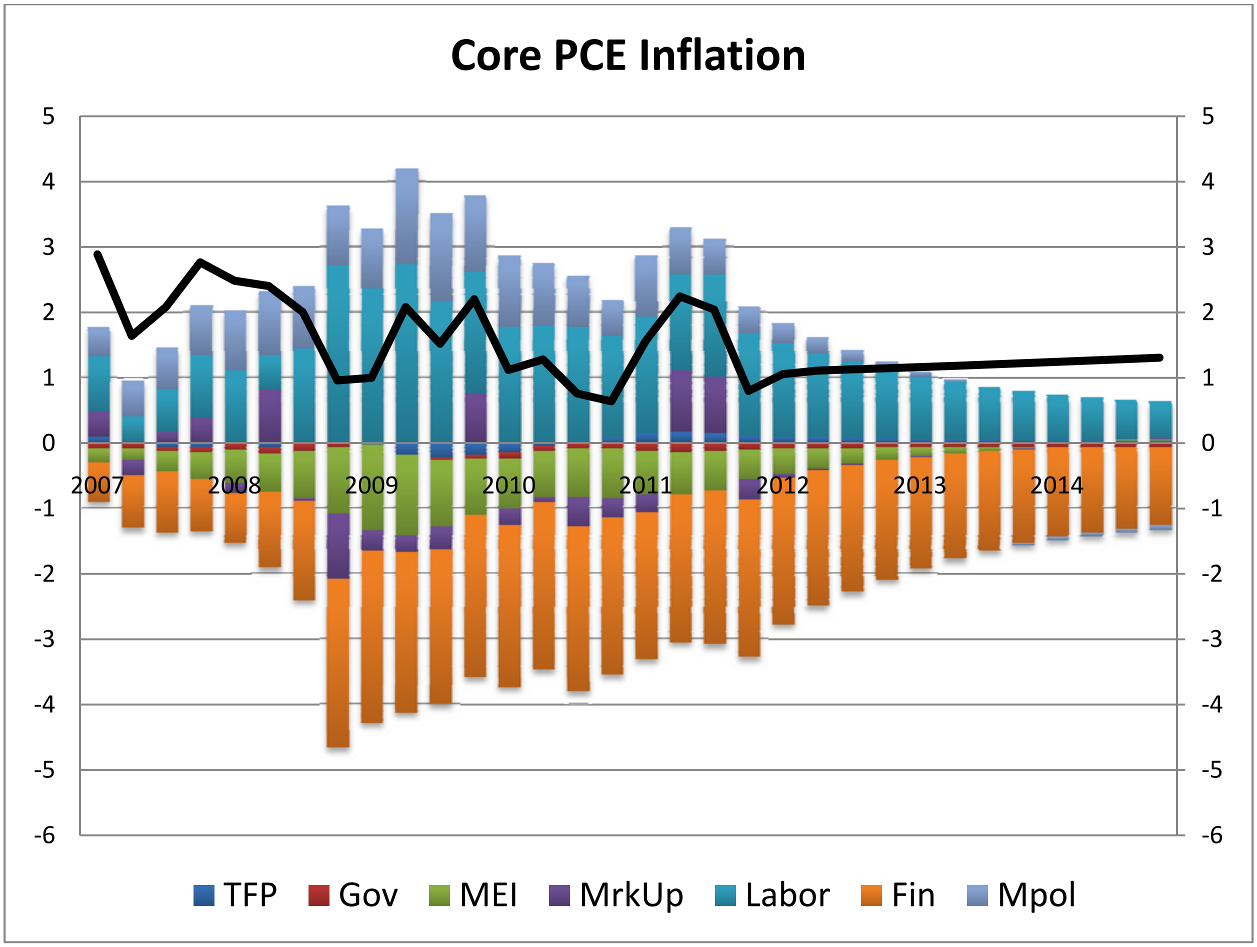
Figure 2a
Conditional Forecast



shocks:

TFP:	Total factor productivity growth shock
Gov:	Government spending shock
MEI:	Marginal efficiency of investment shock
MrkUp:	Price markup shock
Labor:	Labor supply shock
Fin:	Discount factor shock
Mpol:	Monetary policy shock

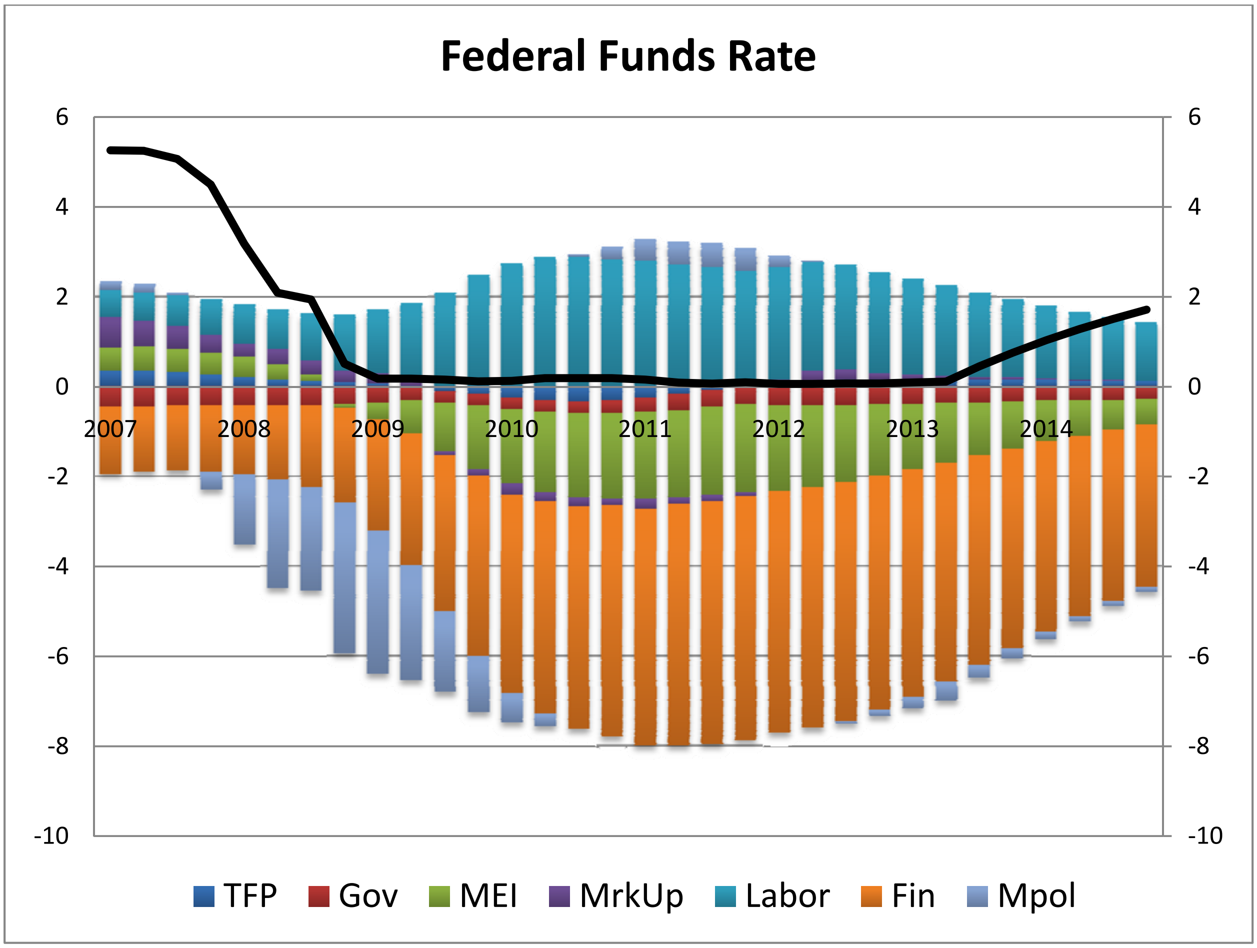
Figure 2b
Conditional Forecast



shocks:

TFP:	Total factor productivity growth shock
Gov:	Government spending shock
MEI:	Marginal efficiency of investment shock
MrkUp:	Price markup shock
Labor:	Labor supply shock
Fin:	Discount factor shock
Mpol:	Monetary policy shock

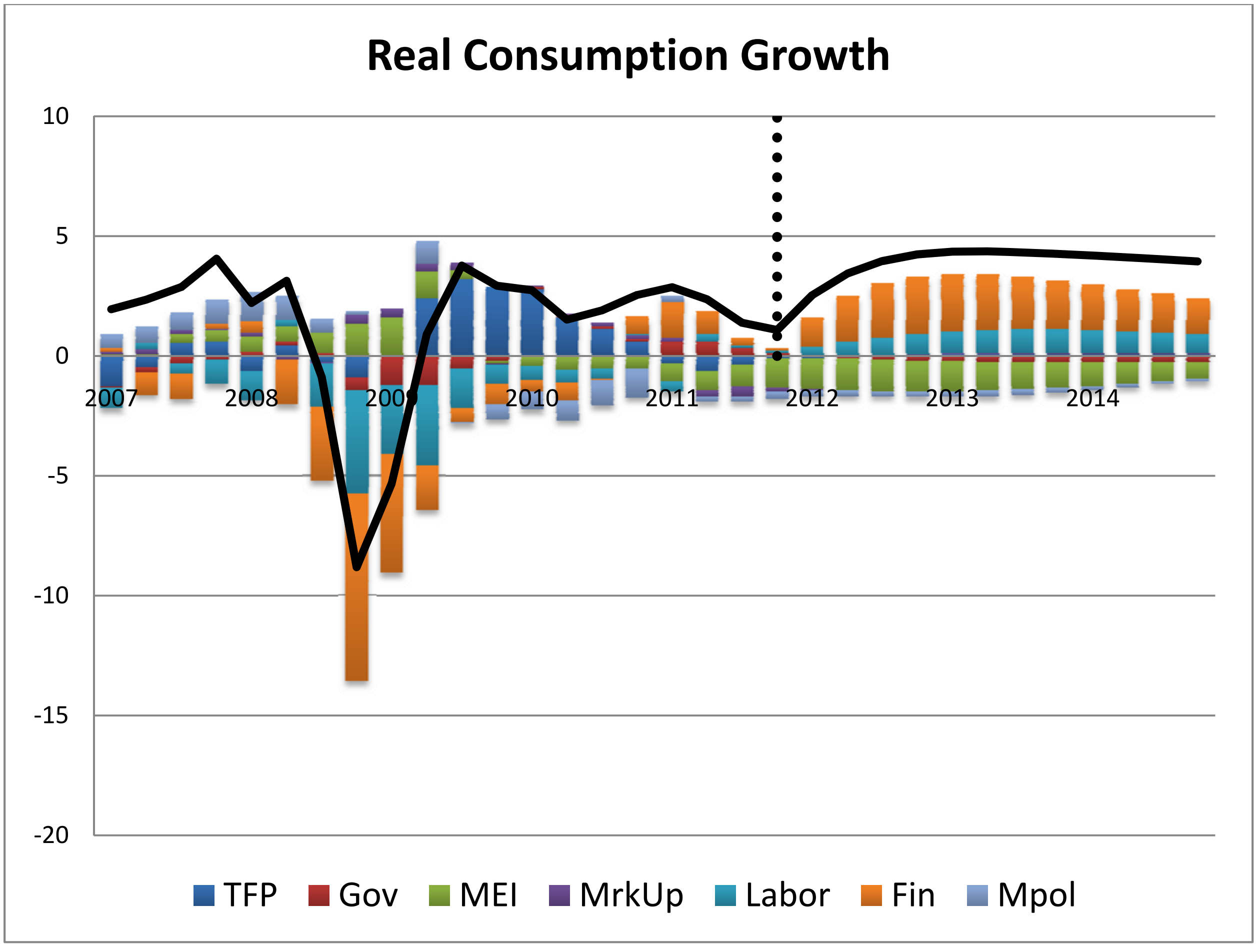
Figure 2c
Conditional Forecast



shocks:

TFP:	Total factor productivity growth shock
Gov:	Government spending shock
MEI:	Marginal efficiency of investment shock
MrkUp:	Price markup shock
Labor:	Labor supply shock
Fin:	Discount factor shock
Mpol:	Monetary policy shock

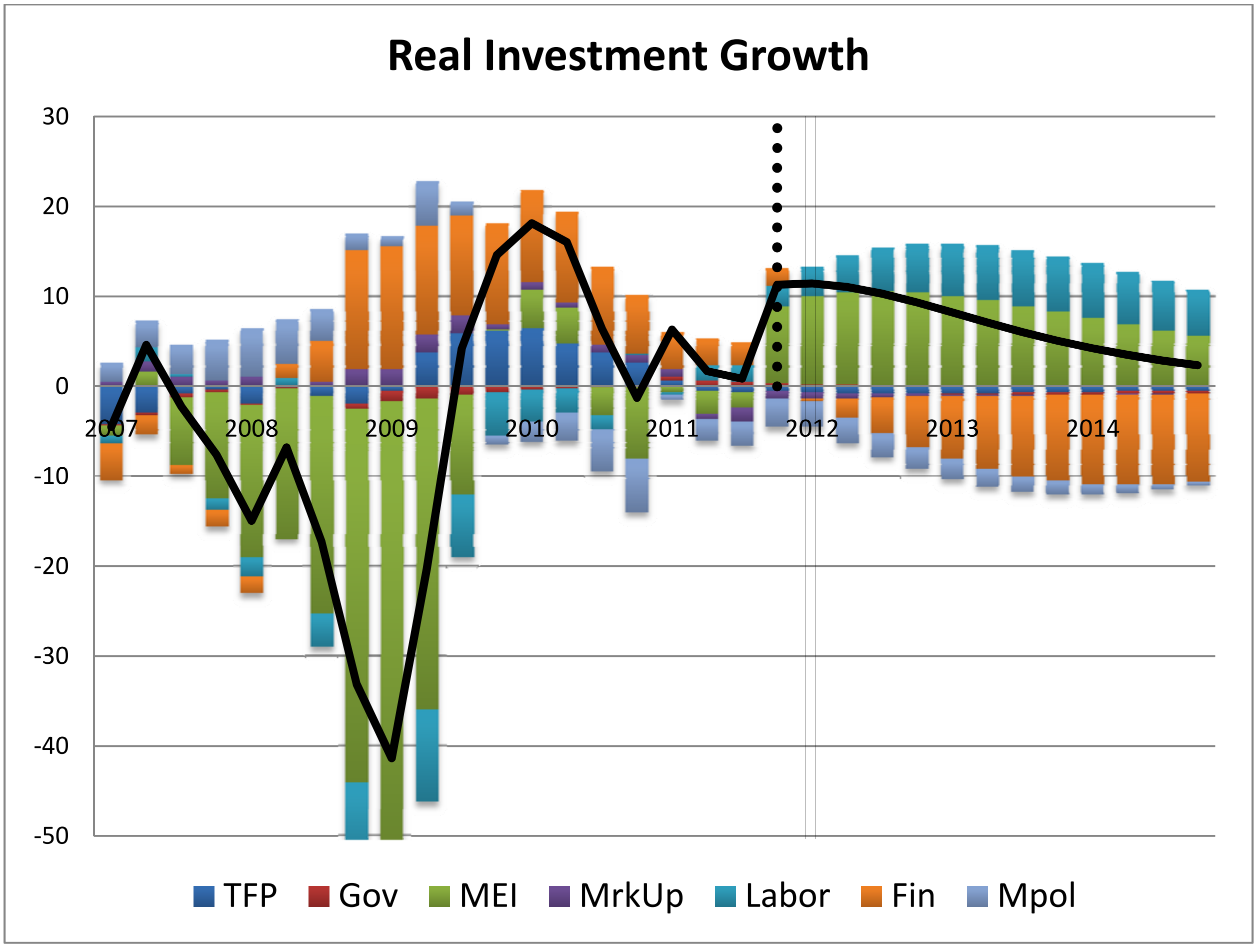
Figure 2d
Conditional Forecast



shocks:

TFP:	Total factor productivity growth shock
Gov:	Government spending shock
MEI:	Marginal efficiency of investment shock
MrkUp:	Price markup shock
Labor:	Labor supply shock
Fin:	Discount factor shock
Mpol:	Monetary policy shock

Figure 2e
Conditional Forecast



shocks:

TFP:	Total factor productivity growth shock
Gov:	Government spending shock
MEI:	Marginal efficiency of investment shock
MrkUp:	Price markup shock
Labor:	Labor supply shock
Fin:	Discount factor shock
Mpol:	Monetary policy shock

Figure 3
Smoothed Shock Estimates For Conditional Forecast Model
(normalized by standard deviation)

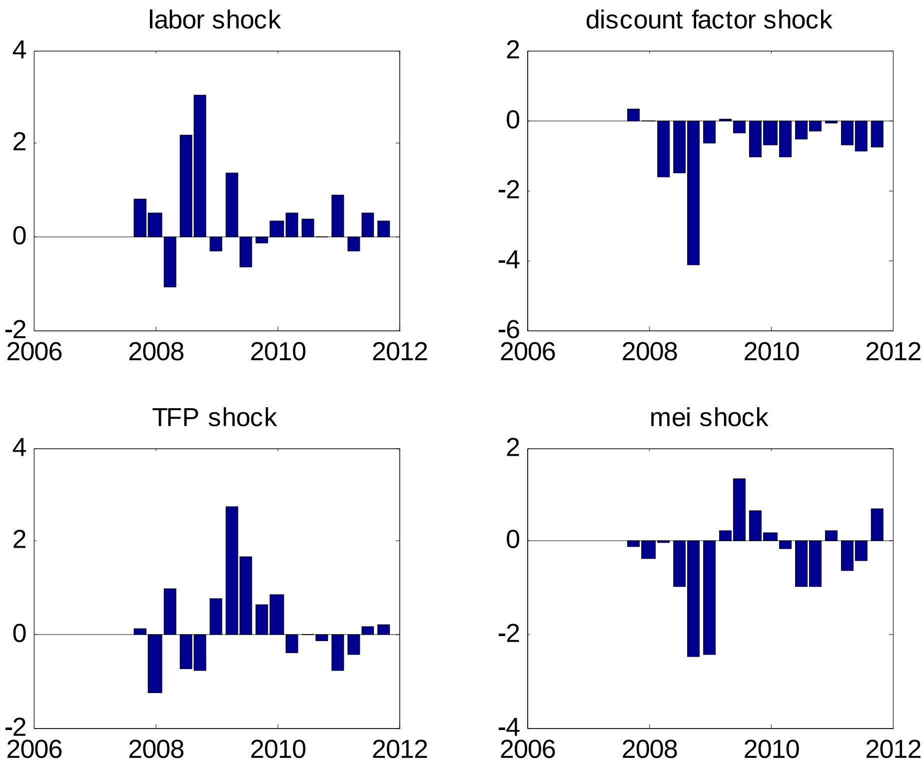
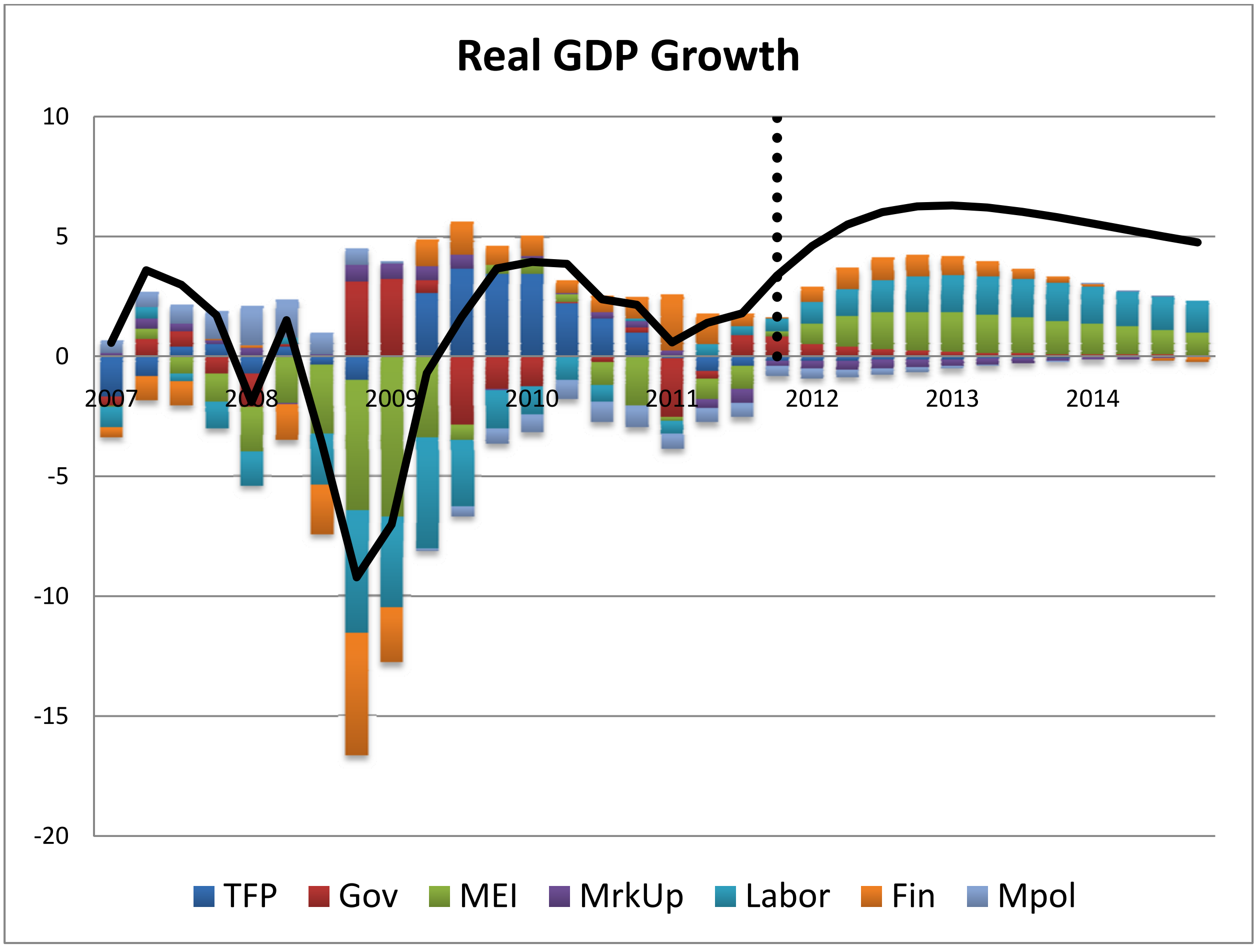


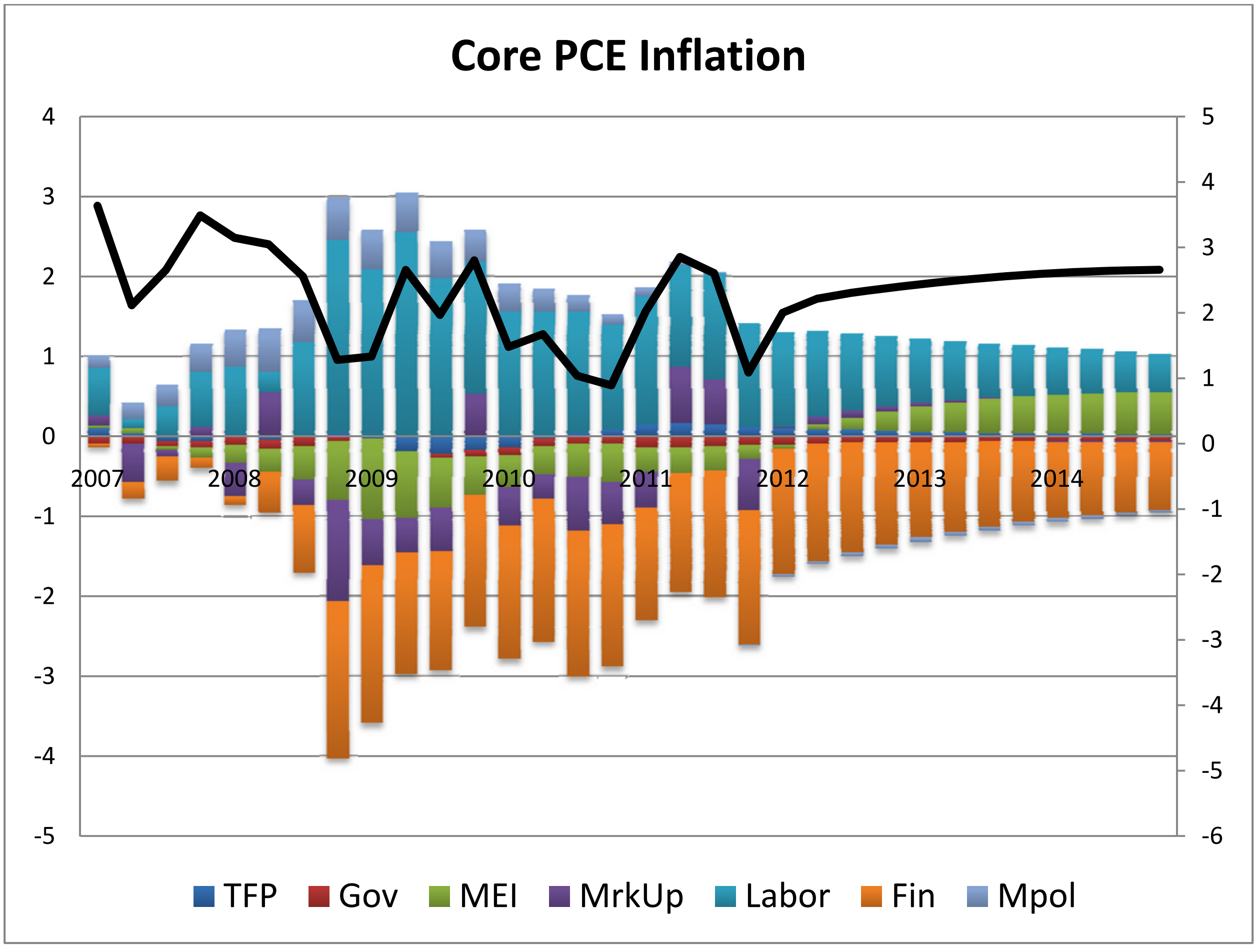
Figure 4a
Unconditional Forecast



shocks:

TFP:	Total factor productivity growth shock
Gov:	Government spending shock
MEI:	Marginal efficiency of investment shock
MrkUp:	Price markup shock
Labor:	Labor supply shock
Fin:	Discount factor shock
Mpol:	Monetary policy shock

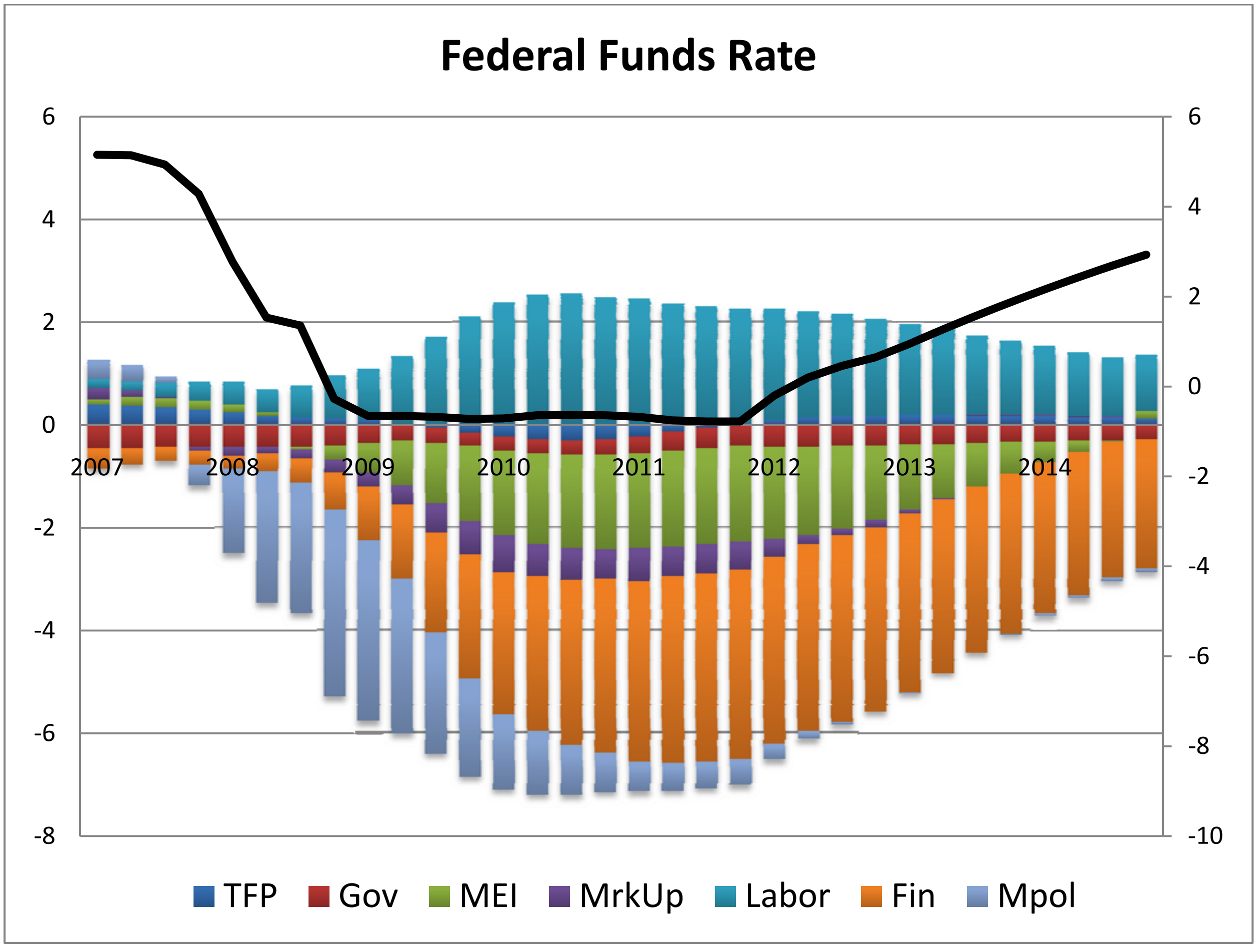
Figure 4b
Unconditional Forecast



shocks:

TFP:	Total factor productivity growth shock
Gov:	Government spending shock
MEI:	Marginal efficiency of investment shock
MrkUp:	Price markup shock
Labor:	Labor supply shock
Fin:	Discount factor shock
Mpol:	Monetary policy shock

Figure 4c
Unconditional Forecast



shocks:

TFP:	Total factor productivity growth shock
Gov:	Government spending shock
MEI:	Marginal efficiency of investment shock
MrkUp:	Price markup shock
Labor:	Labor supply shock
Fin:	Discount factor shock
Mpol:	Monetary policy shock

Figure 5
Smoothed Shock Estimates from Unconstrained Forecast Model
(normalized by standard deviation)