

# News Shocks, Inflation Expectations and Long-Term Interest Rates\*

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## Abstract

This paper attempts to jointly explain the behavior of inflation expectations and long-term bond yields from a macroeconomic perspective. Most papers in the literature rely on a time-varying inflation target to capture the trend component of these variables. I extend previous literature and add news shocks to the inflation target. Overall, introducing news shocks to the target breaks the link between the inflation target and the level factor of the term structure of interest rates, allowing us to obtain low estimates of the target in the first half of the 1980s when nominal yields were high but inflation expectations started to fall.

*Keywords:*

*JEL-classification:*

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# 1 Introduction

Modeling inflation and inflation expectations are main tasks for central banks in order to conduct monetary policy. This is due to the fact that the effects of monetary policy acts through inflation expectations. A large literature has contributed to understand the behavior of these series introducing variable inflation targets or shifting endpoints in inflation. Cogley and Sbordone (2008) show that inflation persistence results mainly from variation in the long-run trend component of inflation, which they attribute to shifts in monetary policy. They find that when a drift in trend inflation is taken into account there is not need for backward-looking components.

Many papers include a very persistent inflation target shock to account for the very low frequency behavior of inflation.<sup>1</sup> Given the importance of this variable, reasonable efforts have been made to estimate it.

However, rational expectations models with a time-varying inflation target estimated using standard macro variables such as output, inflation and the policy rate, fail to match survey data on inflation expectations after 1984 (Del Negro and Eusepi (2011)). To overcome this problem, some papers have included yield curve data in the estimation. Doh (forthcoming) finds that when yield curve information is included, the DSGE model generates inflation expectations that are highly correlated with survey data evidence. However, once we include yield curve data to estimate the implicit inflation target, estimates of this variable peak around 1981 and 1984 when long-term rates peak. This result is inconsistent with the large drop in inflation and inflation expectations that occurred after 1981 (see figure 1).

Alternatively, some papers have departed from the rational expectations framework and introduced learning as a mechanism to model inflation expectations. Models with learning allow for more flexibility and are able to better replicate the data on inflation

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<sup>1</sup>Given that the Federal Reserve does not have an explicit inflation target, the term inflation target in the paper refers interchangeably to the implicit inflation target understood by the agents in the model or the underlying low frequency inflation component.

expectations and long-term rates (Dewachter and Lyrio (2008)).

I follow the literature and model the long-run component of inflation as a time-varying inflation target. My main contribution is to add inflation target news shocks to the standard New Keynesian model with inflation target. News shocks to the inflation target can be interpreted as information agents have today about the expected future level of inflation. This information is available through other variables not present in the baseline New Keynesian model and by construction uncorrelated with other sources of information in the model.

The main goal of the paper is to find some alternative explanations for the joint behavior of inflation expectations and long-term bond yields. In doing so, the paper also provides some new results about the estimation of the policy target for inflation.

To assess the empirical performance of the model, I estimate it using Bayesian methods for the period 1961-2008. The estimated inflation target is similar to the ones obtained in models with learning: the implicit inflation target started to decrease in 1980, some months after Paul Volcker assumed as chairman of the Federal Reserve.

I show that without departing from the rational expectations assumption, adding news shocks to the inflation target improves the fit of the model in two dimensions: fitting survey data on inflation expectations and on long-term nominal yields. Introducing news shocks to the target breaks the link between the inflation target and the level factor of the term structure of interest rates, allowing us to obtain low estimates of the target in the first half of the 1980s when nominal yields were high but survey data on inflation expectations started to fall. News shocks are particularly important explaining the path of long-term rates in three periods: the oil crisis in the mid 1970s, the Volcker disinflation at the beginning of the 1980s and the interest rate conundrum of 2004-2006.

Moreover, (positive) news shocks to the target will pick up, by construction, "inflation scares" episodes defined as a significant long-rate rise in the absence of an aggressive funds rate tightening (Goodfriend (1993)).

The paper also finds some (weak) evidence that news shocks to future inflation target may be related to the stance of fiscal policy. I show that we can reject the null hypothesis that the ratio of primary deficits to debt do not Granger-cause news shocks to the inflation target.

Since the inflation target is a key concept in the paper, it is important to make clear the way one can interpret it. Inflation target does not represent the level of inflation the Fed wants to achieve, but what it is willing to accept at each period of time given the particular circumstances affecting the economy. In the 1970s inflation was high not because the Fed wanted but because they were willing to accept high levels of inflation to accommodate the economy. In that sense, a time-varying inflation target represents variations in the policymaker preferences about the target level of inflation considering the state of the economy.<sup>2</sup> Ireland (2007) formally investigates this view and provides some support for the hypothesis that the Federal Reserve policy has systematically translated short-run price pressures into more persistent movements in inflation. While short-run movements in inflation may occur for many reasons, including an inflation target in the policy rule ties down long-run inflation to monetary policy. It is in that sense that the inflation target represents the low-frequency component of inflation. Following most of the literature, I make the simplifying assumption that the inflation target is an exogenous process.<sup>3</sup>

From the methodological point, the paper coincides with previous literature that show the importance of including expectational data such as survey data or the term structure of interest rates to estimate DSGE models. Moreover, the paper also shows that in order to properly estimate news shocks to the inflation target we need to include

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<sup>2</sup>One could also interpret this as capturing time-variation in the policy coefficients.

<sup>3</sup>Ireland (2007) formally incorporates the link between the inflation target and other shocks allowing the inflation target to respond to supply shocks. However, he cannot statistically reject the exogenous target model where the inflation target moves randomly. His estimated path for the inflation target is similar in a model with exogenous or endogenous target.

data on bond yields.<sup>4</sup>

The paper is related to different strands of the literature. First, it contributes to the recent literature that studies the importance of news shocks in business cycles. Most of this literature focus on news shocks to TFP. A few papers have included news shocks to the inflation target but none of them have looked at long-term yields.<sup>5</sup> I show that inflation target news shocks can not be properly estimated without including data on long-term yields (or data that embeds future inflation expectations). Once we include this data in the estimation, news shocks to the inflation target seem to be an important component in explaining long-run inflation and bond yields movements.

Two papers have looked at the importance of news shocks to model bond yields. Badarinsa and Margaritov (2011) use yields data and estimate a DSGE model with news shocks to TFP, investment-specific technology and monetary policy. They do not include in their model news shocks to the target. They find that around 95% of the long-term variation in yields is explained by a time-varying inflation target. I find that movements in the target explain around 70% of long-term variation in yields being the rest explained by other macro shocks. Moreover I decompose this into anticipated and unanticipated changes in the target generating very different results for the estimation of the inflation target and the model correlation with survey data on inflation expectations.

Kurmann and Otrok (2011) use a VAR approach and show that 60% of movements in the slope are due to news shocks about future TFP. After a positive news shocks to TFP, the federal funds rate falls causing an increase in the spread between long and short rates. However, the reaction of the long-end of the term structure is small. In the current paper, I mostly focus on explaining movements in the long-end of the term structure.

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<sup>4</sup>Similarly, Hirose and Kurozumi (2011) use term structure data to identify anticipated shocks to the policy instrument. Typically, shocks to the policy rate are important in the short-run, while shocks to the inflation target may be also important in the long-run, specially affecting forward rates at long horizons.

<sup>5</sup>See Gomes and Mendicino (2011) and Milani and Treadwell (2011).

The paper is also related to the vast literature that tries to link the term structure of interest rates to perceptions of monetary policy.<sup>6</sup> In general, agents in these models do not have perfect information and try to infer the future stand of monetary policy. For instance, Dewachter and Lyrio (2008) develop a DSGE model in which the rational expectations assumption is replaced by a learning mechanism about the chairman-specific policy rule (and inflation target). They show that introducing constant-gain learning in the macro model generates endogenous stochastic endpoints which act as level factors for the yield curve and account for most of the variation in long-term yields. However, as pointed out by Galí (2008), one caveat of the model is that the gap between the perceived law of motion and the actual law of motion is very large explaining most of the volatility.

In this paper agents have perfect information and some kind of "perceptions" about future policy are introduced as news shocks to the inflation target. Agents have today some information about future policy that they incorporate in the long-horizon forecasts of the short rate. These news can materialize or not, but agents do not make mistakes. While in models with learning inflation expectations lag the inflation target because of imperfect information (or credibility), in my model agents are full-informed and the difference in expectations and the target today comes from too much information, not too little: agents have information about the future value of the exogenous inflation target not included in the rest of the model.

Last, in the last years there has been a rapidly growing literature using structural New Keynesian models together with an affine term structure model to explain features in bond yield data.<sup>7</sup> While all these papers include a time-varying inflation target in

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<sup>6</sup> A non-exhaustive list includes Dewachter and Lyrio (2008), Ellingsen and Söderström (2001), Ellingsen and Söderström (2005), Fuhrer (1996), Kozicki and Tinsley (2001a), and Kozicki and Tinsley (2005).

<sup>7</sup> See, among others, Bekaert, Cho, and Moreno (2010), De Graeve, Emiris, and Wouters (2009), Hördahl, Tristani, and Vestin (2006), Hördahl, Tristani, and Vestin (2008) and Rudebusch and Wu (2008).

order to capture the level factor of long-term rates, none of them includes news shocks to the target. My results complements these line of research showing that anticipated shocks to the central bank implicit inflation target are an important determinant of long-term bond yields.

Following some of the these papers I model log bond prices as an affine function of the state variables where the pricing kernel is consistent with the IS equation. This implies that in the log linearized model the price of risk is constant and the expectation hypothesis holds. As shown in the paper, this seems to be a good approximation once we include news shocks, since in my model these shocks affect future expectations of the short rate diminishing the importance of residual term premiums.<sup>8</sup>

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 presents the general results of the estimation. Section 4 shows the importance of introducing news shocks to the inflation target in order to estimate the underlying inflation component. Section 5 considers survey data on inflation expectations as a form of external validation of the model, while section 6 looks at the importance of news shocks to the inflation target to explain long-term nominal yields. Section 7 concludes.

## 2 The Model

The model in this paper is the textbook New Keynesian forward-looking model where firms have market power and get to adjust their prices with a fixed probability in each period.<sup>9</sup>

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<sup>8</sup>Similarly, Fuhrer (1996), Kozicki and Tinsley (2001b) and Kozicki and Tinsley (2005) show that small differences in the specification of the process for the short rate or failure to model expectations about the short rate, may change the relative importance of short rate expectations and residual term premiums in bond rate movements.

<sup>9</sup>See, for instance, Gali (2008) and Woodford (2003). We could also use a more complete and complicated model as Smets and Wouters (2007) but this would not affect the main results.

A representative infinitely-lived household maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{z_t C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right),$$

where  $z$  is a preference shock,  $N$  hours of work and  $C$  a consumption index given by

$$C_t = \left( \int_0^1 C_t(i)^{1-\frac{1}{\varepsilon_t}} di \right)^{\frac{\varepsilon_t}{\varepsilon_t-1}}$$

with  $C(i)$  denoting the consumption of good  $i$  and  $\frac{\varepsilon}{\varepsilon-1}$  an exogenous markup. Households are subject to a budget constraint.

Firms produce a differentiated good but they use an identical technology

$$Y_t(i) = a_t N_t(i)^{1-\alpha},$$

where  $a$  denotes the aggregate level of technology common to all firms which moves exogenously. Following Calvo (1983), at each period of time firms can reset their prices with probability  $1 - \theta$ .<sup>10</sup>

Final output is

$$Y_t = C_t + g_t,$$

where  $g$  denotes exogenous government expenditure shocks financed by lump-sum taxes.

All exogenous shocks introduced so far,  $z$ ,  $a$ ,  $g$  and  $\frac{\varepsilon}{\varepsilon-1}$  follow an AR(1) process.

The loglinearized version of the Phillips curve and the expectations based IS curve are given by

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \delta (y_t - y_t^P) + \widehat{\varepsilon}_t \quad (1)$$

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<sup>10</sup>Following results in Cogley and Sbordone (2008), Ireland (2007) and Nakamura and Steinsson (2008) I abstract from price indexation and do not include a backward-looking term in the Phillips curve.

and

$$y_t = E_t y_{t+1} - (1 - g_y) \frac{1}{\sigma} (i_t - E_t \pi_{t+1}) - g_y E_t (\hat{g}_{t+1} - \hat{g}_t) - (1 - g_y) \frac{1}{\sigma} E_t (\hat{z}_{t+1} - \hat{z}_t) \quad (2)$$

where  $\pi_t$  is the rate of inflation,  $y_t$  output,  $y_t^P$  the potential output, and  $i_t$  the nominal interest rate. All variables are expressed as deviations from their steady state values. These equations can be derived from first principles where  $\kappa = \frac{(1-\theta)(1-\beta\theta)}{\theta}$ ,  $\delta = \sigma + \frac{\varphi+\alpha}{1-\alpha}$ , and  $g_y$  represents the steady state ratio of government expenditures to output.

Potential output is defined as the equilibrium level of output under flexible prices and constant markups, which is given by

$$y_t^P = \frac{\sigma \frac{g_y}{1-g_y} \hat{g}_t + \hat{z}_t + \frac{\varphi+1}{1-\alpha} \hat{a}_t}{\left( \frac{\sigma}{1-g_y} + \frac{\varphi+\alpha}{1-\alpha} \right)}.$$

We can rewrite equation (2) in terms of the output gap as

$$x_t = E_t x_{t+1} - (1 - g_y) \frac{1}{\sigma} (i_t - E_t \pi_{t+1} - r_t^P) \quad (3)$$

where

$$r_t^P = \frac{\sigma}{(1 - g_y)} E_t \Delta y_{t+1}^P - E \Delta \hat{z}_{t+1} - \sigma \frac{g_y}{(1 - g_y)} E \Delta \hat{g}_{t+1}$$

is the equilibrium real interest rate: the real rate of return consistent with a zero output gap.

The policymaker sets the nominal interest rate such

$$i_t = \omega i_{t-1} + (1 - \omega) \left[ \pi_t^* + \lambda_\pi (\pi_t - \pi_t^*) + \frac{\lambda}{4} x_t \right] + \hat{\epsilon}_t,$$

where  $\epsilon_t \sim N(0, \sigma_\epsilon^2)$  is an i.i.d. shock and  $\pi_t^*$  denotes the inflation target. The process for the inflation target is described at the end of this section.

## 2.1 Bond Pricing

I use the stochastic discount factor of the households as the pricing kernel for the bonds. Under certain assumptions this implies that the price of risk is constant and that the expectation hypothesis holds.<sup>11</sup> The yield on a note of maturity  $m$  at time  $t$  should be equal to the expected average of future short interest rates over the same period, plus a constant term premium ( $\zeta^m$ ):

$$i_t^m = \frac{1}{m} [i_t + i_{t+1|t} + i_{t+2|t} + \dots + i_{t+m-1|t}] + \zeta^m, \quad (4)$$

where  $i_{t+m|t} = E_t(i_{t+m})$ . In practice, all nominal data is demeaned previous to estimation so the model can not tell us anything about the constant term premium  $\zeta^m$ . Moreover, to allow for more flexibility in the estimation, an i.i.d. measurement error  $\tau_t \sim N(0, \sigma_\tau^2)$  is added to equation (4) which is not correlated to other variables in the model. This shock can also be interpreted as the risk premium since the risk premium is the part of yields not explained by the expectation hypothesis.

The results in the paper show that using the expectation hypothesis is a good approximation once we introduce news shocks.

## 2.2 Inflation Target

The inflation target evolves exogenously over time. Following a growing literature on news shocks, I define the inflation target as

$$\pi_t^* = \rho_\pi \pi_{t-1}^* + \eta_t^0 + \eta_{t-i}^i,$$

where  $\eta_{t-i}^i \sim N(0, \sigma_{\eta^i}^2)$  is an i.i.d. random innovation announced in period  $t$  but materialized in a change in  $\pi^*$  only in period  $t+i$ . The inflation target is subject to

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<sup>11</sup>See Bekaert, Cho, and Moreno (2010) and De Graeve, Emiris, and Wouters (2009) for a detailed derivation.

anticipated and unanticipated innovations. The other variables in the model will react to both of these innovations. In other words, agents in the model have an information set larger than the one containing only past and current realizations of the inflation target when they forecast the inflation target. This will affect their consumption and pricing decisions, but mostly it will affect their expectations of future inflation and interest rates.

In the baseline model anticipated shocks are set to five years, while I also study the case of two years anticipated shocks.<sup>12</sup>

News shocks are particularly important to explain the volatility of long-term rates since this variable reacts on impact. Figure 2 shows impulse response functions of inflation, output, short-term rate and 10-year nominal yields to anticipated and unanticipated shocks to the target (where parameters are set to the posterior mean). On impact anticipated inflation target shocks persistently affect long-term rates and not the other variables in the model. This may hint to the fact that news shocks to inflation target can only be identified if one uses data on long-term rates in the estimation. In practice, this is confirmed when I estimate the same model without using long-term rates. In the estimation,  $\sigma_{\eta^i}$  goes to zero.

News shocks are also important to explain movements in forward rates at long horizons. As seen in the figure, after a news shock the short rate is still far from the steady state far-ahead in time, even more than after an unanticipated shock to the target. This is important because as shown in Gürkaynak, Sack, and Swanson (2005) long-term forward rates move significantly in response to economic news.

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<sup>12</sup>One could also assume news shocks in two different periods of time as in Schmitt-Grohé and Uribe (2010), for instance  $\pi_t^* = \rho_\pi \pi_{t-1}^* + \eta_t^0 + \eta_{t-8}^8 + \eta_{t-20}^{20}$ . Using this specification does not change the main results.

### 3 Estimation

Since the main purpose of the paper is to explain movements in long-term interest rates and inflation expectations, I focus here on estimating the main drivers of the business cycle. Since some of the shocks can not be identified in such a simple model, I directly use data on productivity and government expenditures.

In total six quarterly U.S. data series between 1961Q3-2008Q4 are used in the estimation: real output, inflation, short-term nominal interest rate, real government expenditures, productivity and 5-year zero-coupon yields.<sup>13</sup> Output, productivity and government expenditures have been linearly detrended while the rest of the data has been demeaned.

Prior to estimation some parameters of the model are fixed. I do so since small changes in these parameters do not affect the main results, or because in many cases these parameters are not well identified. I set  $\beta = .99$ ,  $\alpha = 1/3$ ,  $\varphi = 2$ ,  $\sigma = 2$ ,  $g_y = 0.2$ ,  $\rho_\pi = .98$  and  $\theta = 2/3$ . These are values commonly used or estimated in the literature. From the series on productivity and government expenditures, I obtain  $\rho_a = .93$ ,  $\sigma_a = 0.8$ ,  $\rho_g = .97$ , and  $\sigma_g = 1$ .

The rest of the parameters are estimated using Bayesian methods. The Metropolis-Hastings algorithm is used to generate draws from the posterior distribution. Convergence was checked for all parameters.

As priors, I choose gamma distributions for all variances, beta distributions for all autoregressive coefficients and normal distributions for the rest of the parameters. All

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<sup>13</sup> The nominal interest rate is the quarterly Federal Funds Rate. Seasonally adjusted real output and inflation (calculated as the change in the seasonally adjusted GDP deflator) are obtained from the Bureau of Economic Analysis (BEA). Real government expenditures corresponds to seasonally adjusted government consumption expenditures and gross investment obtained from the BEA deflated by the GDP deflator. Productivity is measured as the utilization-adjusted quarterly-TFP series for the U.S. business sector produced by John Fernald. The 5-year zero-coupon yield is obtained from Gürkaynak, Sack, and Wright (2007), as well as the 10-year zero-coupon yield reported later in the paper but not used in the estimation. This last series is only available since 1973:Q3 but I use the data in De Graeve, Emiris, and Wouters (2009) from 1966:Q1 to 1973:Q2.

priors are reported in Table 1. I follow Schmitt-Grohé and Uribe (2010) and choose a gamma distribution with mode zero to allow for a positive density at zero for the standard deviations of the shocks.

Moreover, following the same strategy of Christiano, Trabandt, and Walentin (2011) I choose "endogenous priors" to restrict the volatility of inflation.<sup>14</sup> I do so since news shocks add an extra factor affecting the volatility of inflation compared to the standard model. Moreover, in order to match data on long-term rates the model will estimate a high variance of the inflation target at the cost of overpredicting the volatility of inflation.

I estimate three versions of the model: the baseline model with news shocks with 20 lags (5 years), the same model without news shocks to the target, and the baseline model estimated using only standard macro data (no long-term yield data).

### 3.1 Results

All posterior distributions are reported in Table 1. The posterior mean for  $\sigma_{\eta}^{20}$  is 0.11. When I estimate the model without using yield data the posterior goes to zero. As explained in Section 2.2 this is because news shocks that affect the target some periods ahead can not be identified if we do not include data containing expectational information about those periods.<sup>15</sup> Based on this result, whenever I refer to the macro-data model in the rest of the paper the results are for the case when  $\sigma_{\eta}^{20}$  is zero.

Table 2 shows second moments of the data and the median of the simulated moments generated by the different models. Simulations are performed using 500 draws of the

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<sup>14</sup>In their paper, they begin with an initial set of independent priors for the parameters and then penalize for overpredicting the standard deviations of the observed variables. See their appendix for a detailed description of this strategy. In this paper, I only consider the standard deviation of inflation. Not doing so, generates too much volatility of all nominal variables.

<sup>15</sup>Milani and Treadwell (2011) use macro data and estimate the variance of news shocks to the inflation target close to zero. Gomes and Mendicino (2011) use house price data in their estimation and find the posterior mean of the standard deviation of news shocks to the target one and two years ahead to be 0.025 and 0.032. In both papers, values of zero are ruled out by their priors.

posterior for a total of 190 periods (the same number as my sample). Column 2 shows the simulated moments generated by the baseline estimation with news shocks to the inflation target. Overall the model does a good job matching the data: it can replicate over 80% of the volatility of the 10-year interest rate and almost all volatility in the 5-year interest rate.<sup>16</sup>

A model without anticipated shocks, column 3, generates too much volatility in inflation but too little in long-term rates. Also the log marginal likelihood decreases from -765 in the model with news shocks to -842 in the model without news shocks.

When excluding data on the 5-year interest rate in the estimation, column 4, the model does a good job replicating the volatility of inflation and the short-term rate but again does a poor job replicating the volatility of long-term rates. Part of this is due to the fact that news shock do not play any role in this model.

## 4 News and the Inflation Target

One of the main contributions of the paper is to estimate the implicit inflation target. Many papers have done this before and my results complement previous findings.

Figure 3 shows the estimated 95 percent interval of the inflation target for the baseline model and the estimates using only macro data. The main conclusion from the figure is that there is basically no major difference between them. This result is different from previous papers which show that incorporating long-term rate data affects the estimates of the inflation target.

In particular, previous estimates of the inflation target generated by rational expectations models using long-term yield data peak between 1981 and 1984.<sup>17</sup> This is the case

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<sup>16</sup>I also estimate a model where news shocks affect the inflation target 8 periods ahead (two years). Decreasing the number of lags for news shocks does not substantially change the results. It generates higher volatility in long rates at the cost of over predicting the volatility of inflation. This translates into a fall in the log marginal likelihood.

<sup>17</sup>See for instance, Bekaert, Cho, and Moreno (2010), De Graeve, Emiris, and Wouters (2009) and Doh (forthcoming); and Doh (2011) in the case of an estimated nonlinear model.

because in order to match extraordinary high long-term rates between 1981 and 1984, models with rational expectations (even with imperfect information) need very high inflation targets around this period. As shown in the next section, this is inconsistent with survey data on inflation expectations that starts falling in 1981.

My estimated inflation target starts to fall at the beginning of the 1980s independently on which data set we use.

A similar pattern of the inflation target (or inflation endpoints associated to long-run policy goals for inflation) is obtained in models with learning. For instance, Dewachter and Lyrio (2008) estimate the policy target to fall after 1980. However, the perceived target starts to fall some years later, which generate high inflation expectations and high bond yields during the first half of the 1980s.

Overall, introducing news shocks to the target breaks the link between the inflation target and the level factor of the term structure of interest rates, allowing us to obtain low estimates of the target in the first half of the 1980s when nominal yields were high.

## 4.1 Understanding News Shocks

News shocks about the future level of inflation that the monetary authority is going to target may reflect agents' information about a broad set of economic variables not included in the model. Sims (2008) highlights the possible relation between the long-run component of inflation and the stance of fiscal policy. He measures the stance of fiscal policy as the primary deficit divided by market value of marketable Treasury debt which is shown in the top panel of figure 4. He finds that fiscal variables have predictive value in dynamic models, even if other monetary policy indicators are included in the system.

In this section I follow Sims' idea and test if there is any relation between the estimated news shocks and innovations to the stand of fiscal policy. As discussed by Sims, the interpretation is that when agents see changes in the stance of fiscal policy they may expect this to affect future inflation.

The lower panel of figure 4 shows the estimated news shocks and the residuals of an AR(1) regression of the ratio of primary deficit to total debt. A first visual examination does not tell us much, except for the identical size of the innovations in 1975 which correspond to the Tax Reduction Act of 1975 signed by president Ford as part of a stimulus package.

Table 3 shows the results of the bivariate Granger causality test with two lags between the estimated news shocks and these innovations. We can reject the null hypothesis that innovations to the stance of fiscal policy do not Granger-cause news shocks. However, when I run the regression of news shocks on current and past values of these innovations the R-squared is very low. This points out in the direction that even if the stand of fiscal policy may help to forecast news shocks (and inflation expectations), more work should be done to understand the information content of news shocks. Moreover, since the model is estimated with quarterly data is hard to match news shocks with particularly events.

Last, I find that there is no correlation between the estimated news shocks and the other shocks in the model.

## 5 Survey Data

Next, survey data about inflation expectations is used as a form of external validation of the model. One-year inflation expectations are calculated using the median forecasts of the GDP deflator from the Survey of Professional Forecasters from the Federal Reserve Bank of Philadelphia. For the long-run inflation expectations I use the series constructed in Clark and Davig (2011) which is a measure of average CPI inflation expectations ten years ahead.<sup>18</sup>

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<sup>18</sup>We do not have a measure of the GDP deflator inflation expectations ten years ahead which is consistent with our model. The data starts in 1970 in the case of the one-year ahead forecast and in 1980 in the case of the 10-year ahead forecast. I thank Todd Clark and Troy Davig for providing the data.

Figure 5 shows survey and model-implied one-year ahead forecasts of inflation (plotted with a lag of one year) as well as actual inflation and the estimated inflation target in the baseline model. The two vertical lines represent the Volcker period as chairman of the Fed. Inflation target starts falling right after Volcker assumed as chairman. Inflation response is delay and model-generated forecasts as well as survey forecasts start falling after some quarters. Both model-implied and survey forecasts peak at the beginning of the 80s and start to decrease afterwards. Overall, the model-implied forecast of inflation do a good job matching survey data on inflation expectations.

**Correlation** Table 4 shows the correlation between model-implied and survey inflation forecasts one and ten years ahead. The median of these correlations is 0.90 for the case of short-run expectations and 0.84 for long-run expectations.

The table also shows that when we do not use long-term rate data in the estimation (and news shocks are not present since their variance goes to zero), this correlation decreases to 0.85 and 0.72 respectively. Moreover, when we consider the post-Volcker disinflation period after 1984, this correlations deteriorates and is 0.43 in the case of the one-year forecast and zero in the case of the 10-year forecast. This result is in line with Del Negro and Eusepi (2011) who find that a Smets and Wouters (2007)-type model, with perfect or imperfect information, can not fully capture the dynamics of inflation expectations between 1984-2008. They find the correlation between the model-implied and survey inflation expectations to be around 0.25. My model with inflation news shocks greatly improves the ability to match survey data even after 1984 (from 0.43 to 0.85).

In a related paper, Doh (forthcoming) shows that between 1981 and 2004 the correlation between model-generated forecasts and survey data improves once we include yield data in the estimation. I obtain similar results in my model, especially after 1984.

Overall, Table 4 confirms previous literature and tells us that including yield data

in the estimation improves the correlation of model based forecasts and survey data, particularly after 1984. Moreover, including news shocks increase this correlation.

**Levels** Table 5 shows the RMSE of the forecasts generated from the different models and survey data. The table shows that including news shocks not only increases the correlation between the forecasts, but improves on the levels.

This is shown graphically in figure 6. The figure plots the data and model-implied path for the one-year ahead inflation forecast (left panels), 10-year ahead average inflation forecast (middle panels) and 10-year yield (right panels) for the three estimated models.

Two things are important to notice from this figure. First, the model estimated without long-term rates data does a poor job matching long-term rates.

Second, the model without news shocks has difficulties to match one-year ahead survey data particularly in the early 1980s and after 2003. As explained before, this is the case because high interest rates in the beginning of the 1980s push the estimates of the inflation target up during this period generating high inflation expectations that do not match survey data. After 2003, the fact that long rates have been exceptionally low works on the opposite direction pushing the estimated inflation target and inflation expectations down, close to zero, while survey data is around two.

## 6 News and Long-term Interest Rates

As discussed in Section 3.1, the model can explain a large part of the volatility of long-term interest rates. The variance decomposition of output, inflation, the short interest rate and the 5-year interest rate at different horizons are shown in Table 6. As is common in the literature, inflation target shocks account for a large share of the variation in long-term rates. What it is new in this paper is the decomposition of anticipated and unanticipated shocks. At a 10-year horizon, news shocks explain 41

percent of the variation in long-term rates.

Moreover, other shocks in the model seem to be more important than in previous literature. I find that technology, preferences and price markup shocks explain 30 percent of the volatility of 5-year yields in the long-run.<sup>19</sup>

Figure 7 shows the historical decomposition of the 5-year yields (in deviations from the mean). Shocks to the inflation target, anticipated and unanticipated, played an important role mostly between 1975 and 1985 and after 2005. In particular, as I argue below, after 2005 it was news shocks to the inflation target that kept long-interest rates low.

Figure 8 shows the data (thick line) and the counterfactual path of the observables assuming the estimated inflation target is the same as in the baseline model but all shocks are unanticipated. In other words, conditional on the path of the inflation target and the other shocks of the economy equal to the smooth estimates of the baseline model, what the path of the observables would have been if all innovations to the inflation target were unanticipated. The figure shows that the distinction between anticipated or unanticipated innovations to the inflation target is not relevant for output, inflation or the short-term rate. This strengthens the conclusion that anticipated shocks to the inflation target can not be identified looking only at macro variables. However, the path for the 5-year rate is considerably different. Next, I study three periods where these differences are important.

## 6.1 Mid 1970s: The Oil Crisis

At the end of 1974 both inflation and inflation target peaked. This is consequence of the 1973 oil crisis when oil prices dramatically increased. Looking at figure 9 we see that the sharp increase of inflation was caused by markup shocks and inflation target shocks.

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<sup>19</sup>De Graeve, Emiris, and Wouters (2009) and Badarinsa and Margaritov (2011) find that more than 90 percent of the long-run volatility of 5-year yields is explained by inflation target shocks.

Looking closely, inflation target peaked because of a sequence of positive anticipated and unanticipated innovations that affected inflation target in 1973 and 1974. The anticipated ones occurred in 1968 and 1969 but realized in 1973 and 1974.<sup>20</sup> These innovations affected inflation target and inflation in the mid 1970s but impacted long-term rates mostly at the end of the 1960s. As a result, long-term rates did not to peak around 1975 as inflation target did or as they would have done if all innovations to the inflation target were unanticipated (thin line).

## 6.2 Beginning of the 1980s: The Volcker Disinflation

The second period where the differences are important is at the beginning of the 1980s, in the so-called "Volcker disinflation". In this period, both inflation and inflation target dramatically fell. However, long-term rates stayed high until 1986. As shown in the figure, this behavior of long-term rates can not be explained in a model where the inflation target only moves with unanticipated shocks to the inflation target.

In the literature there are different mechanisms that help models to match long-term yield data during this period. For instance, in the macro-finance literature that estimate DSGE models together with long-term rates, the estimated inflation target is still high in the mid 1980s. However, as already mentioned, this is inconsistent with falling inflation and inflation expectations since 1981 (see figure 6 middle row). Alternatively, in models with learning, inflation target indeed fell at the beginning of the 1980s but agents learn about it slowly. In my model, even with rational expectations we can match the data on long-term rates.<sup>21</sup>

The results show that large anticipated innovations to the inflation target hit the economy in 1981 and 1984 pushing long-term interest rates up (see figure 9). One could

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<sup>20</sup>One possible explanation for these shocks in 1968 could be the fact that American involvement in the Vietnam war peaked in 1968.

<sup>21</sup>Fuhrer (1996) finds that long-rates in this period were consequence of high responses (parameters) of the policy rule to the inflation gap.

argue that these innovations to future inflation target are related to the rapid increase that experienced the debt ratio in the U.S. between 1981 and 1986 going from around 20 percent of GDP to 35 percent. Some of these anticipated innovations materialized and pushed inflation up again at the end of the 1980s.

As in Fuhrer (1996) and Kozicki and Tinsley (2001b), my results reject the idea that high term premiums affected bond rates in the 1980s.

### **6.3 2004-2006: The Interest Rate "Conundrum"**

After 2004 the actual data and the counterfactual differ. The counterfactual path for the long-term rate (thin line) shows this variable should have been higher than it was (thick line). This is consistent with what Federal Reserve Chairman Greenspan labeled as the "conundrum" of long-term interest rates in his congressional testimony in February 2005. Usually long-rates move with short-term rates. Between 2004 and 2006 the Federal Reserve continuously increased the target rate 425 basis points while long-rates varied very little.

Figure 8 shows that conditioning on the path for the inflation target, and not allowing for news shocks, long-term rates would have increased as Chairman Greenspan predicted. In the next paragraph, I explain why in the model this is not the case.

First, we observe a decline in productivity since 2005 that pushed the long and short-term rates up. However, in the estimation there also occur negative innovations to anticipated inflation target after 2004. These innovations do not substantially affect other variables in the model except for the long-term rate. In particular, they do not affect the actual inflation target in the period under study and deliver a counterfactual path for the long-term rate above the actual data.

The results in this paper indicate that the interest rate conundrum can be explained by negative news shocks to the inflation target since 2004. In the model without news shocks, the low level of long-term rates can only be matched with a very low inflation

target which is inconsistent with inflation expectations around two percent (see figure 8).

## 7 Conclusions

This paper attempts to jointly explain the behavior of inflation expectations and long-term bond yields from a macroeconomic perspective. Most papers in the literature rely on a time-varying inflation target to capture the trend component of these variables. I extend previous literature and add news shocks to the inflation target.

Overall, introducing news shocks to the target breaks the link between the inflation target and the level factor of the term structure of interest rates, allowing us to obtain low estimates of the target in the first half of the 1980s when nominal yields were high but inflation expectations started to fall.

News shocks are particularly important explaining the path of long-term rates in three periods: the oil crisis in the mid 1970s, the Volcker disinflation at the beginning of the 1980s and the interest rate conundrum of 2004-2006.

One limitation of the paper, like in all papers including an exogenous inflation target, is that I do not explain what causes changes in the Fed's inflation target. Future research is needed in this direction.

Another limitation of the paper is that I do not discuss the plausible determinants of news shocks. This is also left to future research. The preceding analysis showed that there may be a relation between news shocks and the stance of fiscal policy.

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## 8 Tables and Figures

**Table 1: Distribution of the Parameters**

		Prior		Posterior					
		Mean	St. Er.	Baseline model		No news shocks		Macro data	
				Mean	5-95%	Mean	5-95%	Mean	5-95%
$\sigma_z$	Gam	1	1	3.18	(2.9, 3.5)	2.16	(2.0, 2.4)	3.18	(2.8, 3.6)
$\sigma_\varepsilon$	Gam	1	1	0.49	(.43, .56)	0.71	(.65, .76)	0.46	(.40, .53)
$\sigma_{\eta^0}$	Gam	1	1	0.10	(.09, .12)	0.12	(.11, .13)	0.11	(.09, .13)
$\sigma_{\eta^{20}}$	Gam	1	1	0.11	(.09, .12)	-	-	-	-
$\sigma_\tau$	Gam	1	1	0.12	(.10, .13)	0.10	(.09, .12)	-	-
$\sigma_i$	Gam	1	1	0.27	(.24, .30)	0.37	(.33, .41)	0.29	(.26, .32)
$\rho_z$	Beta	0.5	0.2	0.91	(.90, .93)	0.76	(.73, .79)	0.91	(.88, .93)
$\rho_\varepsilon$	Beta	0.5	0.2	0.95	(.93, .96)	0.99	(.99, .99)	0.95	(.93, .97)
$\omega$	Beta	0.5	0.2	0.65	(.60, .69)	0.73	(.69, .77)	0.59	(.53, .64)
$\lambda_\pi$	Norm	1.5	0.2	2.55	(2.3, 2.8)	1.83	(1.7, 2.0)	2.41	(2.2, 2.6)
$\lambda$	Norm	0.5	0.5	0.32	(-.01, .66)	-0.09	(-.18, -.02)	0.48	(.15, .84)

**Table 2: Second Moments**

	Data	Baseline	No news	Macro data
STANDARD DEVIATION				
Inflation	2.39	2.74	3.00	2.43
Output (linear detrended)	2.89	2.21	3.78	2.14
Short-term interest rate	3.27	3.45	2.71	3.37
5-year bond yield	2.53	2.44	1.66	2.06
10-year bond yield	2.38	1.94	1.23	1.51
CORRELATION WITH SHORT RATE				
Inflation	.65	.78	.49	.79
5-year interest rate	.89	.84	.80	.92
10-year interest rate	.85	.74	.78	.87
AUTOCORRELATION				
Inflation	.88	.90	.68	.86
Short-term interest rate	.96	.96	.90	.94
5-year interest rate	.98	.94	.90	.95
10-year interest rate	.98	.97	.96	.95

Annualized data. The table reports the median of the simulated moments.

**Table 3: Bivariate Granger causality test**

Null Hypothesis	F-Statistic	Prob.
News shocks (median) does not Granger-cause def/debt innovations	1.84	0.16
Def/debt innovations does not Granger-cause news shocks (median)	11.17	0.0005
News shocks (median) does not Granger-cause debt growth innovations	.42	0.70
Debt growth innovations does not Granger-cause news shocks (median)	3.65	0.03
News shocks (median) does not Granger-cause def/GDP innovations	1.96	0.14
Def/GDP innovations does not Granger-cause news shocks (median)	8.06	0.0005

Notes: The test includes 2 lags. Def is primary deficit and debt is market value of debt.

The innovations are the residuals of AR(1) regressions. Data 1968-2008.

**Table 4: Correlation between model and survey inflation forecasts**

One-year	1970-2008	1984-2008
inflation expectations		
Baseline model	.90 [.89 – .91]	.85 [.84 – .86]
No news shocks	.76 [.74 – .78]	.84 [.83 – .85]
Macro data	.85 [.84 – .87]	.43 [.34 – .52]
10-year	1980-2008	1984-2008
inflation expectations		
Baseline model	.84 [.83 – .85]	.92
No news shocks	.86 [.85 – .87]	.91
Macro data	.72 [.65 – .78]	.01

Notes: The table reports the median and 95 confidence interval of the correlation between the model-implied inflation forecast and survey data.

**Table 5: RMSE between model and survey inflation forecasts**

	One-year inf. forecast	10-year inf. forecast
	1970-2008	1980-2008
Baseline model	0.85	0.97
No news shocks	1.95	1.46
Macro data	1.13	1.28

Notes: The table reports the median of the RMSE.

**Table 6: Variance Decomposition**

Shock	Baseline model							
	1-year horizon				10-year horizon			
	$y$	$\pi$	$i$	$i^5$	$y$	$\pi$	$i$	$i^5$
$g$	1	-	-	-	2	-	-	-
$\varepsilon$	30	13	15	16	39	7	13	10
$a$	25	10	17	15	26	4	13	7
$z$	43	29	48	32	33	11	29	13
$\eta^0$	-	32	12	21	-	39	20	26
$\epsilon$	1	17	8	-	-	5	2	-
$\tau$	-	-	-	13	-	-	-	2
$\eta^i$	-	-	-	2	-	34	22	41

The table reports median values.

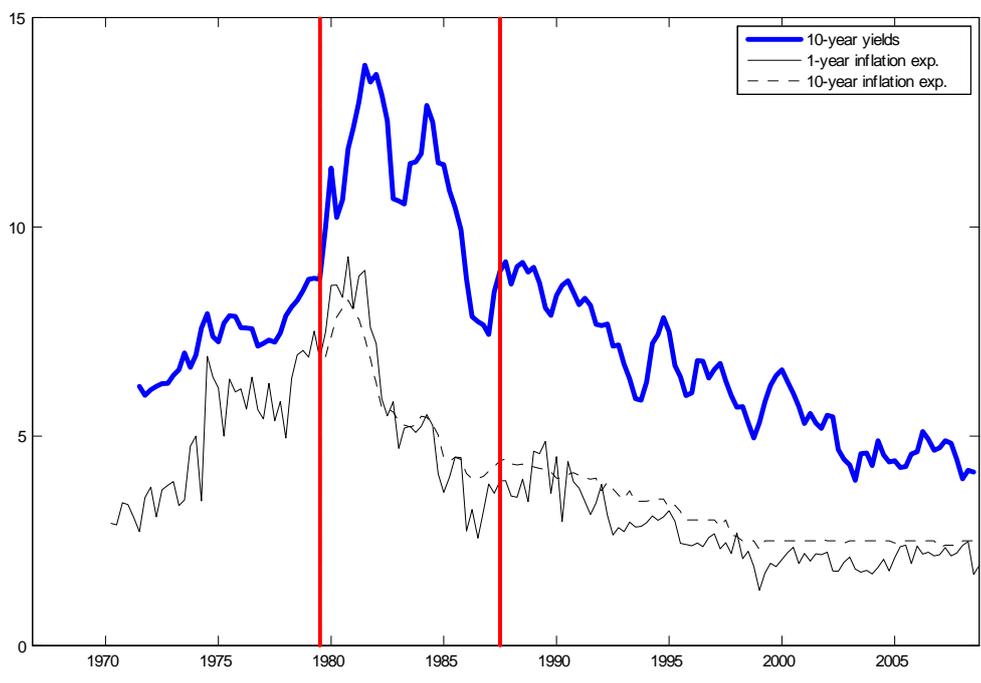


Figure 1:

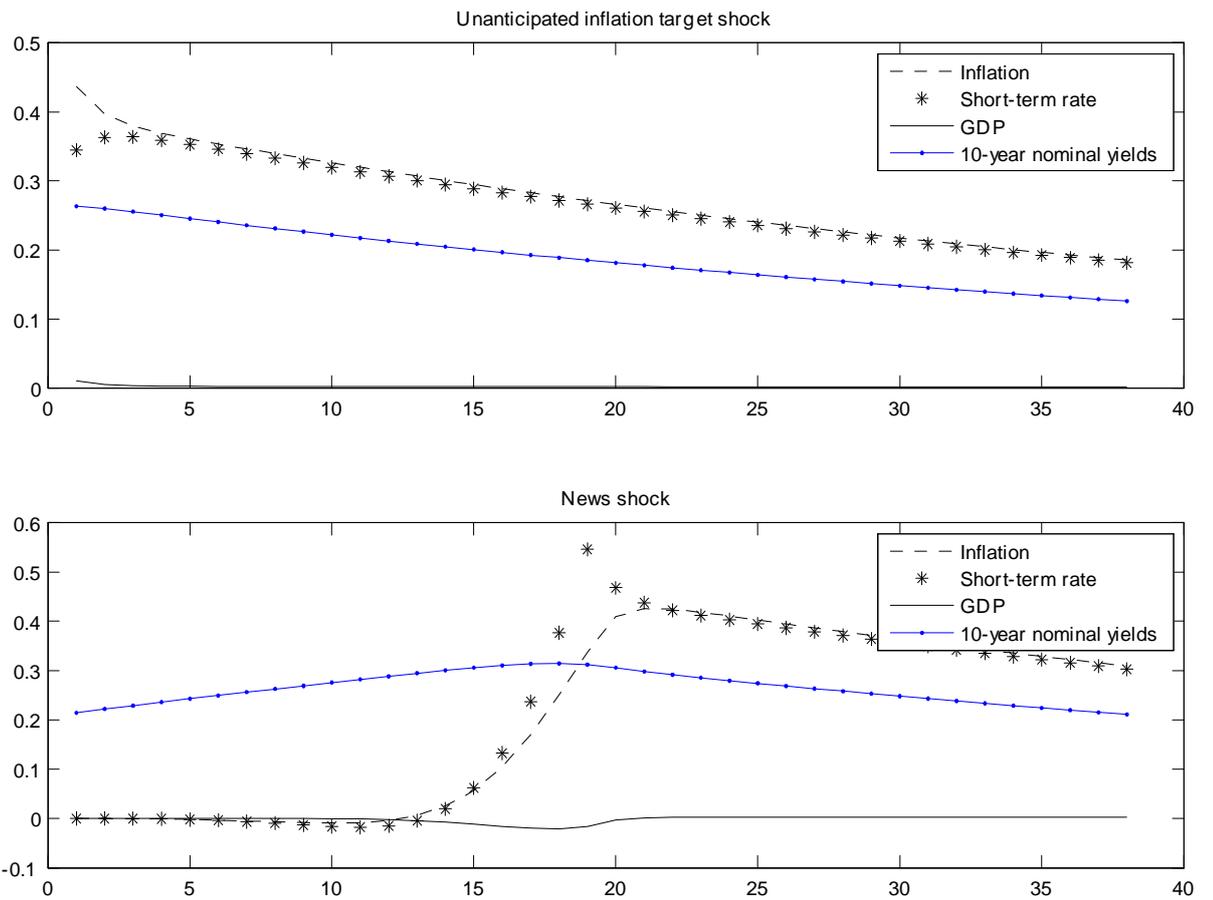


Figure 2: Impulse response functions

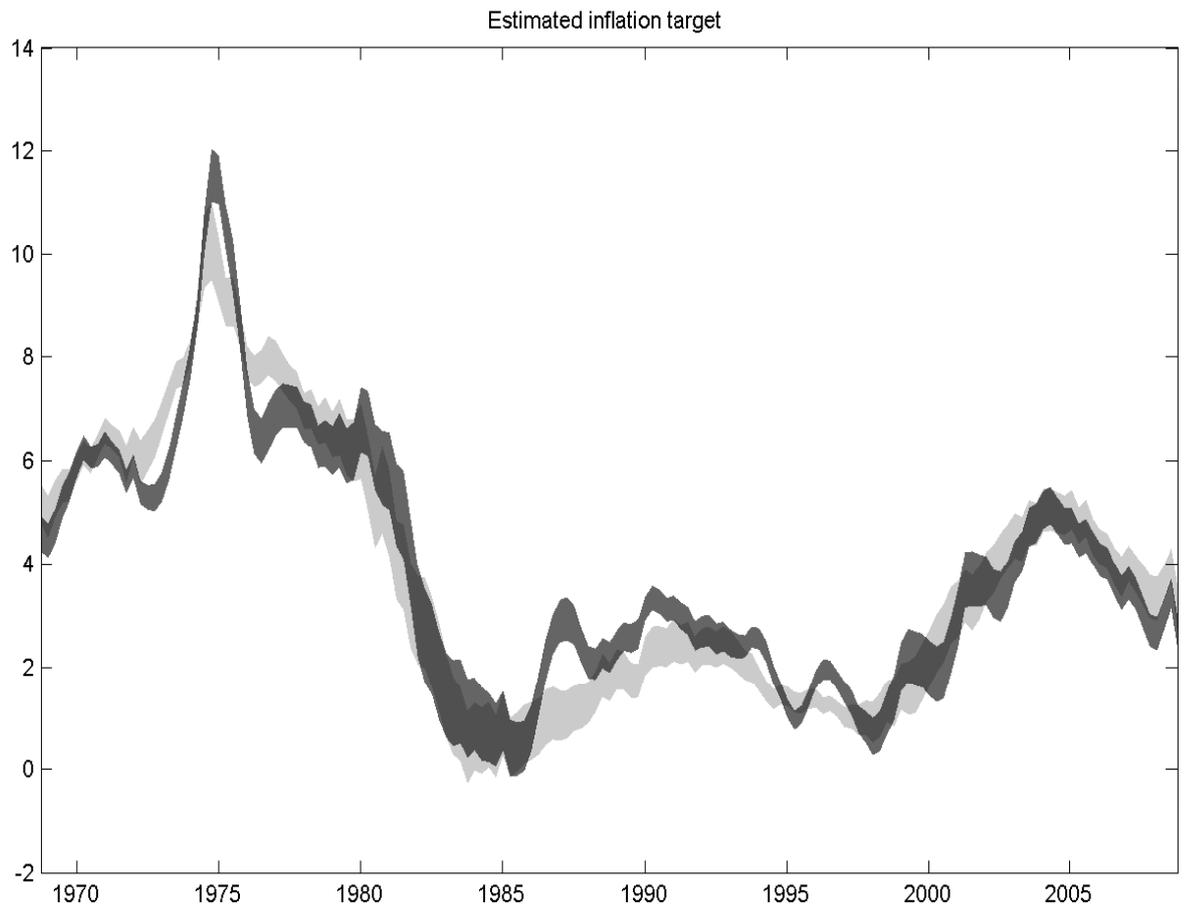


Figure 3: Ninety-five percent confidence bands for the smooth estimates of the inflation target. Dark grey: model with news shocks. Light grey: model estimated using only standard macro variables.

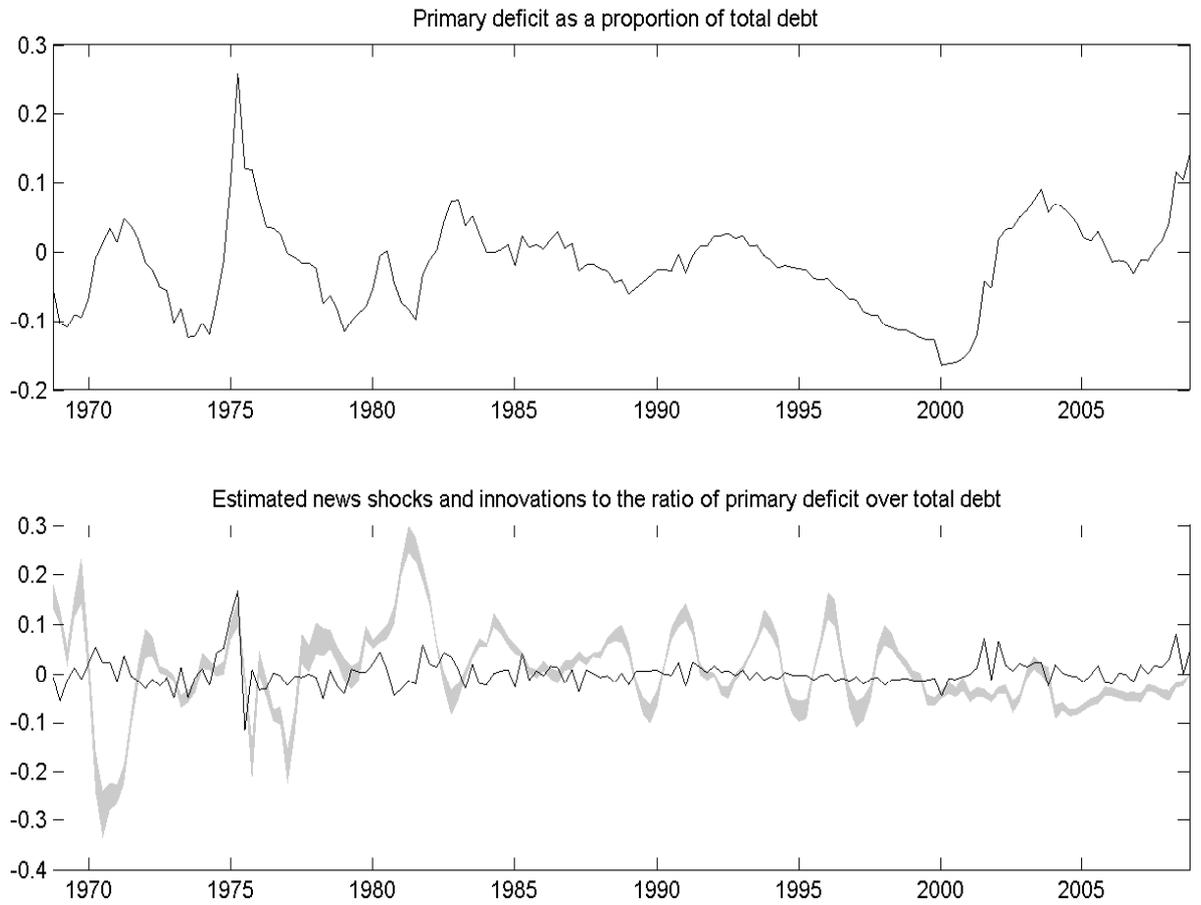


Figure 4: Bottom panel. Grey area is the 95 percent confidence interval for news shocks to the inflation target. The black line are the residuals of an AR(1) regression of the ratio of primary deficit to total debt.

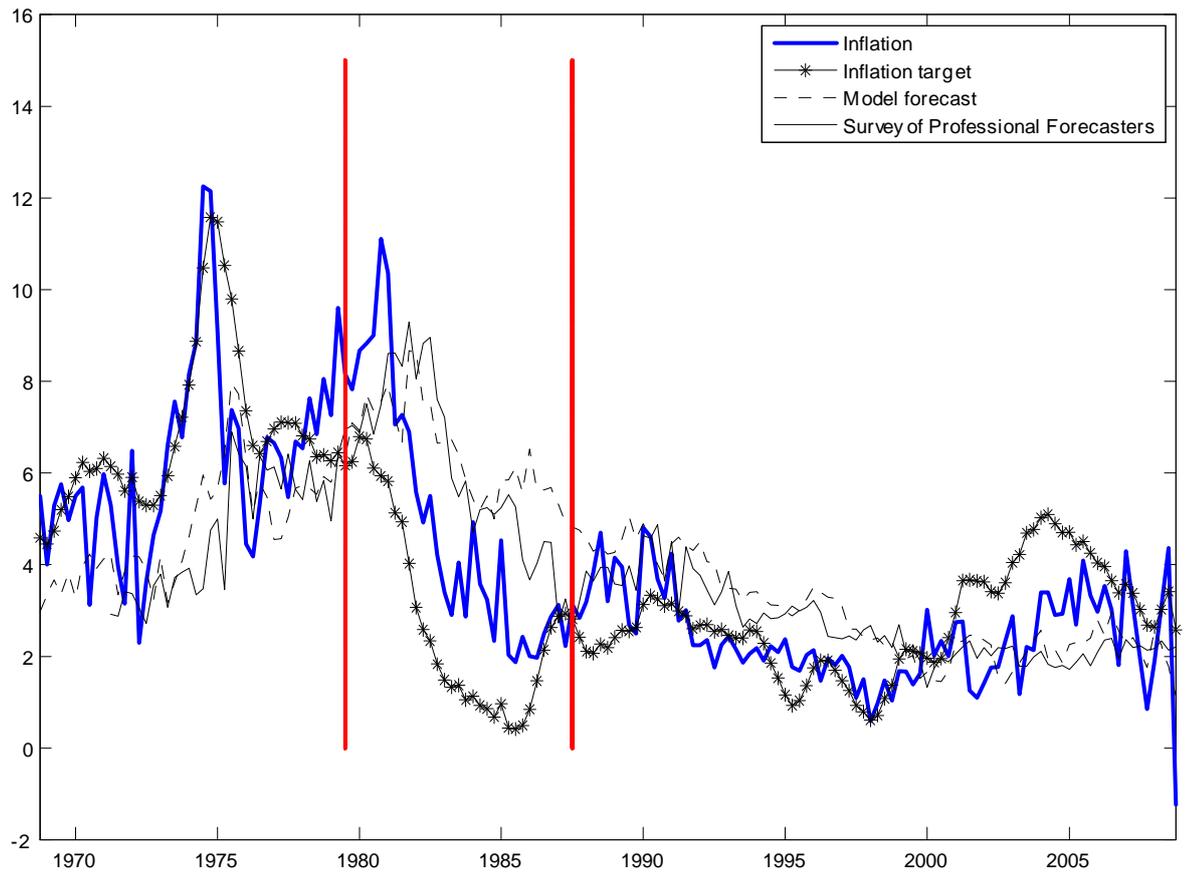


Figure 5: Inflation, inflation target and inflation forecasts. The vertical lines represent the Volcker period as Chairman of the Federal Reserve.

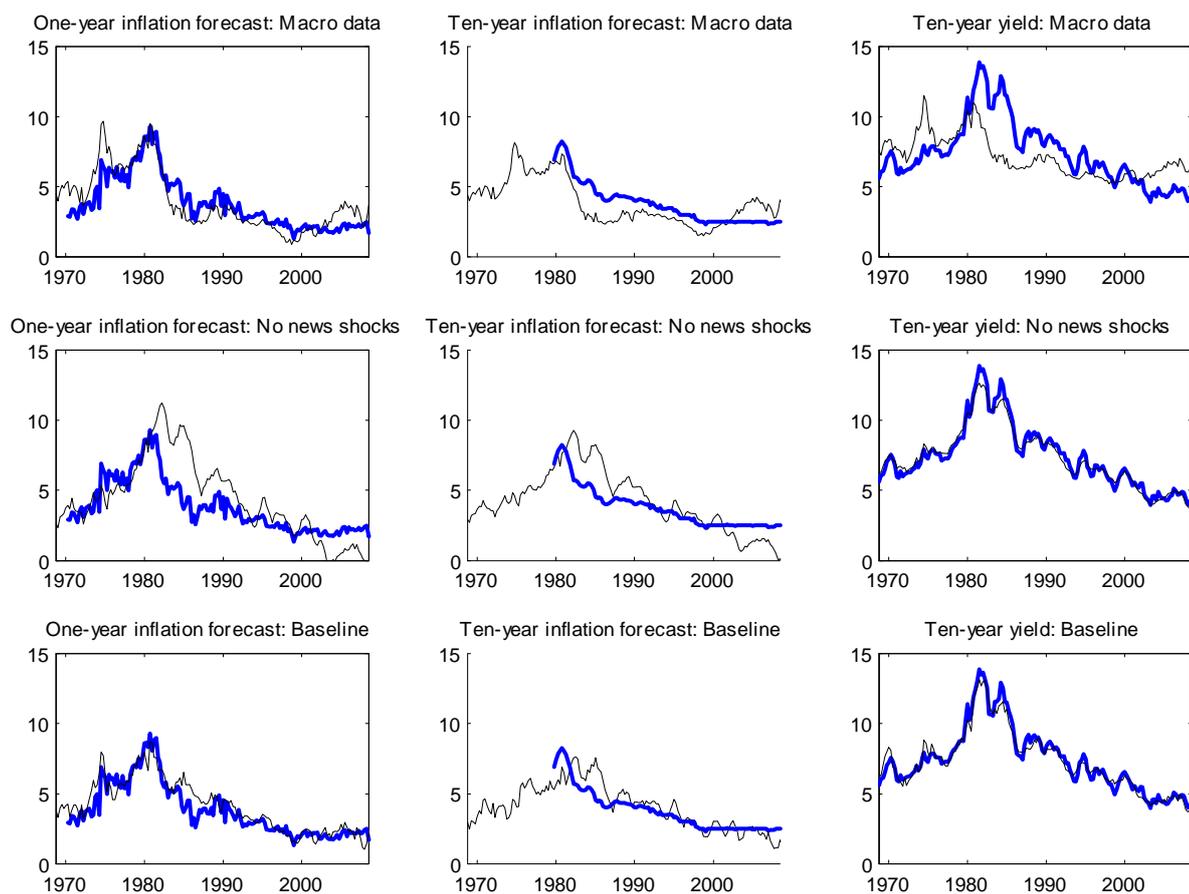


Figure 6: The thick line represents the data of one and 10-year inflation expectations from survey data (left and middle panels) and the 10-year bond yield (right panels). The thin line shows the model-implied values for those variables.

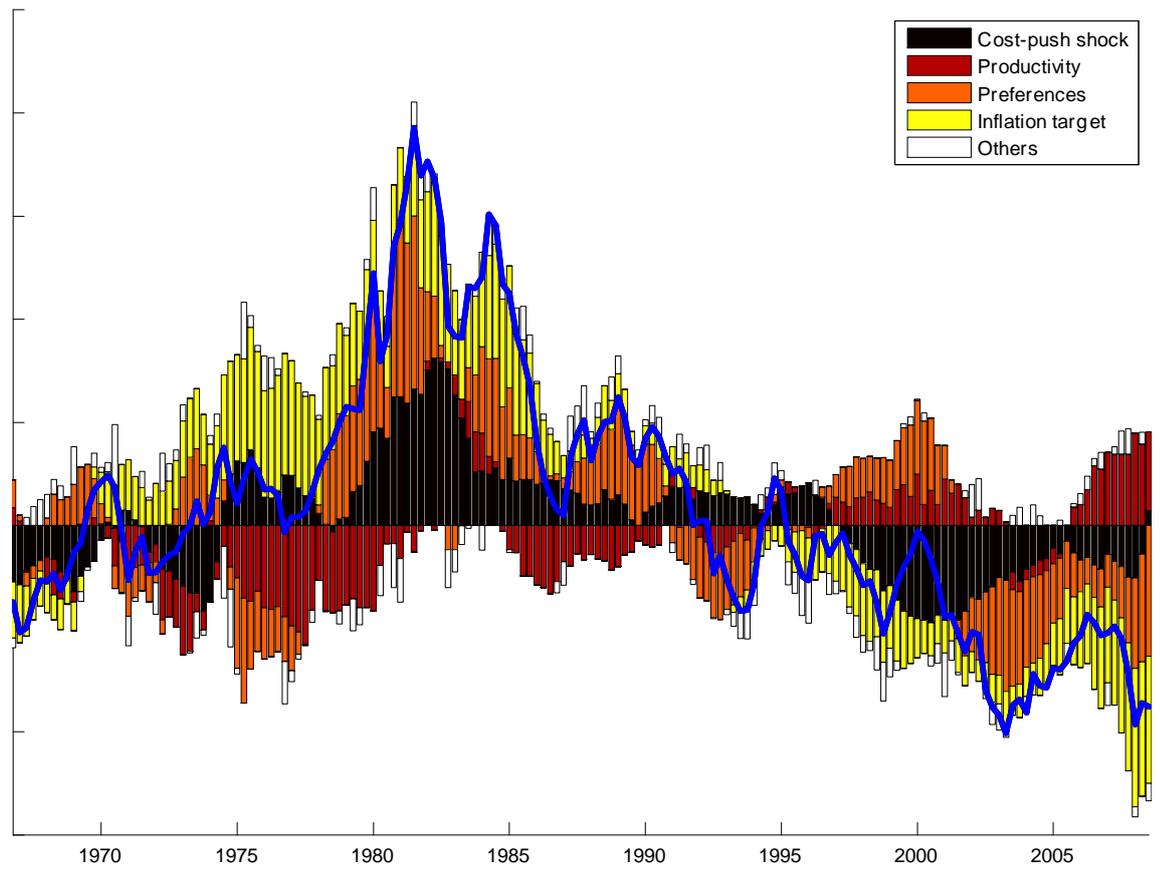


Figure 7: Historical decomposition of the five-year interest rate.

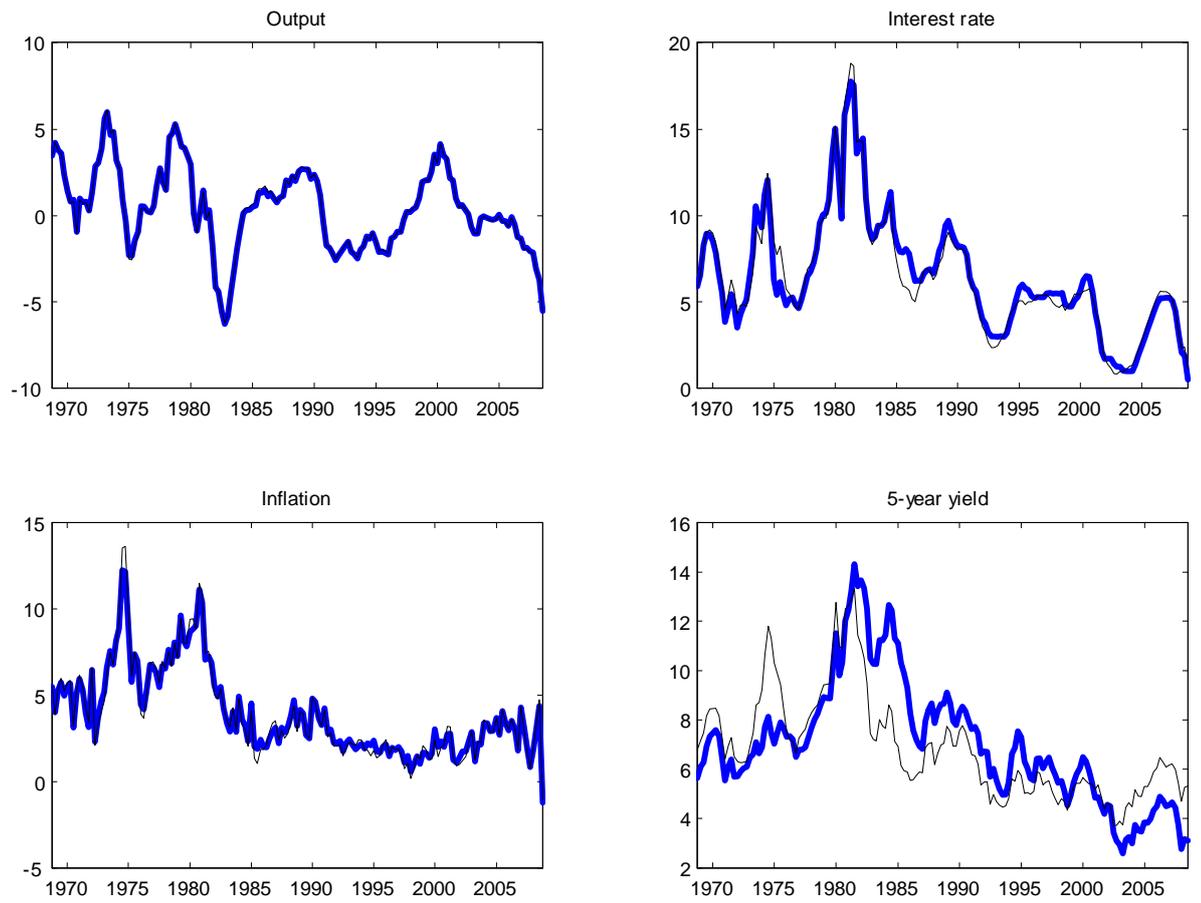


Figure 8: Counterfactual

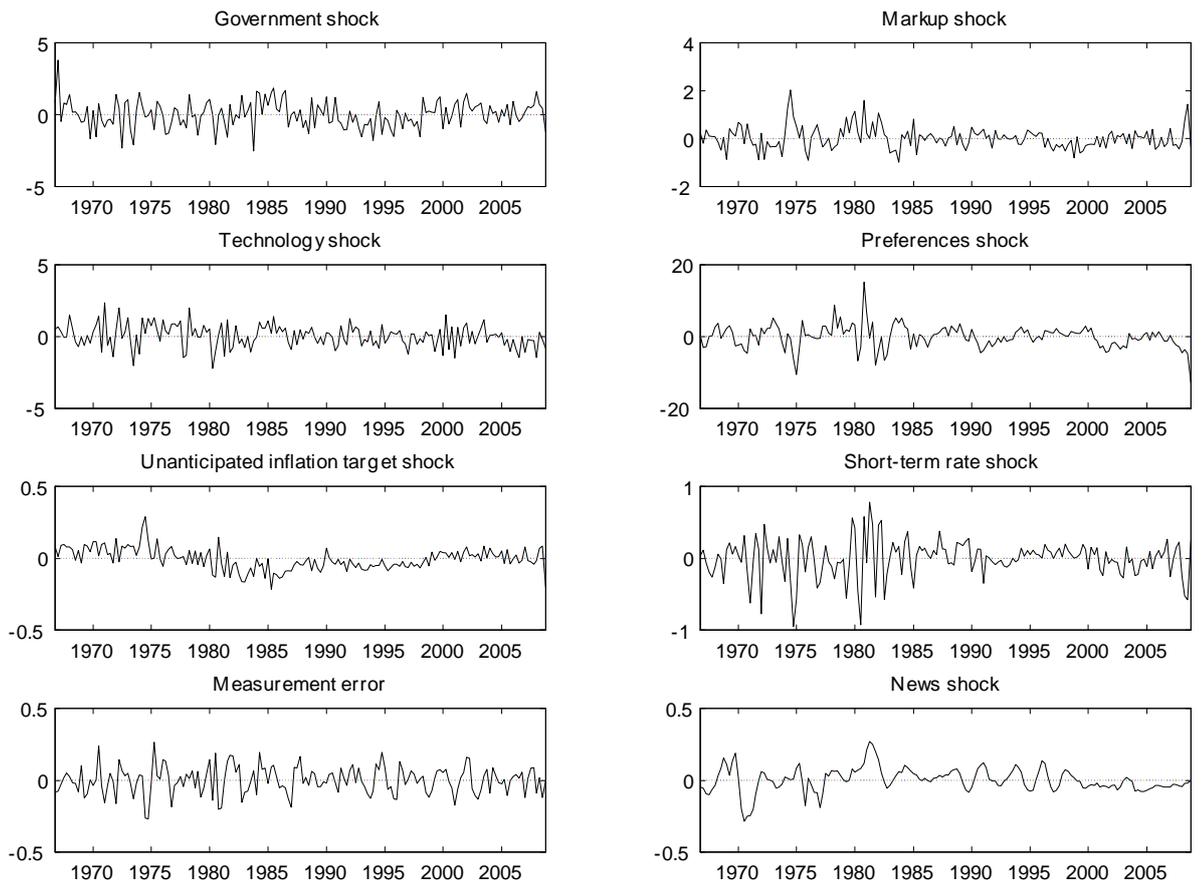


Figure 9: Smooth estimates of the innovations.