ASSESSING ECB’S CREDIBILITY DURING 
THE FIRST YEARS OF THE EUROSYSTEM: 
A BAYESIAN EMPIRICAL INVESTIGATION 

by 
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Assessing ECB’s Credibility During the First Years of the Eurosystem: A Bayesian Empirical Investigation

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Abstract

This paper extends Svensson (1994) “simplest test” of inflation target credibility inside a Bayesian econometric framework. We apply this approach to the initial years of the Eurosystem and obtain various estimates of ECB’s monetary policy credibility. Overall, our empirical evidence is robust to alternative prior assumptions, and suggests that the strategy followed by the ECB was successful in building a satisfactory degree of reputation. However, we find some significant credibility reversals concerning both anti-inflationary and anti-deflationary credibility. These reversals, in turn, are closely related to the evolution of the cyclical macroeconomic conditions in the Euro area.

0.1. JEL classification: C11; E31; E52; E58.

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1. Introduction

The diffusion of monetary policy rules based on inflation targeting in advanced and emerging market economies has reiterated the crucial role exerted by Central Bank credibility. If inflation expectations are well-anchored to an explicitly announced inflation target, less movements in the policy instrument are required, others things being equal, to achieve a given change in the real economy. A higher degree of credibility, moreover, introduces considerable mean reversion of inflation towards the inflation target. As extensively discussed in the literature, these effects jointly translate into a better tradeoff between inflation variability and output gap variability (Fraga et. al. (2003), Svensson (2000a, 2003)).

Empirical work assessing the credibility of inflation targeting regimes has recently marked a significant progress, relying on indirect or direct approaches to estimate the reaction of inflation expectations to this monetary policy rule (see Tronzano (2005) for a critical survey of this literature). While indirect approaches are inherently unable to disentangle between a permanent shift in inflation expectations and other possible structural changes in the economy, most contributions relying on direct approaches fail to derive a quantitative estimate about the degree of inflation target credibility and its evolution over time.

This paper contributes to the applied literature outlining an extension of Svensson (1994) “simplest test” of inflation target credibility inside a Bayesian econometric framework. Since the policy strategy of the European Central Bank (ECB) corresponds to a flexible inflation targeting regime (Svensson (2000b)), we apply the above framework to the initial years of the European Monetary Union (EMU), deriving some estimates about the agents subjective degree of confidence in the inflation targets announced by monetary authorities.

The motivation for this research is related both to the theoretical underpinnings for a welfare-maximizing monetary policy, and to some relevant drawbacks in the applied literature assessing inflation target credibility.

As regards the former issue, the case study addressed in the present paper deserves a special interest because, in the absence of a track record about its commitment to price stability, the newly created ECB was faced with the crucial problem of building a satisfactory reputation towards market participants. Although the launch of the Euro was conditional on having already achieved low inflation, financial and exchange rate stability, and small fiscal deficits, the credibility issue has been the centrepiece of academic and policy discussions since the onset of EMU, together with other relevant topics such as ECB accountability and transparency. At the start of Stage Three of EMU, market participants were very uncertain about the future monetary policy stance, as compared with the Bundesbank tough anti-inflationary reputation. The “genetic” nature of ECB credibility has therefore an intrinsically dynamic character, evolving closely in line with the initial results achieved in terms of price stability (Bini Smaghi (1996)).

Turning to the latter issue, this paper improves on existing research in many respects. Firstly, our approach yields a time-varying estimate about the degree of monetary policy credibility, thus filling a relevant gap in the literature. Secondly, alternative credibility patterns can be inferred conditional on alternative prior assumptions, namely assuming different initial degrees of uncertainty about model’s parameters. This feature is particularly relevant in the present context, given the uncertainty surrounding the transition to EMU, in an environment still characterized by high market segmentation, regional economic disparities, different fiscal positions across member states, and potential asymmetries in the monetary transmission mechanism. Finally,
since Svensson (1994) target-consistent band assumes an upper and a lower threshold for the inflation rate, our approach allows to estimate the degree of monetary policy credibility both as an anti-inflationary and as an anti-deflationary device.

The structure of the paper is as follows. Section 2 lays down the theoretical background, outlining how Svensson (1994) “simplest test” can be extended inside a Bayesian econometric framework. Section 3 explains how this approach can be implemented. We motivate the choice of the nominal interest rate and of the inflation target range, and sketch out the main features of the Markov chain Monte Carlo (MCMC) methodology underlying the empirical investigation. Section 4 contains our empirical findings. Using alternative proxies for the expected real interest rate, we derive some credibility indicators for ECB’s monetary policy, and explore their robustness to alternative prior assumptions. Section 5 concludes.

2. Bayesian Analysis of Inflation Target Credibility

2.1. Theoretical Background

Assume that the Central Bank announces an upper ($\pi_{\text{max}}$) and a lower ($\pi_{\text{min}}$) bound for the domestic inflation rate. Following Svensson (1994), target-consistent (t.c.) maximum and minimum real yields can be constructed, respectively subtracting the lower ($\pi_{\text{min}}$) and the upper ($\pi_{\text{max}}$) inflation targets from a nominal interest rate on government bonds. Defining the nominal yield on a default-less government bond as ($i_t$), the t.c. maximum and minimum real yields correspond therefore respectively to ($i_t - \pi_{\text{min}}$) and to ($i_t - \pi_{\text{max}}$). The above values define a target-consistent band, while Svensson (1994) test consists in assessing whether the real interest rate falls or not inside this interval.

In strict analogy with the rate-of-return band underlying Svensson (1991) credibility test for an exchange rate target zone, this band exploits an arbitrage relationship in order to evaluate Central Bank’s credibility. If the real interest rate falls outside the above band, the announced inflation targets ($\pi_{\text{min}}, \pi_{\text{max}}$) are not credible, since agents could realize a safe minimum profit which is inconsistent with an equilibrium on efficient capital markets. Note, moreover, that since the real interest rate is bounded between a lower and an upper threshold ($i_t - \pi_{\text{max}} \leq r^*_t \leq (i_t - \pi_{\text{min}})$), the arbitrage condition allows to assess the credibility of monetary policy both as an anti-inflationary and as an anti-deflationary device.

Although Svensson (1994) test is quite intuitive, there are some basic shortcomings associated with this approach. First, one can simply check whether a constraint on the real interest rate is satisfied or not, without being able to derive any information about the degree of monetary policy

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1More specifically, if the real interest rate falls below the t.c. minimum real yield, agents could realize a safe minimum profit borrowing in real terms and lending in nominal terms. The converse argument holds if the real interest rate exceeds the t.c. maximum real yield. The arbitrage condition underlying Svensson (1994) test assumes the existence of reliable quotations for real interest rates. However, absent a well functioning market for real bonds, this test can also be performed computing some proxy for expected future real yields on the basis of available information. Since this latter approach is followed in our empirical investigation, the real interest rate is always labelled as $\{r^*_t\}$ in the present paper.

2The relevant constraint for Central Bank’s anti-inflationary credibility is $r^*_t \leq (i_t - \pi_{\text{max}})$. A violation of this constraint points out that inflationary expectations are not consistent (i.e. “too high”) with respect to the upper Central Bank inflation target ($\pi_{\text{max}}$). Turning to the latter credibility constraint ($r^*_t \geq (i_t - \pi_{\text{min}})$), its violation involves the existence of a deflationary bias in monetary policy, namely a situation in which inflationary expectations fall below the minimum inflation target declared by the Central Bank ($\pi_{\text{min}}$).
credibility. Moreover, although the credibility constraint can be checked at each time interval, this framework cannot reveal how Central Bank reputation evolves over time. Any assessment about agents subjective confidence in the consistency of monetary policy with official inflation targets is actually precluded in this set up.

These drawbacks are particularly severe when this “simplest test” is implemented to investigate the performance of the ECB. A large strand of literature suggests in fact that, especially in the early years of operation, a new monetary authority should keep inflation as close as possible to its official targets, in order to accumulate a good track record and gradually build a sound anti-inflationary reputation. In this perspective, monetary policy credibility has therefore a crucial dynamic dimension, evolving according to the effective performance of monetary authorities, which Svensson (1994) approach is clearly unable to account for.

2.2. Extending Svensson (1994) Test in a Bayesian Framework

Consider the credibility constraints defined in the original test corresponding, respectively, to the absence of an inflationary or of a deflationary bias in monetary policy:

\[ r^e_t \geq (i_t - \pi_{\text{max}}) \] (anti-inflationary credibility)

\[ r^e_t \leq (i_t - \pi_{\text{min}}) \] (anti-deflationary credibility)

Introducing the following auxiliary variables:

\[ z_{u,t} = r^e_t - (i_t - \pi_{\text{max}}) \]

\[ z_{l,t} = r^e_t - (i_t - \pi_{\text{min}}) \]

these credibility constraints may equivalently be expressed as:

\[ z_u > 0 \](anti-inflationary credibility)

\[ z_l < 0 \](anti-deflationary credibility)

while a quantitative assessment about the degree of inflation target credibility may be derived analyzing the stochastic properties of the series \( \{z_u, z_l\} \) inside a Bayesian framework.

Following Tronzano-Psaradakis-Sola (2000), the simplest way to model \( \{z_u, z_l\} \) is to assume that these series may be characterized as a constant term plus a random disturbance, namely:

\[ z_u = \mu_u + \varepsilon_t \] (2.1)

\[ z_l = \mu_l + \varepsilon_t \] (2.2)

where \( \varepsilon_t \) is an iid error term distributed as \( N(0, \sigma^2) \).

^3Note, at this purpose, that even if the credibility constraint is satisfied, market agents could still assign a positive probability to future inflation rates falling outside the declared target range. In other words, using Svensson (1994) terminology, whenever \( r^e_t \) falls inside the t.c. band “credibility in expectation” does not imply that “absolute credibility” holds.

^4The launch of the European Monetary Union in January 1999 has stimulated many contributions discussing various issues related to the ECB monetary policy strategy (see, among others, Corsetti-Pesenti (1999)). Bini Smaghi (1996) emphasizes ECB’s credibility as a key requirement to achieve monetary stability, ensuring a smooth and successful transition to EMU.

If these equations are estimated inside a Bayesian framework, the means of the above processes \((\mu_u, \mu_l)\) can be treated as random variables about which agents may form subjective probability statements. The constraints underlying Svensson (1994) test correspond therefore to the posterior probability of \(\mu_u\) being greater than zero (anti-inflationary credibility) and to the posterior probability of \(\mu_l\) being lower than zero (anti-deflationary credibility). A major advantage of this set up is that these probabilities yield a quantitative assessment about the degree of monetary policy credibility. Moreover, since these probabilities can recursively be updated, as soon as new information is available, our approach allows to infer how the degree of inflation target credibility evolves over time.

More formally, focusing for instance on the anti-inflationary credibility constraint, the degree of monetary policy credibility, at time \(t\), can be expressed as:

\[
Pr \{ \mu_u > 0 | z_u(t), z_u(t-1), ..., z_u(1) \} = 1 - \int_{-\infty}^{0} f(\mu_u | z_u(t), z_u(t-1), ..., z_u(1)) \tag{2.3}
\]

where \(f(\mu_u | z_u(t))\) is the posterior pdf for \(\mu_u\) conditional on a prior pdf for \(\mu_u\) and on sample information at time \(t\).\(^6\)

The above discussion relies on the assumption that the time series \(\{z_u, z_l\}\) may be modelled as serially uncorrelated processes. This assumption, however, is not supported by data in the present context. A preliminary data inspection, using alternative proxies for the expected real interest rate \((r^e_f)\), shows actually that \(\{z_u, z_l\}\) can always be characterized as first-order autoregressive processes exhibiting a high degree of persistence. Nevertheless, this empirical framework can be adapted to allow for the existence of serial correlation if equations (2.1)-(2.2) are replaced with the following alternative specifications:

\[
\begin{align*}
  z_u(t) &= \theta_u + \rho z_u(t-1) + \varepsilon_t \quad \text{ (2.4)} \\
  z_l(t) &= \theta_l + \rho z_l(t-1) + \varepsilon_t \quad \text{ (2.5)}
\end{align*}
\]

where \(\rho\) is the autoregressive parameter, and \(\theta_u = \mu_u(1 - \rho)\) and \(\theta_l = \mu_l(1 - \rho)\) are the means of the corresponding conditional models.\(^7\)

>From the alternative specification outlined in equations (2.4)-(2.5) it is apparent that, excluding the case of an explosive stochastic process \((|\rho| > 1)\), the credibility conditions are satisfied whenever \(\theta_u > 0\) (absence of an inflationary bias in monetary policy) and \(\theta_l < 0\) (absence of a deflationary bias). Focusing on the former constraint, this in turn will hold for the parameter space \(\{(\mu_u, \rho) \in \mathcal{R}^2 : \mu_u > 0, \rho < 1\}\), i.e. when the unconditional mean of \(z_u\) is greater than zero and this process is mean-reverting. The anti-deflationary credibility constraint, on the other hand, will hold for the parameter space \(\{(\mu_l, \rho) \in \mathcal{R}^2 : \mu_l < 0, \rho < 1\}\), i.e. when the unconditional mean of \(z_l\) is lower than zero and this process is mean-reverting.

To sum up, given the existence of serial correlation in \(\{z_u, z_l\}\), our empirical test requires not only to assess a constraint on their conditional means \((\theta_u, \theta_l)\), but also to compute the

\(^6\)A similar expression obviously holds in the specular case, i.e. when assessing the absence of a deflationary bias in monetary policy. The relevant posterior probability in this case corresponds to \(Pr\{\mu_l < 0 | z_l(t), z_l(t-1), ..., z_l(1)\}\).

\(^7\)Note that, in this alternative set up, the autoregressive parameter is common to both equations, since \(z_l\) is obtained through a simple downward shift on \(z_u\).
probability of a stationary stochastic process governing the evolution of the above series. In strict analogy with the approach outlined in Tronzano-Psaradakis-Sola (2000), this empirical methodology allows then to distinguish between the following measures of “overall” and “long run” inflation target credibility.

Overall Inflation Target Credibility (Absence of an Inflationary Bias in Monetary Policy) Overall Inflation Target Credibility in this case is defined as the probability of a positive conditional mean ($\theta_u$) in equation (2.4) at each point in time i.e.:

$$\Pr \{ \theta_u > 0 | z_u(t), z_u(t-1), ..., z_u(1) \} = 1 - \int_{-\infty}^{0} f(\theta_u | z_u(t), z_u(t-1), ..., z_u(1)) d\theta_u$$  \hspace{1cm} (2.6)

where $f(\theta_u | z_u(t), z_u(t-1), ..., z_u(1))$ is the posterior pdf for $\theta_u$.

Overall Inflation Target Credibility (Absence of a Deflationary Bias in Monetary Policy) Overall Inflation Target Credibility in this alternative case is defined as the probability of a negative conditional mean ($\theta_l$) in equation (2.5) at each point in time i.e.:

$$\Pr \{ \theta_l < 0 | z_l(t), z_l(t-1), ..., z_l(1) \} = 1 - \int_{0}^{\infty} f(\theta_l | z_l(t), z_l(t-1), ..., z_l(1)) d\theta_l$$  \hspace{1cm} (2.7)

where $f(\theta_l | z_l(t), z_l(t-1), ..., z_l(1))$ is the posterior pdf for $\theta_l$.

Long Run Inflation Target Credibility Long run credibility is related to the stationarity of the $\{z_u, z_l\}$ series which is necessary in order to exclude that the above processes will hit the zero threshold with probability one. Long run inflation target credibility is therefore defined as the probability of a mean-reverting process for $z_t$ at each point in time, i.e.:

$$\Pr \{ \rho < 1 | z_t, z_{t-1}, ..., z_1 \} = \int_{-\infty}^{1} g(\rho | z_t, z_{t-1}, ..., z_1) d\rho$$  \hspace{1cm} (2.8)

where $g(\rho | z_t, z_{t-1}, ..., z_1)$ is the marginal posterior pdf for the autoregressive parameter in the model defined by equations (2.4)-(2.5).

3. Implementing our Approach: Variables Selection and Econometric Framework

The nominal interest rate used in the present paper is the yield on 10-year German government bonds (Bloomberg code: GDBR10). The focus on a medium-long term maturity is in line with earlier empirical investigation relying on the original version of Svensson test (Svensson (1994),

\footnote{We are using the simple notation $z_t$, interchangeably for $z_u$ and $z_l$, since they represent two identical stochastic processes, respectively rescaled upwards or downwards.}
De Grauwe (1996)). In the specific context of this paper, moreover, this focus is consistent with the medium term orientation underlying the ECB monetary policy strategy.\(^9\) As regards the choice of the sovereign issuer, strong support for the use of 10-year German government bonds is provided by the empirical analysis on yield differentials between euro zone government bonds carried out in Codogno et al. (2003). These authors use post-EMU spreads of euro area versus Germany, pointing out that “German bond yields are taken as the reference rates since German bonds have maintained their benchmark status and have continued to display lower yields” (Codogno et al. (2003), p.508, emphasis added).\(^10\)

The quantitative values for the upper and lower inflation targets take into account the developments of ECB's monetary policy strategy and various critical remarks put forward in the current literature.

The ECB has initially defined price stability “as a year-on-year increase in the Harmonized Index of Consumer Prices for the euro area below 2%” (ECB (1999), p.46). This definition is highly ambiguous since it does not specify a lower bound for domestic inflation.\(^11\) In May 2003, while confirming the earlier definition of price stability, the Governing Council stated that “in the pursuit of price stability it will aim to maintain inflation rates close to 2% over the medium term. This clarification underlines the ECB's commitment to provide a sufficient safety margin to guard against the risks of deflation” (ECB (2003), p. 8). This announcement discloses a strategy aiming at stabilizing the inflation rate towards a median numerical value, with monetary authorities committed to neutralize both inflationary and deflationary pressures in the euro area.

In the light of these developments, we set the upper ECB inflation target to 2.5% ($\pi_{\text{max}} = 2.5\%$), while we select two alternative values for the lower threshold (setting $\pi_{\text{min}}$ respectively equal to 1.0% or to 1.5%).

The upper inflation target is consistent with the computations performed in Cecchetti-Wynne (2003), implying that the original 2% ceiling needs an upward revision in order to account for a measurement bias in the HICP, some noisiness in monthly inflation statistics, and central bankers aversion to deflation. Further support in this direction comes from Werner Sinn (2003), where an upper target of 2.5% is recommended, until eurozone convergence is concluded, to foster real wage adjustments in more developed European countries.

Turning to the lower ECB inflation target, the 1% benchmark is supported by the analysis performed in Werner Sinn - Reutter (2001). The main point of this paper is that the structural features of Euroland are markedly different from those of Germany, implying a looser monetary policy in order to account for substantial relative price changes in the process of monetary integration.\(^12\) Although a minimum inflation rate of about 1% is justified on the basis of the

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\(^9\)This medium term approach is clearly defined in the first official ECB Monthly Bulletin (see ECB (1999). As documented in Castelnuovo et al. (2003), the emphasis on a medium term horizon is currently widespread among many inflation targeters Central Banks.

\(^{10}\)Note further that, in line with our empirical investigation, Codogno et al. (2003) focuses exclusively on the 10-year maturity of the term structure, since this is the most actively traded in the euro zone securities market.

\(^{11}\)Svensson (1999) maintains that this operational definition of price stability can be interpreted either as a 0-2 percent or as a 1-2 percent target range. This paper strongly argues in favor of an unambiguous and symmetric inflation target, where both the mid-point and the upper and lower edges of the band are clearly specified.

\(^{12}\)More specifically, this paper obtains a lower ECB inflation target of 0.94% for EU11, of 1.05% for EU15, and of 1.13% for EU21. These results are derived from average growth rates of labour productivity in tradeable and non-tradeable sectors. See Werner Sinn - Reutter (2001), section 2, for the theoretical framework underlying these results.
Balassa-Samuelson effect, this benchmark is likely to be still too conservative when potential upwards distortions in the HICP are properly accounted for.\textsuperscript{13} Since recent deflationary pressures have made policy-makers more “deflation-averse” (as witnessed by the ECB strategy revision in May 2003), there is a strong motivation for assuming an alternative, less conservative minimum inflation threshold, setting $\pi_{\text{min}}$ equal to 1.5%. Note further that if the ECB strategy revision is interpreted as establishing a mid-point inflation target of 2% (and if we assume, as in the present paper, an upper inflation target of 2.5%), a lower limit of 1.5% is the candidate reference value inside a symmetric inflation target band.\textsuperscript{14}

This taken into account, although we retain two alternative values as minimum inflation thresholds, we claim that the less conservative one ($\pi_{\text{min}} = 1.5\%$) is most suitable to evaluate the dynamic pattern of ECB anti-deflationary credibility.

For estimation we use a Bayesian approach based on MCMC posterior simulation. For a survey of these methods, see Chib (2001). In particular, the model we estimate is a simple stationary AR(1) model with Gaussian errors which can easily be treated with a simple two-block Gibbs sampling algorithm. Given the prior structure it is easy to see that the conditional posteriors of $(\theta, \rho)$ and $h$ are conditionally conjugate (i.e. they have the same functional form of the priors) and so they can be easily simulated.

With respect to the methodology used in Tronzano-Psaradakis-Sola (2000), where the usual analytical results valid in a linear regression model (see Zellner, 1971) are used, the methodology used in this paper is entirely based on simulation and it is therefore readily adaptable to allow for features such as non Gaussianity, heteroscedasticity, shifts and drifts in the parameters.

4. Empirical Findings

4.1. Alternative Proxies for the Expected Real Interest Rate

The selection of a proxy for the expected real interest rate is important in order to get reliable empirical estimates from Svensson (1994) test. Existing contributions rely either on backward-looking or on forward-looking indicators. Svensson (1994) uses ex post real interest rates for various industrialized countries, while De Grauwe (1996) employs IMF estimates to compute a “consensus real interest rate” over the period 1981-1994. A drawback of this latter approach is the use of a constant forward-looking variable to evaluate the credibility of inflation targets.

This paper relies on two alternative proxies to define the expected real interest rate.

The former is completely backward-looking i.e., following Svensson (1994), future real yields are approximated through ex post real rates. To this purpose, we subtract from the nominal interest rate the yearly inflation rate in the Euro area, computed through the Harmonized Index of Consumer Prices. This leads to a time-varying proxy for $(r^e_t)$ relying on adaptive expectations.

In order to overcome some drawbacks in the existing literature, we introduce an alternative proxy for $(r^e_t)$. Using official OECD forecasts on long term nominal interest rates and inflation

\textsuperscript{13} As documented in Cecchetti-Wynne (2003), if measured HICP inflation is 1% the probability that prices are actually falling is still quite high (about 0.35), whereas increasing the lower target for the HICP to 1.5% this probability is significantly reduced (to about 0.10).

\textsuperscript{14} In commenting the ECB strategy revision, Monacelli-Surico (2003) observe that it would have been better, in order to establish a sound anti-deflationary reputation, to announce an official mid-point target of 2% for the HICP, declaring an official and symmetric band around this value.
in the Euro area, we compute an ex-ante real interest rate. This variable is then combined with the ex post real rate, producing a weighted average indicator based both on backward and on forward-looking expectations. Since this alternative proxy assigns an equal weight to the ex post real interest rate and to the ex ante real interest rate obtained through OECD forecasts, we label this variable as “hybrid forward-looking” indicator. The use of an “hybrid forward-looking” indicator for \( (r_t^e) \) receives strong support by the literature on inflation dynamics, documenting that survey data on inflation expectations significantly depart from fully rational expectations, and that purely forward-looking Phillips curve models are often severely at odds with the data.

As regards the influence assigned to ex post and ex ante elements, the choice of symmetric weights is consistent with the existing literature. Empirical results obtained in Fuhrer (1997) from US data point out a significantly higher influence of lagged inflation versus expected future inflation in explaining price fluctuations (with an estimated weight of the backward-looking component of about 0.80). Chadha et al. (1992) report an estimated weight of 0.55 on past inflation for the Group of Seven countries whereas, according to the New Keynesian Phillips curve estimates performed in Gali-Gertler (1999), the weight of expected future inflation is significantly higher (ranging from 0.59 to 0.68 according to different specifications of the underlying theoretical model).

In the light of this remarkably mixed evidence, the assignment of an equal weight to backward and forward-looking components ensures, in our opinion, a reasonable degree of accuracy to our credibility estimates.

### 4.2. Assessing ECB’s Monetary Policy Credibility

#### 4.2.1. Backward-Looking Expectations

We use monthly data ranging from the official start of EMU in January 1999 until September 2004. Estimation was carried out recursively, starting from the sample 1999.1 - 2000.12 (24 observations) and adding one observation at each iteration. Our dynamic assessment of ECB’s credibility refers therefore to the period starting in January 2001 and ending in September 2004. We analyze a “benchmark scenario”, based on loose prior assumptions for all model’s parameters. More specifically, the following weakly informative proper priors were selected:

\[
\theta \sim N(\mu_\theta, h_\theta^{-1}), \mu_\theta = 0, h_\theta^{-1} = 0.9 \tag{4.1}
\]

\[
\rho \sim N(\mu_\rho, h_\rho^{-1}), \mu_\rho = 0.95, h_\rho^{-1} = 0.9 \tag{4.2}
\]

\[
S \cdot h \sim \chi^2_\nu, S = 0.05, \nu = 1 \tag{4.3}
\]

---

15Econometric forecasts on long term nominal interest rates and inflation in the Euro area are taken from the OECD Economic Outlook which is officially released on a six-month basis. However, since the expected real return is computed as a weighted average of the above forecasts and ex post real rates, the dynamic pattern of (ret) is continuously changing every month. This represents a significant improvement with respect to the forward-looking indicator used in De Grauwe (1996) which is constant along the whole sample.

16As discussed in Roberts (1997), one important result from the literature analyzing the statistical properties of survey data on inflation expectations is that they are neither purely adaptive nor purely rational. While confirming this empirical regularity, this paper emphasizes how a departure from a fully rational expectations assumption is important in a context where the macroeconomic effects of a new policy regime are explored.

17The robustness of our empirical findings to alternative prior assumptions is discussed in section 4.3.
The prior for the constant term ($\theta$) is centered on zero, while the prior 95% confidence interval ranges from -2.06 to +2.06. The prior for the autoregressive parameter ($\rho$) is centered on 0.95 and is not truncated over the stationarity set, thus allowing to estimate the posterior probability that $\rho$ belongs to the above set. The prior on the precision error term ($h$), finally, is also quite loose, with a prior mean of 20 and a prior variance of $\frac{1}{(0.05)^2} = 800.0$.

Consider first long run inflation target credibility. Figure 1 plots the posterior mean for $\rho$ and its 80% confidence interval.

As revealed by this figure, long run credibility is seriously in doubt only at the very beginning of the sample. The posterior mean for $\rho$ shows an upper spike in June 2001 (reaching an estimated value of 0.99), while the upper confidence interval exceeds the unitary value for most part of 2001. Since 2002 onwards a major improvement is apparent, with the posterior mean of $\rho$ consistently declining and the confidence interval in line with the long run credibility constraint. These results are confirmed by the dynamics of the posterior probability of a stationary stochastic process for $(z_t)$ (Figure 2), which exhibits a large drop in June 2001, while suddenly recovering in subsequent months, and exceeding the value of 0.9 for most of the remaining sample period.

These results have a good economic intuition, given the high degree of uncertainty usually associated with the initial stages of a new policy regime. This evidence is highly supportive of the overall consistency of the monetary policy strategy pointing out that, after a relatively short learning process, the ECB was quickly able to establish a good reputation about its long run commitment to the declared inflation targets.

The relevant anti-inflationary credibility constraint is represented by a positive value of the conditional mean of $(\theta_u)$ in equation (2.4). Figure 3 plots the posterior mean for $\theta_u$ and the 80% confidence bounds for this parameter.

These estimates suggest a reasonable degree of ECB anti-inflationary credibility. The posterior mean for $\theta_u$ is positive across the whole sample, oscillating around 0.4 and 0.5 after a more volatile initial period. The lower bound of the confidence interval, on the other hand, is consistent with the credibility constraint only at the very end of the sample. Further evidence about the degree of anti-inflationary credibility is provided by the dynamics of the posterior probability of a positive value for $\theta_u$ reproduced in figure 4.

This posterior probability exhibits an upward trend along the first years of the EMU, raising from initial values around 0.70-0.80 to end of period estimates oscillating around 0.90. A clear difference is however apparent between the former and the latter part of this period. Along the first half of the sample this probability is highly volatile, occasionally denoting some significant downturns, whereas this tendency disappears in subsequent years.

The unstable pattern of the anti-inflationary credibility indicator in 2001-2002 can be explained by significant inflationary pressures, which led to an all-time peak in HICP inflation at mid-2001. Along this period, Euroland was hit by its first large supply shock, generated by a massive increase in energy prices, while inflation dynamics was further being fueled by a consistent nominal depreciation of the Euro against the US Dollar.

According to our estimates, the anti-inflationary credibility indicator reached an all-time low of 0.705 in July 2001, and experienced a further major decrease to 0.755 in February 2002 (Figure 9).
4). It is interesting to observe that, on both circumstances, official declarations underlined the temporary nature of various negative shocks, thus expressing the view that the medium term outlook for price stability had remained broadly unchanged. Consider, at this purpose, the following quotation from the ECB Monthly Bulletin released in July 2001:

“The current level of HICP inflation, 3.4% in May 2001, mainly reflects the direct effects of the recent increases in food and energy prices and the indirect effects of the pass-through from past developments in import prices. Given the nature of these shocks, and taking into account the current monetary policy stance, it is expected that they will have only a temporary effect on inflation rates. (......) Overall, on the basis of the analysis under both pillars, the current stance of the monetary policy of the ECB should ensure price stability over the medium term” (ECB - Monthly Bulletin - July 2001, pages 5-6).

An analogous view is expressed in the ECB Monthly Bulletin released in February 2002:

“The recent rise in inflation should not have medium-term consequences, as it was largely due to exceptional and short-lived factors, such as particularly adverse weather conditions in some parts of the euro area, which led to strong increases in unprocessed food prices. (......) Overall, the current expectation is that, in the course of 2002, HICP inflation will stabilise at levels safely below 2% in line with the ECB’s definition of price stability” (ECB - Monthly Bulletin - February 2002, page 5).

We finally turn to anti-deflationary credibility, measured as the posterior probability of a negative value for $\theta_1$ in equation (2.5). Figure 5 plots the posterior probability of a negative value for $\theta_1$, assuming, respectively, a larger ($\pi_{\text{min}} = 1\%$) or a smaller ($\pi_{\text{min}} = 1.5\%$) inflation target band.

Independently of the assumed lower inflation bound, we observe one occasional credibility downturn in June 2001; moreover, although dynamic patterns are almost identical, a larger inflation band yields higher estimates for this posterior probability.

The former evidence points out that, assuming backward-looking expectations, ECB’s monetary policy was highly consistent with anti-deflationary credibility (excluding one occasional downturn concomitant with a similar decrease in long run credibility). The underlying intuition is that, under this specific expectations assumption, the credibility constraint is violated whenever HICP inflation is lower than $\pi_{\text{min}}$. Since the beginning of our recursive estimates in January 2000, actual HICP inflation was consistently above the lower inflation bound (under both definitions for $\pi_{\text{min}}$), thus significantly reducing the danger of a deflation risk. As regards the latter empirical evidence, this is closely in line with economic intuition, since a lower bound for domestic inflation increases the likelihood of a monetary policy consistent with the anti-deflationary credibility constraint.

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18Recall from section 2.2 that the anti-deflationary credibility constraint is given by $z_t \leq 0$. Under purely backward-looking expectations $r_t^f \equiv i_t - \pi_t$. Therefore, substituting this value in the definition of $z_t$, the above constraint may be expressed as: $[(i_t - \pi_t) - (i_t - \pi_{\text{min}})] \leq 0$. This latter inequality, in turn, may be simplified to: $\pi_t \geq \pi_{\text{min}}$. 

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Hybrid Forward-Looking Expectations  Consider long run inflation target credibility. On the whole, two relevant features stand out. First, our inferences are robust to alternative definitions for the expected real interest rate. Second, allowing for the existence of a forward-looking component in the mechanism of expectations formation imparts a positive influence on credibility.

As revealed by Figure 6, our empirical evidence is very similar to that achieved in the previous section. The posterior probability of a stationary stochastic process for \(z_t\) confirms a single significant downturn at mid-2001, while along the remaining parts of the sample monetary policy is again highly consistent with official inflation targets. A closer inspection indicates that the estimated credibility decrease in 2001 is smaller (0.74 in this case, versus 0.54 under backward-looking expectations). Moreover, along the subsequent part of the sample, our long run credibility estimates turn out to be permanently higher using the alternative definition for the expected real interest rate.\(^{19}\)

We now focus on ECB’s monetary policy as an anti-inflationary device. Figures 7 and 8 plot, respectively, the posterior mean and confidence interval for \(u\) and the posterior probability of a positive value for this parameter, assuming that \(r^e_t\) reflects hybrid forward-looking expectations.

The anti-inflationary credibility constraint is strongly supported by data. As shown in Figure 7, the posterior mean for \(\theta_u\) is largely positive across the sample, reaching minimum values around mid-2001 but shortly recovering thereafter. This pattern is closely reflected in the evolution of anti-inflationary credibility (Figure 8). The probability that \(\theta_u\) is greater than zero exhibits one single major decrease at 0.85 in July 2001, while we observe a near monotonic increase thereafter. In line with the previous section, the major downturn documented at mid-2001 reiterates the negative effects induced by adverse supply shocks hitting the Euro area.

On the whole, this credibility indicator is broadly similar to that obtained in the previous section, although the assumption of hybrid forward-looking expectations yields a much smoother pattern and a higher degree of Central Bank’s anti-inflationary reputation. The underlying intuition for the better results obtained under hybrid forward-looking expectations is that, along our sample period, they yield higher values for the expected real interest rate \(r^e_t\). Since anti-inflationary credibility is evaluated as the probability that \(r^e_t\) is higher than a minimum target-consistent real yield \((i_t - \pi_{\text{max}})\), higher expected real returns are bound to generate more favourable credibility estimates.

Consider, finally, the degree of anti-deflationary credibility. Figure 9 plots the posterior probability of \(\theta_1\) being lower than zero setting, respectively, a larger \((\pi_{\text{min}} = 1\%)\) or a smaller \((\pi_{\text{min}} = 1.5\%)\) inflation target band.

Insppection of this figure reveals that a larger inflation band \((\pi_{\text{min}} = 1\%)\) leaves our empirical findings basically unaffected, whereas assuming a smaller inflation band \((\pi_{\text{min}} = 1.5\%)\) the de-

\(^{19}\)These better credibility results are further supported by the pattern of the posterior mean for \(\rho\) and its 80% confidence interval (not reported in the paper in order to save space, but available from the authors upon request). The posterior mean for the autoregressive parameter oscillates around 0.85 for most of the sample, thus displaying significantly lower values than those obtained using backward-looking expectations (Figure 1).
gree of anti-deflationary credibility is less favourable under hybrid forward-looking expectations.

The economic intuition behind these results is straightforward. Recall that the relevant constraint for anti-deflationary credibility is given by \( r^e_t \geq (i_t - \pi_{\text{min}}) \) and that, as underlined before, allowing for a forward-looking component generates relatively higher values for the expected real interest rate \( (r^e_t) \). Assuming \( \pi_{\text{min}} = 1\% \), the upper limit of the target-consistent band \( (i_t - \pi_{\text{min}}) \) is relatively high so that, notwithstanding a different expectations assumption, the credibility constraint is never seriously put into question (excluding the occasional decrease at mid-2001). Assuming \( \pi_{\text{min}} = 1.5\% \), the upper limit of the target-consistent band becomes lower and, given the presence of relatively high values for \( (r^e_t) \), the credibility constraint is more seriously binding. Thus, differently from the previous section, we observe a less favourable credibility pattern, with more frequent credibility reversals both at the beginning and towards the end of the sample period.

In section 3 we argued that the credibility indicator derived assuming \( \pi_{\text{min}} = 1.5\% \) is more suitable to assess the ECB’s anti-deflationary commitment. The empirical evidence reported in the lower graph of Figure 9 deserves therefore a particular attention.

Focusing on this evidence, it is interesting to observe that the credibility reversals documented for 2003-2004 are concomitant with a major change in the ECB monetary policy strategy and with some official concerns about the risks of global deflation. These reversals, moreover, are closely in line with other empirical evidence about the developments in long term inflation expectations.

The former observation concerns the ECB strategy revision implemented in May 2003. As discussed in section 3, the underlying motivation for the new definition of price stability was the concern about the risk of significant deflationary pressures in the Euro area during this period. The above risk is fully reflected in the sharp decrease of our credibility indicator, reaching a relative minimum of 0.783 in June 2003.

Increasing fears of strong deflationary pressures were simultaneously spreading on a global scale, in the face of extremely low inflation rates in advanced and developing countries and of a weak global recovery. In this perspective, the following quotation from an official IMF document provides further insights into the June 2003 credibility decrease:

“Global inflation remains very low, with consumer prices expected to increase by less than 2 percent in 2003 in advanced countries (.....) Given the expectation that output gaps in the United States and the euro area will widen further in the short term (.....) a number of observers have expressed concerns that outright deflation could become a more widespread problem. (.....) Since deflation has large potential costs, these concerns reinforce arguments for erring on the side of monetary accommodation at the present juncture, and underscore the importance of central banks’ making clear that they will act aggressively and preemptively to forestall deflation if the need arises“ (IMF - World Economic Outlook - April 2003, p. 10).

Turning to the latter point mentioned above, the overall pattern of our anti-deflationary credibility indicator in 2003-2004 displays some remarkable analogies with other empirical evidence related to the dynamics of long term inflation expectations. Chart B in ECB (2004) (see Box 3, page 30) reports inflation expectations for the Euro area from the Survey of Professional Forecasters (SPF), as well as the SPF probability distribution of a future inflation rate at 2% or above. Broadly speaking, a large decrease in this probability distribution can be interpreted as
an increase in the deflation risk, since a low probability is assigned to the occurrence of significant inflationary pressures. As shown in the above chart, the probability distribution of SPF respondents exhibits two major declines in April 2003 and in March 2004. Quite interestingly, both declines are almost concomitant with those recorded in our anti-deflationary credibility indicator, thus reiterating the accuracy of the Bayesian empirical estimates derived in the present paper.

4.2.2. Alternative Priors Assumptions

Empirical estimates derived in the previous section refer to a “benchmark scenario” based on loose prior assumptions for all model’s parameters. The purpose of this section is to assess the robustness of this empirical evidence to alternative prior assumptions.

In line with the previous analysis, the priors for the means are respectively centered on zero ($\theta^0$) and on 0.95 ($\rho$), while the prior variances are increased in order to model a higher degree of parameters uncertainty. More specifically, we analyze an “intermediate case” in which both prior variances are set to 10, and a “worst uncertainty case” in which these variances are set to 100.

Throughout this section, we focus on the implications of alternative prior assumptions on the degree of anti-inflationary and anti-deflationary credibility. As regards this latter indicator, we refer to the case where $\pi_{\text{min}} = 1.5\%$ since, as motivated in section 3.1, this less conservative minimum inflation threshold is more consistent with ECB’s monetary policy strategy.


The former two figures ([10]-[11]) show the results from Monte Carlo simulations obtained using backward-looking expectations and refer, respectively, to the posterior probability of $\theta_u > 0$ (anti-inflationary credibility) and to the posterior probability of $\theta_l < 0$ (anti-deflationary credibility). The latter figures ([12]-[13]) provide the same information under the alternative assumption to model the real interest rate. Each figure contains three plots, comparing the empirical evidence obtained in section 4.2 with the effects induced by an intermediate degree of parameters uncertainty (“intermediate case”) or by a very high degree of parameters uncertainty (“worst uncertainty case”).

The joint inspection of these figures points out two relevant empirical regularities:

1. The overall pattern of credibility indicators mimics that characterizing the benchmark scenario. However, in almost all circumstances, alternative prior assumptions generate consistently lower estimates.

2. The gap between credibility estimates under the benchmark scenario and alternative prior assumptions decreases as new sample information is used to generate posterior probabili-

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20 All additional information about the simulations performed in this section (posterior means and posterior confidence intervals of parameters) is available from the authors upon request. We omit to present empirical estimates concerning long run inflation target credibility, since these results are qualitatively and quantitatively similar to those obtained for other credibility indicators.

21 Note however that, assuming a larger inflation band (i.e. setting $\pi_{\text{min}} = 1.0\%$), the empirical evidence is broadly unaffected with respect to that presented in this section.
ties. This convergence to the benchmark scenario, moreover, is usually slower under backward-looking expectations.

Focusing on the former evidence, we observe that progressively increasing prior variances leaves the overall patterns broadly unaffected. This holds both under backward-looking and under hybrid forward-looking expectations, pointing out the robustness of empirical estimates presented in section 4.2.

The introduction of higher uncertainty generates however significant scale effects on credibility levels. As shown in the above figures, posterior probabilities associated with the benchmark scenario are consistently higher than those obtained in the “intermediate case” which, in turn, exceed estimates recorded under the “worst uncertainty case”. Thus, although replicating previous patterns, our credibility indicators turn out to be quite sensitive to alternative prior assumptions (particularly as far as anti-inflationary credibility is concerned, see Figures [10] and [12]).

Our Bayesian extension of Svensson’s test combines prior information with sample information to obtain posterior densities about relevant model’s parameters. During the initial part of the period, sample information is relatively limited, while prior information plays a prominent role in estimating the above densities. Thus, imposing higher prior variances (i.e. higher parameters uncertainty) tends to generate lower posterior probabilities (i.e. lower credibility estimates), particularly along initial iterations, since available sample information is combined with much disperse priors about the true value of model’s parameters. The underlying economic intuition is that an increased degree of uncertainty about the consistency of ECB’s strategy with official inflation targets reduces, other things being equal, the degree of monetary policy credibility.

Turning to the latter empirical regularity, the intensity of negative effects induced by higher uncertainty decreases over time. Moreover, the convergence to benchmark scenario estimates is apparently faster using hybrid forward-looking expectations.

Consider, at this purpose, the anti-inflationary credibility indicators under the above expectations assumption. As shown in Figure 12, during the July 2001 “credibility crisis” the positive gap between the benchmark and the “worst uncertainty scenario” is quite large, but this gap is progressively absorbed in subsequent periods, and virtually vanishes at the end of the sample. Focusing on the anti-deflationary credibility indicators (Figure 13) substantially replicates the above findings. As documented in Figure 10, convergence is instead slower using backward-looking expectations, leaving a positive discrepancy in end of period estimates.

This convergence in posterior probabilities is strictly related to the above discussion. As time goes by, and new sample information accumulates, alternative prior assumptions exert a reduced influence in the estimate of posterior densities. The negative effects associated with higher parameters uncertainty tend therefore to become less severe, with posterior probabilities more closely reflecting the benchmark scenario analyzed in section 4.2. The underlying economic intuition is that agents subjective estimates about monetary policy credibility are progressively sharpened over time, dissipating the initial effects induced by higher uncertainty, as agents observe the implementation of ECB’s strategy and evaluate its consistency with official inflation targets.

The faster convergence emerging with hybrid forward-looking expectations suggests that a wider information set contributes to smooth out the negative effects induced by higher prior variances. Under backward-looking expectations, the arbitrage condition underlying Svensson’s test relies on adaptive expectations, whereas our alternative assumption incorporates additional
information from official OECD forecasts, thus conforming more closely to the classical concept of rational expectations. Viewed in this perspective, the existence of different speeds of adjustment towards the “benchmark scenario” is not surprising: intuitively, a more efficient use of available information ensures a faster correction of the credibility bias arising from greater initial uncertainty.

5. Concluding Remarks

This paper extends Svensson (1994) “simplest test” of inflation target credibility inside a Bayesian econometric framework. Our contribution fills one relevant gap in the applied literature, since the original version of Svensson (1994) test does not allow neither to estimate the degree of monetary policy credibility nor to assess how Central Bank’s reputation evolves over time. The empirical framework outlined in the present paper provides instead some time-varying estimates about the degree of anti-inflationary and anti-deflationary credibility; this approach, moreover, yields a quantitative assessment about the long run consistency of monetary policy with official inflation targets.

Using two alternative proxies for the expected real interest rate, relying respectively on “backward-looking” and “hybrid forward-looking” expectations, we apply the above framework to estimate the degree of monetary policy credibility during the first years of the Eurosystem. This represents an interesting case study because, given the need to ensure a smooth transition from Bundesbank’s monetary policy to the new regime, and absent a track record about its commitment to price stability, the ECB was faced with the crucial problem of establishing a satisfactory reputation towards market participants.

Overall, the empirical evidence obtained in this paper suggests that the monetary policy strategy followed by the ECB was highly successful in this regard. According to our estimates, long run inflation target credibility exhibits one occasional decrease at mid-2001, but displays a steady increasing trend thereafter. This credibility indicator, moreover, reaches notably high values during the second half of the sample, while our results are robust to alternative definitions for the expected real interest rate. This evidence points out that the ECB strategy was quickly able to establish a satisfactory degree of confidence about the long run consistency of monetary policy with the primary objective of price stability.

Turning to the empirical findings concerning other credibility indicators, our results are broadly in line with the existing literature, albeit with some important qualifications. Analyzing the ECB track record during the first four years through survey data and expected inflation rates implicit in French long term indexed government bonds, Lugaresi-Rotondi (2003) conclude that monetary policy credibility was perfect. While sharing the positive judgment about the ECB policy strategy expressed by these authors, our paper challenges the presumed existence of full monetary policy credibility. As discussed in section 4, although documenting an increasing credibility trend since the inception of EMU, our Bayesian investigation detects some significant credibility reversals during the initial years of the Eurosystem. These reversals involve both anti-inflationary and anti-deflationary credibility, and closely reflect the evolution of the cyclical macroeconomic conditions in the Euro area.

As regards ECB’s anti-inflationary reputation, our analysis reveals a highly unstable pattern in 2001-2002 using backward-looking expectations; during this period Euroland was suffering from some large negative supply shocks, while inflationary expectations were further being fu-
eled by a consistent depreciation of the Euro/Dollar nominal exchange rate. Turning to ECB’s anti-deflationary reputation, our empirical estimates assuming a lower inflation target of 1.5% and hybrid forward-looking expectations point out two major decreases in 2003-2004. Quite interestingly, these credibility reversals are concomitant with a significant change in the macroeconomic outlook of the Euro area (as witnessed by increasing fears of deflationary pressures and by the ECB strategy revision at mid-2003), and closely mimic some additional external evidence about the evolution of long term inflation expectations.

This empirical evidence is robust to alternative prior assumptions, as shown by the overall patterns of credibility indicators which turn out to be broadly unaffected imposing a higher degree of uncertainty about model’s parameters. These alternative simulations, however, generate negative scale effects on credibility levels, since posterior probabilities associated with a more uncertain environment are consistently lower than those obtained under the benchmark scenario. Note, moreover, that the above gap decreases as new sample information is used to compute posterior probabilities, while this convergence process is apparently faster when hybrid forward-looking expectations are used. Overall, these results have a good economic intuition, implying that the adverse effects on credibility induced by higher parameters uncertainty tend to die out over time, as agents observe the effective implementation of ECB’s monetary policy strategy and evaluate its consistency with official inflation targets. In this perspective, the faster convergence documented under hybrid forward-looking expectations discloses the positive influence of a larger information set, which allows agents to make a more efficient use of available information, thus conforming more closely to a rational expectations assumption.

The analysis carried out in the present paper can be fruitfully extended along two main directions: the former is represented by the use of higher frequencies data, while the latter involves more sophisticated approaches to model the real interest rate. The use of a nominal interest rate sampled at higher frequencies (weekly or daily data) might provide further original evidence inside our bayesian framework, where agents continuously update their subjective probability distributions on the basis of new sample information. Although this extension is likely to require an heteroscedasticity correction in the MCMC estimation algorithm, it would allow to pinpoint significant short run credibility fluctuations which cancel out at the monthly frequency. Turning to the latter topic, the choice of fixed and symmetric weights to build our hybrid forward-looking indicator, although receiving a reasonable support by the existing evidence, is admittedly ad hoc. Some recent comparative research shows that inflation targeting regimes tend to strengthen the effect of forward-looking expectations on inflation, thus weakening the weight of its inertial component (Corbo et al. (2001)). This taken into account, relaxing the simple assumption of the present paper, and letting the weights on backward and forward-looking components to optimally vary on the basis of some learning mechanism, would represent an important extension of this research.

References


[14] International Monetary Fund (2003), World Economic Outlook, April.


Figure 1: Posterior mean and confidence interval for $\rho$; Backward looking expectations

Figure 2: Posterior probability of $\rho < 1$, Backward looking expectations
Figure 3: Posterior mean and confidence interval for $\theta_u$; Backward looking expectations

Figure 4: Posterior probability of $\theta_u > 0$; Backward looking expectations
Figure 5: Posterior probability of $\theta_l < 0$; Backward looking expectations. $\pi_{\text{min}} = 1\%$, $\pi_{\text{min}} = 1.5\%$

Figure 6: Posterior probability of $\mu < 1$; Hybrid forward-looking expectations

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Figure 7: Posterior mean and confidence interval for $\theta_u$; Hybrid forward-looking expectations

Figure 8: Posterior probability of $\theta_u>0$; Hybrid forward-looking expectations
Figure 9: Posterior probability of $\theta_l < 0$; Hybrid forward looking expectations. $\pi_{\min} = 1\%$, $\pi_{\min} = 1.5\%$

Figure 10: Posterior probabilities of $\theta_u > 0$; Backward-looking expectations; Alternative prior assumptions
Figure 11: Posterior probabilities of $\theta_{\leq 0}$, Backward-looking expectations; Alternative prior assumptions

Figure 12: Posterior probabilities of $\theta_{>0}$, Hybrid forward-looking expectations; Alternative prior assumptions
Figure 13: Posterior probabilities of $\theta < 0$, Hybrid forward-looking expectations; Alternative prior assumptions

- prob $\theta < L$ benchmark prior
- prob $\theta < L$ prior variance = 100, pimin=1.5%
- prob $\theta < L$ prior variance = 10, pimin=1.5%
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