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Searching for the Natural Rate of Interest: a Euro-Area Perspective

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Editorial

In the present paper, a time-varying natural rate of interest is estimated for the euro area using a multivariate unobserved components model. The problem of aggregating interest rate data for the pre-EMU period is directly addressed, and a simple method in order to adjust the risk premia in the interest rate data prior to 1999 is proposed. The authors show that, for the pre-EMU period, using risk-unadjusted policy rates leads to periods of high risk premia being erroneously taken as monetary policy replies to the output gap; by contrast, using risk-adjusted policy rates yields an estimate of the reaction of monetary policy to the output gap corresponding approximately to an increase of 40 basis points for a 1% positive deviation of output from potential output. A positive deviation of inflation from its trend of 1% is estimated to have triggered approximately a 1.2% increase in short-term interest rates.

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Searching for the Natural Rate of Interest: a Euro-Area Perspective

Jesus Crespo Cuaresma, Ernest Gnan and Doris Ritzberger-Gruenwald[1]

Abstract

A time-varying natural rate of interest is estimated for the euro area using a multivariate unobserved components model. The problem of aggregating interest rate data for the pre-EMU period is directly addressed, and a simple method in order to adjust the risk premia in the interest rate data prior to 1999 is proposed. We show that, for the pre-EMU period, using risk-unadjusted policy rates leads to periods of high risk premia being erroneously taken as monetary policy replies to the output gap; by contrast, using risk-adjusted policy rates yields an estimate of the reaction of monetary policy to the output gap corresponding approximately to an increase of 40 basis points for a 1% positive deviation of output from potential output. A positive deviation of inflation from its trend of 1% is estimated to have triggered approximately a 1.2% increase in short-term interest rates.

JEL Classification Numbers: E43, E52, C32.

Keywords: Natural rate of interest, unobserved components models, monetary policy, Taylor rule.

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1. Introduction

Estimates of the "natural rate of interest" or "equilibrium rate of interest" are a prerequisite for calculating many popular monetary policy rules and monetary stance indicators. Feedback rules such as Taylor's (1993) use the natural rate as the intercept term. Another recently much-discussed indicator of the stance of monetary policy, the "real interest-rate gap" (see e.g. Neiss and Nelson, 2001), is defined as the deviation of the actual short-term rate from the natural rate of interest. Obviously, to the extent that such rules were to be considered by monetary authorities, a "correct" estimate of the natural rate is central for successful macroeconomic stabilisation. This paper offers alternative estimates for the euro area, based on time-series analysis, with a special focus on the complications and potential pitfalls due to the regime change and the resulting break triggered by the inception of EMU.

The concept of the natural rate of interest goes back to Wicksell (1936) (see Woodford (2002) for a reinterpretation of the Wicksellian concept), who stated that "there is a certain rate of interest on loans which is neutral in respect to commodity prices, and tends neither to raise nor to lower them". Following Laubach and Williams (2001), the natural rate of interest may be defined as the real interest rate consistent with output equalling potential and stable inflation. As the growth of potential output varies, also the natural rate of interest rate varies.

In monetary policy regimes where the short-term interest rate is the primary policy instrument, the natural rate of interest provides a measure of the stance of monetary policy. In this context, it is useful to define the natural rate of interest in terms of the real *short-term*[2] interest rate where output converges to potential and inflation is stable (cf. Bomfim, 1997). In such a setting, the natural rate of interest is seen as a medium-run "anchor" for monetary policy.

[2] As pointed out in Laubach and Williams (2001), further advantages of using short-term, rather than bond, rates are (1) that inflation expectations are much less prone to measurement error for money-market rates than for a multi-year horizon. (2) The time-preference of money and thus the term premium may itself be time-varying and would thus have to be estimated. Other studies, e.g. those prepared in the mid-nineties by the OECD (see Orr, Edey and Kennedy, 1995, and Christiansen and Pigott, 1997) and the G10 (for a summary see Jenkinson, 1996) addressed the evolution of long-term interest rates. These studies identified a number of economic variables (rate of return on capital and the associated level of desired investment; falling public and private savings and the level of public debt; the history of a country's inflation; and the movement of oil prices) which drive the trend change in real bond rates. However, they explained very little of the shorter-run movements, which was attributed by the authors to bond rates being driven by largely unobservable shifts in market expectations, including international spillovers. In addition, in the run-up to EMU, expectations about future EMU participation ("convergence plays") became a major determinant for prospective euro area countries´ bond market rates. Obviously, using short-term rates largely avoids the latter three types of complications associated with a study of long-term real interest rates.

Various methods have been explored to estimate time-varying natural rates of interest (TVNRI). Several authors have developed estimated stochastic dynamic general equilibrium (SDGE) models with sticky prices and wages, within which the behavior of the natural rate of interest and the real interest rate gap in the face of various shocks is simulated. The SDGE model for the euro area in Smets and Wouters (2002) generates a natural real rate that covaries strongly with the actual real interest rate, but is substantially *more* volatile. In fact, their estimated natural rate fluctuates widely between +10 and –7 during the nineties, which appears somewhat counter-intuitive.

Laubach and Williams (2001) employed a small-scale macroeconomic model to estimate a TVNRI for the US. By jointly estimating the natural-rate of interest, potential output and the trend growth rate using the Kalman filter, they found significant variation of the natural rate of interest, driven by changes in trend growth, over the past four decades.[3] They conclude that policy makers' mismeasurement of the NRI can substantially deteriorate macroeconomic stabilisation policy. Carrying this work further, Orphanides and Williams (2002) investigate the performance and robustness of various forms of extended Taylor-type rules in the face of an unknown degree of uncertainty about the "true" real-time values of the natural rates of unemployment and interest. As uncertainty about the unemployment gap increases, optimal policy involves far more interest-setting inertia; the role of the natural rate of interest as a benchmark for policy rates diminishes sharply and converges towards zero. Instead, a "difference rule", deriving the policy-rate level from its past level, the divergence of inflation from target and the change in the rate of unemployment – with no reference to the natural rates - becomes preferable. If there is uncertainty about the magnitude of misperceptions on the natural rates, they show that it is advisable to err on the side of greater uncertainty.

The present paper pursues yet another approach for estimating a time-varying natural rate of interest for the euro area, based exclusively on the statistical characteristics of the data, without imposing any conditions derived from economic theory, and aiming for a dynamic model as parsimonious as possible. Multivariate structural time-series models provide a flexible framework for the dynamic specification of unobserved components (the natural rate of interest being one) and allow for exploiting the potential cross-correlation across the series studied and its unobservables. Furthermore, given the fact that the general dynamic

[3] Recently, Brzoza-Brzezina (2003) compares the Kalman filtering estimates of the natural rate of interest for Poland with those resulting from structural vector-autoregressive (SVAR) models and finds little difference between them.

specification nests a wide variety of models, testing down to the model for which the data gives more evidence can be done in a straightforward manner.

The remainder of the paper is structured as follows. Section 2 describes the data, motivates and explains the multivariate unobserved components technique, and presents a first set of estimates for the natural rate of interest and the real interest-rate gap. Section 3 presents a method for constructing a risk-premium adjusted three-month money market interest-rate series for the euro area prior to EMU. Section 3 discusses the additional uncertainty generated by real-time estimation and the implications of relatively wide confidence bands around the estimates. Section 4 tests our TVNRI estimates for leading-indicator properties with regard to euro-area inflation. Section 5 estimates feedback rules, using our TVNRI estimates, for the euro area and compares the estimates of the aggregate responses of monetary policy to changes in inflation expectations and the output gap across specifications of the pre-EMU interest rate series. Section 6 concludes.

2. Multivariate unobserved components estimates

2.1 Data

European monetary union started just three and a half years ago, which, from an economic point of view, means that the cyclical behaviour of the euro area economy has not fully unfolded. From an econometric point of view, three and a half years do not – even with monthly data - provide a sufficient number of observations for medium-run economic analysis. Therefore, empirical work seeks to extend the time series into the past by generating synthetic aggregate euro area data. The issue is how to appropriately calculate aggregate series backwards[4] as there are a number of complications and potential pitfalls which may seriously distort econometric estimates.

For our estimates, we require output, inflation and a short-term market interest rate. We approximate output by seasonally adjusted industrial production (source Eurostat), the reason being mainly the monthly availability of this series, as opposed to quarterly national accounts data. For inflation, we use the euro-area Harmonized Index of Consumer Prices (HICP) excluding energy and unprocessed food as published by Eurostat backwards to

[4] This question has been addressed extensively in various official fora (inter alia, Eurostat and the European Monetary Institute/ECB) before the start of EMU.

January 1991. Taking a measure of "core inflation" is in line with the literature and aims at eliminating – to the extent possible – price disturbances not driven by demand shocks. For the short-term interest rate, we use monthly averages of the three-month money market interest rate as compiled backwards by the ECB.[5]

2.2 Specification of the multivariate unobserved components model

In the spirit of the methodology developed mainly in Harvey (1989), we specify a multivariate unobserved components model in order to extract the trend component of the ex-ante real interest rate. Consider the vector $z_t = (r_t \;\; y_t \;\; \pi_t)'$ composed by real interest rates (r_t), [6] (logged) industrial production (y_t) and inflation (π_t). We are interested in decomposing z_t into a trend component, a cyclical component and an irregular component in an additive fashion, such that

$$z_t = \mu_t + \phi_t + u_t\,; \;\; u_t \sim \text{NID}(\mathbf{0}, \mathbf{\Sigma_u}), \tag{1}$$

where μ_t, the multivariate trend component, is assumed to follow a (multivariate) random walk with drift, where the drift itself follows a random walk, that is,

$$\mu_t = \mu_{t-1} + \kappa_{t-1} + \tau_t\,; \;\; \tau_t \sim \text{NID}(\mathbf{0}, \mathbf{\Sigma_\tau}), \tag{2}$$

$$\kappa_t = \kappa_{t-1} + \psi_t\,; \; \psi_t \sim \text{NID}(\mathbf{0}, \mathbf{\Sigma_\psi}). \tag{3}$$

The errors in the specification of the trend, τ_t and ψ_t, are assumed to be mutually uncorrelated and uncorrelated with u_t. The cyclical component is specified as a sine-cosine wave with time-evolving parameters,

$$\begin{pmatrix} \phi_t \\ \phi_t^* \end{pmatrix} = \rho \left[\begin{pmatrix} \cos\lambda & \sin\lambda \\ -\sin\lambda & \cos\lambda \end{pmatrix} \otimes I \right] \begin{pmatrix} \phi_{t-1} \\ \phi_{t-1}^* \end{pmatrix} + \begin{pmatrix} \omega_t \\ \omega_t^* \end{pmatrix}, \tag{4}$$

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[5] The ECB computes euro area three-month money market rates prior to 1999 from national data, using PPP-adjusted GDP weights (base-year 1995). We also considered a series from Reuters, which uses ECU money market rates prior to 1999. The two series differ considerably, the reasons being, inter alia, that the ECU currency basket did not coincide 1:1 (in terms of both currency basket range and weights) with the currencies included in the euro from 1 January 1999, and that the ECU market rate at times diverged – for various reasons - substantially from its theoretical value (defined as the weighted average of the rates of its basket currencies). For these conceptual weaknesses of the ECU-based series, we opted for the ECB aggregate three-month money market series (monthly averages).

[6] We use ex-ante real interest rates, defined as the prevailing interest rate in period *t* minus the inflation rate between period *t-1* and *t*. This implies that the monetary authority assumes that inflation follows a random walk.

where $(\omega_t \; \omega_t^{*})' \sim$ NID($\mathbf{0}$, $I \otimes \mathbf{\Sigma_\omega}$), $\rho \in (0,1)$ and $\lambda \in (0,\pi)$. The error in the cyclical component is furthermore assumed to be uncorrelated with the errors in the other components. The cyclical frequency, λ, and the cycle damping factor, ρ, are thus assumed to be equal across variables.

The structural time-series model described above is able to exploit the common statistical features of the series to be studied simultaneously by allowing correlation across the individual error processes in a given unobserved component. The estimation of the parameters of interest can be carried out using maximum likelihood methods after setting the prediction error decomposition using Kalman filtering (for details see Harvey, 1989).

Furthermore, the prediction error decomposition enables us to retrieve the "smoothed" and "filtered" estimates of the unobservable states. The smoothed unobserved states are just $\alpha_t^s = E(\alpha_t \mid \{z_t\}_{t=0}^T)$, while the filtered states are $\alpha_t^f = E(\alpha_t \mid \{z_t\}_{t=0}^t)$. That is, the smoothed estimates exploit the information contained in the whole sample, while the filtered estimates form conditional expectations on the unobservable state at time *t* using information up to *t-1*. The filtered estimates will be also referred to as "real time" estimates.[7] The specification of a smooth trend in the multivariate unobserved components model (which implies that the trend component does not contain the error term τ_t) improved the fit significantly and was therefore imposed for the estimation using euro area data.

Notice that the identification – in economic terms - of the TVNRI (and of potential output as well as equilibrium inflation) is based on the notion that the estimated cyclical component should correspond to the business cycle. The starting values for the parameters of the cycle in the optimisation algorithm were thus specified to lie in intervals corresponding to plausible business cycle frequencies and persistence.[8] The three trends extracted by means of this estimation procedure can be interpreted as potential output, trend inflation and the (time-varying) natural rate of interest. Notice that the econometric setting implicitly assumes that the variables involved in the analysis are I(1). Although the assumption could seem unreasonable for the real interest rate (and possibly for inflation) in long samples, for the

[7] It should be noticed that our concept of "real time" estimates does not coincide with that of e.g. Orphanides (2001), who used actual forecasts and projections available in the period considered in order to evaluate monetary policy.

[8] Starting values for the cyclical frequency λ were set such that the corresponding cyclical period lies between three and five years, and the ρ parameter was initiated at values ranging between 0.8 and 0.99. The estimated parameters were robust to the choice of starting values for λ and ρ in this range. An unreasonably short-lived cycle was isolated if the starting values of λ was chosen to be too large.

sample given Augmented Dickey Fuller tests could not reject the null of a unit root in the series involved in the analysis at any reasonable significance level.

2.3 Estimation results

The estimation of the multivariate unobserved components model using the original nominal interest rate dataset isolates a cycle with a frequency, λ, of 0.18 radians, corresponding to a cyclical period of around three years. The estimated damping factor, ρ, for the cycle is 0.97, a result that matches the range of cyclical persistence of economic variables reported in the literature (see, e.g., Harvey and Jaeger, 1993). While the residuals present no significant first-order autocorrelation (as measured by the Durbin-Watson test statistic) for any of the series included in the multivariate specification, the residuals from the real interest-rate series reject the null hypothesis of normality for the Jarque-Bera test at any reasonable significance level.[9]

Figure 1 shows the estimated natural rate of interest. The natural rate reflects the trend of the actual real rate, which is strong but gradually flattening over the nineties. Since the start of EMU, the behavior of the natural rate is rather flat, slightly above 2%. The TVNRI contrasts sharply against a fixed estimate based on the simple sample average of 3.8%. The medium-run dynamics of the TVNRI in the 1994-2002 period are relatively similar to the results of Giammarioli and Valla (2003), who used a calibrated SDGE model.

The amplitude of the output gap resulting from the estimation (the smoothed cyclical component of industrial production) is considerably smaller than that obtained by Hodrick-Prescott filtering industrial production series. This feature has been widely documented in the literature (see e.g. Harvey and Jaeger, 1993, or Cogley and Nason, 1995) and seems to be due to the fact that the Hodrick-Prescott filter tends to isolate spurious cycles.

The real interest-rate gap, i.e. the difference between the actual and time-varying natural real interest rates, broadly mirrors the estimated evolution of the output gap. According to this measure, monetary policy was rather tight in late-1992 and early-1993, and less so in 1995 and in 2000. It was loose in 1991, 1993/1994, in 1999 and from late-2001 onwards. A real interest-rate gap based on the simple sample average yields a sharply different assessment;

[9] For detailed results of the estimation of the structural time-series models see Appendix.

according to such a measure, monetary policy would have been mostly restrictive up to the mid-nineties and consistently expansionary ever since.

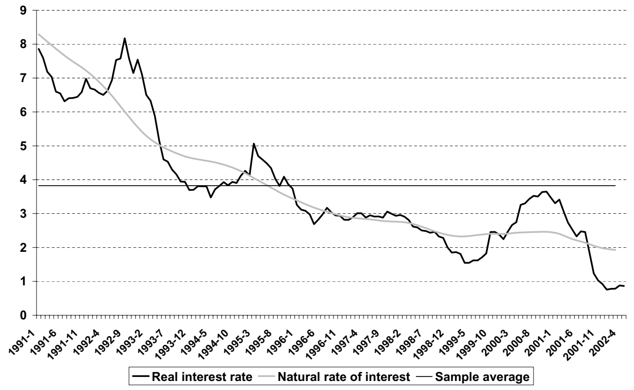

Figure 1: Real interest rate with time-varying natural rate of interest: smoothed estimate and sample average.

3. Adjusting for risk premia prior to EMU

One major feature of the above estimates was a very high TVNRI in the first half of the nineties and a much lower level since then. We suspect that the high level of rates in the first half of the nineties is (at least partly) attributable to risk premia linked to the exchange rate tensions within the ERM and unsustainable fiscal positions prior to EMU. If the aim is to estimate a TVNRI and a derived real interest rate gap suitable for monetary policy analysis in EMU, risk premia which no longer exist in the new regime of EMU should be excluded from the estimation. These risk premia would be expected to include exchange rate risk premia (as experienced at various occasions within the Exchange Rate Mechanism of the European Monetary System) and (probably to a lesser extent, given the short run nature of the interest rate used in the estimations) default risk premia to the extent that they may have been reduced by the Stability and Growth pact. In other words, we seek to generate a TVNRI exclusively driven by output and inflation.[10] We therefore develop a method to eliminate these risk premia from national nominal money market rates, which we in turn use to

[10] We abstract from modelling other general factors driving real interest rates, such as time preference parameters.

construct a new, risk-adjusted synthetic time series for aggregate euro area three-month money-market rates prior to 1999.

In our model, the risk premium on each national money market rate is defined to be the part of the (nominal) interest rate spread with the German short term-interest rate that cannot be explained by differentials in inflation expectations and/or business cycle desynchronization. The adjustment of the series is done as follows. First, the risk premium (which need not be assumed to be constant through time) is extracted for each country. Given the working definition of the interest-rate risk premium above, the interest rate spread with Germany is regressed on the output gap differential between the country of interest and Germany and the inflation forecast differential. That is, for country *k*,

$$s_t^k = \beta_0 + \beta_1(g_t^k - g_t^{GER}) + \beta_2[E(\pi_{t+12}^k \,|\{\pi_s^k\}_{s=1}^t) - E(\pi_{t+12}^{GER} \,|\{\pi_s^{GER}\}_{s=1}^t)] + \gamma_t \,, \tag{7}$$

where s_t^k is the interest rate spread between country *k* and Germany, g_t^k is the output gap[11] of country *k*, the inflation forecasts are obtained by computing the conditional expectation after fitting an autoregressive process[12] to the inflation data ranging up to period *t*, γ_t is assumed to be a random shock and *E(·)* is the expectation operator. Notice that all other factors affecting the risk premium different from differentials in inflation expectations and the business cycle indicator are assumed to be captured by γ_t.

After estimating equation (7), the original series of nominal interest rates (i_t^k) are adjusted by substracting the estimated constant and the residuals from the estimation. The adjusted series is thus

$$i_t^{adj,k} = i_t^k - \hat{\beta}_0 - \hat{\gamma}_t \,. \tag{8}$$

Given the potential correlation between the error and the regressors (in the sense of correlation between inflation expectations and exchange rate-driven risk premium, for instance), lags ranging between six and twelve months of the output gap and inflation differentials were used as instruments in the estimation of (7). Durbin-Wu-Hausman tests

[11] The output gap series used for each country corresponds to the cyclical component of industrial production resulting from estimating a multivariate unobserved components model using data on real interest rates, inflation and industrial production.

[12] The lag length of the autoregressive process that is fitted to the inflation data is chosen to be the one that minimizes the Akaike Information Criterion for the data available at each time point *t*. The lag length is thus revised with each realization of inflation, so as to model changes in the persistence of inflation through time. In all cases the range of lags taken into account for the choice was between one and twelve.

and Sargan tests confirm both the need for instruments and the validity of the instruments used. The only exception is Portugal, where the Durbin-Wu-Hausman indicated that no instrumental variable estimation was necessary and OLS estimation was used. The source of national data is BIS for the national money market rates and Eurostat for inflation and industrial production. Incomplete datasets for Portugal and Finland were augmented using data from the Bank of Portugal and the Bank of Finland, respectively.

Figure 2: Interest-rate risk premium (euro-area aggregate),
risk-adjusted and unadjusted real interest-rate series.

The left panel of Figure 2 shows the estimated aggregated risk premium for the countries of the euro area prior to 1999, revealing the suspected high risk premia of up to 2½% and more around the ERM crisis of 1992/1993 and the exchange rate tensions of 1995. It also shows that, as to be expected, the risk premia virtually vanished until the end of 1998. The right panel of Figure 2 compares the adjusted 3-month nominal interest rate for the euro area[13] with the original unadjusted series. The adjusted real interest-rate series shown in the left panel of Figure 3 fluctuated between slightly less than 1% and 3½% from 1994 until spring 2002.[14]

[13] The aggregation has been done using weights based on the relative GDP (at PPP prices) of each country in the EMU aggregate. The relative GDP data is annual, so it is left unchanged across months in a given year.
[14] Thus, given our definition of the interest rate risk premium, only premia relative to Germany are taken into account. Therefore, the aggregated series may as well contain extra (potentially time-varying) risk premia with respect to the rest of the world that need not be symmetric across countries.

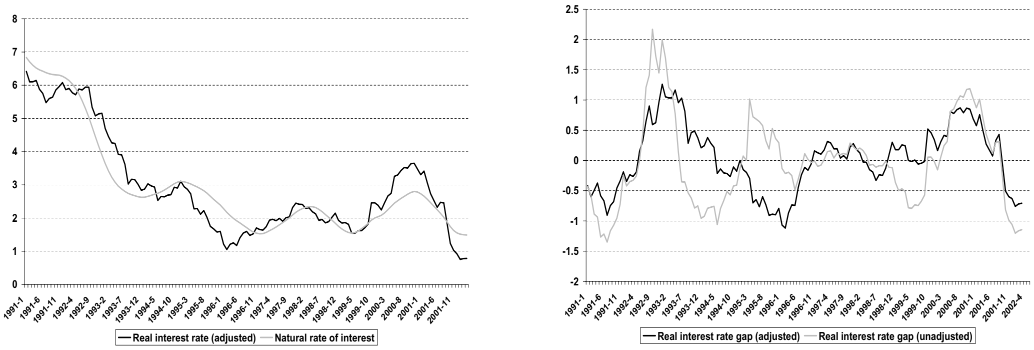

Figure 3: Natural rate of interest for risk-adjusted real interest-rate data; real interest rate gap for risk-adjusted and unadjusted data

Using the risk-adjusted euro-area three-month money-market series, we re-estimate the TVNRI. The cyclical frequency estimated for the multivariate unobserved components model with the adjusted interest rate series is 0.11 radians, which corresponds to a cyclical period of around four and a half years. None of the residual series present significant first-order autocorrelation, and the null of normal distribution of the residuals cannot be rejected at 5% significance level for any of the series.

The risk-adjusted natural rate of interest is shown in the left panel of Figure 3. Leaving aside the start of the estimate, the natural rate now fluctuates between 1½% and and 3¼% between 1994 and now. The average of the real interest rate over the sample period at slightly below 3% is much lower and more in line with rule-of-thumb estimates. Compared to the risk-unadjusted estimates, the TVNRI now traces the actual real market rate more closely, its cyclical behaviour is far more pronounced; as a corollary to this, the real interest-rate gap fluctuates less now. Comparing the risk-adjusted and unadjusted real interest rate gaps (see right panel of Figure 3) reveals substantial differences in the first half of the nineties, but also non-negligible differences particularly in 1999 (up to 80 basis points), in 2000 and in 2002 (30-40 basis points each). In several instances (1993/1994, 1995/1996, 1999), even the sign of the risk-adjusted real interest-rate gap estimate is opposite from the unadjusted one. In other words, the risk-adjusted real interest-rate gap and the unadjusted one would have yielded opposite monetary policy advice during these periods. Contrary to the unadjusted estimate, euro area monetary policy is now no longer qualified as expansionary in 1999 and is also considered less expansionary in 2002. On the other hand, the adjusted real interest-rate gap suggests a lesser degree of restrictiveness during the upswing in 2000/2001. More generally, the adjusted estimates suggest smoother and more cautious changes in the Eurosystem's policy stance.

4. Real-time estimates and confidence bands

For practical monetary-policy purposes, estimates of the natural rate need to be done "real time", i.e. on the basis of data available only up to the point in time where the monetary-policy decision is taken. As new data become available, the original estimates are continuously revised reflecting the richer information set available. Figure 4 shows the divergence between real-time estimates of the TVNRI ("filtered") and those based on the entire sample ("smoothed") since the start of EMU.[15] The left panel is based on the unadjusted interest-rate series, the right panel uses the risk-adjusted money-market series as derived in Section 3. The real-time estimation error reaches up to half a percentage point for both series. This is also reflected in the real interest-rate gaps derived from these four natural-rate series. Our estimates confirm the finding pointed out in the literature (see e.g. Orphanides, 2001, Orphanides and Williams, 2002, Laubach and Williams, 2001) that policy rules based on unobserved macroeconomic variables, such as the natural rates of output, unemployment or interest rate – or the derived "gaps" - involve a substantial margin of error if applied "real-time" and should thus be used cautiously.

Figure 4: Filtered and smoothed TVNRIs,
original and risk-adjusted data.

[15] We abstain from showing and interpreting the - even bigger - divergencies for the period before 1999 since the number of data points available for these real-time estimates becomes quite small, given our initial choice of investigating only data starting from January 1991.

But even the smoothed series, based on the full-sample estimates, suffer from substantial uncertainty, as shown in Figure 5. Wrapping a 75% confidence band around our estimates of the TVNRI, deviations between the actual and natural real rates of interest are shown to be insignificant during most of the nineties and up to most recently. In EMU, the estimate based on the unadjusted interest-rate series (left panel) signals periods of loose monetary policy in 1999 and from late-2001 and a restrictive stance in 2000. However, after adjusting for risk-premia (right panel), the Eurosystem´s monetary policy can no longer be qualified as either significantly expansionary or restrictive, except for some months of tightness in the year 2000.

Figure 5: TVNRIs and 75% confidence intervals (original and risk-adjusted data), as compared to the real interest rate (original or risk-adjusted)

5. Leading indicator properties of the real interest rate gaps for inflation

The real interest-rate gap is a widely used measure of the monetary policy stance. However, the analysis carried out so far illustrates clearly that the point estimates of the real interest-rate gap may differ substantially depending upon the statistical technique used in identifying the natural rate of interest. Significant differences about the stance of monetary policy arise as well if the euro-area interest rate series is adjusted for interest-rate premia in the pre-EMU period. On this last point, we are interested in the advantages or disadvantages of using the adjusted series for monetary policy evaluation. This section compares the adjusted and unadjusted series in terms of the properties of the real interest-rate gap emerging from both datasets as a leading indicator of inflation in the euro area.

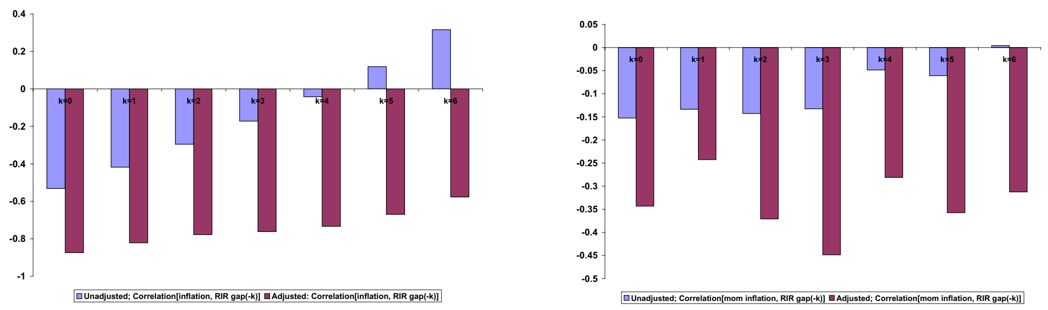

Figure 6: Leading indicator properties:
Risk-unadjusted and adjusted real interest-rate gaps

Figure 6 shows the correlation between monthly (right part) and annual (left part) inflation and the real-time (i.e. filtered) estimates of the ex-ante real interest gap[16] at different lags, *k*, ranging from zero to six months. The correlations refer to the period between January 1999 and March 2002.[17] The correlation up to a lag of six months appears always negative for the risk-adjusted real interest gap series, while the correlation between the real interest gap emerging from the unadjusted series and inflation turns positive for lags of more than five (monthly inflation rate) or four (annual inflation rate) months. The correlation is higher in absolute terms for the adjusted series at all evaluated lags, giving a clear indication of the superior leading-indicator properties of the adjusted real interest-rate gap. The negative correlation between the (adjusted) real interest-rate gap and inflation is consistent with economic theory (see e.g. Neiss and Nelson, 2001). This suggests that the real interest rate gap resulting from the adjusted interest-rate series may serve better as an indicator of the monetary policy stance than the one calculated from the original series of aggregated EMU short-term interest rates.

6. Risk-premium adjustment and euro-area feedback rule estimates

The aim of this section is to investigate the differences in the ex-post assessment of monetary policy induced by the use of risk-adjusted interest rate data.[18] In this section we assume that

[16] The filtered estimates of the real interest rate gap were computed using the multivariate unobserved components approach for both series.
[17] The complete sample of national interest rates up to 1998:12 is required to perform the adjustment, so real-time estimates based on adjusted data prior to 1999 would be misleading as it would not be representative of the information that is available to the monetary policy authority at a given point in time.
[18] For similar exercises using raw interest rate data see e.g. Gerdesmeier and Roffia (2003) and Kwapil (2003).

monetary policy in the euro area can be represented by an interest-rate feedback rule à la Clarida, Gali and Gertler (1998), such that the central bank sets the short-term interest rate ($\tilde{i}_t$) according to the following rule:[19]

$$\tilde{i}_t = i_t^* + \delta[E(\pi_{t+12} - \pi_{t+12}^* \mid \Omega_t)] + \gamma[E(g_t \mid \Omega_t)], \qquad (9)$$

where i_t^* is the time varying nominal interest rate targets. Monetary policy reacts to changes in the deviation of expected inflation from some bliss value (π_t^*) and to changes in the expected output gap, g_t. We further assume interest rate smoothing, so that the actual interest rate is given by

$$i_i = (1-\eta)\tilde{i}_t + \eta i_{t-1} + \varsigma_t, \qquad (10)$$

where $\eta \in [0,1]$ is the smoothing parameter and ς_t is an i.i.d. error. Combining (9) and (10), we can write

$$i_t = (1-\eta)r_t^* + (1-\eta)\delta(\pi_{t+12} - \pi_{t+12}^*) + (1-\eta)\gamma g_t + (1-\eta)\pi_{t+12} + \varphi_t, \qquad (11)$$

where r_t^* is the natural, time varying, real interest rate (defined as the natural nominal interest rate minus expected inflation), and the error term, φ_t, is a linear combination of the error in (10) and and the forecast errors in predicting the inflation rate, its "normal rate", π_t^*, and the output gap. The estimation of equation (11) was carried out using the general method of moments, as suggested in Clarida, Gali and Gertler (1998). The instruments used were past values of inflation, interest rate and the output gap. The output gap is taken to be the smoothed estimates of the cyclical components of output and inflation in the multivariate unobserved components model for the risk-unadjusted interest-rate data. The natural rate of interest data correspond to the smoothed estimates of the TVNRI and the inflation target is taken to be the smoothed estimate of the trend in inflation extracted from the multivariate unobserved components model with the original interest rate data.

Table 1 reports the estimates of the structural parameters in (11) using risk-unadjusted and adjusted data (and thus unadjusted and adjusted TVNRIs). The estimated parameters corresponding to reactions of monetary policy to inflation and the output gap are higher for

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[19] For the pre-EMU period, this amounts to the assumption that the (weighted) average of euro area central banks' monetary policies can be represented by means of an aggregate reaction function.

risk-unadjusted interest rate data than for adjusted data, although there is no statistically significant difference for the reaction to inflation deviations from trend. Notice that there is a basic difference in the interpretation of the parameter associated to the reaction to inflation in our specification compared to that of Clarida, Gali and Gertler (1998). In the case of targeting a fixed level of inflation (as in Clarida, Gali and Gertler, 1998), disinflationary monetary policy corresponds to an estimate of δ significantly greater than one. In contrast, when the targeted level of inflation is assumed variable, as in our case, a δ parameter not significantly different from one (as is the case in the setting with adjusted interest rate data) is still consistent with disinflation, given the decreasing trend of inflation.

Monetary policy reaction functions, euro area 1991:01-2002:03

Parameter	Risk-unadjusted interest rate data	Risk-adjusted interest rate data
η	0.825*** (0.009)	0.831*** (0.013)
δ	1.515*** (0.272)	1.232*** (0.374)
γ	0.979*** (0.374)	0.386*** (0.118)
Sargan test	16.921 (p-value=0.963)	16.399 (p-value= 0.971)

* (**) [***] stands for significance at the 10% (5%) [1%] significance level. Estimation carried out by GMM, using past values of interest rates, inflation and the output gap as instruments.

Table 1: Estimated reaction functions (euro area, 1991:01-2002:3)

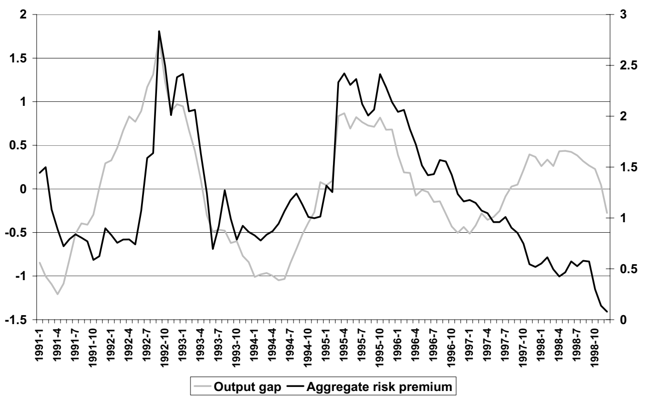

Figure 7: Aggregate risk premium and the output gap

Substantial differences, however, appear in the estimate of the reaction of aggregate monetary policy in EMU to the output gap. For unadjusted data the results imply that monetary policy reacted in a one-to-one fashion to the output gap, an estimate more than twice greater than the one corresponding to the adjusted interest rate data. The source of these contradictory results appears to lie in the risk-premium component of the aggregate interest rate data in the pre-EMU period. The time variation of the interest rate risk premium happens to coincide closely with the cyclical variation in the output gap (see Figure 7).[20] Thus, if a reaction function as above is estimated for pre-EMU aggregate euro area monetary policy using non-risk-adjusted nominal interest rates, the dynamics of policy interest rates which are actually driven by risk premia are *erroneously* taken to be reactions of monetary policy to the output gap. This is confirmed by our finding that the correlations between the national interest-rate risk premia and the corresponding output gaps are negative or not significantly different from zero in all individual euro area countries, with the exception of Finland.[21] The high response coefficient of monetary policy to the output gap when using risk-unadjusted data seems to be thus a statistical artefact. The coefficients estimated on the basis of risk-adjusted interest rate data are more in line with the estimates reported, e.g., by Clarida, Gali and Gertler (1998).

7. Summary and conclusions

This paper pursued five objectives: first, to estimate time-varying natural rates of interest for the euro area, using a structural statistical model; second, to explore the consequences of pre-EMU national interest-rate risk premia on TVNRI estimates; third, to evaluate the robustness of such estimates in real-time settings and when bearing in mind the wide confidence bands of such estimates; fourth, to explore the leading indicator properties of our real interest rate gap estimates for euro area inflation; and to estimate feedback rules for monetary policy in EMU, focusing on the differences implied by the use of raw aggregate interest rate data for the pre-EMU period.

We estimate the TVNRI by means of a multivariate unobserved components approach, with aggregate monthly euro area data (January 1991 to March 2002) on ex-ante real interest

[20] The correlation between the aggregate risk premium and the output gap is 0.685.
[21] The correlations range between -0.66 for Netherlands and 0.35 for Finland. The lack of synchronization across national business cycles explains, thus, the coincidence of expansions and risk premium in the pre-EMU aggregate series and therefore the relatively higher response of monetary policy to the output gap implied by the estimation of feedback rules for the euro area using raw aggregated interest rate data.

rates, core inflation and industrial production; the (unobserved) trend component in the real interest rate for the euro area is taken to be the natural rate of interest. Our first estimate is based on simple aggregated money market rates for the pre-EMU part of our sample and yields a TVNRI that falls from 8% in early 1991 to around 2% by the start of EMU and has remained there ever since. This contrasts sharply against a fixed estimate based on the sample average of 3.8%.

However, simple aggregate money-market interest rate data were, in particular until the mid-nineties, distorted by various risk premia no longer relevant in the new regime of the euro area. We extract those risk premia from national interest rate data and derive a synthetic measure of the aggregate euro area money market interest rate. The risk premium is hypothesized to be the part of each country's (nominal) interest-rate spread with Germany unexplained by differentials in inflation expectations and output gap desynchronization. The estimated risk premium is found to have coincided closely with the bouts of ERM tensions in the early and mid-nineties and converges towards zero by end-1998. On the basis of the regime-change-adjusted interest-rate series, we re-estimate the TVNRI: it now fluctuated between 1 and 3½% between 1994 and Spring 2002. The average over the full sample period is close to 3%.

The real interest-rate gaps derived from the unadjusted and adjusted TVNRIs differ substantially in terms of the derived real interest-rate gaps, thus yielding different ex post assessments of European monetary policies pre-EMU and in EMU. In several instances (1993/1994, 1995/1996, 1999), the risk-adjusted and the unadjusted real-rate gap would have yielded opposite monetary policy advice. Contrary to the unadjusted estimate, euro area monetary policy is now no longer qualified as expansionary in 1999 and is also considered less expansionary in 2002. On the other hand, the adjusted real interest gap suggests a lesser degree of restrictiveness during the upswing in 2000/2001. More generally, the adjusted estimates suggest smoother and more cautious changes in the Eurosystem's policy stance. For practical monetary policy estimates we also explore to what extent "real-time" estimates deviate from full sample estimates. We find that the real-time estimation error reaches up to half a percentage point for both the risk premia-unadjusted and adjusted series. This confirms the finding in the literature that policy rules based on unobserved macroeconomic variables, such as the natural rates of output, unemployment or interest rate – or the derived "gaps" - involve a substantial margin of error if applied "real-time" and should thus be used cautiously. The rather wide 75% confidence bands around our TVNRI estimates further add to practical difficulties in applying TVNRI-based monetary stance indicators or feedback rules.

We conclude the paper with two policy applications. First, we find the risk-adjusted real interest gap to perform considerably better as a leading indicator for euro area inflation than the non-adjusted series. Second, using our TVNRI estimates, we estimate monetary policy feedback rules for the euro area, in order to assess ex post the relative weights attached to inflation and output stabilisation by the ECB Governing Council and by its predecessor pre-EMU euro area central banks. We show that, for the pre-EMU period, using risk-unadjusted policy rates leads to periods of high risk premia being erroneously taken as monetary policy replies to the output gap; by contrast, using risk-adjusted policy rates yields an estimate of the reaction of monetary policy to the output gap corresponding approximately to an increase of 40 basis points for a 1% positive deviation of output from potential output. A positive deviation of inflation from its trend of 1% is estimated to have triggered approximately a 1.2% increase in short-term interest rates.

Appendix: Estimation results for the multivariate unobserved components models

A) Results using original interest rate data:

Hyperparameter	Estimate
ρ	0.969
λ	0.178
$\mathbf{\Sigma_u}$	$\begin{bmatrix} 0.005 & & \\ -0.001 & 0.0005 & \\ -7.27\times10^{-5} & -7.64\times10^{-5} & 3.23\times10^{-5} \end{bmatrix}$
$\mathbf{\Sigma_\psi}$	$\begin{bmatrix} 0.0002 & & \\ -0.0003 & 0.0004 & \\ 1.94\times10^{-5} & -2.69\times10^{-5} & 1.90\times10^{-6} \end{bmatrix}$
$\mathbf{\Sigma_\omega}$	$\begin{bmatrix} 0.032 & & \\ -0.004 & 0.005 & \\ 0.0002 & 5.44\times10^{-5} & 1.97\times10^{-6} \end{bmatrix}$

Residual analysis:

	Real interest rate	Inflation	Industrial production
Standard error	0.218	0.094	0.008
Jarque-Bera statistic	26.85	2.306	1.655
Durbin-Watson statistic	2.019	1.892	1.926

B) *Results using adjusted interest rate data*

Hyperparameter	Estimate
ρ	0.961
λ	0.11
$\mathbf{\Sigma_u}$	$\begin{bmatrix} 0 & & \\ 0 & 0 & \\ 0 & 0 & 3.26\times10^{-5} \end{bmatrix}$
$\mathbf{\Sigma_\psi}$	$\begin{bmatrix} 0.002 & & \\ -0.0001 & 0.0001 & \\ 6.55\times10^{-5} & -6.48\times10^{-6} & 2.51\times10^{-6} \end{bmatrix}$
$\mathbf{\Sigma_\omega}$	$\begin{bmatrix} 0.027 & & \\ -0.007 & 0.007 & \\ 0.0001 & -8.42\times10^{-5} & 1\times10^{-6} \end{bmatrix}$

Residual analysis:

	Real interest rate	Inflation	Industrial production
Standard error	0.182	0.093	0.008
Jarque-Bera statistic	3.726	2.666	0.542
Durbin-Watson statistic	1.962	1.917	1.846

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July 21, 2003	Jesus Crespo Cuaresma, Ernest Gnan, Doris Ritzberger-Gruenwald	84	Searching for the Natural Rate of Interest: a Euro-Area Perspective