Inflation risk premia in the US and the euro area

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Motivation

- Nominal and real bond yields are often used by central banks to extract information of relevance for monetary policy.

- Break-even inflation rates used as an indicator of markets' inflation expectations / a measure of central bank credibility

- Break-even rates are a noisy measure due to the existence of premia; notably: inflation risk premia (but also zero-coupon effects, liquidity premia)

- How large are inflation premia in the US and the euro area? What are their properties/determinants?
Outline of the presentation

- Methodology
- Data and estimation method
- Results: inflation risk premia; raw vs. premium-adjusted break-even rates; properties and macro determinants
Methodology

• Inflation risk premium filtered from the overall term premium filtered from yields: plenty of measurement uncertainty

• Guidance from intuition/theory? Inflation risk premium should be proportional to inflation variability, hence positive and increasing in maturity
  
  – in theory a negative premium is possible; sign depends on covariance between inflation (real returns on bonds) and SDF (consumption)
  
  – recent empirical results point to mostly positive inflation premia, but the magnitude varies: + and sizeable in Buraschi and Jiltsov (2005) and Ang et al. (2006); small but + for long maturities in Durham (2006) and D’Amico et al. (2007). Euro evidence in Garcia and Werner (2008): small and ++.
Methodology

- Important to include relevant information: index-linked and macro data; survey data

- Consistency with macro dynamics: inflation expectations derived from a "structural," empirically plausible macro-model

- No-arbitrage restrictions added to the macro structure: the nominal and real term structures are modelled to be arbitrage-free and mutually consistent

→ Macro-based interpretations of term structure dynamics, including dynamic responses of yields, premia, and break-even inflation rates to structural shocks
The model: Macro

inflation: \[ \pi_t = \bar{\pi} + \mu_\pi E_t \pi_{t+} + (1 - \mu_\pi) \delta_\pi \pi_{t-} + \delta_x x_t + \varepsilon^\pi_t \]

gap: \[ x_t = \mu_x E_t x_{t+} + (1 - \mu_x) \zeta_x x_{t-} - \zeta_r (r_t - E_t [\pi_{t+1}]) + \varepsilon^x_t \]

short rate: \[ r_t = \bar{r} + (1 - \rho) [\beta (E_t \pi_{t+12} - \pi^*_t) + \gamma x_t] + \rho r_{t-1} + \eta_t \]

target: \[ \pi^*_t = \phi_{\pi^*} \pi^*_{t-1} + u^\pi_t \]
Key ingredients of the model: intuition

Macro: model

\[
\begin{bmatrix} X_{1,t+1} \\ E_t X_{2,t+1} \end{bmatrix} = H \begin{bmatrix} X_{1,t} \\ X_{2,t} \end{bmatrix} + K r_t + \xi_{t+1}
\]

\[r_t = -F \begin{bmatrix} X_{1,t} \\ X_{2,t} \end{bmatrix}\]

Macro: solution

\[X_{2,t} = C X_{1,t}\]

\[X_{1,t+1} = M X_{1,t} + \xi_{1,t+1}\]

Finance: assumption on stochastic discount factor \(\rightarrow\) nominal / real pricing kernels

\[Y_t = A + B X_{1,t}\]

\[Y^*_t = A^* + B^* X_{1,t}\]
The model: Market prices of risk

Market prices of risk determined empirically as affine functions of the states

\[ \lambda_t = \lambda_0 + \lambda_1 \times States_t \]

We use

\[
\lambda_t = \begin{pmatrix} \lambda_{01} \\ \lambda_{02} \\ \lambda_{03} \\ \lambda_{04} \end{pmatrix} + \begin{pmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} & \lambda_{14} \\ \lambda_{21} & \lambda_{22} & \lambda_{23} & \lambda_{24} \\ \lambda_{31} & \lambda_{32} & \lambda_{33} & \lambda_{34} \\ \lambda_{41} & \lambda_{42} & \lambda_{43} & \lambda_{44} \end{pmatrix} \begin{pmatrix} \pi_t^* \\ r_t \\ \pi_t \\ x_t \end{pmatrix}
\]

Each row of \( \lambda_t \) determines the price of risk associated with each of the states; these vary over time with the level of the states.
The inflation risk premium

The short-rate inflation premium can be written as

\[ r_t = r_t^* + E_t [\pi_{t+1}] + prem_{\pi,t}^1 + \frac{1}{2} \Sigma_{\pi} \Sigma_{\pi}' \]

where

\[ prem_{\pi,t}^1 = -\Sigma_{\pi} (\lambda_0 + \lambda_1 X_{1,t}) \]
\[ \Sigma_{\pi} \equiv C_{\pi} \Sigma \quad \text{“amount of risk”} \]
\[ \lambda_t = \lambda_0 + \lambda_1 X_{1,t} \quad \text{“price of risk”} \]
Estimation

• Bayesian Maximum Likelihood using Kalman Filter; we exploit prior information on structural economic relationships.

• Real yields enter the likelihood function late in the sample (US - 2003; euro area - 2004); reduces initial liquidity problems.

• Survey data information (inflation and short-term interest rate) explicitly included in the estimation.

• Estimation using simulated annealing to reduce risk of local maxima.
Data - US sample: January 1990 — April 2008

- Macro data: y-o-y inflation, output gap (log-GDP in deviations from CBO estimate of potential; ARIMA forecast/interpolation)

- Nominal yields: 1-, 3-, 6-, 12-m, 3-, 5-, 10-y zero-coupon rates (Fed Board)

- Real yields: 3-, 5-, 7-, and 10-y zero-coupon rates extracted from US TIPS (as of 2003)

- Survey data: 3-m rate and inflation in 2/4 quarters and next 10 years (SPF)
Data - euro sample: January 1999 – April 2008

- Macro data: y-o-y inflation, output gap (log-GDP in deviations from a quadratic trend, as in CGG98; ARIMA forecast/interpolation)

- Nominal yields: 1-, 3-, 6-, 12-m, 3-, 5-, 10-y zero-coupon rates extracted from German bond prices and EUR money market rates

- Real yields: 3-, 5-, 7-, and 10-y zero-coupon rates extracted from French and German HICP-linked bonds

- Survey data: 3-m rate in 3/12 months (Consensus); inflation 1, 2, 5 years ahead (SPF)
Results: Inflation and estimated inflation target - US
Inflation and estimated inflation target: euro area
Term structure of average risk premia: US
Term structure of average risk premia: euro area
Estimated 10-year US premia

- -- nominal premium
- --- inflation premium
US 10-year break-even inflation rates and survey inflation forecasts
Euro area 10-year break-even inflation rates and survey inflation forecasts
Estimated US 10-year inflation risk premium and output gap
Estimated US 10-year inflation risk premium and inflation
Estimated euro 10-year inflation risk premium and output gap

![Graph showing estimated euro 10-year inflation risk premium and output gap from 2000 to 2009. The solid line represents the 10-year inflation premium, and the dashed line represents the output gap (rescaled).]
Estimated euro 10-year inflation risk premium and inflation
Responses to an output gap shock: US

- 2y break-even rate to gap
- 10y break-even rate to gap
- 2y expected inflation to gap
- 10y expected inflation to gap
- 2y inflation premium to gap
- 10y inflation premium to gap
Responses to an inflation shock: US
Responses to an output gap shock: euro area
Responses to an inflation shock: euro area

By break-even rate to inflation

10y break-even rate to inflation

By expected inflation to inflation

10y expected inflation to inflation

By inflation premium to inflation

10y inflation premium to inflation
Conclusions

- Using a macro-finance model for real and nominal term structure dynamics, we provide estimates of the size and dynamics of inflation risk premia in the US and the euro area.
- Our framework allows us to obtain macro interpretations of term structure and premia dynamics.
- Inflation risk premia are positive and relatively small on average; they vary over time, mostly in response to output gap and inflation changes.
- Break-even inflation rates are therefore a noisy measure of inflation expectations, but, at least in the US, much of their variation seem to be due to changes in expected inflation.
Extra slides
Figure 1a: US nominal zero-coupon yields
Figure 1b: Euro area nominal zero-coupon yields
Figure 2a: US real zero-coupon yields
Figure 2b: Euro area real zero-coupon yields
Figure 3a: US zero-coupon break-even inflation rates
Figure 3b: Euro area zero-coupon break-even inflation rates