DOES THE EURO-ZONE DIVERGE? A STRESS INDICATOR FOR ANALYZING TRENDS AND CYCLES IN REAL GDP AND INFLATION

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Abstract

This paper presents a stress indicator for the Euro-zone that summarizes developments of trends and cycles in real GDP and inflation in the member countries. Stress in a country is defined as the difference between the country's actual short-term interest rate and the interest rate that would prevail if that country was able to follow an "optimal" monetary policy. The optimal monetary policy rule corresponds to the policy rule that was adopted by the country in the pre-EMU period and depends on the trend growth rates of GDP and consumer prices as well as on the related cyclical components. The main results are that stress in the Euro-zone is mainly due to different trend growth rates and that for most of the Euro-zone countries interest rates have been too low over the 1999-2005 period. Stress in Germany is close to zero, implying that the ECB continues the policy of the Bundesbank.

JEL Code: E31, E32, E58.

Keywords: stress indicator, Taylor rule, monetary union, divergence, trends, cycles.

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1 Introduction

In a recent article, Charles Wyplosz (2006) argued forcefully that the foundation of the European monetary union (EMU) happened more for political reasons than because of a strong belief that the potential European member countries constitute an optimum currency area. A monetary union entails advantages and disadvantages for the individual member countries. A monetary union lowers transaction costs in international trade and eliminates part of the exchange rate uncertainty. On the other side, each country looses the ability to conduct an independent monetary and exchange rate policy for smoothing business cycles and facilitating necessary changes of relative prices. Weighting the positive and negative aspects one can conclude that the benefits of a monetary union will dominate if the international mobility of labor as well as wage and price flexibility are high, if inflation rates are similar and national business cycles are highly correlated.

In the nineties of the last century there appeared a great number of studies which argued that the member states of the planned European monetary union do not form an optimum currency area: Real wages were rigid and the mobility of labor low, shocks were asymmetrically distributed among countries, inflation rates very different and the correlation between the national business cycles rather low. Paul Krugman (1993) pointed out that a monetary union will lead to higher specialization which implies that sector specific shocks will imply less synchronized national business cycles. The opposite suggestion was launched by Frankel and Rose (1998). They argued that the criteria for an optimum currency area are endogenous and that a monetary union will intensify international trade and synchronize economic activities. Countries could constitute an optimal currency area after launching a monetary union even if they do not ex ante.

At the time of the creation of the European monetary union the skeptical views dominated among economists. A prominent example was Martin Feldstein (1997) who expected that EMU will perpetuate structural unemployment and will raise the inflation rate as well as the likelihood of intra-European conflicts and protectionism.

Empirical studies in recent years showed that such horror scenarios not happened in reality. In the empirical literature there seems to emerge a consensus that the co-movements of real and nominal variables are relatively high in the Euro-zone and that cyclical asymmetries are relatively small among the member states (see for example Benalal et al., 2006, and Giannone and Reichlin, 2006). Nevertheless, from time to time we see a heated debate in the policy area concerning a potentially increasing divergence process.

Against this background, the aim of this paper is to analyze the development of the dispersion of real GDP and consumer price inflation across the Euro-zone countries from 1970 to 2005. For both variables we decompose the observed time series into a trend and a cycle component. In contrast to other studies we do not use a single method for this decomposition but apply different approaches in order to minimize statistical distortions. We then develop a stress indicator for the Euro-zone. According to Clarida et al. (1998) stress in a particular member country is defined as the difference between the country's actual short-term interest rate and the interest rate that would prevail if that country was able to follow an "optimal" monetary policy. The optimal monetary policy rule corresponds to the policy rule that was adopted by the country in the pre-EMU period. Aggregate stress in the Euro-zone is computed as a weighted average of country-specific stresses. This summary measure depends on the trend growth rates of GDP and consumer prices of each member country as well as on the related cyclical components. The proposed stress indicator can serve as a useful measure of relevant divergence tendencies in the EMU.

The main result of our analysis is that stress in the Euro-zone is mainly due to different trend growth rates of GDP and consumer prices. For most of the Euro-zone countries interest rates have been too low over the 1999-2005 period and would, on average, be higher by one or – depending on the construction of the stress indicator – two percentage points, if the countries were able to continue following the optimal policy rule they adopted in the pre-EMU period. By contrast, cyclical dispersion is rather low and the related stress is only minor in relation to the trend component of stress. An important finding of the analysis is that stress in Germany is close to zero all over the 1999-2005 period, implying that the ECB continues the policy of the German Bundesbank.

The paper is structured as follows. In Section 2 we decompose real GDP and consumer prices into a trend and a cycle component and look at traditional measures of dispersion across countries. In Section 3 we develop the stress indicator for the Euro-zone. Section 4 summarizes the main results and concludes.

2 Trends and cycles in real GDP and consumer price inflation

2.1 Determination of trends and cycles

Extracting the trend and cycle component from an observed time series is not a trivial task. There exist a number of filters with different “philosophies” and assumptions for accomplishing this decomposition. This is a serious practical problem as the estimated cycles differ sometimes dramatically between different approaches (see for example Canova, 1998).

The most popular approaches used in the literature are the Hodrick-Prescott filter (Hodrick and Prescott, 1997), the Baxter-King filter (Baxter and King, 1999), the Christiano-Fitzgerald filter (Christiano and Fitzgerald, 1999) and the Rotemberg filter (Rotemberg, 1999). In some sense all these methods are ad-hoc filters, as their implementation is not based on the characteristics of the time series under consideration. For this reason, we estimate an Unobserved Components model, which delivers a model-based filter that is consistent with the data (for a discussion see Harvey and Trimbur, 2003).

The most used filter for decomposing a time series into trend and cycle is the *Hodrick-Prescott* filter. The trend is determined by the requirements that it should be not too far away from the actual time series and that it should show a smooth behavior, measured by the squared change of the trend growth rate. The relative weight of the second requirement is determined by a smoothing parameter, which is to be determined a-priori and is set to the standard value of 1600. The cycle is constructed by subtracting the estimated trend from the observed series. The *Baxter-King* and *Christiano-Fitzgerald* filters for extracting the cycle are band-pass filters. They are based on the idea that the business cycle is defined by a sharp range of frequencies which corresponds typically to a periodicity in the range of 6 to 32 quarters. This “ideal” filter is approximated in the *Baxter-King* approach by a symmetric moving average with a finite lead/lag length (in this paper: 8 quarters). The *Christiano-Fitzgerald* filter is asymmetric and uses all observations for estimating the cyclical component. For both the Baxter-King and the Christiano-Fitzgerald filters the trend component is constructed by subtracting the high-frequency component (periodicity between 2 and 32 quarter) from the original time series. The *Rotemberg* filter is based on the basic assumption of a “very smooth” trend. This idea is implemented by the requirement that the covariance between the cycle in period t and period $t+16$ be as small as possible, provided that the change in the trend growth rates over some horizon (lead/lag of 5 quarters) is uncorrelated with the cycle in t. In order to mitigate the end point problem we use the forecasts of the OECD for 2006 and 2007 in the Economic Outlook (June 2006).

In the *Unobserved Components* model the log of the observed time series x_t is specified as the sum of a trend, a cycle and an irregular component:

$$x_t = T_t + C_t + I_t \,. \tag{1}$$

The *trend component* T_t represents the long-run development of the series and is specified as a random walk with a possibly time-varying drift rate μ_t:

$$T_t = T_{t-1} + \mu_{t-1} + \varepsilon_t \,. \tag{2}$$

The level impulse ε_t is a white noise variable with mean zero and variance σ_ε^2. The drift rate μ_t is allowed to vary over time and is also defined as a random walk:

$$\mu_t = \mu_{t-1} + \xi_t \,. \tag{3}$$

The drift impulse ξ_t is a white noise variable with variance σ_ξ^2. The model specified in equations (2) and (3) implies that the trend component follows an $IMA(2,1)$-process. Special cases emerge when we set the variance of the shocks to zero. If both are zero, we get a deterministic linear trend. If σ_ξ^2 is zero and σ_ε^2 is strictly positive, the model collapses to a random walk with a constant drift rate. The opposite case with a strictly positive σ_ξ^2 and σ_ε^2 equal to zero gives an integrated random walk with a usually smooth trend component. This is the specification we use in the following.

The *cycle* C_t captures the business cycle fluctuations around the trend component and is modeled as the sum of M subcycles with different frequencies:

$$C_t = \sum_{i=1}^{M} C_{t,\,i} \ . \tag{4}$$

The specification of the total cycle as the superposition of subcycles with different frequencies is able to represent some ideas of classical business cycle theory (e.g., the existence of Kitchin or Juglar cycles) and to capture several forms of business cycle asymmetries (for some alternative specifications see Harvey and Trimbur, 2003).

Each subcycle is specified as a vector $AR(1)$ process:

$$\begin{pmatrix} C_{t,\,i} \\ C^*_{t,\,i} \end{pmatrix} = \rho_i \begin{pmatrix} \cos\ \lambda_i^C & \sin\ \lambda_i^C \\ -\sin\ \lambda_i^C & \cos\ \lambda_i^C \end{pmatrix} \begin{pmatrix} C_{t-1,\,i} \\ C^*_{t-1,\,i} \end{pmatrix} + \begin{pmatrix} \kappa_{t,i} \\ \kappa^*_{t,i} \end{pmatrix}. \tag{5}$$

C^* appears only by the construction of the recursion and has no intrinsic interpretation. The period of subcycle i is $2\pi / \lambda_i^C$ with λ_i^C the frequency in radians. The damping factor ρ_i with $0 < \rho_i \leq 1$ ensures that $C_{t,\,i}$ is a stationary $ARMA(2,1)$ process with complex roots in the AR-part (see Harvey, 1989). This guarantees a quasi-cyclical behavior of $C_{t,\,i}$. The shocks $\kappa_{t,\,i}$ and $\kappa^*_{t,\,i}$ are assumed to be uncorrelated white noise variables with common variance $\sigma^2_{\kappa_i}$. They induce a stochastically varying phase and amplitude of the wave-like process. The total cycle C_t is an $ARMA(2M, 2M-1)$ process with restricted MA-parameters. Some pre-testing revealed that a model with $M = 2$ subcycles delivers a good representation of most of the time series analyzed in the following.

The *irregular* I_t is specified as a white noise process.

2.2 The data

Most of the data has been taken from the Economic Outlook Database of the OECD, Volume 2006 release 01. It is quarterly, covers the period 1970 Q1 – 2007 Q4, and includes the forecasts published in the OECD Economic Outlook June 2006. Real GDP, Y_t, is measured by the series

"Gross Domestic Product (Market prices), Volume", which is converted into euros for the pre-1999 period. For Austria no quarterly data was available in the Economic Outlook Database, Volume 2006 release 01. Thus, we linked three different time series: For the period 1970 Q1 – 1987 Q4 we used quarterly data published in the Economic Outlook Database, Volume 2005 release 01; for the period 1988 Q1 – 2005 Q4 quarterly data was taken from the OECD Main Economic Indicators Database; for the period 2006 Q1 – 2007 Q4 we finally used the annual forecast for 2006 (2.5%) and 2007 (2.2%) as published in the OECD Economic Outlook June 2006 and distributed these growth rates over quarters under the assumption of constant quarter-on-quarter growth rates. German data was linked to Western German data before 1991. For the period 1970 Q1 – 1990 Q4 real GDP was taken from the Economic Outlook Database, Volume 2005 release 01, and multiplied by a factor 1.13 (which is the average of 1991 Q1-Q4 unified Germany divided by average of 1991 Q1-Q4 Western Germany).

The consumer price index, P_t, is measured by the series "Consumer Price Index, harmonized". For some countries (Austria, Belgium, Finland, France, Germany, Italy and Spain) there is no data available in the Economic Outlook Database, Volume 2006 release 01, before 1991. Again we took the missing data (1970 Q1 – 1990 Q4) from the Economic Outlook Database, Volume 2005 release 01.

2.3 Results

For all five detrending approaches the analyzed time series are the log of real GDP, $y_t = \ln Y_t$, and the log of the consumer price index, $p_t = \ln P_t$. The trends of both variables are denoted by $\overline{y}_t$ and $\overline{p}_t$. The trend growth rate of real GDP is given by $g_t^{\overline{Y}} = \overline{y}_t - \overline{y}_{t-4}$, and the GDP cycle is measured by the output gap, which is calculated as $\hat{y}_t = y_t - \overline{y}_t$. The trend inflation rate is given by $\overline{\pi}_t = \overline{p}_t - \overline{p}_{t-4}$; the cyclical inflation rate is simply the residual between headline inflation and trend inflation, $\hat{\pi}_t = \pi_t - \overline{\pi}_t$. In order to get a single measure of the trend and cycle in GDP and prices for each country we calculated the unweighted median of all methods. Figure 1 shows the detailed results for German GDP (top panel) and the medians of all approaches (bottom panel). The medians of the output gaps for all countries are displayed in Figure 2, the medians of all trend growth rates in Figure 3. Figure 4 to Figure 6 show the corresponding results for consumer prices.

Figure 1: Output gaps (left panel) and trend growth rates (right panel), Germany

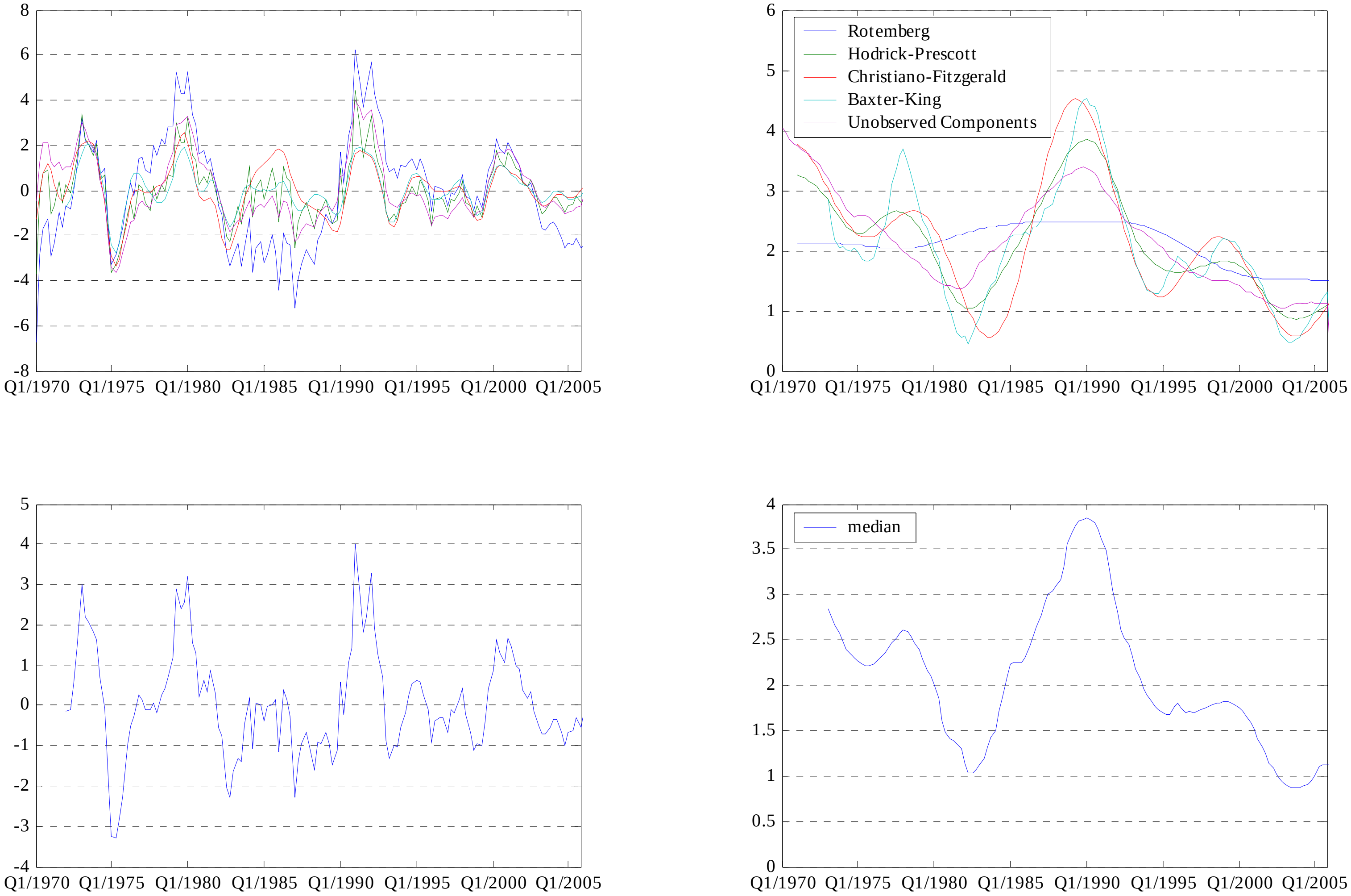


Figure 2: Median output gaps ($\hat{y}_{i,t}$)

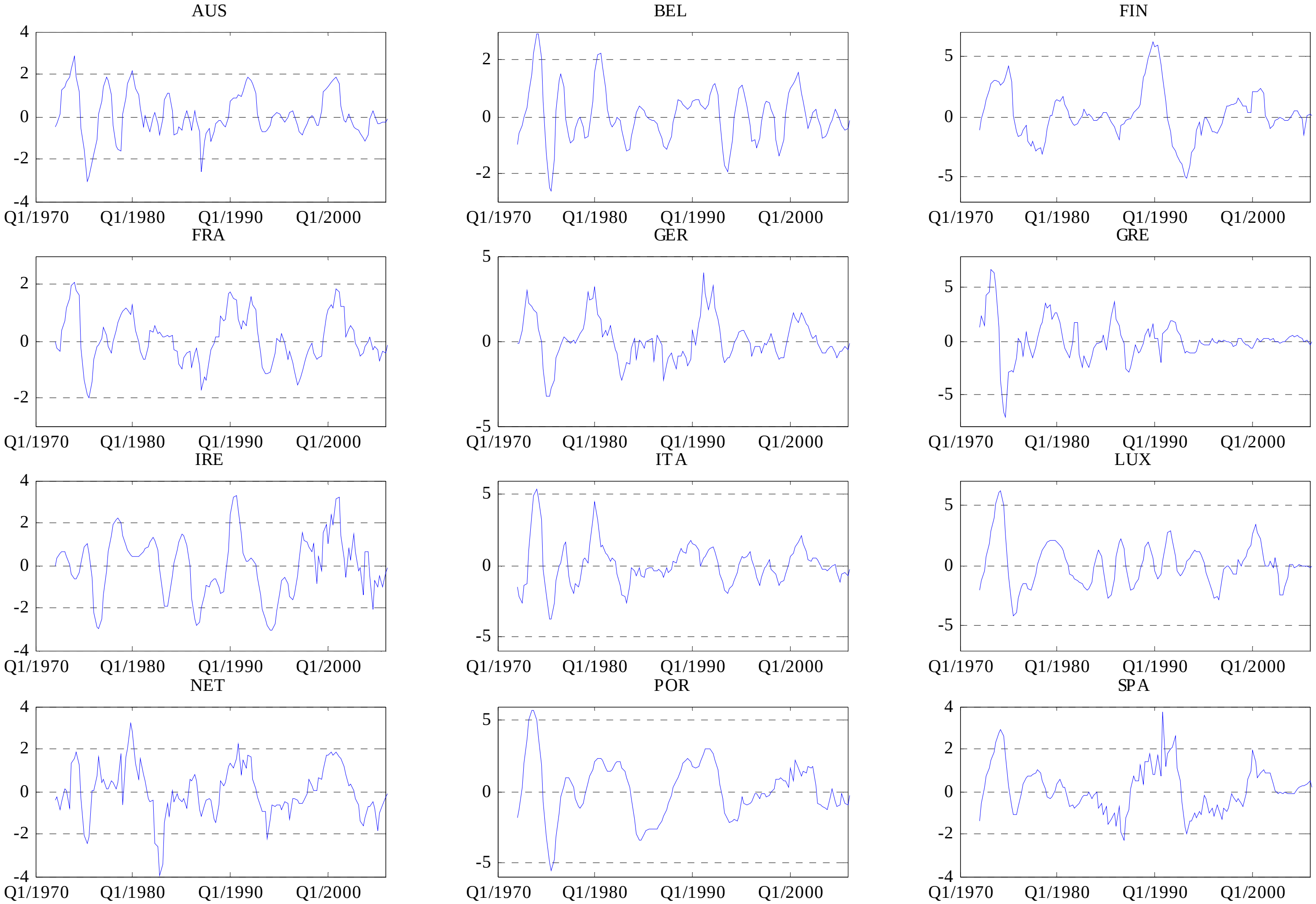


Figure 3: Median trend growth rates ($g_t^{\bar{Y}}$)

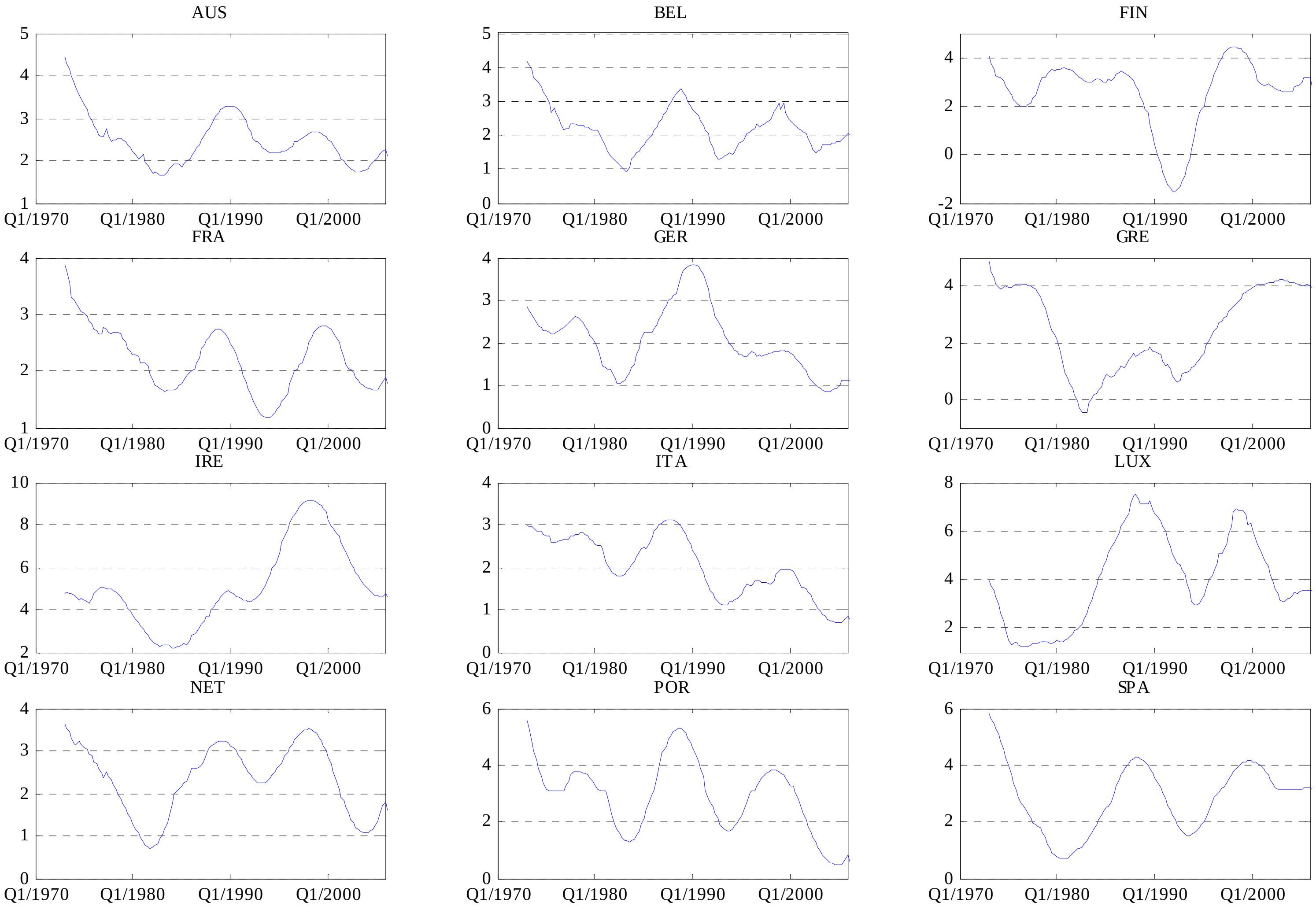


Figure 4: Cyclical inflation rates (left panel) and trend inflation rates (right panel), Germany

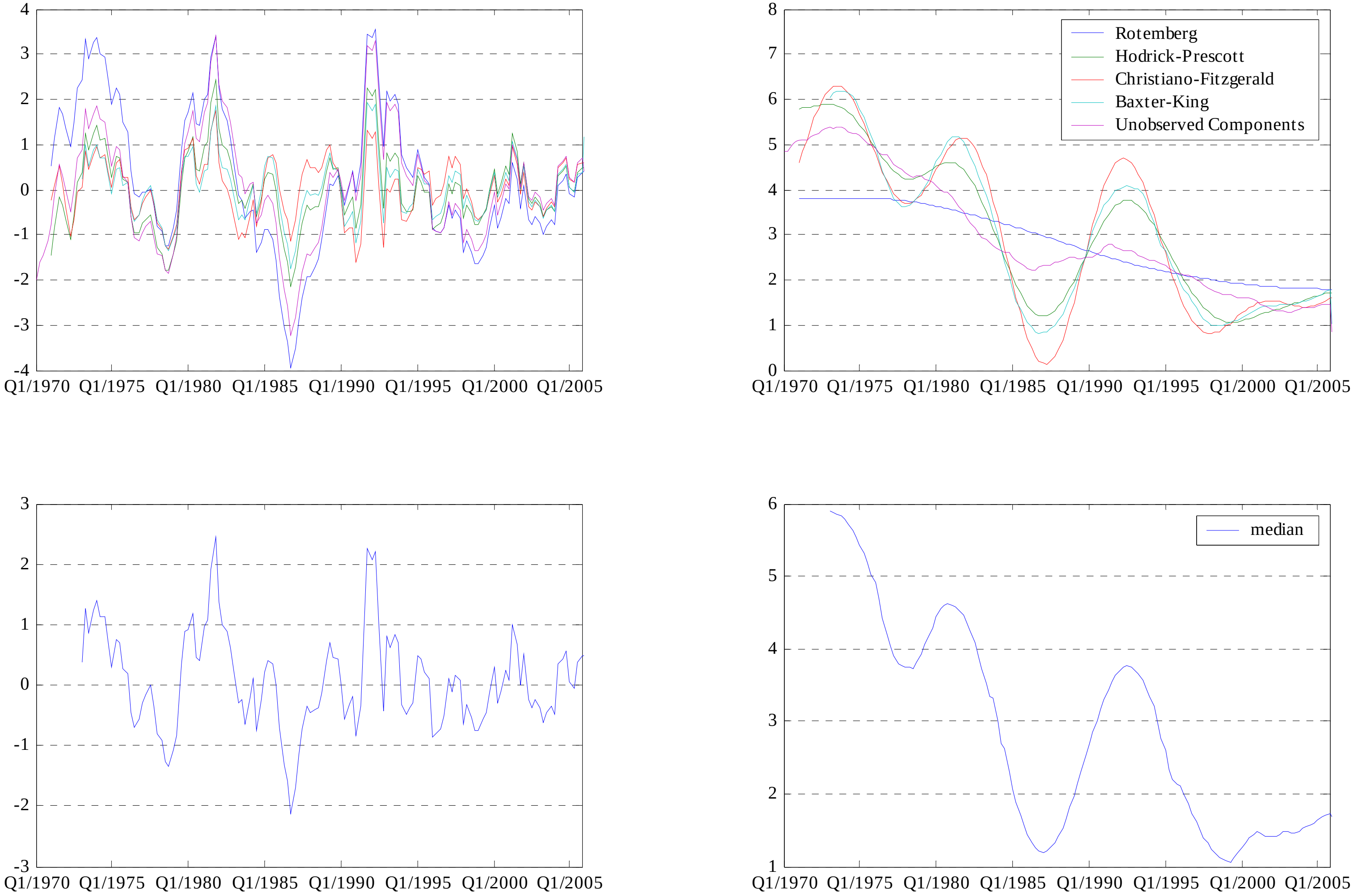


Figure 5: Median cyclical inflation rate ($\hat{\pi}_{i,t}$)

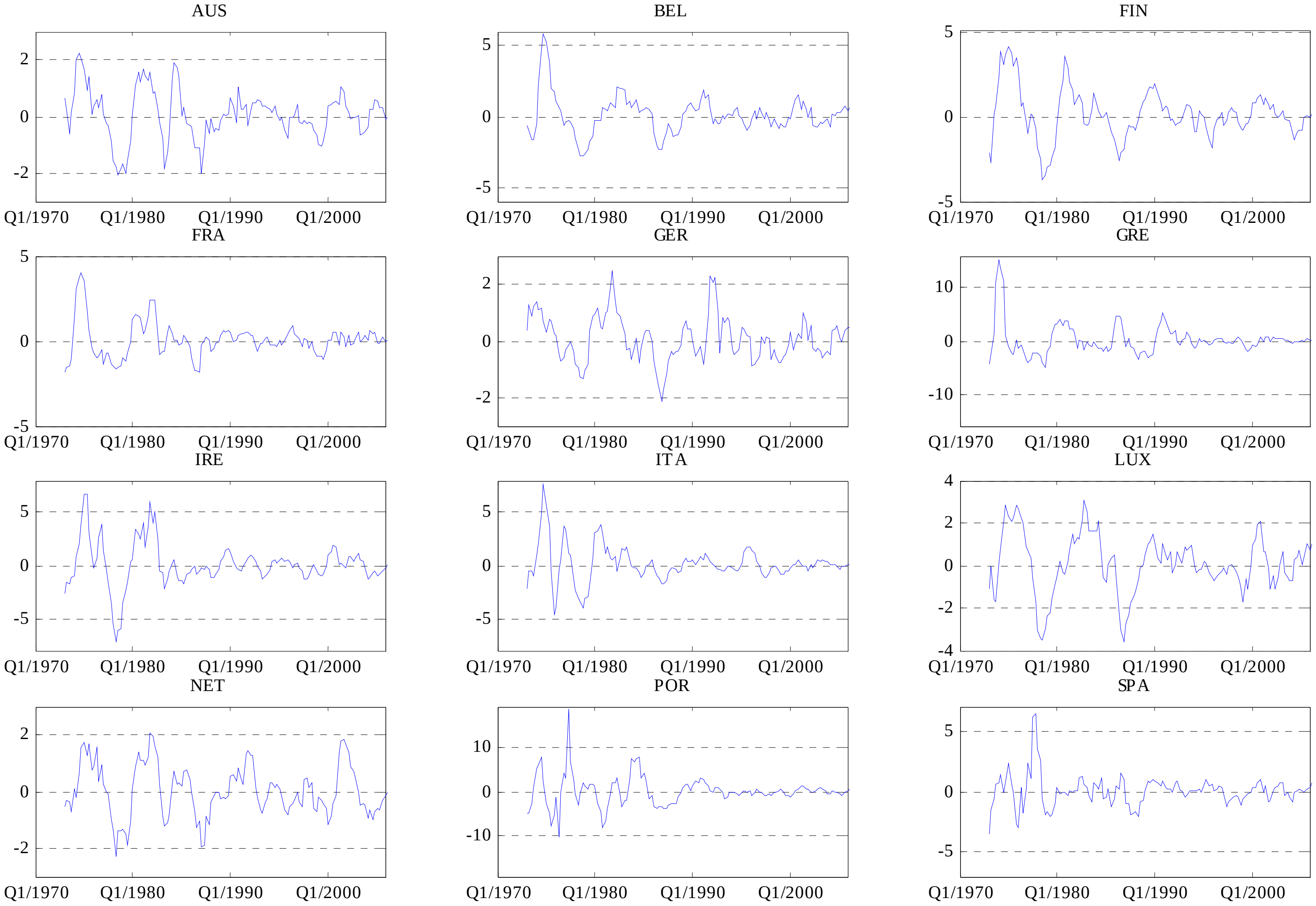
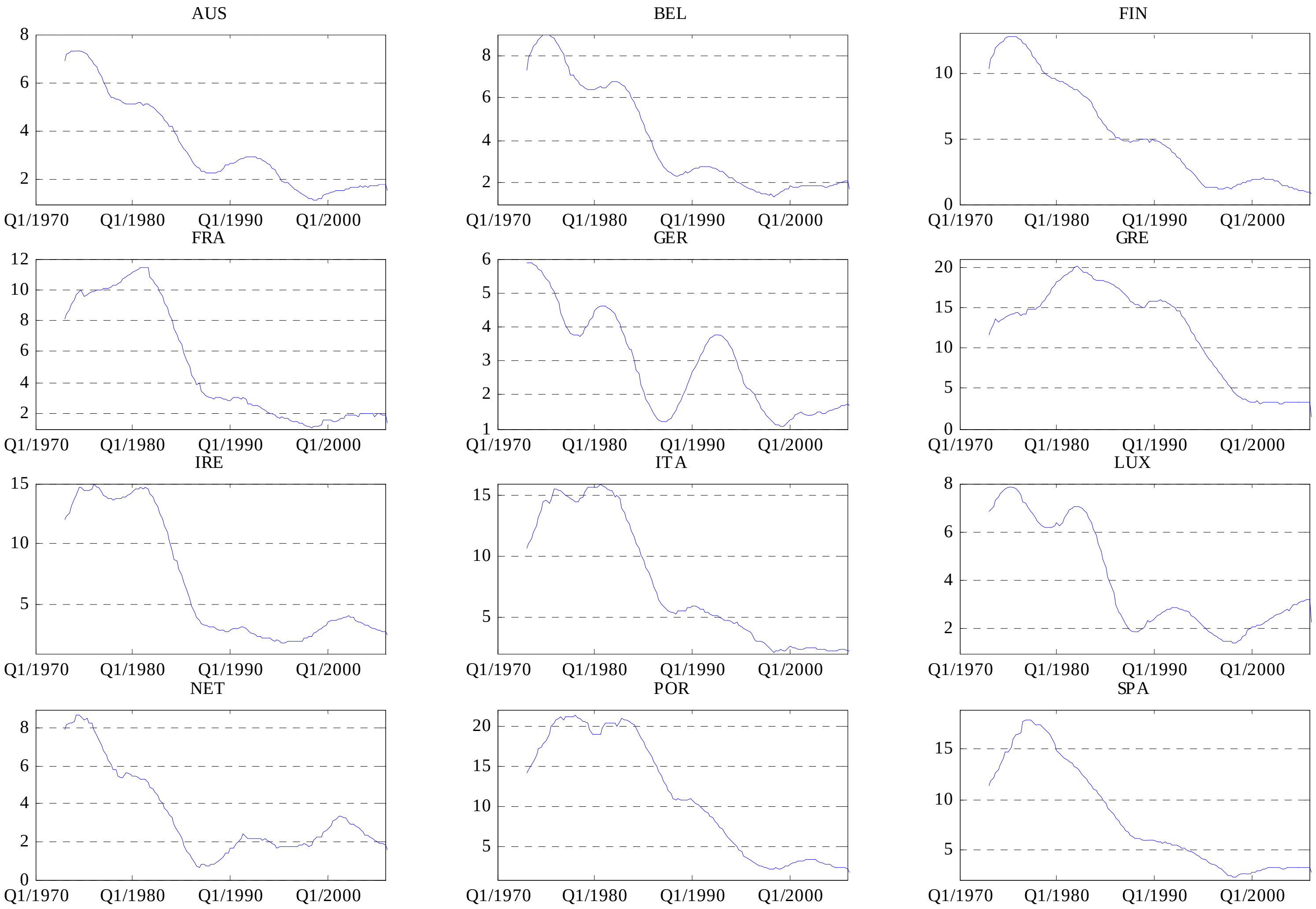


Figure 6: Median trend inflation rate ($\bar{\pi}_{i,t}$)



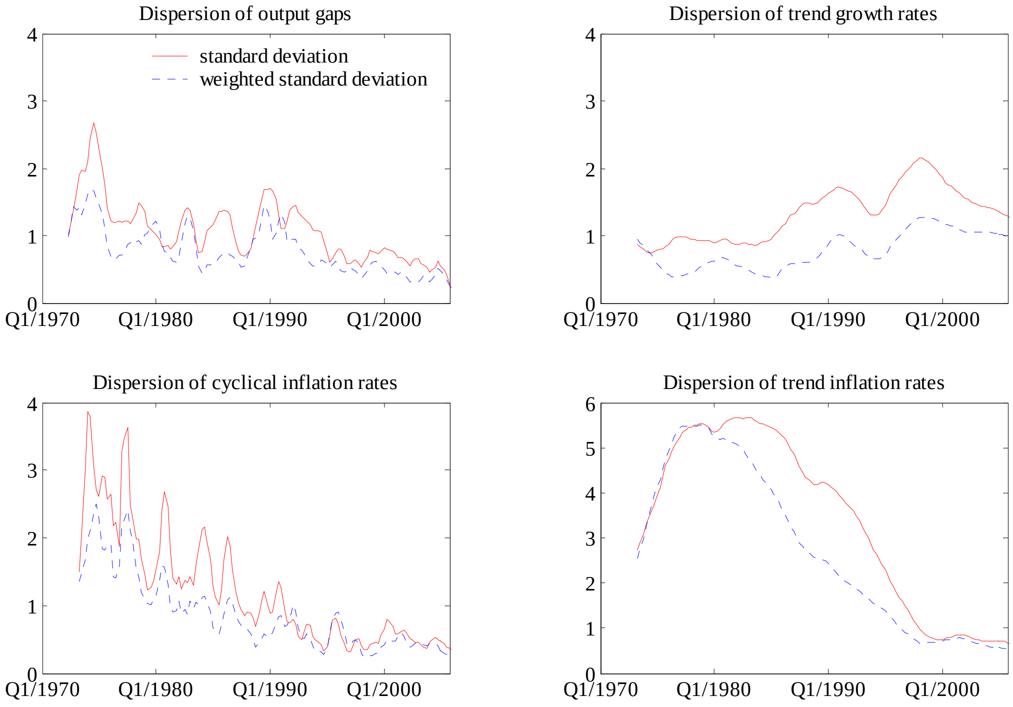
2.4 Dispersion of trends and cycles

A popular measure of convergence is the dispersion of trend growth rates and cycles (see for example ECB, 2003, and Benalal et al., 2006). In its most simple version it is given by the standard deviation of the variable under consideration, x, at time t. If the countries' economic sizes differ from each other it is convenient to calculate a weighted standard deviation:

$$sdw_t = \sqrt{\sum_{i=1}^{N} w_{i,t}\left(x_{i,t} - x_t^{avgw}\right)^2 \Bigg/ \frac{(N-1)\sum_{i=1}^{N} w_{i,t}}{N}}\,, \qquad (6)$$

where $w_{i,t}$ is the weight for the i^{th} country, N is the number of countries, and x_t^{avgw} is the weighted mean of the observations. The country weights are given by country i's value of real GDP relative to the value of real GDP of all $N = 12$ EMU countries, $w_{i,t} = Y_{i,t} \Big/ \sum_{j=1}^{12} Y_{j,t}$.

Figure 7: Dispersion of trends and cycles



Notes: The lines have been smoothed using a centered three-quarter moving average.

The upper left panel of Figure 7 shows the unweighted and weighted standard deviations of the output gaps in the Euro-zone countries. In most periods the weighted measure is lower than the unweighted. This implies that the degree of business cycle synchronization among the largest countries (especially Germany, France and Italy) is higher than between the larger and smaller or within the smaller countries. In the seventies and eighties the weighted standard deviations fluctuates between 0.5 and 1.5. During the past 15 years we observe a more or less steady decline in the dispersion of output gaps in the Euro-zone, for both the weighted and unweighted standard deviation.

The upper right panel shows the dispersion of the trend growth rates. In contrast to the output gaps, the dispersion of trend grows rates increased remarkably from the beginning of the seventies to the end of the nineties. Since 1998 there exists a clear reduction in the dispersion.

The dispersion measures for the cyclical (lower left panel) and the trend component (lower right panel) of the inflation rate show a dramatic change over the past 30 years. For both components there is a clear and pronounced tendency to a more homogeneous inflation development in the Euro-zone countries. This is especially important for the trend inflation rates: After a peak in the fist half of the eighties the standard deviation declined steadily from a value of over 5 to less than 1.

The figures show that the dispersion of the cyclical components of GDP and inflation is lower since the start of the Euro system than it was ever during the past 30 years. There is no sign of a cyclical divergence in recent years. The dispersion of the trend growth rate of inflation has now the lowest values observed in the past three decades. The dispersion of the trend growth rate of GDP is still at relatively high level, but is declining since the start of the euro system.

3 A stress indicator for the euro-zone

Instead of calculating and interpreting various measures of dispersion for the trend and cycle component of real GDP and consumer price inflation, it would be desirable to combine all these elements into a single indicator whose evolution over time provides important information concerning the adequacy of a single monetary policy for each of the EMU member countries. Clarida et al. (1998) were the first to propose a so-called stress indicator, which they used to analyze the causes of the 1992/93 crisis of the European Monetary System (EMS). Generally spoken, stress in a monetary system occurs when for whatever reason a central bank is unable to set its policy instrument optimally.

More specifically, stress in country i, $S_{i,t}$, is defined as the gap between the current nominal interest rate in country i, $i_{i,t}$, and the interest rate that would prevail in country i if it was able to follow an optimal interest rate policy, $i_{i,t}^{*}$:

$$S_{i,t} = i_{i,t} - i_{i,t}^{*}. \tag{7}$$

In the case of $S_{i,t} > 0$, actual monetary policy is too tight, whereas for $S_{i,t} < 0$ monetary policy too loose. Of course, a stress indicator only makes sense in a monetary arrangement in which the central bank of country i is not able to adjust its policy instrument $i_{i,t}$ autonomously. A monetary union, as the EMU, is a prime example for such an arrangement.

For the construction of a stress indicator for the current EMU we proceed in two steps. In a first step (Section 3.1) we estimate a Taylor rule for each country for the period starting in 1982 Q1 and ending in 1998 Q4.[1] A Taylor rule belongs to the class of simple monetary policy rules that provide two types of information to a central bank that aims at stabilizing inflation around a target level and output around its trend:

$$i_{i,t}^{\text{Taylor}} = \bar{i}_{i,t} + f_i\left(\hat{y}_{i,t}, \hat{\pi}_{i,t}\right). \tag{8}$$

On the one hand, the Taylor interest rate, $i_{i,t}^{\text{Taylor}}$, is pinned down by the neutral interest rate, $\bar{i}_{i,t}$, which corresponds to the nominal interest rate that would prevail if all prices were flexible. Woodford (2003, Chapter 4) refers to this rate as the Wicksellian natural rate of interest. Put more practically, the neutral interest rate is equal to the nominal interest rate that would prevail if the output gap was closed and inflation was at target. On the other hand, the Taylor rule prescribes the central bank how to adjust its operating target whenever the output gap, $\hat{y}_{i,t}$, or the inflation gap, $\hat{\pi}_{i,t}$, deviates from zero. Thus, it represents a feedback rule that leads to cyclical movements of the nominal interest rate around the neutral interest rate, which are governed by

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[1] As Greece only entered the EMU in January 2002, the Greek Taylor rule was estimated over the period 1982 Q1 – 2001 Q4.

the feedback term $f_i\left(\hat{y}_{i,t},\hat{\pi}_{i,t}\right)$. Here we assume that the estimated Taylor rules correspond to an optimal simple rule, i.e. $i_{i,t}^{\text{Taylor}} = i_{i,t}^{*}$, that is followed by each central bank in the pre-EMU period. Thus, the feedback coefficients to deviations of inflation from target and output from trend not only contain the structural parameters of each country, but also the preferences of each central bank towards inflation and output stabilization (Woodford, 2003, Chapter 7).

In a second step (Section 3.2) we calculate the stress indicator for each country and for total EMU in the post-1999 period, in which the ECB sets the common interest rate i_t so that $i_{i,t} = i_t$ for all countries i.[2] The ECB also implements its monetary policy according to a policy rule, which ideally represents a weighted average of national preferences and national structural parameters. But since we are interested in the adequacy of the common monetary policy for national stabilization purposes, this rule needs not to be estimated. The stress indicator rather compares the common monetary policy with the monetary policy that would be implemented, if each country still was able to set interest rates autonomously according to the country-specific optimal rule, which we estimated for the 1982-1998 period. Of course, the countries have never been subject to a fully autonomous monetary policy in that period as most of them followed some kind of exchange rate target against the German mark. But the possibility to readjust the par-value in the EMS as well as the existence of capital controls provided each central bank with some leeway to pursue domestic policy objectives. Note that a basic assumption underlying this procedure is that both the structural parameters and the preferences did not change following the implementation of the common central bank. While this assumption should be uncontroversial with respect to structural parameters, the unchanged preferences could be questioned against the background of the delegation of monetary policy decision-making to a new and independent supranational institution that has been agreed upon by all participating countries by signing the Maastricht Treaty.

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[2] For Greece stress was calculated from 2002 Q1 on (see footnote 1).

3.1 Taylor rule estimation

For the estimation of the Taylor rule we assume the following empirical specification for the pre-1999 period, which takes account of interest rate smoothing, i.e. a lagged nominal interest rate as additional explanatory variable:

$$i_{i,t} = \beta_{i,1} i_{i,t-1} + \left(1-\beta_{i,1}\right)\left(g_{i,t}^{\bar{Y}} + \bar{\pi}_{i,t} + c_{i,t} + \beta_{i,2}\hat{\pi}_{i,t} + \beta_{i,3}\hat{y}_{i,t} + \beta_{i,4}x_{i,t}\right) + \varepsilon_{i,t}\,. \tag{9}$$

The dependent variable, $i_{i,t}$, is the nominal 3-month inter-bank rate, which is taken from the Eurostat database. The country-specific neutral nominal interest rate, $\bar{i}_{i,t}$, is equal to the sum of the trend growth rate of real GDP, $g_{i,t}^{\bar{Y}}$ (which is calculated as $\ln \bar{Y}_{i,t} - \ln \bar{Y}_{i,t-1} = \bar{y}_{i,t} - \bar{y}_{i,t-1}$), the trend inflation rate, $\bar{\pi}_{i,t}$, and a time-varying intercept term, $c_{i,t}$. The cyclical inflation rate and the output gap are given by $\hat{\pi}_{i,t} = \pi_{i,t} - \bar{\pi}_{i,t}$ and $\hat{y}_{i,t} = y_{i,t} - \bar{y}_{i,t}$, respectively. Finally, $x_{i,t}$ denotes the quarter-on-quarter change of the nominal exchange rate against the German mark (an increase is a depreciation). Note that all variables are in percent and that $\hat{y}_{i,t}$, $g_{i,t}^{\bar{Y}}$, $\hat{\pi}_{i,t}$ and $\bar{\pi}_{i,t}$ are the medians computed in Section 2.

This specification deviates from a typical Taylor rule (as for example originally proposed by Taylor, 1993) in several aspects. First, the smoothing term is basically included for empirical reasons as the observed tendency of central banks to adjust interest rates only gradually in response to news leads to a high autocorrelation in the nominal interest rate. Second, the exchange rate term is added in order to account for the countries' effort to stabilize their currencies against the German mark (see Clarida et al., 1998, for a similar approach).

The final aspect, which is the time-varying neutral nominal interest rate, needs some more consideration, as our way of dealing with it is a novelty. The great majority of papers estimating Taylor rules assume that the neutral nominal interest rate is constant over time. Basically, a regression of the following type is run:

$$i_{i,t} = \beta_{i,1} i_{i,t-1} + \left(1-\beta_{i,1}\right)\left(c_i + \beta_{i,2}\hat{\pi}_{i,t} + \beta_{i,3}\hat{y}_{i,t} + \beta_{i,4}x_{i,t}\right) + \varepsilon_{i,t}\,, \tag{10}$$

where the estimate of c_i represents the neutral nominal interest rate. Only recently some authors applied Kalman filter techniques to account for time variability of the intercept (see for example

Boivin, 2005, and Leigh, 2005). As the implied law of motion of the neutral nominal interest rate is an atheoretic random walk, in our paper we go one step further and propose a decomposition of the time-variable neutral nominal interest rate that is motivated by theoretical considerations.

The first component is the neutral real interest rate, which is approximated by the trend growth rate of real GDP, $g_{i,t}^{\bar{Y}}$. With reference to Knut Wicksell's natural real rate of interest, in New Keynesian macroeconomics the neutral real interest rate is defined as the equilibrium real rate of return in an economy where prices are fully flexible and where consequently aggregate demand equals potential output at all times (see Woodford, 2003, Chapter 4, among others). In such a set-up intertemporal utility maximization by representative households yields a log-linear relationship between the real interest rate and the (expected) growth rate of per capita consumption. Under the assumption of a constant capital stock and a constant population the growth rate of per capita consumption is equal to the growth rate of potential (or, to be more precise, flexible-price) output, which is affected inter alia by the rate of technological progress. If the latter is assumed to be the main source of stochastic disturbances, the neutral real interest rate should vary over time and it should be positively correlated with the growth rate of potential output.

The second component of the neutral nominal interest rate is the trend inflation rate, $\bar{\pi}_{i,t}$, which is assumed to reflect the country-specific inflation target. It is clear that this measure only is a crude proxy of the countries' true inflation target, above all in periods when countries followed a strict disinflationary policy. This is one of the reasons why we introduced the time-varying intercept term $c_{i,t}$ as a third component, which captures those movements of the neutral interest rate that are not contained in either the trend growth rate of real GDP or the trend inflation rate.

For the estimation of the Taylor rule we transform the non-linear regression model (9) into a linear estimation equation:

$$\left(i_{i,t} - g_{i,t}^{\bar{Y}} - \bar{\pi}_{i,t}\right) = \tilde{c}_{i,t} + \beta_{i,1}\left(i_{i,t-1} - g_{i,t}^{\bar{Y}} - \bar{\pi}_{i,t}\right) + \tilde{\beta}_{i,2}\hat{\pi}_{i,t} + \tilde{\beta}_{i,3}\hat{y}_{i,t} + \tilde{\beta}_{i,4}x_{i,t} + \varepsilon_{i,t}, \qquad (11)$$

where $\tilde{c}_{i,t} = \left(1-\beta_1\right)c_{i,t}$ and $\tilde{\beta}_{i,j} = \left(1-\beta_{i,1}\right)\beta_{i,j}$ for $j = 2,3,4$. Equation (11) is estimated using the Kalman filter. The unobserved state variable $\tilde{c}_{i,t}$ is assumed to follow a random walk:

$$\tilde{c}_{i,t} = \tilde{c}_{i,t-1} + \xi_{i,t} \,. \tag{12}$$

The estimated coefficients are presented in Table 1. $\beta_{i,1}$ is the smoothing parameter. With the exception of Greece the estimated parameters are highly significant and are in the range between 0.5 and 0.9. The estimated values for $\beta_{i,2}$ and $\beta_{i,3}$ show that central banks reacted positively to the cyclical inflation rate and the output gap. The estimated positive values for $\beta_{i,4}$ imply that a depreciation of the nominal exchange rate against the German mark induced a higher short term interest rate.

In addition to the basic model (equations (11) and (12)), we estimated a restricted model where we set the variance of $\xi_{i,t}$ a priori to zero, which implies that the parameter $c_{i,t}$ is constant over time. The difference between the maximized log likelihood function for the unrestricted and for the restricted model is given by dLF. A likelihood ratio test shows that in most cases the hypothesis of a constant intercept term can be rejected.

The time-varying intercept is shown in Figure 8. It is interesting to see that for most of the countries a similar picture emerges. In the 1980s the intercept term increased, reached its maximum during the 1992/93 EMS crisis, and fell again thereafter. The increase in the intercept term can be interpreted as a positive premium that emerges in a fixed rate system when the inflation differential to the anchor country is high and when financial markets require a risk premium for expected depreciations. Moreover, as most of the countries followed a disinflationary policy, which implies a decreasing inflation target over time, the positive intercept compensates for the underestimation of the true inflationary gap, $\hat{\pi}_{i,t} = \pi_{i,t} - \overline{\pi}_{i,t}$. The fall of the intercept term following the crisis reflects the convergence process in the run-up to EMU and the countries' gain in monetary policy credibility due to their commitment to the EU common currency project. Interestingly, there are some countries, in which a negative intercept appears prior to EMU entry. These countries share the common feature that trend growth rates of real GDP at the end of the 1990s were much higher (more than 4 %, in Ireland even 9 %) than in most other countries. Given that short-term nominal interest rates had already converged to low German levels as a result of the upcoming EMU entry, the negative intercept term can be interpreted an early indicator for stress in these countries as the high trend growth rates would require a more restrictive monetary policy stance.

Table 1: Taylor rule estimation, 1982 Q1 – 1998 Q4

	AUS	BEL	FIN	FRA	GER	GRE	IRE	ITA	LUX	NET	POR	SPA
$\beta_{i,1}$	0.68 (10.0)	0.74 (9.7)	0.88 (18.7)	0.54 (3.4)	0.70 (10.1)	0.13 (0.7)	0.71 (7.3)	0.73 (10.7)	0.76 (13.8)	0.79 (12.7)	0.87 (9.2)	0.65 (5.4)
$\tilde{\beta}_{i,2}$	0.33 (3.1)	0.22 (2.1)	0.13 (1.0)	0.41 (3.3)	0.14 (1.4)	0.28 (1.6)	0.23 (2.4)	0.07 (2.1)	0.27 (2.6)	0.05 (0.5)	0.15 (3.2)	0.07 (0.6)
$\tilde{\beta}_{i,3}$	0.19 (2.1)	0.27 (2.2)	0.27 (4.3)	0.40 (2.2)	0.15 (2.4)	0.26 (0.8)	0.20 (1.2)	0.38 (3.4)	0.15 (2.5)	0.26 (4.6)	0.08 (0.7)	0.08 (0.4)
$\tilde{\beta}_{i,4}$	1.52 (2.3)	0.30 (3.3)	-0.00 (0.1)	0.10 (1.9)	--	0.07 (0.5)	0.12 (1.3)	0.03 (0.9)	0.29 (2.8)	0.44 (4.9)	0.11 (2.5)	0.04 (1.4)
$\beta_{i,2}$	1.02	0.84	1.08	0.89	0.48	0.29	0.79	0.27	1.13	0.22	1.14	0.20
$\beta_{i,3}$	0.58	1.03	2.22	0.88	0.50	0.30	0.68	1.37	0.64	1.25	0.59	0.23
$\beta_{i,4}$	4.75	1.17	-0.01	0.22	--	0.08	0.42	0.12	1.23	2.10	0.80	0.13
dLF	8.7 [0.00]	4.5 [0.00]	0.6 [0.27]	4.9 [0.00]	5.5 [0.00]	8.9 [0.00]	3.2 [0.01]	0.7 [0.24]	1.3 [0.11]	3.6 [0.01]	0.6 [0.27]	6.0 [0.00]

Note: t-values are shown in parentheses; probabilities of the likelihood ratio test (dLF) are shown in brackets.

3.2 Stress indicator

Country-specific stress is calculated for the post-1999 period by replacing $i^*_{i,t}$ in equation (7) with the estimated Taylor rule:

$$S_{i,t} = i_t - \left(c_i + g^{\bar{Y}}_{i,t} + \bar{\pi}_{i,t} + \beta_{i,2}\hat{\pi}_{i,t} + \beta_{i,3}\hat{y}_{i,t}\right). \qquad (13)$$

As we are interested in the deviation of the optimal interest rate for country i from the common interest rate i_t, we ignored the smoothing term and only used the so-called target rate for the calculation of the country-specific stress. The target rate indicates the optimal interest rate that would be set by the central bank if it were able to instantaneously adjust its policy rate to the target rate level. For obvious reasons the exchange rate term was also ignored.

The main problem for the calculation of stress is the intercept term, c_i, which was allowed to vary in the pre-EMU period and for which an assumption has to be made for the EMU period. In this context the crucial question is: what would be the premium on the neutral nominal interest rate if the countries had not participated at the EMS or if the countries had not decided to join EMU? Of course there is no clear answer to this question, so that we have to make an assumption. Specifically, we applied two variants for the setting of c_i in the EMU period. For the first, which is presented in the following, c_i is calculated as the mean of the time-varying intercept term in the 5 years before EMU entry, $c_i = c_{i,5} = 1/20 \sum_{t=1994Q1}^{1998Q4} c_{i,t}$ (see Table 2).[3] The second variant, which is presented in Appendix 2, simply sets c_i to zero. The difference between both is a constant, which takes the values for each country shown in Table 2 and which shifts upward (in the case of $c_{i,5} > 0$) or downward (in the case of $c_{i,5} < 0$) the country-specific stress that is computed for $c_i = 0$.

Table 2: Intercept term $c_{i,5}$ for the EMU period

	AUS	BEL	FIN	FRA	GER	GRE	IRE	ITA	LUX	NET	POR	SPA
$c_{i,5}$	-0.15	0.16	-0.44	1.65	0.10	2.15	-3.85	2.62	-2.28	-0.83	-0.39	0.40

The results for $c_i = c_{i,5}$ are shown in Figure 9. While in Germany (and to some extent also in Austria and Belgium) stress is close to zero in the EMU period, it is generally negative in most of the other countries. This implies that above all in Greece, Spain, Italy, Ireland (before 2003) and France the monetary policy of the ECB is too expansionary if it is evaluated by the countries' pre-EMU central bank policy. In Greece, for example, interest rates would have been 7 percentage points higher if the Greek central bank still had the means to set policy rates autonomously. The picture slightly changes when $c_i = 0$. The French and the Italian stress curves shift upward and are now closer to zero, while negative stress in Ireland, Luxembourg and the Netherlands is more pronounced.

The fact that stress in Germany is close to zero (the mean over the period 1999 Q1 – 2005 Q4 is 0.27 percentage points in the case of $c_i = c_{i,5}$) leads us to conclude that the ECB follows an interest rate rule that is similar to the rule implemented by the Bundesbank in the pre-EMU period. In other words, the ECB sets policy rates in a way the Bundesbank had also done it, if it still were in charge of it. If we now assume that the ECB exactly follows the Bundesbank rule, country-specific stress in the remaining countries can be decomposed into a component which is due to the neutral interest rate differential (the trend component of stress, $S_{i,t}^{trend}$) and a component which is due to the policy feedback to asynchronized movements in the output gap and the cyclical inflation rate (the cyclical component of stress, $S_{i,t}^{cyclical}$):

---

[3] For Greece $c_i = c_{i,5} = 1/20 \sum_{t=1997Q1}^{2001Q4} c_{i,t}$.

$$\begin{aligned} S_{i,t} \quad & \approx i_{GER,t} - i_{i,t} = \\ & = \left(\bar{i}_{GER,t} - \bar{i}_{i,t}\right) + \left(f_{GER}\left(\hat{y}_{GER,t}, \hat{\pi}_{GER,t}\right) - f_i\left(\hat{y}_{i,t}, \hat{\pi}_{i,t}\right)\right) = \\ & = S_{i,t}^{trend} + S_{i,t}^{cyclical}. \end{aligned} \tag{14}$$

The difference between $S_{i,t}$ and $i_{GER,t} - i_{i,t}$ is due to stress in Germany as the replacement of the area-wide interest rate, i_t, with the German interest rate, $i_{GER,t}$, only holds exactly, if stress in Germany is equal to zero: $i_{GER,t} = i_t - S_{GER,t}$.

The results of the decomposition are shown in Figure 10 (in the case of $c_i = 0$). Except for a few periods in Finland, Ireland and Luxembourg, cyclical stress due to differing policy responses to asynchronized movements in the output gap and the cyclical inflation rate is limited. Thus, cyclical convergence in the euro-zone is high. Negative stress mainly results as a consequence of neutral nominal interest rates that are too low compared to the "real" determinants of the country-specific neutral nominal interest rate. A further decomposition of the trend component of stress shows that negative stress is basically due to trend growth rates of real GDP and consumer prices that are much higher in countries like Greece, Ireland, Luxembourg and Spain (see Figure 11). In the case of Luxembourg and Ireland the high trend growth rates are (partially) compensated by the negative estimates of the intercept term. This explains why stress increases in these countries when, when we set $c_i = 0$. Moreover, Figure 11 also reveals that negative stress in France and Italy is mainly caused by the high (positive) estimate of the intercept term c_i, which disappears when we set $c_i = 0$.

Instead of analyzing stress in the EMU on a country level, it would be desirable to get an aggregate measure of stress for total EMU. For this purpose we propose the following two stress indicators:

$$S_{avg,t} = \sum_{i=1}^{12} w_{i,t} S_{i,t} , \tag{15}$$

which is the weighted average of country-specific stresses, and

$$S_{abs,t} = \sum_{i=1}^{12} w_{i,t} \left| S_{i,t} \right| , \tag{16}$$

Figure 8: Estimated time-varying intercept in the pre-EMU period ($c_{i,t}$)

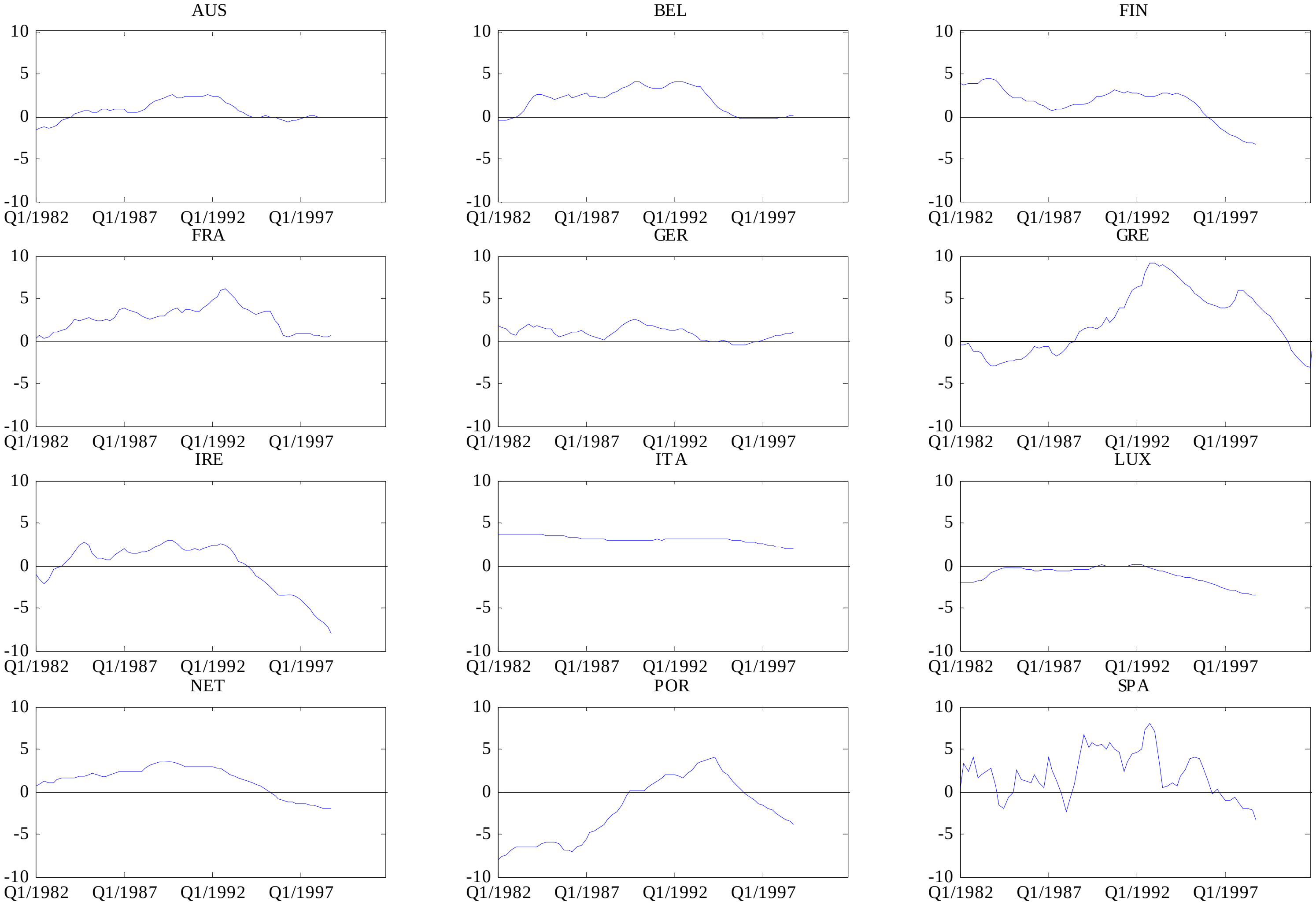


Figure 9: Country-specific stress ($S_{i,t}$)

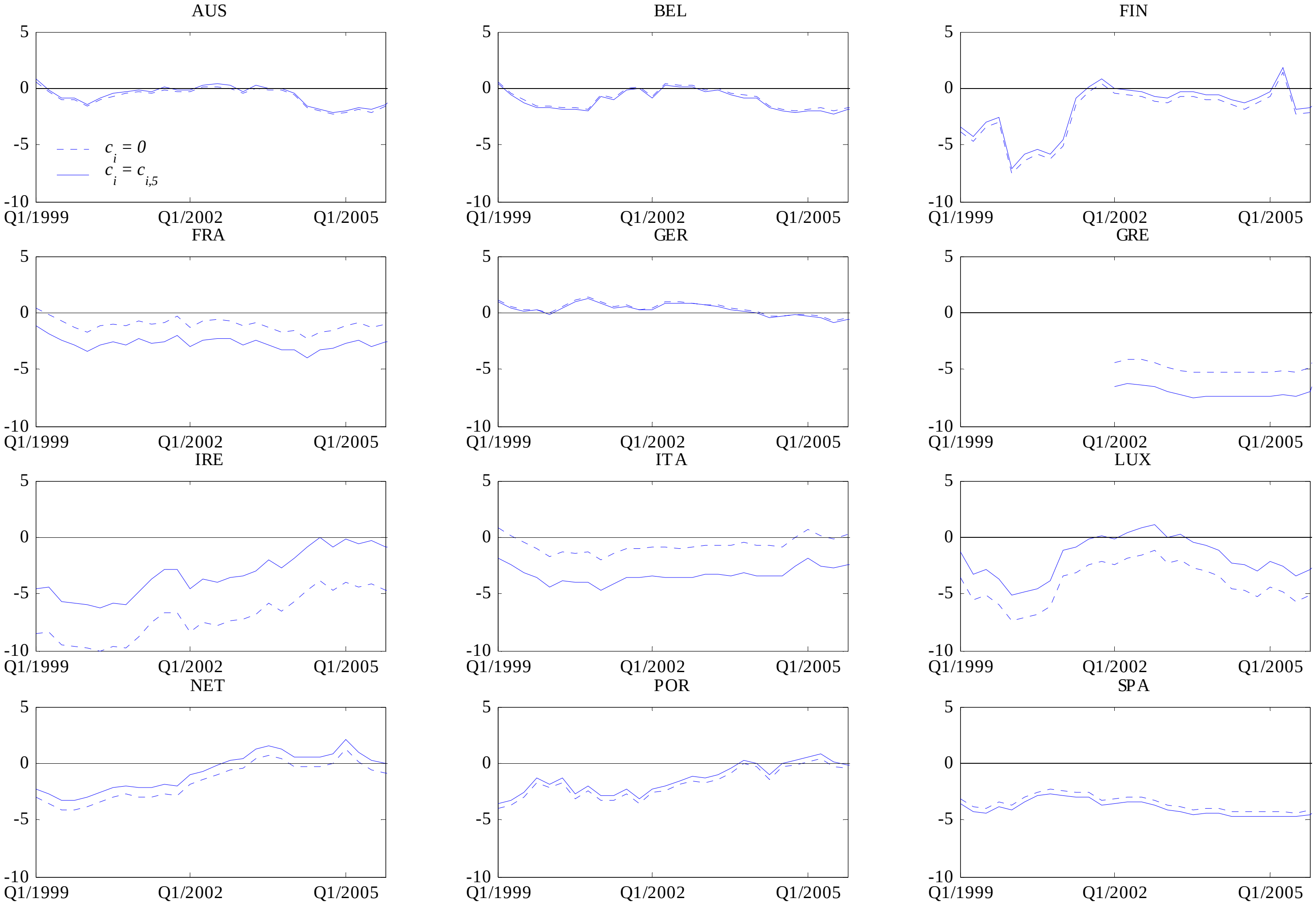


Figure 10: Stress decomposition

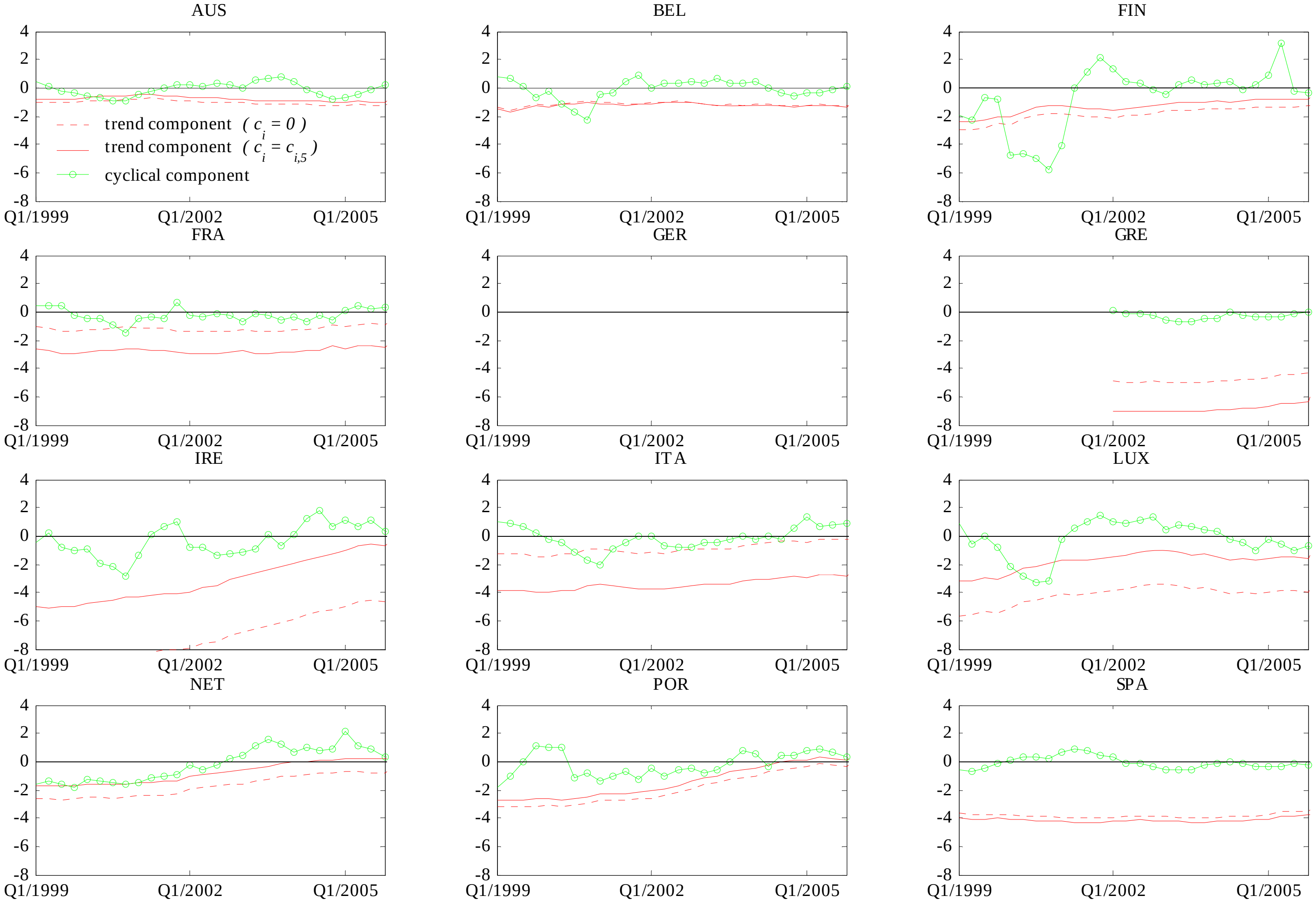
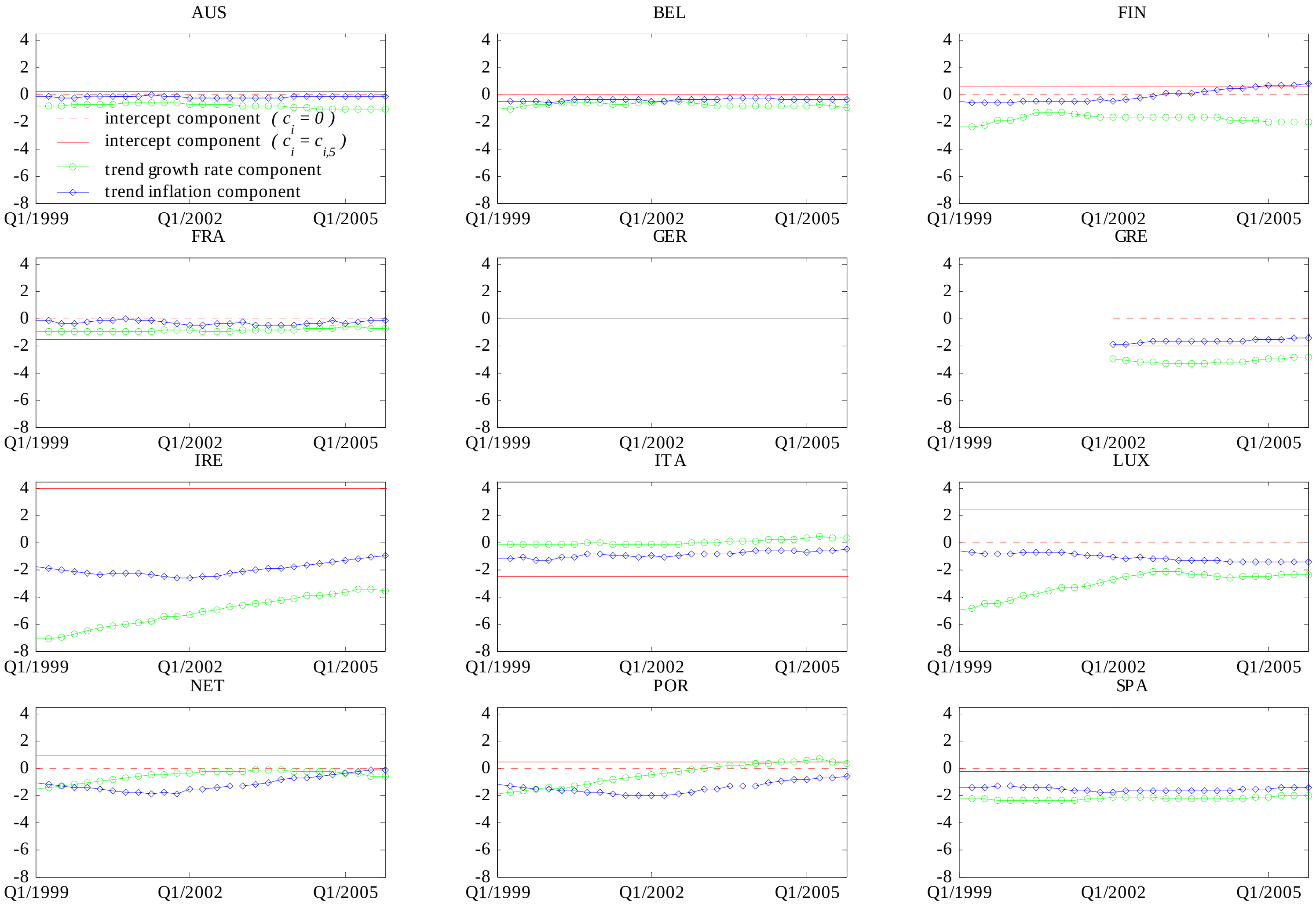


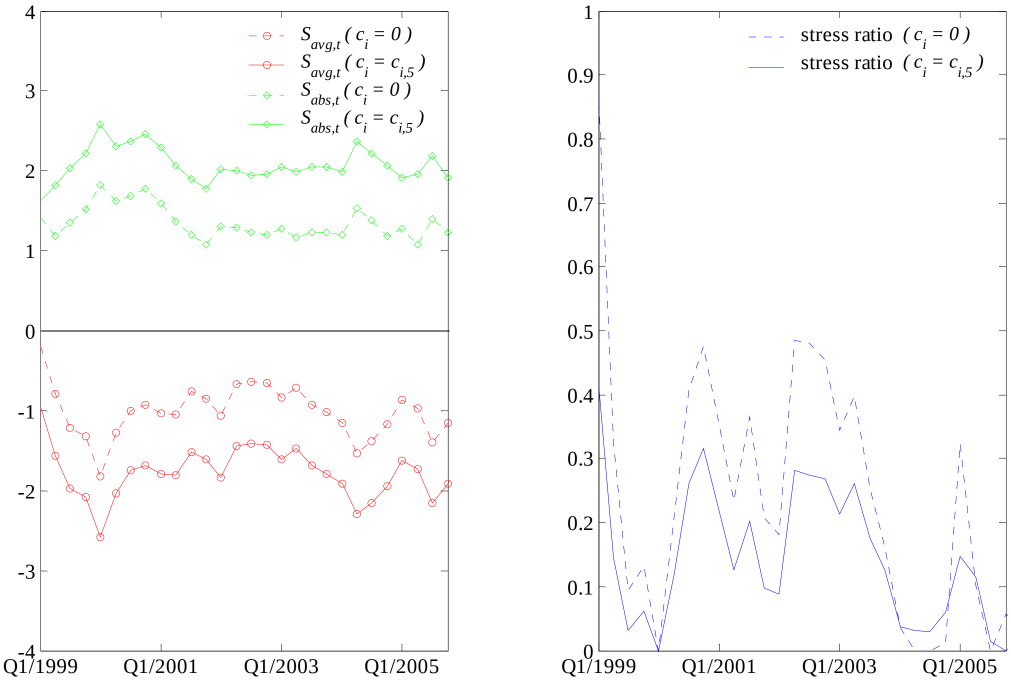
Figure 11: Decomposition of the trend component of stress ($S_{i,t}^{trend}$)



which is the weighted average of absolute values of country-specific stresses.

The levels of the stress indicators provide some important information concerning the evaluation of the common monetary policy. $S_{avg,t}$ measures the deviation of the actual ECB interest rate from the average of the country-specific optimal interest rates. As it closely fluctuates around -1.8% all over the EMU period (see Figure 12), the indicator tells us that the ECB policy has been too expansionary and that nominal interest rate should have been 1.8 percentage points higher in order to match the average of the country-specific optimal interest rates. The value of $S_{avg,t}$, however, largely depends on the choice of the intercept term c_i. If we set $c_i = 0$, $S_{avg,t}$ shifts up by around 0.8 percentage points, which reduces the gap between the current ECB interest rate and the interest rate that would be optimal, if it were computed according to the pre-EMU central bank policies.

Figure 12: Stress indicators



$S_{abs,t}$ is a more comprehensive stress measure as it does not discriminate between negative and positive country-specific stresses. In particular, a comparison between $S_{abs,t}$ and $\left|S_{avg,t}\right|$ allows us to draw conclusions about the synchronization of the signs of country-specific stresses. For this purpose we calculated a so-called stress ratio, $\left(S_{abs,t} - \left|S_{avg,t}\right|\right) / S_{abs,t}$, which by construction varies between zero and one. The lower the stress ratio, the more synchronized country-specific signs of stress and the easier it would have been for the ECB to attenuate stress in all countries and thereby average stress (as measured by both, $S_{abs,t}$ and $S_{avg,t}$) by adjusting the common interest rate into the one or the other direction. During the EMU period the ratio fluctuates around 0.15 and is always below 0.5, which is an indicator for the prevalence of equally signed (negative) country-specific stresses. Hence, stress could have been reduced by an increase of the policy rate. If we set $c_i = 0$, the stress ratio increases. This is due to the fact that the source of synchronized stress (which below will turn out to be the trend component of stress) becomes less important.

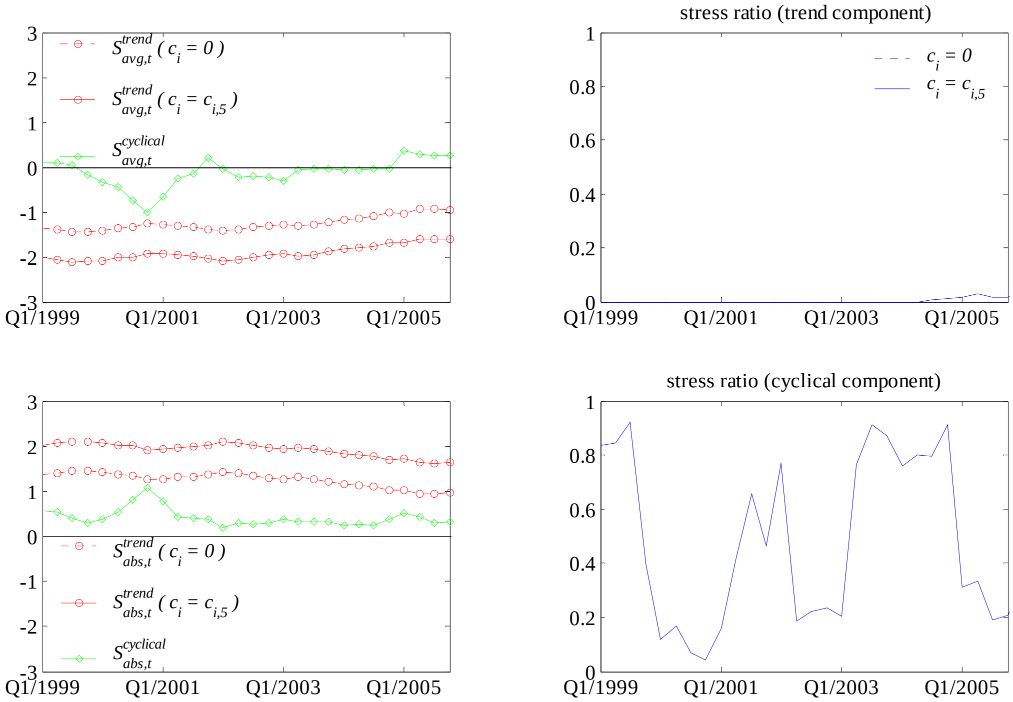
For the aggregate stress indicators the same decomposition as before can be made. The trend component and the cyclical component are calculated as follows:

$$S_{avg,t}^{n} = \sum_{i=1}^{12} w_{i,t} S_{i,t}^{n} \text{ and } S_{abs,t}^{n} = \sum_{i=1}^{12} w_{i,t} \left| S_{i,t}^{n} \right|, \tag{17}$$

where $n = \{trend, cyclical\}$. The decomposed stress indicators are shown in Figure 13. The upper left panel depicts the weighted averages of the country-specific stress components ($S_{avg,t}^{trend}, S_{avg,t}^{cyclical}$), whereas the lower left panel depicts the weighted averages of absolute values of country-specific stress components ($S_{abs,t}^{trend}, S_{abs,t}^{cyclical}$). The right panels show the stress ratios for both, the trend component and the cyclical component.

Figure 13 shows that the cyclical component of $S_{avg,t}$ fluctuates closely around zero. Thus, asynchronized cyclical movements in the inflation rate or real GDP are only an unimportant source of stress, which is also confirmed by the low value of $S_{abs,t}^{cyclical}$. The cyclical component of the stress ratio has an interesting pattern. Periods with a high ratio (indicating that there are asynchronized country-specific cyclical movements, which cancel out each other) are followed by periods with a low ratio (indicating that common shocks hit the EMU, which lead to equally signed stress in all countries) and vice versa. A marked example with a ratio close to zero is the aftermath of the burst of the New Economy bubble, in which $S_{avg,t}^{cyclical} < 0$. Monetary policy of the ECB has been overly expansionary in all countries, if it is evaluated by the pre-EMU central bank policies.

Figure 13: Decomposition of stress indicators



The great part of overall stress is explained by its trend component, as $S_{abs,t}^{cyclical}$ remains below $S_{abs,t}^{trend}$ throughout the EMU period. The fact that the trend component of the stress ratio is zero (or close to it) indicates that stress due to the neutral interest differential is equally signed in all EMU countries. The value of $S_{avg,t}^{trend}$ suggests that ECB interest rates have been on average 1.9 percentage points too low. If we set $c_i = 0$, the cyclical components of the stress indicators remain unaffected. By contrast, the trend components shift by about 0.7 percentage points towards the zero line, which basically explains the aforementioned reduction of aggregate stress in the case of $c_i = 0$.

Having stated that there is stress due to diverging trend growth rates of consumer prices and real GDP in the EMU and that the level of it depends to a certain extent on the value of the intercept term in the Taylor rule, the final question that we have to address is whether or not this stress reinforces itself. For this purpose the evolution of the various stress indicators over time provide some important information. A look back to Figure 12 shows that even though aggregate stress (as measured by $S_{avg,t}$) is negative all over the EMU period, it remained more or less constant and fluctuated around -1.8%. Regressing both indicators, $S_{avg,t}$ and $S_{avg,t}$, on an intercept term and a time trend yields that the coefficient on the latter is only insignificantly different from zero. At first sight the picture seems to change when we look at Figure 13. Above all the trend component of aggregate stress moves in the direction of the zero line over time. Concluding from this observation that stress diminishes, however, is incorrect. To see this it is important to recall that the decomposition of stress into a trend and cyclical component was made under the assumption that stress in Germany is equal to zero. A look back to Figure 9, however, shows that $S_{GER,t}$ steadily falls by 1.4 percentage points from $+0.9\%$ to -0.5% over the EMU period. Taking into account that the German weight, $w_{GER,t}$, is about 30%, the increase of $S_{avg,t}^{trend}$ in Figure 13 by 0.4 percentage points from -2.0% to -1.6% is more or less compensated by the decrease in German stress. In sum, there are no signs that stress in the EMU aggravated over time.

4 Conclusion

The aim of the present paper was to analyze whether the Euro-zone diverges. For this purpose we developed a stress indicator that combines the trend and the cycle component of real GDP and consumer price inflation of all 12 EMU countries in a single measure. The main result of our analysis is that stress in the Euro-zone is mainly due to different trend growth rates of GDP and consumer prices. For most of the Euro-zone countries interest rates have been too low over the 1999-2005 period and would, on average, be higher by one or – depending on the construction of the stress indicator – two percentage points, if the countries were able to continue following the optimal policy rule they adopted in the pre-EMU period. By contrast, cyclical dispersion is rather low and the related stress is only minor in relation to the trend component of stress. An important finding of the analysis is that stress in Germany is close to zero all over the 1999-2005 period, implying that the ECB continues the policy of the German Bundesbank.

The result that stress is negative in most EMU countries, however, does not mean that the Euro-zone diverges. We rather find that the absolute value of stress remains more or less constant over time. Thus, even though the monetary policy of the ECB tends to be too loose for the majority of EMU member countries, so far any stress-reinforcing tendencies cannot be identified.

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