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Is it Really More Dispersed? Measuring and Comparing the Stress From the Common Monetary Policy in the Euro Area

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Is it Really More Dispersed? - Measuring and Comparing the Stress From the Common Monetary Policy in the Euro Area

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Abstract

The ECB's *one size* monetary policy is unlikely to fit all euro area members at all times, which raises the question of how much monetary policy stress this causes at the national level. I measure monetary policy stress as the difference between actual ECB interest rates and Taylor-rule implied optimal rates at the member state level. Optimal rates explicitly take into account the natural rate of interest to capture changes in trend growth. I find that monetary policy stress within the euro area has been steadily decreasing prior to the recent financial crisis. Current stress levels are not only lower today than in the late 1990s, they are also in line with what is commonly observed among U.S. states or pre-euro German Länder.

JEL Classification Codes: C22, E53, E58

Keywords: euro area, currency union, European Central Bank, ECB, Taylor rule, real natural rate, common monetary policy, monetary policy stress, inflation

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[I]t is important to redress a common belief which is unfounded, in my opinion, namely that the euro area as a whole is significantly more heterogeneous economically, with more dispersion and higher levels of standard deviation of a number of important indicators than the US.

— Jean-Claude Trichet, *keynote address at the "ECB and its Watchers XIII" conference, Frankfurt am Main, 10 June 2011*

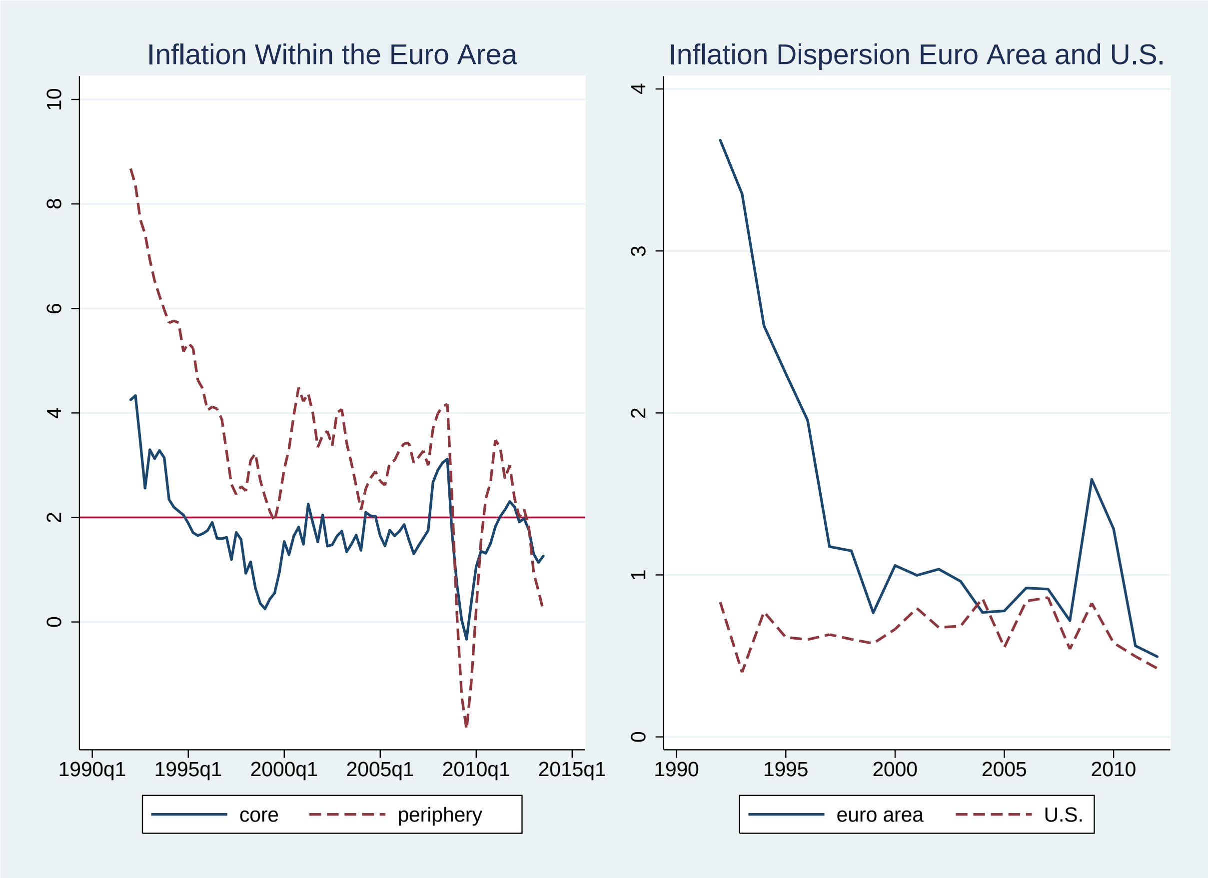
1 Introduction

Economic heterogeneity in the euro area is widely perceived as a major obstacle for the common monetary policy. Since the introduction of the euro, the European Central Bank (ECB) has frequently been under political pressure as its policy is usually evaluated from a national rather than a European perspective. Against this background, public or political debates habitually arrive at the conclusion that the interest rate policy of the ECB is misguided.[1]

Indeed, when looking at inflation, heterogeneity rather than harmony seems to be the hallmark of the euro area. Inflation rates converged before the introduction of the euro in 1999, but they diverged again when the Maastricht criteria lost their grip and the countries in the euro area periphery outgrew the ones in the core (Figure 1, left panel). This reflected real income convergence and catch-up effects in the periphery, amplified by falling real interest rates, real estate and construction booms, as well as idiosyncratic developments such as the lingering impact of German reunification. Some of these growth and, to a lesser degree, inflation divergences have reversed in the aftermath of the great recession of 2007–2009 as peripheral booms deflated while core countries got through the economic turmoil relatively unscathed. However, overall heterogeneity continues to befuddle observers who wonder how a single monetary policy can serve such persistently differing macroeconomic policy needs.

An argument can be made that the *one size has to fit all* approach of the ECB could be fueling these divergences. Per its Maastricht mandate, the ECB's common monetary policy is oriented at the consumption-weighted euro area aggregate. By definition, this implies that its policies will be too permissive by the standards of higher-than-average inflation countries and too restrictive by the standards of those with rates of inflation below average. In principle, this can amplify already diverging developments. For example, an already overheating economy could see real activity and inflation accelerating further if, for the given common nominal interest rate, higher rates of inflation fed into higher inflation expectations and lower ex ante real interest rates. The opposite holds for economies with below-average inflation.

[1] For example, in 2007 Nicolas Sarkozy blamed the ECB for being responsible for the financial difficulties of the aircraft manufacturer Airbus (FT 2007). In a similar vein, the ECB's accommodative monetary policy for the last two years has often been described in Germany as a discrimination against German savers (FT 2013).



Note: The figure graphs the average annualized inflation in the core countries (France and Germany) and periphery countries (Greece, Ireland, Portugal, and Spain) together with the standard deviation of the inflation across 11 euro area member states (original membership plus Greece, excluding Luxemburg) and 31 U.S. states. The left panel also includes the ECB inflation target of 2 percent. While average inflation rates (left panel) are reported on a quarterly basis (1992q1–2013q3), inflation dispersion (right panel) is reported on an annual basis (1992–2012).

Figure 1. Euro Area and U.S.: Comparison of Inflation Rates

Inflation heterogeneity is however not unusual for large currency areas (Figure 1, right panel). The standard deviation of inflation rates among euro area members considerably exceeded the standard deviation among U.S. states prior to 1999, but fell to comparable lower levels thereafter.[2] Some heterogeneity in inflation can even be beneficial from an adjustment perspective. Absent the buffers provided by nominal exchange rates, inflation differentials are an important adjustment mechanism in response to asymmetric shocks (ECB 2005). However, the recent peripheral boom-and-bust period demonstrates that not every divergence in inflation among euro area members can be justified by such arguments. Lasting inflation differentials can also be the result of misaligned fiscal policies or serious structural differences among member states.

[2] A similar picture holds when comparing the volatility of labor costs across these two currency areas. The dispersion of output growth has been similar even before the introduction of the euro.

Last but not least, the sometimes populist overtone in European public and political debates on the appropriate policy stance might distract from the fact that such discussions take place in other currency areas as well. With economic dispersion being present also among U.S. states, the voting behavior of regional Federal Reserve (Fed) presidents in the Federal Open Market Committee (FOMC) might be driven by regional rather than national economic conditions (e.g. Gildea, 1992; Meade and Sheets, 2005). In the past, several lawsuits have questioned the constitutionality of regional representatives and a proposed legislation called for the exclusion from regional Fed presidents from the FOMC.[3] A similar behavior is observable for regional representatives in the German Bundesbank council. In pre-euro Germany regional conditions influenced the voting behavior of policy makers as well (e.g. Berger and de Haan, 2002).

Against this background, the aim of this paper is to measure the adequacy of the ECB interest rate policy for its member states using the concept of monetary policy stress. Following Clarida *et al.* (1998), monetary policy stress for a specific country is defined as the difference of the actual policy rate determined by the common central bank for the currency area overall and the Taylor-rule implied optimal rate which would prevail if policy would be determined by the same central bank focused on this country's economic conditions alone. These optimal country rates explicitly take into account the natural rate of interest to capture changes in trend growth but assume that the preferences of policy makers at the aggregate and national level are the same. Proceeding in two steps, I first compare the stress for the euro area across time to analyze how the adequacy of the one-size policy has evolved in the past. I find that monetary policy stress within the euro area has been steadily decreasing prior to the recent financial crisis. Although it has been picking up again lately, stress levels are below of what have been observed in the first years of the euro. Next, to shed light on the question whether the stress associated with the common monetary policy is a cause for concern in the euro area, I compare the stress within the euro area with the stress in the U.S. and pre-euro Germany. Monetary policy stress measured for the euro area is in line with what is commonly observed among U.S. states and only slightly higher than among pre-euro German Länder.

The remainder of the paper is organized as follows. The next section discusses the related literature. Section 3 describes the empirical methodology and data. Section 4 proceeds to analyze monetary policy stress for the euro zone in some detail and draws the comparison with the U.S. and pre-euro Germany. Finally, Section 5 concludes.

2 Related Literature

This paper complements a larger literature on the economic heterogeneity of the euro area. Starting with inflation differentials, asymmetric shocks and the different transmission of common shocks have frequently been stressed as important in this regard. For example, Angeloni and Ehrmann (2007) see national demand shocks as the main contributor to the observed dispersion

[3] See the U.S. State Court case Melcher v FOMC 664, F.2d 510 (D.D.C. 1986) together with the U.S. State Court of Appeals case 836 F.2d 561 (D.C.Cir.1987) and the "The Monetary Policy Reform Act of 1991", where the hearings on the bill were held, but which was not brought to a vote before Congress.

of inflation rates while Honohan and Lane (2003) regard the asymmetric transmission of exchange rate shocks as pivotal. On the structural side, several factors have been identified to contribute to price dispersion. Andersson *et al.* (2009) find differences in product market regulation to be important, Beck *et al.* (2009) see differing costs of non-wage input factors and regional structural differences as main drivers, while Jaumotte and Morsy (2012) point more generally to labor market institutions. In contrast, price effects from income convergence along the lines of Balassa-Samuelson are said to have been more transitional and moderate in nature.[4] This corresponds with my results that monetary policy stress converged from elevated to lower but not to zero levels over time.

Similarly, previous studies comparing intra-euro area and intra-U.S. inflation differentials support the result that monetary stress levels in the two regions have converged to comparable levels. For example, Rogers (2007) finds a comparable dispersion of traded goods prices and Beck *et al.* (2009) report only small differences in the dispersion of inflation overall. Price level divergences are found to be persistent both within the euro area and the U.S. (Cecchetti *et al.* 2002; ECB 2003), with the degree of persistence being higher in the euro area (ECB 2005).

Broadly mirroring the findings for inflation, output growth differentials among euro area countries are comparable to what can be observed in other currency areas (e.g. Benalal *et al.*, 2006; Giannone and Reichlin, 2006). While country-specific factors explain a considerable share of these differences in cyclical behavior, the literature on business cycle synchronization mainly stresses two driving factors for the comovement of business cycles. Common shocks seem to be an important source of volatility together with the cross-border transmission of country-specific shocks due to trade and financial integration.[5] With regard to Europe and the euro area, Lumsdaine and Prasad (2003) find traces of a common cycle, whereas Negro and Otrok (2008) and Canova *et al.* (2007) do not. Focusing on the effect of the recent financial crisis, Gächter *et al.* (2012) show that the synchronization among the euro area weakened in the aftermath of the crisis. This corresponds with my picture of monetary policy stress which seems to increase after 2008.

Related to my question, a smaller set of papers discusses optimal monetary policy under economic heterogeneity in the euro area. Following Benigno (2004), Benigno and Lopez-Salido (2006) show that monetary policy in a currency union might be more effective when taking into account differing degrees of price rigidities. Fendel and Frenkel (2009) suggest that the ECB policy might indeed react to inflation differentials within the euro area. Angeloni and Ehrmann (2007) show that inflation targeting by the ECB also minimizes inflation dispersions within the currency area.

[4]See de Haan (2010) for a recent survey. The ECB (2003) argues that at least part of the inflation differentials are explained by Balassa-Samuelson effects. However, Honohan and Lane (2003) and Rabanal (2009) find little evidence of convergence effects for Ireland and Spain, respectively.

[5]See, for example, Gregory *et al.* (1997), and Kose *et al.* (2003) on common shocks. Commonalities due to spillovers via trade or financial linkages seem to be more controversial. While, for example, Frankel and Rose (1998) see a positive relationship, Canova and Dellas (1993) disapprove of it. Furthermore, a strand of this literature focuses on intra-national business synchronization, see e.g. Hess and Shin (1998) and Del Negro (2002) on within country fluctuations for the U.S.

Closer to my approach are Flaig and Wollmershäuser (2007) as well as Lee and Crowley (2009), who show that monetary policy stress within the euro area has been fairly stationary over the sample (1999–2005 and 1999–2007, respectively). However, these studies differ from mine in the way optimal country-specific interest rates and monetary policy measures are obtained.[6] Most related to my approach is the work by Sturm and Wollmershäuser (2008), who also assess the monetary policy stress for euro area members based on a Taylor rule estimation for the ECB. I add to their work by allowing for a time-varying intercept in the monetary policy rule capturing differences in equilibrium real interest rates both over time and across member states. This turns out to be a crucial extension given the wide dispersion of growth and inflation rates especially in the early years of the euro. Importantly, I also put the monetary policy stress measured for the euro area into perspective by conducting a similar exercise for U.S. states and pre-euro German Länder. Last but not least, my data set adds additional observations covering the recent financial crisis.

3 Methodology

The approach to reveal the potential stress stemming from a common monetary policy requires a number of steps. First, I quantify the hypothetical policy rate that each state would optimally set if monetary policy had not been delegated to the common central bank. Second, I compare these optimal rates with the actual interest rate set for the currency union, for example by the ECB. Third, I take the difference between the actual and the optimal interest rate as an indicator of monetary policy stress that can be further analyzed and compared across time and different currency areas.

3.1 Taylor Rule Estimation and Data

Identifying the optimal rate requires making assumptions about policy preferences. I assume that all members of a currency union - by revealed preference - share the same inflation and output gap target and attach the same weight on the stability of inflation relative to the output gap (Sturm and Wollmershäuser, 2008). As a consequence, I am able to identify the policy reaction function currency area members would hypothetically apply to conduct monetary policy at the national level by estimating a reaction function for the central bank operating policy for the currency union. I estimate a Taylor-type policy that, in addition to Taylor's (1993) original contribution, includes the natural real rate of interest and allows for interest rate smoothing:

$$i_t = (1 - \rho) \left(\alpha + \phi_r r_t^n + \phi_\pi \pi_t + \phi_x x_t\right) + \rho i_{t-1}. \tag{1}$$

According to equation (1), the short-term nominal interest rate i_t varies with the natural real rate r_t^n, the rate of inflation π_t and the output gap x_t, but the central bank is assumed to adjust

[6] Flaig and Wollmershäuser (2007) solely use pre-euro country-specific estimates to obtain artificial optimal rates, while Lee and Crowley (2009) compute monetary policy stress as the difference between optimal rates and the predicted ECB policy rate.

the interest rate only gradually, with ρ measuring the degree of persistence. The constant α captures the non-zero inflation level targeted by the central bank, among other things.

The natural real rate is the interest rate consistent with the flexible price equilibrium that would ensure a zero inflation rate and a closed output gap of zero. As Woodford (2003a, Ch. 4) shows, the central bank aims to move the policy rate with the natural real rate to steer the actual economy as closely as possible to the flexible price outcome. For this reason, a simple policy rule such as equation (1) should include the natural rate (Woodford, 2001). To approximate r_t^n, I turn to the Euler equation of a representative household, which can be interpreted as linking the natural real rate to the growth rate of trend output.[7]

Including the lagged interest rate in equation (1) accounts for the fact that central banks commonly adjust interest rates in small steps. Empirically, Clarida *et al.* (1998) find a significant degree of interest rate inertia for the U.S. Fed and the German Bundesbank. Sauer and Sturm (2007) verify this for the ECB. Woodford (2003b) shows that inertia can be rationalized by, among other things, a desire of central banks to steer expectations.

To calculate optimal interest rates implied by the equation above, I will need starting values for the lagged interest rate. For this reason, I also estimate a policy function without taking into account the inertia object:

$$i_t = \alpha + \phi_r r_t^n + \phi_\pi \pi_t + \phi_x x_t. \tag{2}$$

I estimate equations (1) and (2) using a generalized method of moments (GMM) procedure to control for the possible endogeneity of the explanatory variables. To deal with the possibility of autocorrelation I use a Newey-West heteroskedasticity and autocorrelation consistent (HAC) weighting matrix.[8] Following Clarida *et al.* (1998), my instruments are the lagged values of the explanatory variables together with lagged values of the growth rate for a commodity price index and the real exchange rate. The validity of the instruments is tested by using the standard Hansen's (1982) J-statistic.

I use data from various sources. The key source for the euro area data is the International Monetary Fund's *International Financial Statistics*. Data for the U.S. states are obtained from the Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS). German Länder data are taken from the German Statistical Office. Euro area data is on a quarterly frequency ranging from 1994q1–2012q4. For the U.S. and Germany only annual data is available. The U.S. sample ranges from 1976–2012. The German sample excludes the Bretton Woods period and ranges from 1973–1999. My sample includes 11 euro area countries (original member countries, plus Greece but excluding Luxembourg), 51 U.S. states (counting the District of Columbia as an additional state) and 16 German Länder (before 1991 only West-German Länder are included). Whereas my CPI data is complete for the euro area, I only have data for selected metropolitan areas for the U.S. and no consistent CPI information for German Länder. In what

[7] See Appendix A for the details. Benalal *et al.* (2006) show that a great deal of the dispersion of real GDP growth rates within the euro area is due to lasting trend growth differences.

[8] The bandwith of the kernel used in determining the HAC covariance matrix is determined by applying the algorithm of Newey and West (1994).

follows, I relate the CPI data to the corresponding U.S. state in which the metropolitan area is located. By doing so, I obtain CPI data for a subsample of 31 U.S. states. Using the U.S. inflation rate, I calculate an aggregated inflation rate for the missing states. In the German case, I proxy state-specific with national inflation, which effectively limits the policy rule to the output argument. All interest rates and inflation are expressed in annual rates.[9]

3.2 Taylor-Rule Implied Optimal Rates and Monetary Policy Stress

I calculate what would be the optimal interest rate for every member country by applying the estimated policy rule for the common central bank to individual member countries. According to equation (1) the implied optimal rate of a member state j is given by:

$$i_{j,t} = \left(1 - \rho^{CB}\right)\left(\alpha^{CB} + \phi_r^{CB} r_{j,t}^n + \phi_\pi^{CB} \pi_{j,t} + \phi_x^{CB} x_{j,t}\right) + \rho^{CB} i_{j,t-1}, \tag{3}$$

where the subscript j indicates country-specific data while the superscript CB stands for the estimated coefficients for the ECB, the Fed, or the Bundesbank. The starting value for the lagged interest rate $i_{j,t-1}$ is drawn from the estimate of equation (2).[10]

The monetary policy stress of each member state (or country) is expressed as the gap between the rate actually set by the common central bank and the implied optimal interest rate according to equation (3). I define country-specific stress $\mathcal{S}_{j,t}$ of state j at time t as:

$$\mathcal{S}_{j,t} \equiv i_{CB,t} - i_{j,t},$$

where $i_{CB,t}$ is the area-wide effective interest rate and $i_{j,t}$ is the rate, which would be optimal for the member state j according to its economic development. According to this definition, monetary policy stress is measured in units of the nominal policy rate. A positive value for $\mathcal{S}_{j,t}$ then indicates that the policy conducted in the currency area is too tight for this particular state while a negative value indicates a too expansionary policy for state j.

To analyze these tensions in more detail and to identify the driving factors of monetary policy stress, I decompose $\mathcal{S}_{j,t}$ into a structural and a cyclical part. For this purpose I replace the interest rate $i_{CB,t}$ with the estimation equation obtained from equation (1) and rearrange it according to:

$$\begin{aligned}\mathcal{S}_{j,t} &= \left(1 - \rho^{CB}\right)\phi_r^{CB}\left(r_{CB,t}^n - r_{j,t}^n\right) \\ &\quad + \left(1 - \rho^{CB}\right)\left[\phi_\pi^{CB}\left(\pi_{CB,t} - \pi_{j,t}\right) + \phi_x^{CB}\left(x_{CB,t} - x_{j,t}\right)\right] + \rho^{CB}\left(i_{CB,t-1} - i_{j,t-1}\right) + u_{CB,t} \\ &= \left(1 - \rho^{CB}\right)\mathcal{S}_{j,t}^{struc} + \left(1 - \rho^{CB}\right)\mathcal{S}_{j,t}^{cycl} + \rho^{CB}\mathcal{S}_{j,t-1} + u_{CB,t},\end{aligned} \tag{4}$$

where $u_{CB,t}$ are the residuals from estimating equation (1). I define differences in the time-varying intercept as the structural part of the stress $\mathcal{S}_{j,t}^{struc}$, whereas the cyclical part $\mathcal{S}_{j,t}^{cycl}$ is defined as the gap between inflation rates and output gaps. Accordingly, the structural part

[9] See Appendix A for further details on the data set and calculations.

[10] As a robustness check for the euro area, I also calculate starting values implied by the actual country-specific interest rates before 1999 (see Appendix B).

is determined by differences in the natural rates of interest. Dispersion in the natural rate are driven by trend growth differentials capturing differences and changes in the structural framework of member states. This is especially helpful for accounting for the transition process that took place within the euro area after the introduction of the common currency. The cyclical part of the stress occurs due to asynchronous business cycles within the currency area.

When calculating monetary policy stress, I have to account for the zero lower bound (ZLB) monetary policymakers have been facing in the last years. For this reason, I enforce a minimum of zero percent on the calculated member state interest rates. In practice the ZLB is only relevant for the euro area and the U.S., mostly during the crisis period. Note that the decomposition along the lines of equation (4) is not feasible when the ZLB is binding.

Although constraining country-specific interest rates at zero is appropriate from a practical point of view as national central banks would also face such a constraint, this keeps me from computing the stress euro area members and U.S. states face from 2009 onwards. Therefore, in a second step I do not constrain optimal national rates and allow them to become negative. To be consistent I permit the reference interest rate of the ECB and the Fed to become negative as well. As with the optimal rates for the member states, I employ equation (1) to compute an artificial optimal interest rate for both central banks using equation (2) to obtain starting values.[11]

To compare the stress across different currency areas, I compute aggregated measures of monetary policy stress, in particular the mean and dispersion of stress across member states. Specifically, I calculate the unweighted and weighted mean as:

$$\bar{\mathcal{S}}_t^{uw} \equiv \frac{1}{n}\sum_j \mathcal{S}_{j,t} \quad \text{and} \quad \bar{\mathcal{S}}_t^{w} \equiv \sum_j w_j \mathcal{S}_{j,t}, \tag{5}$$

together with the unweighted and weighted standard deviation for n member states as:

$$\mathcal{D}_t^{uw} \equiv \sqrt{\frac{1}{n-1}\sum_j \left(\mathcal{S}_{j,t} - \bar{\mathcal{S}}_t^{uw}\right)^2} \quad \text{and} \quad \mathcal{D}_t^{w} \equiv \sqrt{\frac{n}{(n-1)\sum_j w_j}\sum_j w_j \left(\mathcal{S}_{j,t} - \bar{\mathcal{S}}_t^{w}\right)^2}.$$

The weights w_j are given by the relative economic size of the member state j measured by the ratio of its GDP to the GDP of the currency area for the year 2006.[12] Another aggregated stress gauge assumes that negative and positive stress levels are harmful to a same degree by looking at the mean of the absolute stress measures:

$$\bar{\mathcal{S}}_t^{uw,abs} \equiv \frac{1}{n}\sum_j |\mathcal{S}_{j,t}| \quad \text{and} \quad \bar{\mathcal{S}}_t^{w,abs} \equiv \sum_j w_j |\mathcal{S}_{j,t}|.$$

In contrast to the average measures (5), the absolute measures do not allow a “netting” of negative and positive stress readings.

[11]These artificial interest rates matches the actual interest rates until 2009 fairly well. For the ECB and Fed the interest rates become negative for 2009q2–2011q1 and 2009–2011, respectively.

[12]For the German Länder I take the year 1998.

My approach, while necessarily based on a number of critical assumptions, should provide a good first-cut indication of the stress from monetary policy within a currency area. Clearly, central banks deviate in their institutional goals. Furthermore, actual decision making might take into account extraordinary considerations such as financial stability. That said, it is by now widely accepted that Taylor-type rules provide a good second-best approximation of optimal monetary policy and that, in many cases, real-world central bank behavior is in line with such rules. Another question is whether the economies of member states are sufficiently similar to support the singular policy rule approach chosen. For example, Flaig and Wollmershäuser (2007) estimate different policy functions across euro area member states. However, such an approach comes with its own caveat as it requires an extended sample deep into the pre-Maastricht period (back to 1982 in the case of Flaig and Wollmershäuser (2007), for example). This does not only threaten to ignore the effects of the institutional convergence process taking place prior to the introduction of the euro, it also ignores the constraints European exchange rate arrangements imposed on national policy rates. Finally, my analysis does not allow for feedback between member state-specific policies and the economy. This would clearly be a desirable feature but would require a much more sophisticated multi-country DSGE approach.

4 Results

I first discuss monetary policy stress within the euro area over time. Proceeding with a comparison across currency areas, I contrast stress measures for the euro area with those for the U.S. states and pre-euro Germany. The latter requires narrowing down the model in order to make it compatible across all currency areas. Finally, I provide the results of several robustness checks.

4.1 The Stress within the Euro Area

Table 1 (first two columns) presents the results for the estimation of the policy rule described by equation (1) and (2) based on aggregated euro area data for the period 1994q1–2007q4. Due to the short history of the euro area, I include the years 1994–1998 to increase the sample size. During those years most euro area member states conducted monetary policy in a coordinated way. Observations after 2007 are excluded due to possible distortions caused by the financial crisis.[13] The estimated coefficients are largely in line with the findings of other studies (e.g. Gerlach-Kristen, 2003; Gerdesmeier and Roffia, 2004; Sauer and Sturm, 2007). The reason for the relatively low estimate of the smoothing parameter ρ and the negative sign of the constant α is the addition of the time-varying but persistent real natural rate r_t^n to the conventional set of explanatory variables. The Taylor stability principle is fulfilled.[14]

The stress measures for the euro area are summarized in Figures 2-4. Figure 2 plots the country-specific stress $\mathcal{S}_{j,t}$ for all sample countries over time. A number of facts emerge. First, monetary policy stress is an inevitable part of a currency union with a minimum of macroeconomic heterogeneity such as the euro area. A *one size* monetary policy will, as a rule, not

[13] As a robustness check I later include this period as well, see Appendix B.
[14] For the Taylor principle see e.g. Woodford (2003a, Ch. 4).

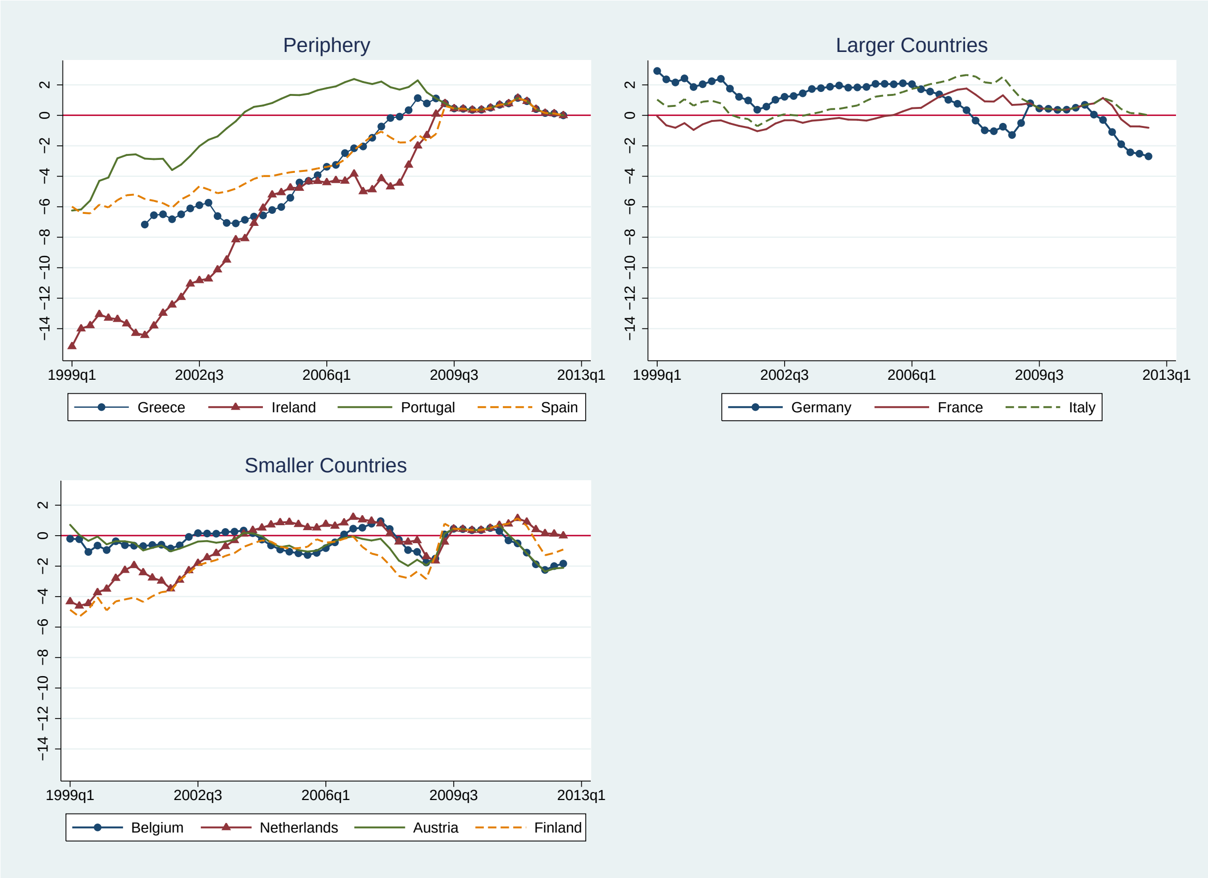
Table 1. Estimated Policy Functions of the ECB, U.S. Fed, and German Bundesbank

	ECB		U.S. Fed		pre-euro Bundesbank	
	Eq. (1)	Eq. (2)	Eq. (1)	Eq. (2)	Eq. (1)	Eq. (2)
Lagged interest rate	0.723 (0.012)		0.583 (0.083)		0.331 (0.020)	
Constant	-7.606 (0.874)	-10.405 (2.194)	-9.935 (3.413)	-11.051 (0.863)	-4.582 (0.413)	-1.328 (0.290)
Natural rate of interest	1.327 (0.096)	1.643 (0.259)	1.140 (0.347)	1.187 (0.083)	0.902 (0.056)	0.527 (0.041)
Inflation rate	1.000 (0.150)	1.398 (0.282)	1.815 (0.458)	2.216 (0.134)	1.514 (0.035)	1.313 (0.022)
Output gap	1.116 (0.039)	0.849 (0.107)	1.634 (0.661)	0.430 (0.205)	0.551 (0.053)	0.212 (0.065)
Sample	1994q1–2007q4		1976–2007		1973–1999	
J-statistic	3.349 (p=0.91; df=8)	4.391 (p=0.73; df=7)	7.518 (p=0.48; df=8)	2.471 (p=0.93; df=7)	2.237 (p=0.99; df=10)	2.070 (p=0.99; df=9)

Note: Standard errors are given in parentheses below the estimated values. The GMM instrument set includes lags 1 to 2 of the interest rate (when estimation includes the inertia objective), natural rate of interest, inflation, output gap, annualized growth rate of a commodity price index (including oil prices for the euro area, excluding oil prices for the U.S. and Germany), annualized growth rate of the real exchange rate and a constant. For Germany, the annualized growth rate of an oil price index is added to the set of instruments.

be optimal for all member states at the same time. This is apparent from Figure 2, as for some countries the policy has been too tight (positive stress), while at the same time being too expansionary (negative stress) for other members. Second, monetary policy stress seems to be persistent in the sense that stress readings remained either positive or negative for longer periods for most of the countries. Third, monetary policy stress was particularly high and negative for the periphery at the beginning of the monetary union but decreased significantly over time. Based on Figure 2, the optimal policy rate for Ireland, Greece, Portugal, and Spain would have been between 600 and 1,500 basis points higher than the actual policy rate in the first year of euro area membership.[15] During the first decade of the euro, monetary policy has been continuously too expansionary for Ireland, Greece and Spain. However, stress levels fell systematically over this period, converging to levels comparable to other member states. Over the same time period, monetary policy has been too restrictive for Germany, for which the optimal rate would have been 200 basis points lower. In the aftermath of the financial crisis, this trend reversed. From a German perspective, a shift to a more restrictive policy would have be desirable, while the stress has been positive in the periphery. Lastly, in 2009, with the ECB policy rates close

[15] Interestingly, this results extends into the pre-euro period. Comparing actual peripheral (as well as some small-country) policy rates with the rates implied by my estimated policy rule (1) shows increasing divergence prior to 1999 as nominal interest rates converged. These additional results are available upon request.



NOTE: Monetary policy stress is measured in percentage points. During 2009q3–2010q3 the ZLB becomes binding for all countries so that the stress readings tend towards zero.

Figure 2. Euro Area: Country-Specific Monetary Policy Stress, 1999q1–2012q3

to zero percent, the ZLB became binding for all member states, driving stress levels basically to zero.[16]

How did monetary policy stress develop for the euro area as a whole? To answer this question, Figure 3 depicts the (cross-sectional) summary statistics of monetary policy stress over time. Looking at the unweighted mean (upper left panel), the policy rate set by the ECB seems to have been below the average optimal rate of member states for much of the sample, but this gap has been falling since 1999. This reduction in stress is also apparent from the mean of absolute stress measures (upper right panel) or the standard deviation (lower panel) which ensures that positive and negative values do not cancel out. However, unweighted measures do not justice to the ECB's mandate. The ECB is charged with maintaining price stability for the euro area overall. As a consequence, it should place a higher weight on developments in larger than in smaller member states. Indeed, whereas the downward trend in the absolute mean as well as in the standard deviation is still evident, the average stress level in weighted terms tends to

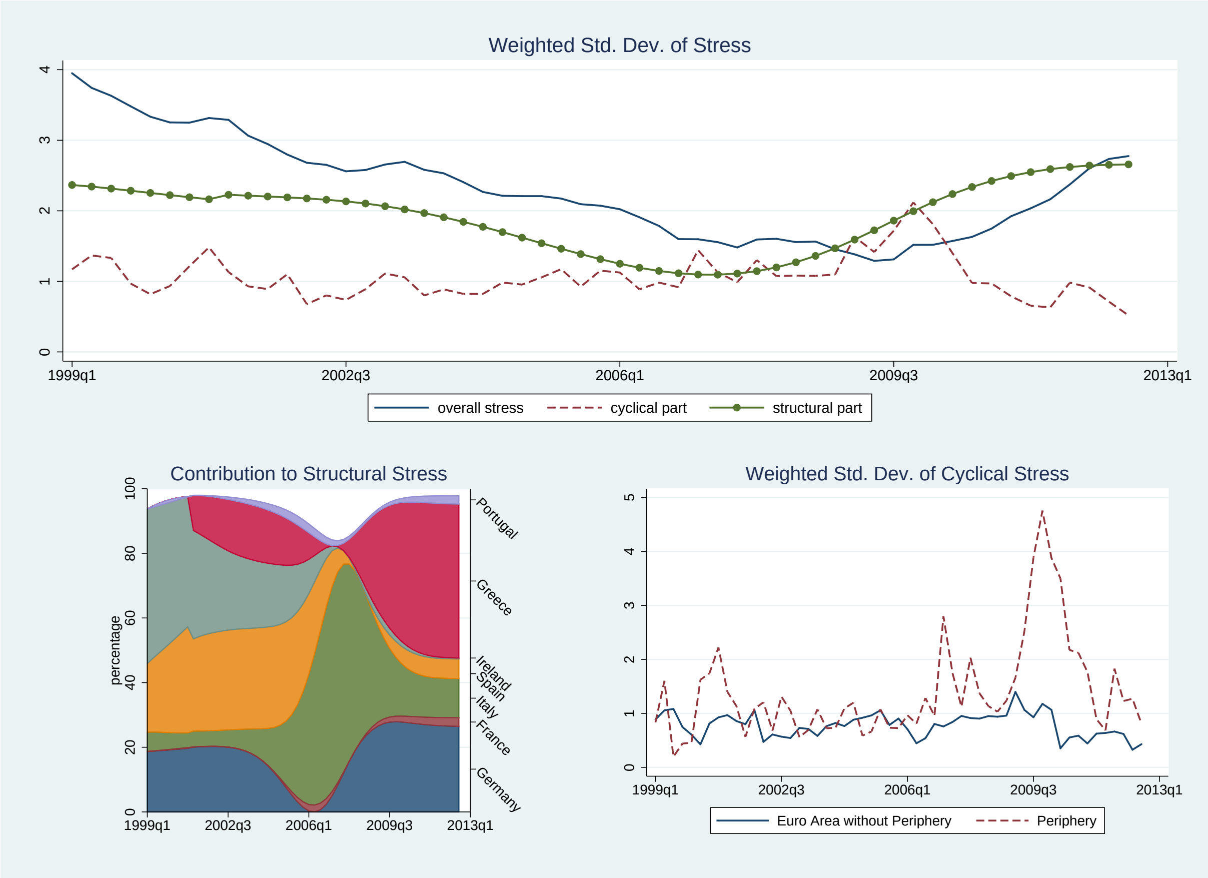
[16]As the ECB has never lowered its policy rate to zero (its lowest value is 25 basis points), stress remains slightly positive when the ZLB is binding.

NOTE: The lower panel differentiates between the stress obtained when a minimum of zero percent is enforced on all interest rates and when this constraint is lifted. Weighted statistics are calculated by using the relative economic size of member states.

Figure 3. Euro Area: Summary Measures of Monetary Policy Stress, 1999q1–2012q3

fluctuate around zero. The positive and negative member state stress effectively canceling out when weighted according to GDP share. This strongly suggests that the ECB did indeed target the euro area as a whole when setting policy rates. During 2009q3–2010q3, when the ZLB became simultaneously binding for all member states, the dispersion of stress dropped to zero (lower panel).

Even when not accounting for the ZLB by allowing interest rates to become negative, monetary policy stress remains below the historical levels seen in the first years of the euro area. Enforcing a minimum of zero percent on the calculated interest rates might be appropriate from a technical point of view as national policy makers would also face the ZLB. However, it conceals the stress which occurred after 2009 during the euro crisis and the two-speed recovery in the aftermath of the financial crisis. To make this stress visible, I allow calculated interest rates to become negative. Monetary policy stress is then computed by comparing these national rates with an unconstrained artificial rate for the ECB computed by using the estimation results for equation (1). Figure 3 (lower panel) contrasts the stress measures I obtain when accounting for



NOTE: Interest rates are not constrained at zero percent. The lower right panel shows cyclical stress for the periphery (Greece, Ireland, Portugal, and Spain) and the remaining countries of the euro area (Austria, Belgium, Finland, France, Germany, Italy, and the Netherlands).

Figure 4. Euro Area: Decomposition of Monetary Policy Stress, 1999q1–2012q3

the ZLB with the stress computed with unconstrained rates. Until 2009 when the ZLB becomes binding for national as well as the ECB interest rates, the results do not differ.[17] Afterwards monetary policy obtained with unconstrained interest rates remains on levels observed before the crisis and below the heights reached after the euro introduction.

Finally, Figure 4 presents the decomposition of monetary policy stress into its structural and cyclical component.[18] While cyclical stress does not exhibit a trend, it is clearly the structural stress component - linked to differences in natural real rates or trend growth - that is driving overall stress levels (upper panel). A decline in structural stress during the first decade of the euro pushed down the dispersion in monetary policy stress which reached its lowest level in 2009. Since then, overall stress has been increasing again due to the anew intensification of structural

[17] The advantage of using the standard deviation when looking at the ZLB is that the results do not depend on the way interest rates of the ECB are obtained. Depicting the effect of the ZLB on the other summary statistics are available upon request.

[18] The presentation focuses on the weighted standard deviation, but the same pattern is observable in decomposition of the other summary statistics. Furthermore, I use unconstrained interest rates as the decomposition is not feasible when the ZLB is binding.

stress. This confirms the results of Flaig and Wollmershäuser (2007) who also identify the structural part as the driving force in monetary policy stress. Differentiating these developments by country sheds further light on the underlying forces. The lower left panel decomposes the structural stress to identify the contribution of every country to the dispersion of the structural stress. For a better overview, only the largest countries together with the peripheral countries are depicted. The initial decline in stress during the first decade is mostly driven by peripheral countries. Greece, Ireland and Spain explain more than half of the dispersion in stress during 1999–2008. Notably, Greece and Germany are responsible for the anew intensification of stress since 2009. This is in line with Gächter *et al.* (2012) who show that the weakening business cycle synchronization of the euro area is driven by the diametrically opposed developments in Greece and Germany. A likewise decomposition for the cyclical stress does not identify a single country to be the driving force of this stress. However, comparing the extent of cyclical stress in the periphery with the remaining euro area yields further interesting insights. The lower right panel depicts the standard deviation of the cyclical stress for these two regions. Over the sample period the dispersion of the cyclical component is slightly higher among the countries at the periphery compared with the other member states.

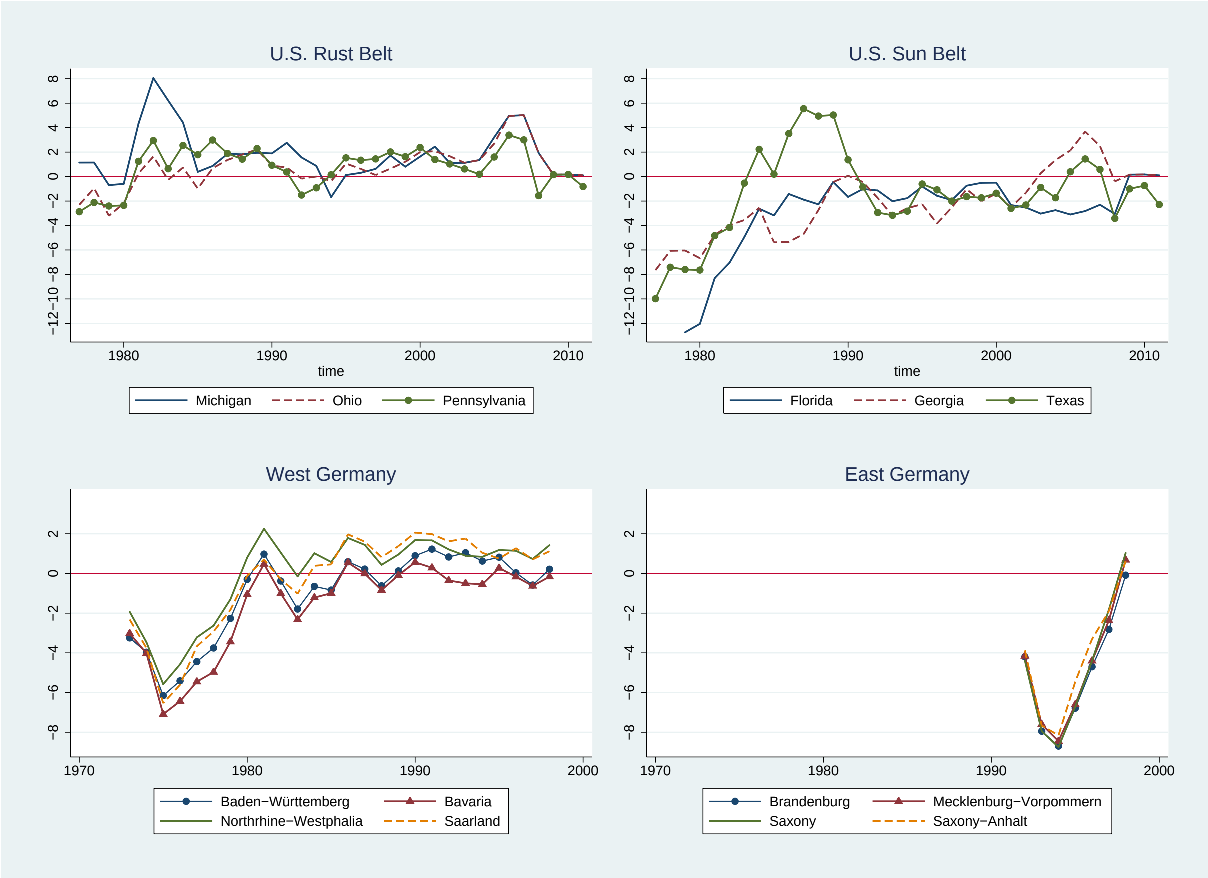
My findings are fairly robust along other dimensions as well. To check the robustness of my results, I, inter alia, change the calibration of the natural rate of interest, modify the way how starting values are identified, or use a calibrated instead of an estimated rule for computing optimal rates. All these alternatives yield broadly similar results (see Appendix B).

4.2 Comparing Monetary Policy Stress of Different Currency Unions

Is the level of monetary policy stress diagnosed for the euro area high or low by international standards? Answering this question requires narrowing down my model to make it comparable across currency areas. I only have annual data for the U.S. states, so I switch to an annual frequency when comparing the euro area with the U.S.[19] Since for the German Länder I lack state-specific price indices, the comparison across all currency areas is limited to the stress coming from output gap and natural rate differentials. Table 1 (third to sixth column) summarizes the estimation results for the two policy rate models I am using for my comparison. They are in line with findings of other studies (e.g Clarida *et al.*, 1998; Clausen and Meier, 2005) except for the differences in the level of the smoothing parameter and the constant discussed earlier. All models fulfill the Taylor principle.

State-specific stress for the U.S. and - to a lesser extent - for pre-euro Germany show similar patterns as described for the euro area. Figure 5 depicts the monetary policy stress for selected U.S. states (upper panel) and selected German Länder (lower panel) for the period 1977–2011 and 1973–1998, respectively. Starting with the U.S., I contrast the so-called *Rust Belt* region with the *Sun Belt* region. The former describes the region specialized in steel production and the manufacturing industry and which straddles the Northeastern states around the Great Lakes. The latter comprises states in the South where most of the agricultural, technology as well as

[19] For the euro area, I do not re-estimate equation (1) and (2) with annual data. To maximize degrees of freedom, stress measures are based on quarterly data but converted into the lower frequency by averaging observations.

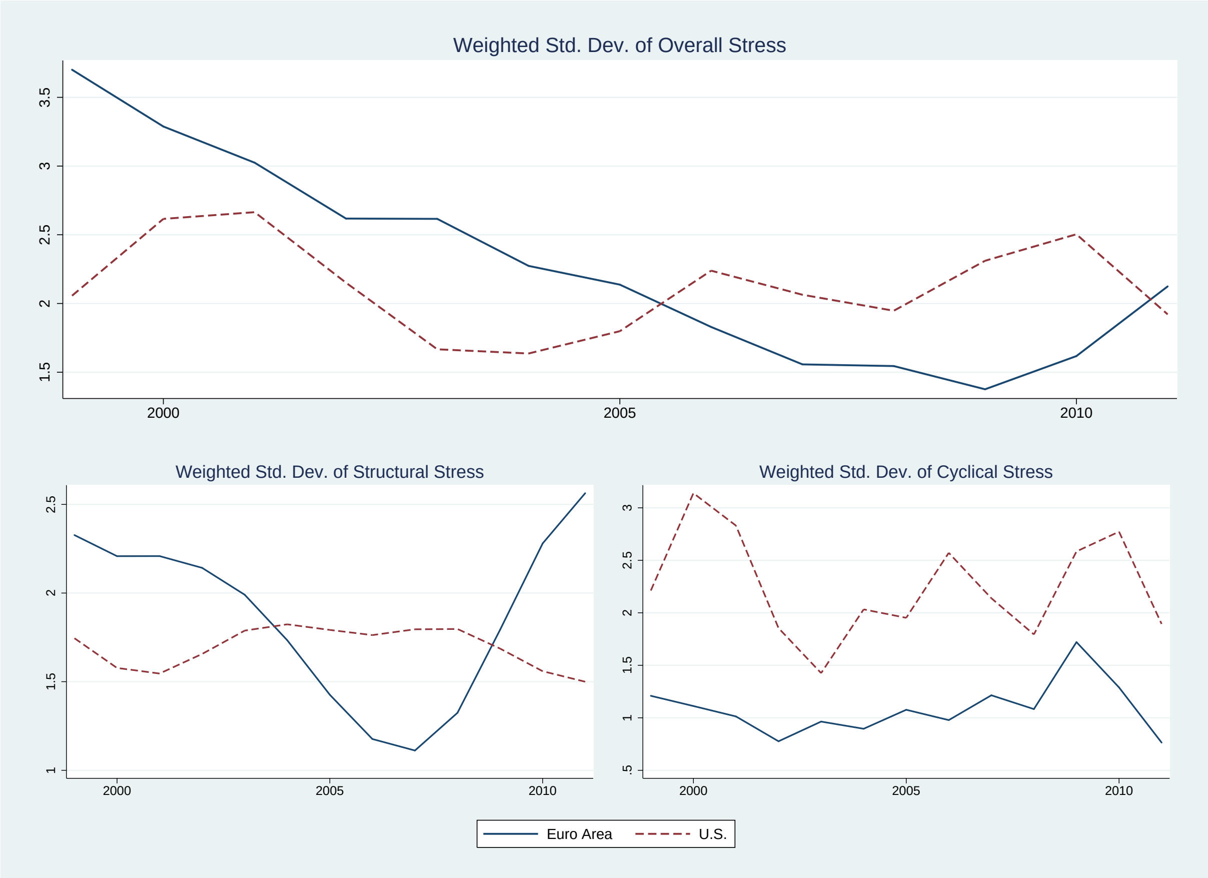


NOTE: The figure graphs the country-specific monetary policy stress for selected U.S. states for 1977–2011 (upper panel) and for selected German Länder for 1973–1998 (lower panel).

Figure 5. U.S. and Germany: Country-Specific Monetary Policy Stress for Selected U.S. States and German Länder

petrochemical industries are located. The decline in the steel and coal industry in the second half of the 20th century has led to a sustained economic decline of the *Rust Belt*. This is reflected by positive stress readings for Michigan, Ohio, and Pennsylvania (upper left panel), making monetary policy too tight for this region for the last 30 years. At the same time, the *Sun Belt* boomed in the decades after World War II. Monetary policy has been too expansionary for Florida, Georgia, and Texas as stress levels have been negative most of the time since the beginning of the sample. Thus, by comparing two, in economic terms, different regions, monetary policy stress also seems to be persistent among U.S. states making the *one size* policy of the Fed also not a perfect fit for every region of the U.S. at all times.

In contrast, Germany seems to be less heterogenous in terms of monetary policy stress, except for the years after the reunification. First, I contrast different regions for Germany. The two states Northrhine-Westphalia and Saarland heavily depended on the coal and steal industry in the past, while in the two southern states Baden-Württemberg and Bavaria agricultural and technology industries are located. Both regions have undergone a comparable transition to



NOTE: Interest rates are not constrained at zero percent.

Figure 6. Euro Area and U.S.: Comparison of Monetary Policy Stress, 1999–2011

the *Rust Belt* and *Sun Belt* in the U.S. However, state-specific stress for these two German regions does not exhibit such a clear pattern of persistence. Merely, for Northrhine-Westphalia and Saarland it can be argued that stress readings were mostly positive between 1980–1999, making monetary policy too tight for these states.[20] However, the reunification in 1991 clearly bore a challenge for the Bundesbank. Monetary policy stress has been highly negative for East Germany after the reunification (lower right panel) as the boom in East Germany demanded a tighter policy than the one conducted by the Bundesbank.

I proceed with the direct comparison of monetary policy stress for the euro area and the U.S. On average, stress in the euro area is not higher than in the U.S. Figure 6 displays the weighted standard deviation of the overall monetary stress and its decomposition into a structural and cyclical part. Overall stress levels (upper panel) are comparable across these two currency areas. Interestingly, the decomposition of stress reveals that while monetary policy stress in the euro

[20] The highly negative stress readings during the 1970s are caused by the policy uncertainty due to the transition from a fixed to a floating exchange rate regime (end of Bretton Woods) together with the historically unprecedented surge in commodity prices in 1973–1974. The related rise in inflation pushed down monetary policy stress in Germany, but as all Länder were affected to the same extent, this did not cause a rise in the dispersion of monetary policy stress.

NOTE: Interest rates are not constrained at zero percent. Cyclical stress is now only driven by output gap differentials.

Figure 7. Euro Area, U.S. and Germany: Comparison of Monetary Policy Stress, 1973–2011

area is mainly driven by structural stress, in the U.S. cyclical stress seems to be generally higher than within the euro area. In total, overall monetary policy stress in the euro area seems to be in line with what is observed among U.S. states.

In a final step, I compare the results for the euro area, U.S., and Germany. Figure 7 shows that monetary policy stress is broadly similar in all currency areas. Note that the focus on natural real rate and output gap differences does not significantly alter the comparison of euro area and the U.S. That said, overall stress levels increased for the early euro area period to levels comparable to what could be observed in the U.S. in the late 1970s. Another notable feature of Figure 7 is the sharp increase in German monetary policy stress in the aftermath of the German reunification in 1990 driven mostly by higher structural stress. It is tempting to point out the similarity of the consequences of integrating an initially heterogeneous set of member states into a common currency area with a single monetary policy. As in the euro area, the high levels of structural stress for the German Länder had been decreasing steadily over time. Before reunification, German structural and cyclical stress measures were relatively low compared to the U.S. and the euro area towards the end of the sample period.[21]

I confirm the robustness of these comparative findings to the number of states included in a currency area. For the U.S. results I check if there is a *law of large number* effect first and then distinctively include all 51 states in the comparison of the euro area, the U.S. and Germany. Varying the number of states does not significantly alter the results of the comparison exercise (see Appendix B).

5 Conclusion

The ECB, charged with maintaining price stability within the euro area, steers monetary policy focused on aggregate euro area developments. However, a *one size* monetary policy is unlikely to fit the needs of all euro area member states at all times. This raises the question of how much monetary policy stress this might cause at the national level. To shed light on this issue, I measure monetary policy stress as the difference between actual ECB interest rates and Taylor-rule implied optimal rates at the member state level. Optimal rates explicitly take into account the natural rate of interest to capture changes in trend growth.

My results indicate that monetary policy stress within the euro area had been steadily decreasing prior to the crisis. The euro started amidst high levels of monetary policy stress, driven by large differences between member states' underlying growth trends and the associated real natural rates. These differences were particularly developed between the peripheral countries of Greece, Ireland, and Spain compared with the rest of the euro area members. During the first decade of the euro, trend growth converged. As a result, the ECB's policy rate got closer to the optimal rate for more euro area members so that measured monetary policy stress declined steadily until 2009. With the start of euro crisis in 2009, monetary policy stress increased again due to the anew divergence in trend growth. This divergence is mainly driven by Germany and Greece moving into the opposite direction.

Current monetary stress levels are not only lower today than in the late 1990s, they are also in line with what is or was commonly observed among U.S. states or pre-euro German Länder. Although somewhat limited by data availability, the cross-sectional comparison also reveals interesting parallels. For example, measured monetary policy stress increased temporarily in the aftermath of German reunification, suggesting that subjecting a relatively heterogeneous set of economies to a single monetary policy can come at a price.

My approach comes with caveats that could be addressed in future research. In particular, it would be interesting to expand the concept of policy stress to include financial stability considerations. Moreover, incorporating the analysis into a more sophisticated multi-country DSGE approach would allow a more complete modeling of the counterfactual scenarios underlying the computation of monetary policy stress.

[21]Cyclical stress is now only driven by output gap differentials.

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Appendix A Data Descriptions and Calculations

My sample includes 11 euro area members (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain), either all 51 U.S. states (counting the District of Columbia as a separate state) or 31 U.S. states on which I have CPI data (Alaska, Arizona, California, Colorado, Connecticut, District of Columbia, Delaware, Florida, Georgia, Hawaii, Illinois, Indiana, Kansas, Kentucky, Massachusetts, Maryland, Maine, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Oregon, Pennsylvania, Texas, Virginia, Washington, Wisconsin, West Virginia). These 31 states represent 84 percent of the U.S. according to their GDP in 2006. All 16 German Länder are included in my sample (Baden-Württemberg, Bavaria, Berlin, Brandenburg, Bremen, Hamburg, Hesse, Lower Saxony, Mecklenburg-Vorpommern, Northrhine-Westphalia, Rhineland-Pfalz, Saarland, Saxony, Saxony-Anhalt, Schleswig-Holstein, Thuringia).

Interest Rates

All interest rate data is taken from the *International Financial Statistics* (IFS). The nominal short-term interest rate for the euro area is given by the EONIA and is provided as quarterly average ranging from 1994q1–2012q4. The Federal Funds Rate for the U.S. and the call money market rate for the Bundesbank are on an annual basis. They range from 1976–2012 and 1973–1999, respectively.

Inflation Rates

Inflation rates are calculated on an annualized basis from CPI indices. For the euro area the HICP is provided by the ECB, ranging from 1994q1–2012q4. The CPI data for the U.S. Fed and the Bundesbank are taken from the IFS. They range from 1976–2012 and 1973–1999, respectively. All CPI data for the euro area member states are taken from the IFS as well, ranging from 1998q1–2012q4. The CPI price data for the U.S. is only available for selected metropolitan areas and is provided by the Bureau of Labor Statistics (BLS). I relate these data to the corresponding states in which the metropolitan areas are located. If more than one metropolitan area is located in a particular state, I will take the average of these indices. Some metropolitan areas include counties of several different states. If this happens and I do not have any other series that can be exclusively related to these states, the corresponding data will be assigned equally to these states. The aggregation becomes complicated for those states, on which I have more than one series from metropolitan areas, which are ranging over different states. If this happens, I will take the weighted average of these series. The weights are given by the proportion every metropolitan area contributes to the state according to the population living in the area. Population data is from 2009 and is provided by U.S. Census Bureau. By this method I am able to obtain CPI data for 31 U.S. states. The remaining 19 states are aggregated to one artificial state for which I can calculate a CPI taking the data I have on the 31 states and the national CPI Index for the

U.S. Fortunately, the results of my study are not sensitive to how the aggregation of CPI data is conducted. I do not have price data on German Länder.

Output Gap Measures

Output gap data are derived by a HP filter (with $\lambda = 1,600$ for quarterly data and $\lambda = 6.25$ for annual data, see Ravn and Uhlig (2002)) expressing it as the deviation of the logarithm of actual real GDP from its trend. Real GDP data for the euro area is taken from the IFS, ranging from 1990q1–2012q4 (for the ECB the series starts in 1995q1, for Ireland in 1997q1, and Greece in 2001q1). The data will be seasonally adjusted if that has not been already done by the source. For the U.S. these data is provided by the Bureau of Economic Analysis (BEA) and is available for all 51 U.S. states on an annual basis, ranging from 1976–2012. The real GDP of the German Länder comes from the German Federal Statistical Office on an annual basis, ranging from 1973–1999.

Natural Rate of Interest

From the utility maximization of an infinitely lived household I obtain a standard Euler equation explaining the optimal intertemporal allocation of consumption:[22]

$$u_C\left(C_t\right) = \beta E_t\left[u_C\left(C_{t+1}\right)\frac{1+i_t}{1+\pi_{t+1}}\right], \tag{A.1}$$

where β is the subjective discount factor and $u\left(C_t\right)$ a utility function depending on the level of real consumption C_t. Market clearing results in $C_t = Y_t$, with Y_t being real output. Substituting $\pi_t = 0$ and $Y_t = Y_t^n$ in equation (A.1) with Y_t^n being the long-term natural level of output, I obtain an expression for the natural rate of interest r_t^n:[23]

$$1 + r_t^n = \frac{1}{\beta}E_t\left[\frac{u_C\left(Y_t^n\right)}{u_C\left(Y_{t+1}^n\right)}\right].$$

Assuming a constant elasticity of substitution (CES) utility function $u\left(C_t\right) = \frac{C_t^{1-\sigma}}{1-\sigma}$ and applying the logarithm I finally obtain:

$$1 + r_t^n = -\ln\beta + \sigma\left[\ln Y_{t+1}^n - \ln Y_t^n\right] - \sigma g_t.$$

This equation is in line of Laubach and Williams (2003) and Garnier and Wilhelmsen (2005) describing the natural rate of interest as a linear function of trend growth. When dealing with quarterly data, I multiply the above expression by 4 to obtain annual rates. As the forecast error $g_t = \ln Y_{t+1}^n - E_t\left[\ln Y_{t+1}^n\right]$ turns out to be small, I finally neglect it when computing the natural rate. The calibrated parameters are $\beta = 0.99$ when dealing with quarterly data, $\beta = 0.96$ when

[22] For the derivation see e.g. Woodford (2003a, Ch. 4).

[23] By setting $\pi_t = 0$, I assume that monetary policy achieves its target in the long run. For simplicity I assume zero inflation in the derivation of the natural rate of interest. A positive inflation target will then be reflected in the constant of the policy rule (1) and (2).

dealing with annual data and $\sigma = 1.4$.[24] The natural level of output is given by the trend output obtained when calculating the output gap measures.

Additional Variables

The country weights used in the calculations of the weighted mean and standard deviations are obtained from nominal GDP data. For the euro area as well as for the U.S. states I calculate these weights using data for 2006 taken from the IFS and the BEA, respectively. For the German Länder weights are calculated for 1998 taking data from the German Federal Statistical Office.

In the GMM equation additional instruments besides the lagged explanatory variables are included. In the estimation for the ECB the commodity price index (including oil prices) is taken from the IMF World Economic Outlook (WEO) and the real exchange rate comes from the IFS. For the U.S., the commodity price index (excluding oil prices) is taken from the WEO, whereas the real exchange rate is taken from the IFS. In the estimation for the Bundesbank the commodity price index (excluding energy prices) and a world oil price index are taken from the OECD. The real exchange rate comes again from the IFS.

Appendix B Robustness Checks

I first comment on the robustness check for the euro area and proceed with the robustness checks for the comparison of monetary policy stress of different currency areas.

Euro Area

This section presents various robustness checks showing that the results discussed in the main text are fairly robust for most countries along a number of important dimensions. In detail, I conduct the following tests:

1. I drop the lagged interest rate from my estimation of the policy rule, so that I am now merely using equation (2) for calculating the artificial interest rates for every member state.

2. The calibration of the natural rate of interest r_t^n is changed by setting $\sigma = 1$, thus using a log-utility function in the Euler equation.

3. Instead of using the contemporaneous equation (2) to identify starting values for the lagged interest rate in the policy function, I use actual pre-euro interest rate data and take the mean rates of 1998 for every country (for Greece I take the year 2000) as starting value.

4. The data sample used in the estimation is extended to 2009q1 to include the financial crisis. However, I still exclude the quarters from 2009q2 onwards because of the zero lower bound.

[24] For the calibration of the reciprocal of the intertemporal elasticity of substitution σ, I follow Smets and Wouters (2003, 2007) who confirm this value for the euro area as well as for the U.S.

5. In a last step, I calibrate the policy rule instead of estimating it. I use the original Taylor rule and augment it with the natural rate of interest r_t^n:

$$i_t = -5.61 + r_t^n + 1.5\pi_t + 0.5x_t.$$

The coefficient for the inflation rate 1.5 and the output gap 0.5 are set according to Taylor (1993) while the coefficient of the natural rate of interest 1 is taken from the theoretical considerations of Woodford (2001). The original Taylor rule includes only a constant intercept, which is equal to one. Since the rule above includes the time-varying intercept $\bar{i}_t \equiv \alpha + r_t^n$, I set α equal to -5.61 so that the mean intercept over the sample for the ECB will be equal to 1.

Figure B.1 summarizes the robustness checks for all countries included in my sample. Computing the stress measures for every of the above alternatives and for the baseline model, the figure presents the distribution of these measures by showing their minimum and maximum. For most member states this band is fairly narrow indicating that my results are robust along the discussed alternatives. As my comparison of monetary policy stress uses aggregated measures, in a next step, I analyze how these summary statistics are affected by varying the estimation equation.

Figure B.2 contrasts the aggregated monetary policy stress under the baseline scenario with the stress obtained under the above discussed alternatives. Every panel includes the weighted standard deviation of these measures obtained under the baseline scenario together with one or two robustness checks.[25] Starting with the first two alternatives, the upper left panel of Figure B.2 shows that neither modification alters the results significantly. Dropping the inertia term merely increases the variability of the policy rate. Changing the calibration of r_t^n does not alter the results at all. This is because the constant included in the estimation equation together with the coefficient of r_t^n absorb changes in the calibration of the discount factor β and the intertemporal elasticity of substitution σ. In the upper right panel, I analyze the impact of alternative assumptions regarding the starting values for the lagged interest rate in the policy function together with the effect of extending the estimation sample. Using actual pre-euro interest rate data as starting values, monetary policy stress is lower in 1999, but starts to align with the stress levels under the baseline scenario soon after. This suggests that the convergence of actual interest rates in the immediate run-up to the euro was out of line with the economic conditions of member states. Prolonging the sample and including the financial crisis in the estimation sample has negligible effects on the aggregated stress level. In a last exercise, I contrast in the lower left panel the baseline scenario with the results obtained with a calibrated rule. While the stress under the calibrated rule also exhibits a clear trend over the period of study, the dispersion fluctuates more strongly as the calibrated rule does not include an element of inertia.

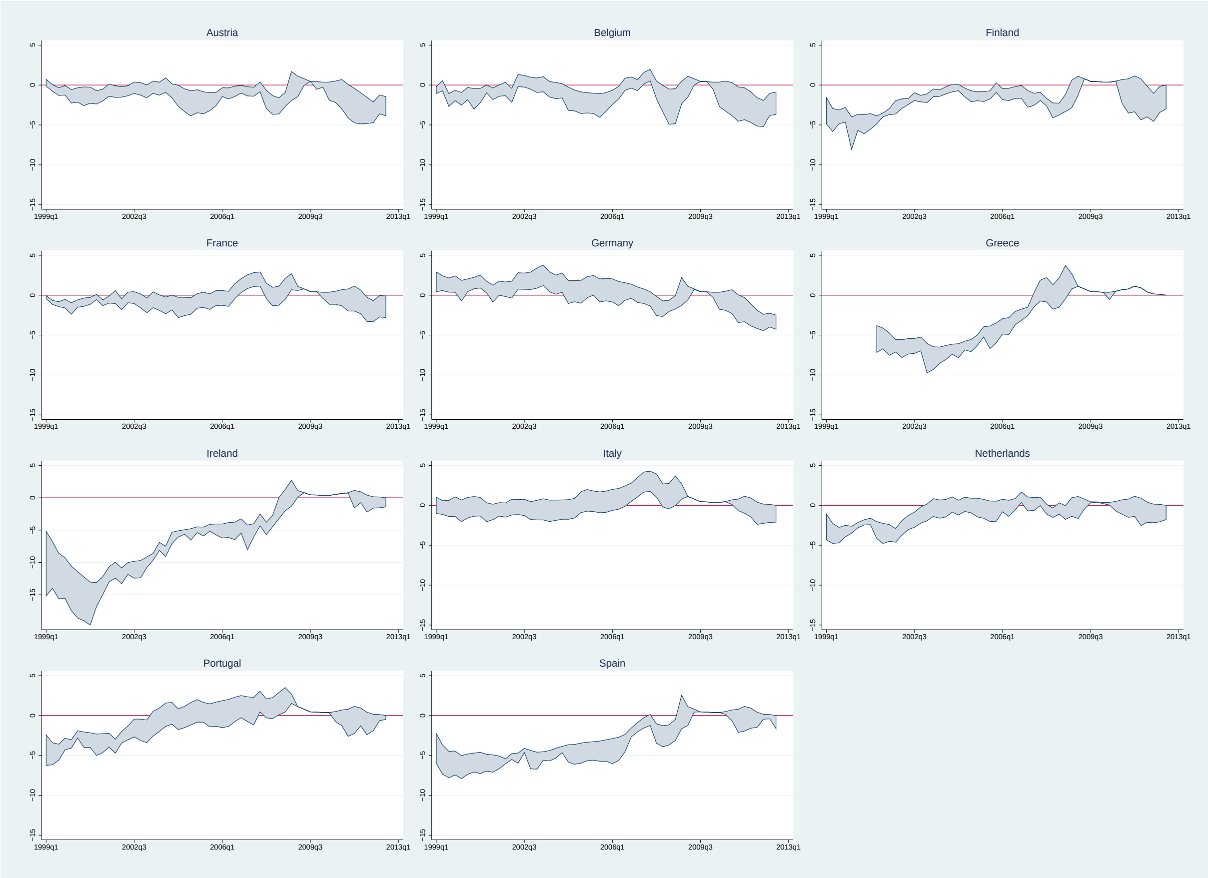
[25] I present the weighted standard deviation here but the results do not differ when using any other summary statistic.

Cross-Currency Union Comparison

I conduct two robustness checks for the cross-currency union comparison showing that the results are robust to the number of states included in a currency area. Starting with the comparison of the euro area with the U.S., I check if there is a *law of large number* effect in the U.S. results, as the Fed has to balance more states than the ECB. To that end, I compute the aggregated stress measure based on only the largest eleven U.S. states for which I have CPI data.[26] Figure B.3 depicts the weighted standard deviation of monetary policy stress from 1977 onwards and shows that this does not significantly alter the comparison with the euro area.

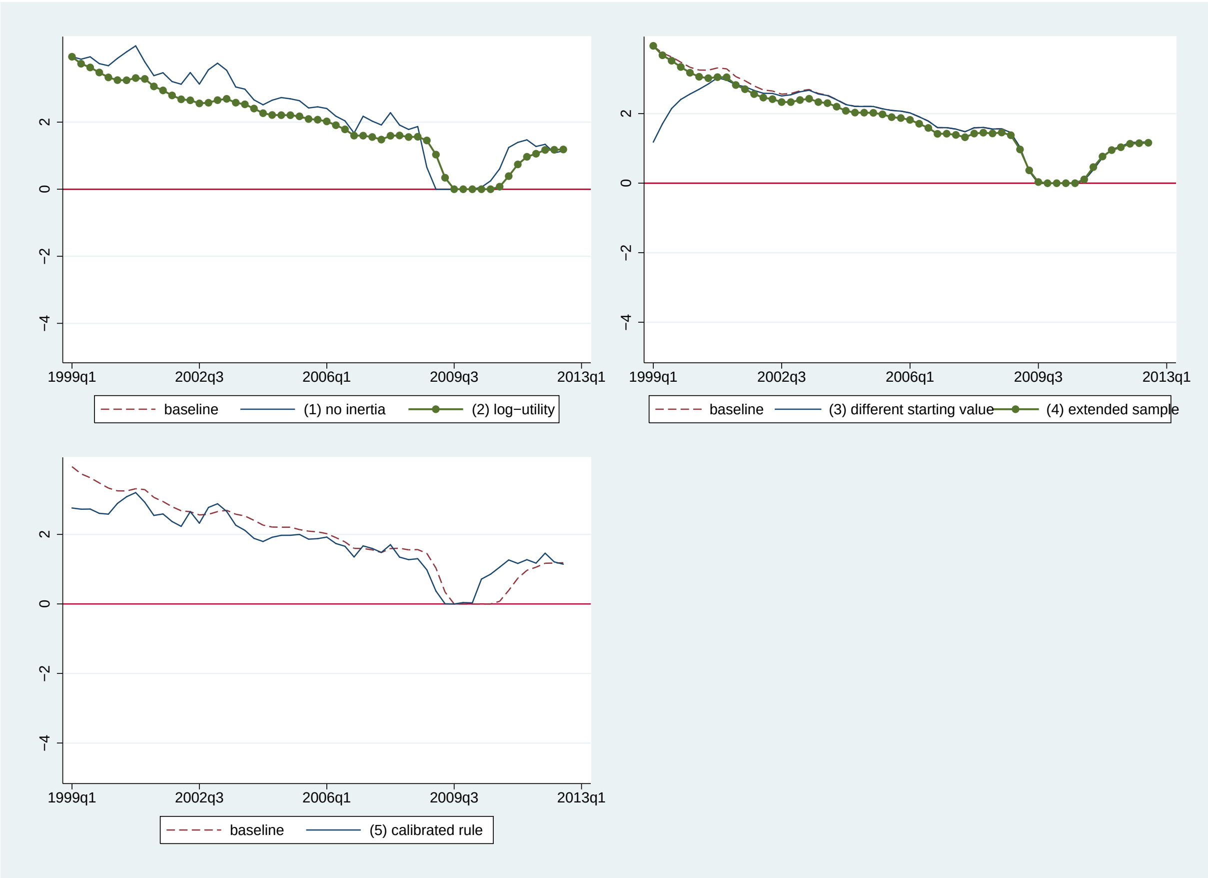
In a second robustness check, I consider all U.S. states when computing monetary policy stress. In the comparison of results for the euro area, U.S., and Germany I narrow down the model and proxy state-specific inflation with national inflation to make the model comparable across all areas. This means, I am no longer limited to include only 31 U.S. states, on which I have CPI data, but I can distinctively include all 51 U.S. states in my sample. Figure B.4 shows that this does not significantly alter the comparison of the currency areas.

[26] The reduced state sample includes California, Florida, Georgia, Illinois, Michigan, New Jersey, New York, Ohio, Pennsylvania, Texas, and Virginia representing about 60 percent of U.S. GDP in 2006. A caveat to this exercise is that the actual Federal Funds Rate is set with an eye on the U.S. overall economy.



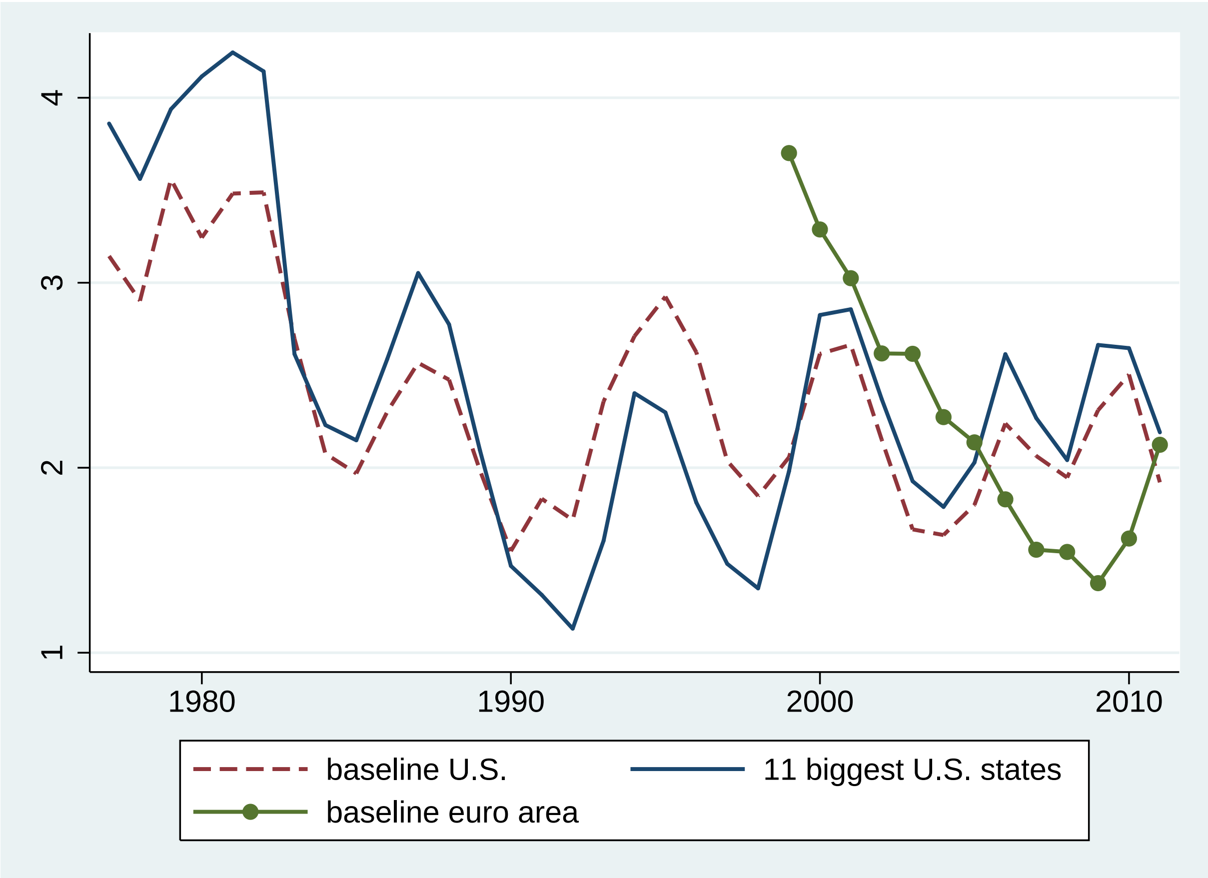
NOTE: The graph summarizes the robustness checks by showing the minimum and maximum of monetary policy stress measures obtained with the discussed alternatives in the appendix and the baseline model.

Figure B.1. Euro Area: Summarizing Country-Specific Robustness Checks



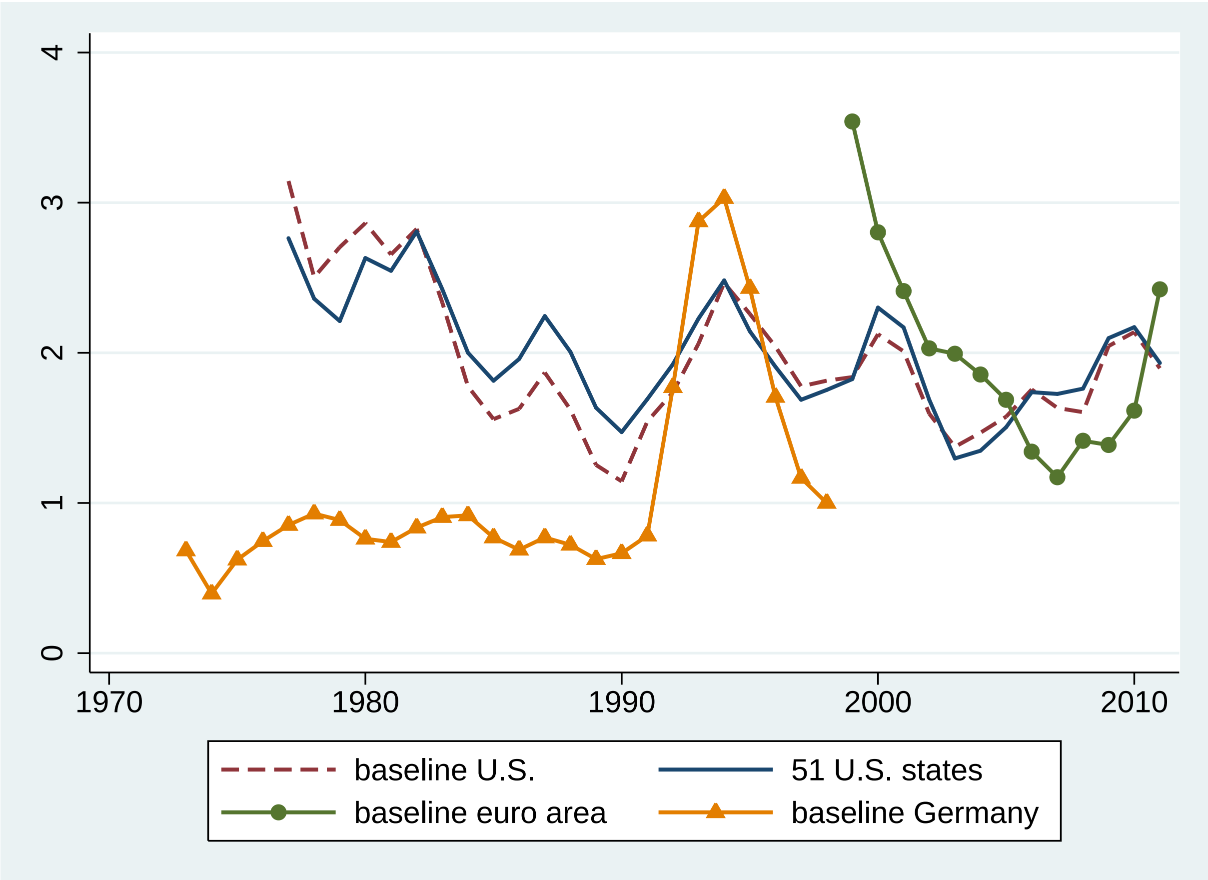
NOTE: The graph shows the weighted standard deviation of monetary policy stress measures obtained with the discussed alternatives. Every panel includes the results of the baseline model and compares these with the results obtained when dropping the lagged interest rate from the estimation equation (1), using a log-utility function for the natural rate of interest (2), using pre-euro data for identifying starting values (3), extending the estimation sample to include the financial crisis (4), and using a calibrated instead of an estimated rule to compute optimal country-specific rates (5).

Figure B.2. Euro Area: Robustness of Summary Measures of Monetary Policy Stress



NOTE: The graph shows the weighted standard deviation of monetary policy stress measures for the euro area and the U.S. It compares the results obtained with the baseline model with monetary policy stress for an artificial currency area consisting of the 11 biggest U.S. states (for which CPI data are available).

Figure B.3. Euro Area and U.S.: Varying Number of U.S. States



NOTE: The graph shows the weighted standard deviation of monetary policy stress measures for the euro area, the U.S., and Germany. It compares the results of the baseline model where the U.S. results are obtained by using only a subsample of 31 states (and aggregating the data for the remaining states) with the results obtained when distinctively differentiating between 51 U.S. states.

Figure B.4. Euro Area, U.S., and Germany: Varying Number of U.S. States

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