Structural Breaks in Inflation Dynamics within the European Monetary Union

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Abstract

Keywords: inflation rate, structural break, EMU, Generalized Logistic Distribution, euro.

1. Introduction

Ever since the beginning of the European Union, the topic of a common currency was a controversial issue. Although the Economic and Monetary Union (EMU) is now a fact, the discussion about the economic effects of the Euro is far from being settled. The controversial topics range from the question of whether or not the Euro–zone is indeed an optimal currency area (OCA) all the way to the very survival of the Euro in light of the budgetary problems of a number of its member states. The effects of monetary unions on a number of macroeconomic indicators, with inflation being the most important one in this context is in the center of an ongoing debate, for instance the question about short-run and steady-state inflation uncertainty dealt with in Caporale and Kontonikas (2009), or the structural convergence of the inflation rates in EU countries which is the topic of an investigation by Palomba, Sarno, and Zazzaro (2009).

The way towards the EMU basically consisted of 3 stages: stage I (1990-1994) as a phase of liberalization, stage II (1995-1998) a phase of convergence and stage III (1999-2001) the transition period, which ended with the introduction of the euro as legal tender. Any new countries who want to join the EMU are first obliged to fulfill the Maastricht which, besides setting rules for government debts and interest rates, also requires the participation in the ERM II for two years, while the exchange rates towards the euro are not allowed to cross the nominal band. These criteria acknowledge, that a stable inflation rate is one of the key goals of every good macroeconomic policy. Emerson, Gros, Italianer, Pisani-Ferry, and Reichenbach (1992) makes it clear, that a high inflation rate is also more variable and uncertain and thus causes more relative price variability, leading to a less efficient price mechanism. Failing to stabilize inflation leads to severe economic problems. Throughout the literature, there is still a considerable degree of uncertainty as to what extent the introduction of the euro, or monetary unions in general, affect the inflation rate. There are a number of reasons for suspecting changes. Given that a country experienced quite volatile inflation rates, its efforts to meet the convergence criteria were likely to lead to an alteration at least in the mean (since this was required for a number of countries) and possibly in the volatility of their respective inflation rates as well. The EMU requires a country to possibly change a number

of economic policies, which can only be achieved by big transitionally efforts.
We contribute to this debate by developing a new method for testing for structural breaks in the dynamics of the inflation rates, which focuses on these changes and thereby upon the effect of the EMU on a number of European countries both within and without the Euro–zone. The framework developed in this paper allows testing for any significant changes of a countries inflation dynamics and thus helps interpreting the effects of the EMU. For this purpose, we developed a new estimation approach building on previous research by Zeileis and Hornik (2007).
Two of the three most important channels that change inflation, the money supply and the degree of openness are subject to fundamental changes once a country joins a monetary union. The original countries participating in the Exchange Rate Mechanism (ERM) had to synchronize money supply growth and interest rates in order to fix exchanges rates or otherwise risk the chance of severe disequilibria. Any new country willing to join must first participate in the second exchange rate mechanism (ERM II) with their currencies floating in a rather narrow band against the euro, which basically requires the same synchronization tools.
Openness, i.e. the inflow of new goods and services or the abolishment of tariffs and capital restraint and regulations, is more likely to generate deflationary pressure, due to the substitution of cheaper goods for more expensive ones. Since deflation is rather unusual, with general price increases being the norm, the logical conclusion is that the most important inflationary channel are changes in money supply. These changes in turn are influenced by a countries monetary policy and the credit behavior of its banking industry. External shocks, like the spillover effects of a hike in oil prices or the financial crisis may be important as well.
Economic theory unfortunately does not provide any clear foundation for a proper answer whether or not the creation of a monetary union between two or more states is likely to reduce or increase the variability or even the level of the inflation rate. An interesting approach to this question is taken by Holtemöller (2007). What he finds out via simulations of different interest rate rules is that the standard deviation of the home CPI inflation rate can be substantially reduced by joining a monetary union. The effects of joining a monetary union on inflation variability in his framework depend on structural parameters like risk aversion, price flexibility, export demand elasticity, openness and shock correlations. However, due to the fact that not all of these parameters are known and that their interaction as well has to be estimated, the whole model is very dependent on a variety of assumptions.
The remainder of this paper is structured as follows: section 2 presents the data, section 3 presents the model and the estimation techniques used, section 4 illustrates our approach using Slovenia as an example, section 5 presents the results and section 6 concludes.

2. Data

HICP series[1] from Jan.1990–Mar.2010 are obtained for 21 countries the Organisation for Economic Cooperation and Development (2010). Countries included are Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, and United Kingdom. Latvia and Lithuania as well as Bulgaria and Romania are excluded due to data scarcity. Cypria and Malta are not included since they are very small economies.

The countries in this sample can be divided into three different groups. First the euro countries (Austria, Belgium, Estonia, France, Finland, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Slovakia, Slovenia and Spain). Second, the EU members not participating in the ERM II: Czech Republic, Hungary, Poland, United Kingdom, and Sweden. Denmark stands on its own as a member of the EU and the ERM II, but not yet a member of the EMU.

[1] seasonally unadjusted

3. Model

To monitor changes in the dynamics of the inflation rates, we follow the usual strategy employed when testing for structural breaks. First, the model is fitted for the whole sample using the generalized logistic distribution. This then enables testing for the stability of the parameter estimates. If there is evidence of significant changes, one proceeds by computing the number and the timing of the break points.
This framework allows to trace the evolution of mean, variance and skewness of the inflation series and thus interpreting deviations in any of these parameters as possibly due to a change in monetary policy, is made feasible. Any huge intervention or change is captured by fluctuations in the parameter stability of the series and can be quantified and related to a distinct time frame.
The correlation dynamics of the series is of less importance to this framework, which concentrates on changes in mean, variance and skewness and does not focus on autocorrelation.

3.1. Generalized Logistic Distribution

The data suggested that the use of a normal distribution might cause some estimation problems, since most of the time series exhibit asymmetric properties (with sometimes rather strong skewness) and – compared to the normal distribution – a fatter tail. To accommodate for this fact, the use of the generalized logistic distribution (GL) with its relative low degree of complexity, seemed appropriate. On the one hand, it is a simple distribution and on the other hand, it is flexible enough to capture essential properties of the data. For the inflation series $y_t = 100 \cdot log(HICP_t/HICP_{t-1})$ we therefore assume a GL distribution as defined in Johnson, Kotz, and Balakrishnan (1995):

$$f(y|\theta, \sigma, \delta) \quad = \quad \frac{\frac{\delta}{\sigma} \cdot \exp^{-\frac{y-\theta}{\sigma}}}{(1 + \exp^{-\frac{y-\theta}{\sigma}})^{(\delta+1)}} \tag{1}$$

with location θ, scale σ and shape δ. For $\delta = 1$ the distribution simplifies to the logistic distribution, for $\delta < 1$ it is skewed to the left and for $\delta > 1$ it is skewed to the right (see appendix A for more details).
In econometrics, the logistic distribution is often used in income distributions and growth models. This is due to its fatter tail, which fit these kind of data somewhat better. Wong and Bian (2005) employ a GL distribution in a regression model with autocorrelated errors. They use this type of distribution rather than a Student's t-distribution, as to model the fact that these are oftentimes non symmetric and severely left or right skewed. A similar GL distribution is also used in Tolikas, Koulakiotis, and Brown (2007) who analyze extreme risk and value–at–risk in the German stock market, although they do not use a shape parameter. Regarding inflation rates, the GL distribution is — to our best knowledge — only used in context to expected inflation. Batchelor and Orr (1988) use a logistic distribution (not its generalization) to model the distribution of mean expected inflation rates.

3.2. Estimation

Under the assumption, that y_t is distributed according to the generalized logistic distribution, we test for the hypothesis that the parameter vector $\hat{\phi}$ stays stable over time:

$$H_0 : \phi_t = \phi_0 \quad (t = 1, ..., n)$$

against the H_1 of changes in at least one of the parameters. We first estimate the parameters of the GL–distribution by means of maximum likelihood $\hat{\phi} = \underset{\phi}{argmax} \sum_{t=1}^{n} \log f(y_t|\phi)$. The parameter stability is assessed using the empirical scores $s(y_t|\hat{\phi})$ as measures of model deviation.[2] The empirical scores process $efp(\cdot)$ captures deviations from a hypothesized zero mean over time and is given by:

$$efp(t) \;=\; \hat{V}^{-1/2} n^{-1/2} \sum_{i=1}^{\lfloor nt \rfloor} s(y_i|\hat{\theta}, \hat{\sigma}, \hat{\delta}) \quad (0 \leq t \leq 1),$$

where $\hat{V}^{-1/2}$ is some consistent estimator of the variance of the scores, which is used to decorrelate the series as to avoid problems due to serial correlation. Then a functional central limit theorem (FCLT) for $efp(\cdot)$ is employed, which converges to a 3-dimensional Brownian bridge:

$$efp(\cdot) \xrightarrow{d} W^0(\cdot)$$

3.3. Test

After the empirical fluctuation process is computed, it conveys information about departures from the H_0 of parameter stability over time. For a precise quantification of the actual deviation from its hypothesized zero–mean path, the main idea of the test statistics presented here is to aggregate the $efp(\cdot)$ in such a way as to be able to construct a test statistics so that critical values and p values can be derived. In this paper, we employ the Supremum of LM (supLM) test by Andrews (1993). This test is well suited for single break alternatives and performs better if more than just one of the distribution parameters change. It is given by:

$$\underset{t \in [0.1, 0.9]}{sup} \frac{\| efp(t) \|_2^2}{t(1-t)}$$

where the appropriate p–values can be computed using:

$$\underset{t \in [0.1, 0.9]}{sup} \frac{\| W^0(t) \|_2^2}{t(1-t)}$$

The supLM test computes a test statistics for all possible change points in a given time frame and rejects the null of no change if the maximum is too high.

[2] for details see Appendix A and Zeileis and Hornik (2007)

3.4. Breakpoint Estimation

If a break is detected via the supLM test, the next step is estimating the number and the timing of these break points. Breakpoints $\tau_1, ..., \tau_B$ are estimated via maximization of the full segmented likelihood:

$$\sum_{b=1}^{B+1} \sum_{t=\tau_b+1}^{\tau_b} \log f(y_t|\phi^{(b)})$$

If the test statistics is significant, at least one break is estimated. In principle, the optimal segmentation (i.e. the concrete dates of a break) can be computed once B (the number of breakpoints) is known. However, B needs to be based on the observed data as well. The solution is to compute the timing of the breaks for a number of different values for B and then choose B by means of an information criterion, in this case the LWZ (Liu, Wu and Zidek) as developed in Liu, Wu, and Zidek (1997). All parameters $\tau_1, \ldots, \tau_B, \phi^{(1)}, \ldots, \phi^{(B+1)}$ can be estimated jointly using dynamic programming.[3]

[3]More details for this estimation technique are provided in Zeileis, Shah, and Patnaik (2010).

4. An Example

For an illustration of the method, consider the case of Slovenia. The data collected encompasses the period from Jan 1996 onwards. During the beginning of this period, Slovenia experienced very high inflation rates but was successfull in continually decreasing them. A glance at the data suggests a break around 2003/04, with an evident change in the mean.

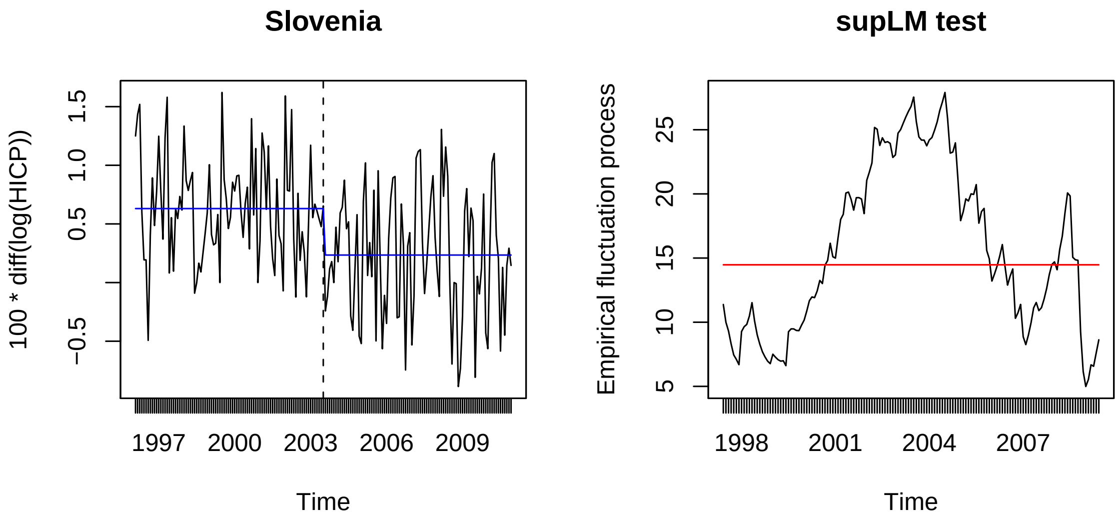

Figure 1: Slovenia: breakpoint estimate and supLM test

The supLM test confirms this belief by picturing a hike of the $efp(\cdot)$ around 2003. The LWZ criterion suggests one break point, which is estimated at August 2003.
In this year, Slovenia introduced a number of financial reforms and severely decreased the year on year growth of money supply. Combined, these actions were enough to ensure the succesfull participation in the ERM II a year later.

5. Results

Country	Segment	Mean	Variance	Skewness	ERM	ERM II	Euro
The Eastern Countries							
CzechRepublic	Feb 1995–Jul 1998	0.697	0.337	1.139	–	–	–
	Aug 1998–Dec 2010	0.177	0.206	0.979			
Estonia	Feb 1996–Mar 1998	0.865	0.420	0.404	–	Jun 2004	Jan 2011
	Apr 1998–Dec 2010	0.336	0.195	0.732			
Hungary	Feb 1995–May 1998	1.606	1.024	0.870	–	–	–
	Jun 1998–Dec 2010	0.491	0.310	0.708			
Poland	Feb 1996–May 2001	0.855	0.422	0.669	–	–	–
	Jun 2001–Dec 2010	0.202	0.120	−0.471			
Slovakia	Feb 1995–Feb 2004	0.563	0.338	1.139	–	Nov 2005	Jan 2009
	Mar 2004–Dec 2010	0.178	0.081	1.139			
Slovenia	Feb 1996–Jul 2003	0.631	0.211	0.588	–	Jun 2004	Jan 2007
	Aug 2003–Dec 2010	0.235	0.331	0.199			
Italy and Spain							
Italy	Feb 1990–May 1996	0.414	0.042	0.970	Mar 1979	–	Jan 1999
	Jun 1996–Dec 2000	0.168	0.020	0.726			
	Jan 2001–Dec 2010	0.186	0.317	−0.308			
Spain	Feb 1992–Dec 2000	0.282	0.057	0.709	Jun 1986	–	Jan 1999
	Jan 2001–Dec 2010	0.234	0.333	−0.361			
Ireland							
Ireland	Feb 1995–Jun 2008	0.257	0.202	−0.719	Mar 1979	–	Jan 1999
	Jul 2008–Dec 2010	−0.148	0.148	−1.891			
No change countries							
Greece	Feb 1995–Dec 2010	0.325	1.434	0.424	Mar 1998	Jan 1999	Jan 2001
Netherlands	Feb 1990–Dec 2010	0.178	0.292	0.606	Mar 1979	–	Jan 1999
France	Feb 1990–Dec 2010	0.155	0.073	−0.090	Mar 1979	–	Jan 1999
Finland	Feb 1990–Dec 2010	0.166	0.132	0.166	Oct 1996	–	Jan 1999
Non participating countries							
Sweden	Feb 1990–Jan 1993	0.475	0.570	1.139	–	–	–
	Feb 1993–Dec 2010	0.155	0.183	0.542			
UK	Feb 1990–Apr 1992	0.569	0.385	1.138	–	–	–
	May 1992–Dec 2010	0.168	0.147	−1.175			
The other countries							
Austria	Feb 1990–Sep 2007	0.164	0.057	0.609	Jan 1995	–	Jan 1999
	Oct 2007–Dec 2010	0.167	0.149	−0.076			
Belgium	Feb 1991–Jul 2000	0.149	0.063	−0.159	Mar 1979	–	Jan 1999
	Aug 2000–Dec 2010	0.076	0.108	0.201			
Denmark	Feb 1990–Jun 2000	0.166	0.091	−0.745	Mar 1979	Jan 1999	–
	Jul 2000–Dec 2010	0.162	0.174	1.007			
Germany	Feb 1995–May 2000	0.088	0.060	0.924	Mar 1979	–	Jan 1999
	Jun 2000–Nov 2003	0.109	0.156	0.997			
	Dec 2003–Dec 2010	0.160	0.169	0.097			
Luxembourg	Feb 1995–Dec 1998	0.088	0.013	0.251	Mar 1979	–	Jan 1999
	Jan 1999–Dec 2010	0.312	0.260	−0.609			
Portugal	Feb 1990–May 1992	0.884	0.186	1.139	Apr 1992	–	Jan 1999
	Jun 1992–Dec 2010	0.366	0.117	0.620			

Table 1: Break point and parameter estimates and ERM information

The table above presents the break dates and the parameter values of the segments as well as the dates of entry into the ERM/ERM II and the date of euro introduction.
In a prior inspection, Belgium and Luxembourg were very similar. However, this degree of similarity in the original series as provided by the OECD, actually could be traced back – according to their national statistical offices – to the inclusion of sales (winter and summer) in January 1999 for Belgium and January 2000 for Luxembourg which was demanded by a Commission regulation, details may be found in: European Commission (2010).[4] This lead to a 6 month seasonality pattern (January and July) after the inclusion of sales periods into the HICP. We corrected for this by estimating dummies for these month and subtracting them from the original time series. In the case of Belgium, the estimated break was postponed to late 2007, coinciding with the Austrian break. The time after the break is characterized by an increase in mean and a severe increase in the variance and can be traced back to two major influences: the beginning of the financial crisis and potentially some spillover effects of higher oil prices.
The first of these groups are the Eastern European countries: the Czech Republic, Estonia, Hungary, Poland, Slovakia and Slovenia. In almost all of these countries, the mean and the variance of their inflation rates declined in the later part of the 90ies. Most of them experienced a break in 1997/1998, with Poland, Slovakia and Slovenia somewhat later. The break during the late 90ies is a result of these countries efforts to curb in inflation by decreasing money supply and indicates the time when these countries actually overcame the biggest transitionary shocks on their way towards free market economies. The case of Slovenia was already described. Slovakia is very similar, as its inflation dynamics too changed roughly one year prior to ERM II entry.
Another combination of countries with rather identical results are the two biggest southern European countries, Italy and Spain. Both of them experienced high rates of inflation in the early 90ies. Afterwards, in the phase leading up to the monetary union, mean and variance were greatly reduced. This trend changed significantly soon after the fixing of the exchange rates leading to higher mean and much higher variances then ever before since the beginning of the HICP series.
Ireland can be considered a rather special case. It is the only economy where the effects of the ongoing financial crisis of 2008 are visible. We find a structural break in 2008 following the strong contraction triggered by the bursting of the Irish housing bubble and a beginning deflation.
Another interesting group consists of 4 economically rather different countries. In none of them do we find any evidence of a change in inflation dynamics. Whereas France, Finland and the Netherlands are on the lower side of the inflation margin, the Greek inflation rate exhibits some very strange behaviour. It has by far the highest variance of all series and seems to be completely different from them.[5]

[4]In addition to Belgium and Luxembourg, there are a number of other countries, where the sales periods are regulated by law. France has an individual time span regulated by each department. This should pose no problem, since there is no global state level solution. In Greece there are also two set sales–periods in winter and summer. In Italy the sales periods are fixed each year by the Chambers of Commerce. Portugal has two set sales periods as well, but for two month (January and February as well as Mid–July to Mid–September. The source for this information is European Consumer Centres (2010). Dummies were estimated for Belgium, Luxembourg and Portugal. Italy and Greece were not estimated, since – as in the case of France – these periods do not seem to be set for the whole country at once.

[5]This suggested some possible data problems, but unfortunately numerous efforts of communication failed with official sources failed.

The last group with clear patterns consists of the two countries that decided not to be part of any European Monetary System[6], the United Kingdom and Sweden. Both have a clear break in the early 90ies, and both of these breaks can be traced back to crisis, the currency crisis of the United Kingdom cumulating into the "Black Wednesday" in 1992 and the run on the Swedish currency in the same year.

No clear interpretation is available for: Austria, Belgium, Denmark, Germany, Luxembourg and Portugal. For Austria, we observe a change in 2007, possibly explained by the oil price shock, which is the official explanation of the Statistics Austria. Belgium changed in 2000 with a clear reduction in mean and an increase in variance. In the case of Denmark we observe a increase in variance after 2000 with a very distinct change in skewness. Germany saw an increase in its inflation mean and volatility after 2000. Luxembourg suffered a severe increase in variance, similar to Italy and Spain. Portugal on the other hand was successfull in reducing its very high inflation rate substantially following the participation in the ERM arrangement.

A disturbing trend seems to be the rise in inflation volatility in almost half of the euro countries. A very volatile inflation rate is unlikely to contribute to greater macroeconomic stability. Although Grier and Perry (2000) find no evidence, that higher inflation uncertainty raises the average inflation rate – at least in the case of the USA – Jarociǹski (2010) finds a positive correlation between the level and the standard deviation of inflation. This finding might be still more problematic if we take into account that on average the skewness parameter has decreased substantially in most of the euro–zone countries indicating that in future higher inflation rates are more likely.

[6]If we ignore the short participating time of both countries in the EMS.

5.1. Inflation Differentials

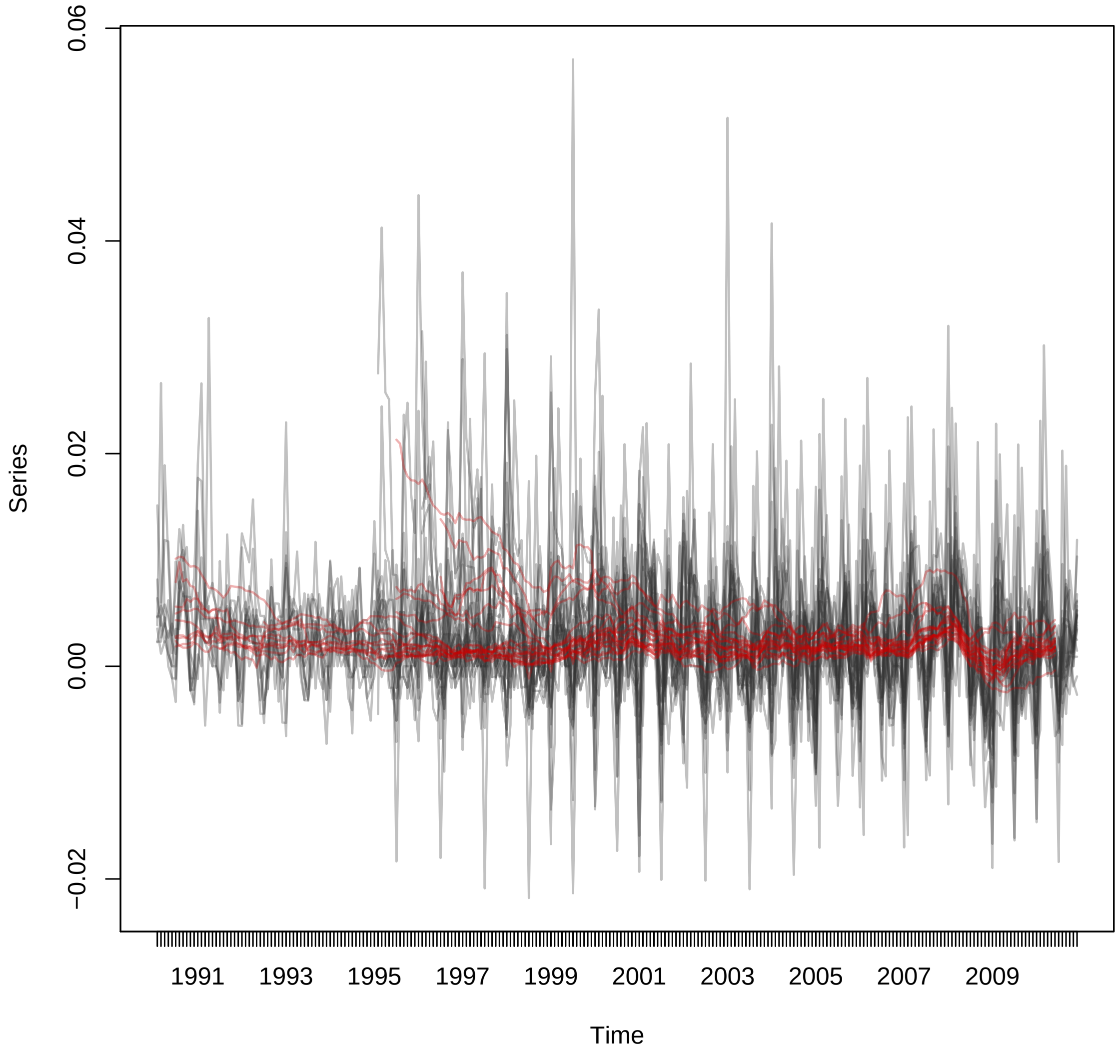

Figure 2: Inflation rates and mean inflation rates over time

The disparity of the national inflation rates is still an issue, many researchers, like Hofmann and Remsperger (2005) still find a considerable amount of inflation differentials. Caporale and Kontonikas (2009) estimate short-run and steady-state inflation uncertainty in 12 EMU countries and find a considerable degree of heterogeneity across EMU countries in terms of average inflation and its degree of persistence. In a paper examining structural convergence of the inflation rates in EU countries, Palomba *et al.* (2009) try to answer the question if during the 1990s the inflation rate dynamics of EU countries become more similar. They find that convergence over time of inflation dynamics was only partly observable. In a paper studying core inflation and using an aggregated euro area inflation rate, Morana (2000) finds three regimes (roughly 1980—1984, 1984—1993 and 1993—2000) governing the core inflation rate. Concerning inflation differentials, we present a graph depicting the inflation rates and a rolling mean estimation, where the mean is calculated using the first moment of a fitted GL distribution. If more countries have the same inflation rate in a given month, the lines are overlapped and thus get darker.[7] We do see that many of these countries follow a rather similar path. One event clearly visible is the financial crises and the short deflationary phase starting somewhere around the autumn of 2007 and lasting a few months. However, only a small number of countries exhibits a break around this time (Austria and Ireland).

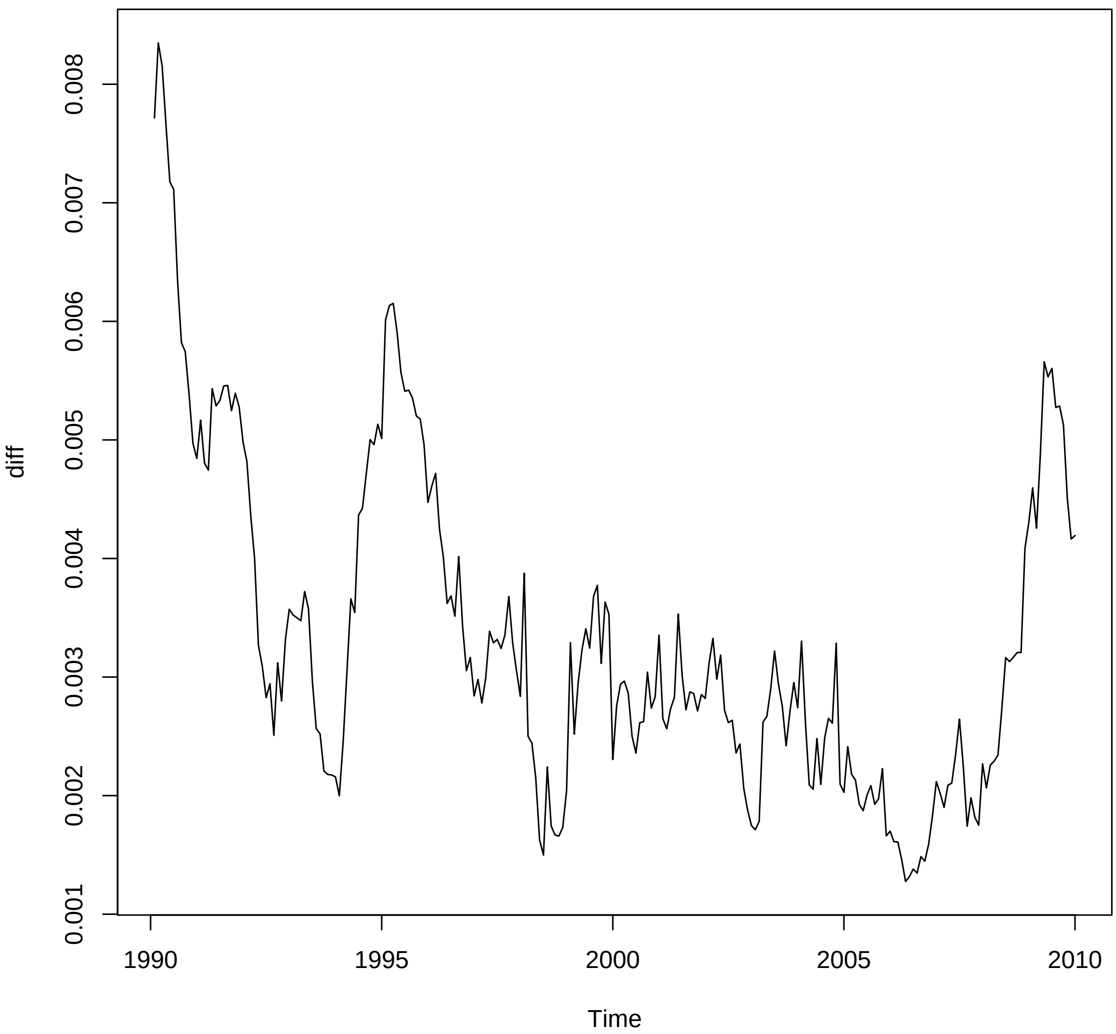

Figure 3: Differences in Euro excluding Estonia, Slovenia and Slovakia

Concerning the mean of the inflation rates, we see a clear convergence pattern. This result is

[7]We wold see one black line if all countries would show the same month–on–month increase at any one time.

reinforced by plotting the difference between the highest and the lowest mean inflation rate in the euro subsample, excluding the new Euro–member states Estonia, Slovakia and Slovenia.[8] After a short hike at the beginning of the convergence phase in 1995, the difference declined clearly to a fraction of its previous value. However, the financial crisis clearly contributed to widening of the convergence gap. Our finding contradicts Busetti, Forni, Harvey, and Venditti (2007) who find that from 1980—1997 there was convergence of inflation rates, but afterwards there is some diverging behavior. This does not quite go along with the depicted means, that do not indicate stronger divergence after 1997 but a continuing decrease of inflation differentials until the hikes after 2008.

However, this is not the case for variance, where we find clear evidence of an increase. Doing the same thing for volatility, we see the second moment almost tripling after 1995.[9] This of course does make some economic sense, since the convergence criteria and the ECB focus on mean inflation only and do not take volatility into account.

[8] Including them blurs the clear result somewhat by driving the difference up, since at the beginning, these countries still had very high inflation rates.

[9] Due to a very low volatility of countries like Spain and Luxembourg at the beginning.

6. Conclusion

Computational Details

The results shown are computed with a new R package **glogis**, which is an enhancement to the already existing R package **strucchange**, which currently does not support a GL distribution. The tests and the graphical illustration of the empirical fluctuation process were developed in Zeileis and Hornik (2007), the second part of the results - the dating procedure and the illustration of the densities fitted for the subsamples (divided by the breaks) - can be found in Zeileis *et al.* (2010).

A. GL Distribution

The moments of the GL distribution as given in equation 1 are:

$$\begin{aligned} E(y) &= \theta + \sigma(\gamma(\delta) - \gamma(1)) && (2) \\ Var(y) &= \sigma^2(\gamma'(\delta) + \gamma'(1)) && (3) \\ Skew(y) &= \frac{\gamma''(\delta) - \gamma''(1)}{(\gamma'(\delta) + \gamma'(1))^{3/2}} && (4) \end{aligned}$$

where $\gamma(\cdot)'$ and $\gamma(\cdot)''$ are its first and second derivatives, respectively.
The log-likelihood is:

$$\begin{aligned} \log f(y|\theta, \sigma, \delta) &= \log(\delta) - \log(\sigma) && (5) \\ &- \frac{1}{\sigma}(y - \theta) - (\delta + 1) \\ &\times \log(1 + \exp^{-\frac{y-\theta}{\sigma}}) \end{aligned}$$

The resulting score function, where the scores are the derivatives of the log–likelihood function, has three components $(s_\theta, s_\sigma, s_\delta)$, with $\tilde{y} = \exp^{-\frac{y-\theta}{\sigma}}$. These are employed in equation 2 for the construction of the test statistics and are a means of measuring the estimation error in a maximum likelihood framework.

$$\begin{aligned} s_\theta(y|\theta, \sigma, \delta) &= \frac{\delta \log f(y|\theta, \sigma, \delta)}{\delta\theta} && (6) \\ &= \frac{1}{\sigma} - (\delta + 1) \cdot \frac{\frac{1}{\sigma}\tilde{y}}{(1 + \tilde{y})} \\ s_\sigma(y|\theta, \sigma, \delta) &= \frac{\delta \log f(y|\theta, \sigma, \delta)}{\delta\sigma} && (7) \\ &= -\frac{1}{\sigma} + \frac{1}{\sigma^2}(y - \theta) - (\delta + 1) \times \frac{\frac{1}{\sigma^2}(y - \theta)\tilde{y}}{(1 + \tilde{y})} \\ s_\delta(y|\theta, \sigma, \delta) &= \frac{\delta \log f(y|\theta, \sigma, \delta)}{\delta\delta} && (8) \\ &= \frac{1}{\delta} - \log(1 + \tilde{y}) \end{aligned}$$

The scores of the parameters $\phi = (\theta, \sigma, \delta)$ sum up to 0: $\sum_{t=1}^{n} s(y_t|\hat{\phi}) = 0$. The first order condition is given by:

$$\sum_{i=1}^{n} s(y_i|\hat{\theta}, \hat{\sigma}, \hat{\delta}) = 0 \tag{9}$$

B. Graphs

(... less space, more on one page ...)
Here we present the actual data where the blue lines in the graphs correspond to the estimated mean of the series.

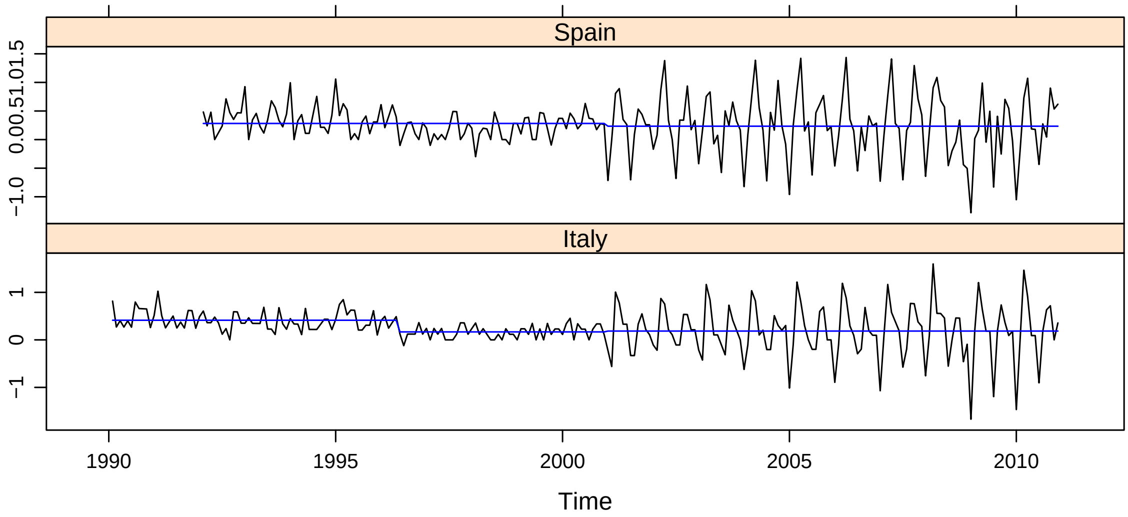

Figure 4: Italy and Spain

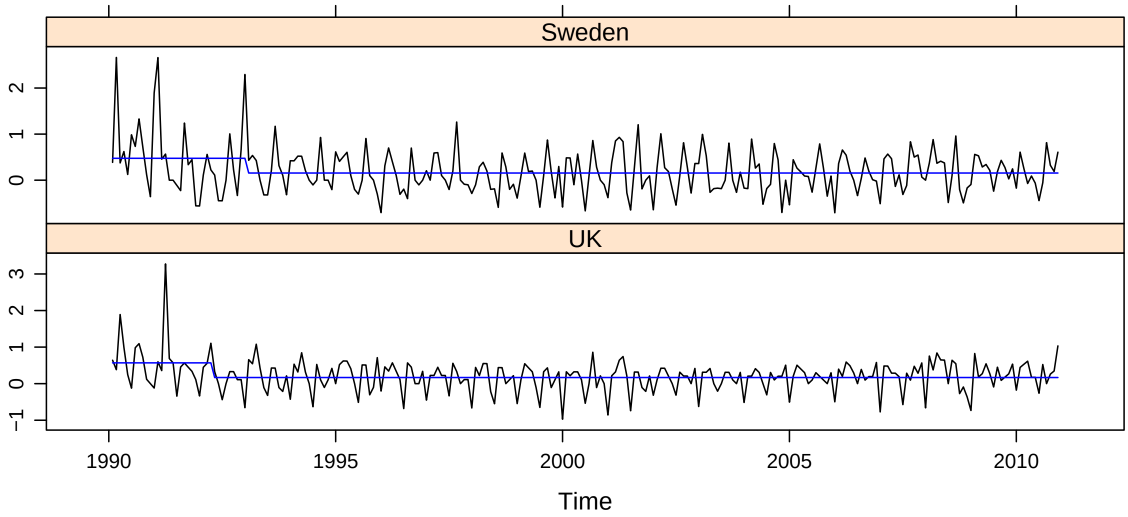

Figure 5: Sweden and United Kingdom

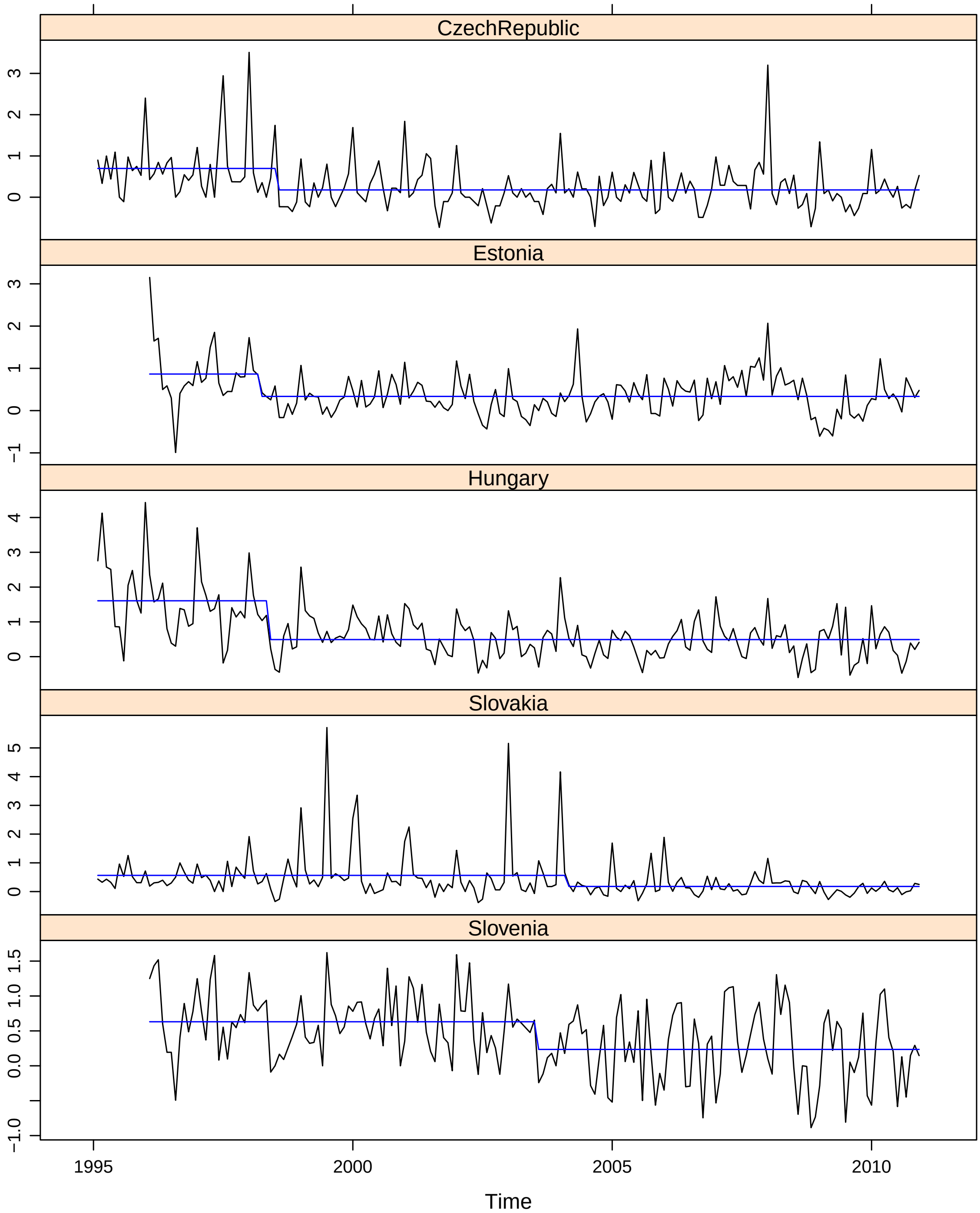

Figure 6: The Eastern Countries

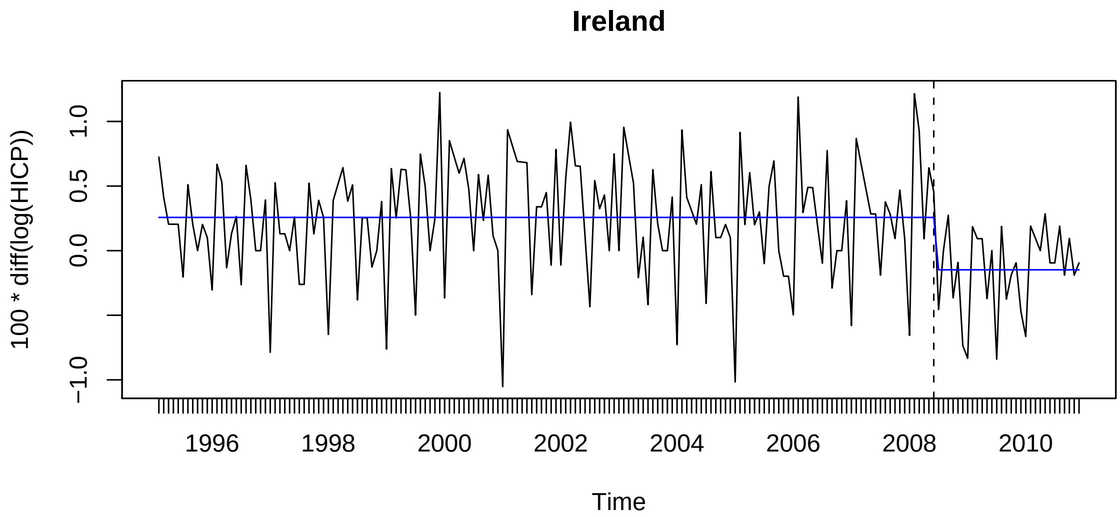

Figure 7: Ireland

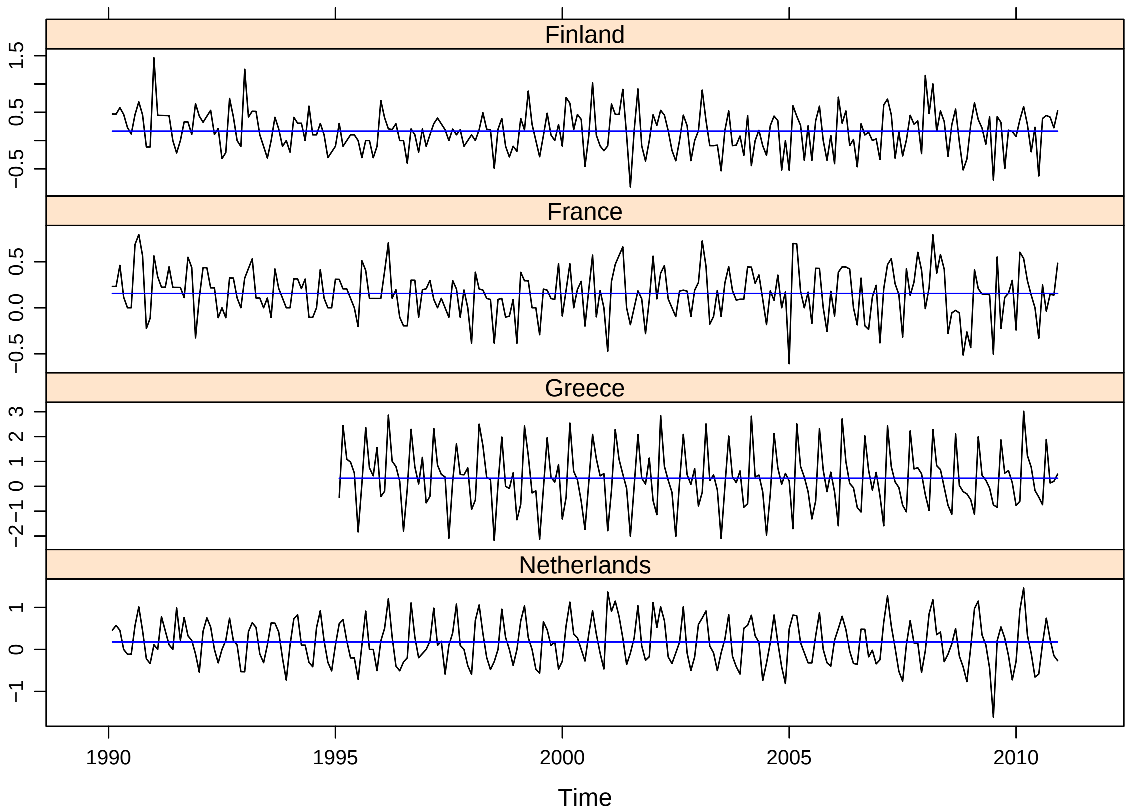

Figure 8: Nochange Countries

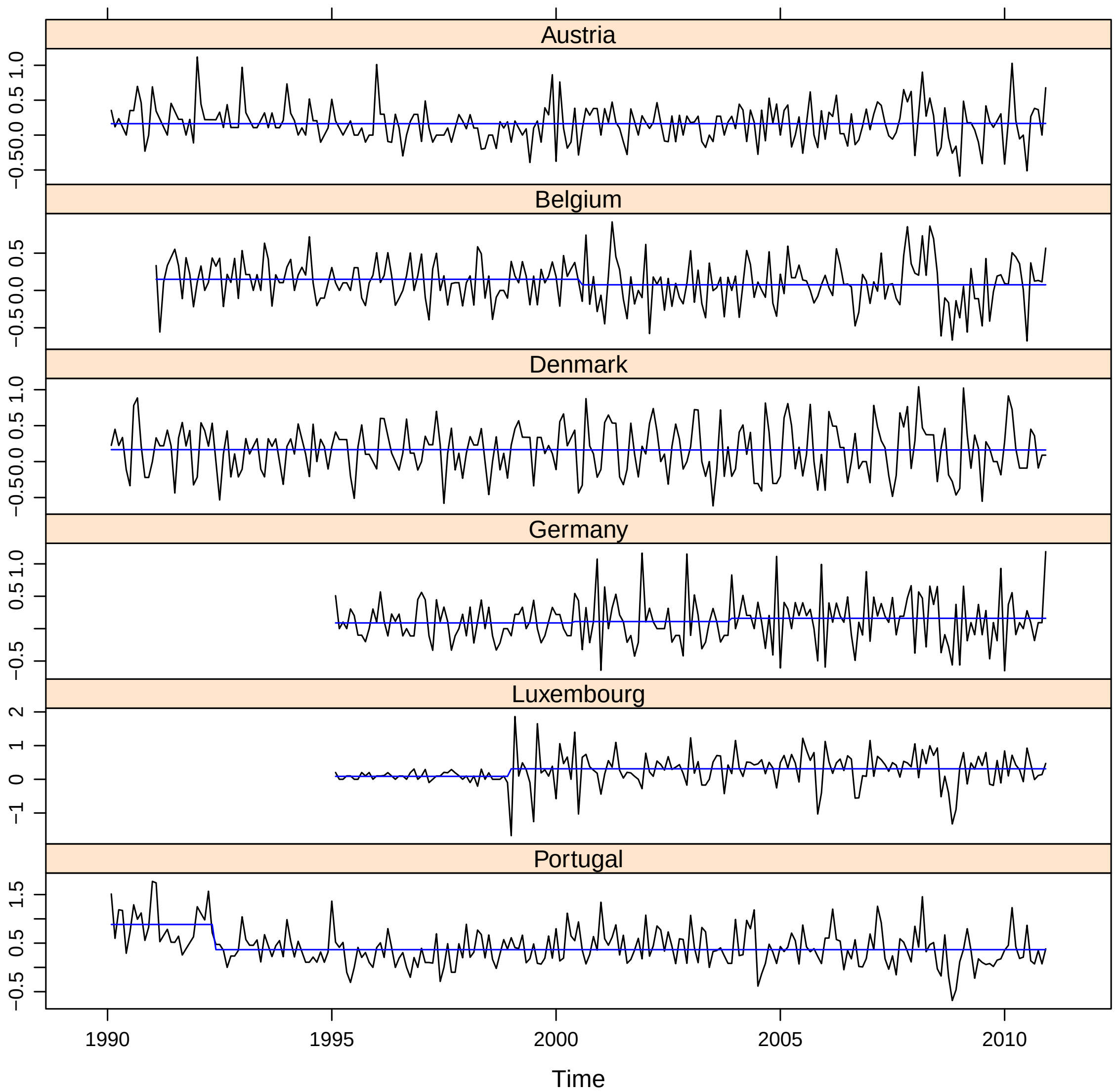

Figure 9: Countries without discernible pattern

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