# Structural Breaks in Inflation Dynamics within the European Monetary Union

Thomas Windberger, Achim Zeileis

`http://glogis.R-Forge.R-project.org/`

# Overview

- Introduction and Data
- Model
- Example
- Results
- Conclusion

# Introduction and Data

- Did European Monetary Union (EMU) change inflation dynamics?
- Economic reasons
  - Former Council for Mutual Economic Assistance (COMECON) member states
  - Ex-Yugoslavia countries
  - Southern European countries
  - Central European countries
- Harmonised Index of Consumer Prices (HICP) for 21 countries. Monthly unadjusted data up to March 2010
- Source: OECD Statistics
- 3 groups
  - EURO countries
  - EU members without Exchange Rate Mechanism II (ERM II)
  - ERM II countries

# Model

- Our approach:
  - Track evolution of distribution over time for each country
  - Investigate changes in mean, variance, and skewness over time
  - Idea: Identify changes associated with intervetions, crises, etc.
- Of less interest in this analysis:
  - Correlation over time (e.g., ARIMA, GARCH)
  - Correlation between countries (e.g., VAR)
- Selected method:
  - Maximum likelihood for flexible distribution: Generalized logistic distribution allowing for fat tails, and potential skewness
  - Testing and dating of structural breaks
  - Neglect correlation structure or treat as nuisance parameter

# Generalized Logistic (GL) Distribution

For return series $y_t = 100 \cdot log(HICP_t / HICP_{t-1})$ ($t = 1, \ldots, n$) we assume a GL distribution given by:

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

with location $\theta$, scale $\sigma$ and shape $\delta$.
Moments:

$$\begin{aligned} E(y) &= \theta + \sigma(\psi(\delta) - \psi(1)) \\ VAR(y) &= \sigma^2(\psi'(1) + \psi'(\delta)) \\ SKEW(y) &= \frac{\psi''(\delta) - \psi''(1)}{(\psi'(1) + \psi'(\delta))^{\frac{3}{2}}} \end{aligned}$$

# Framework

Assuming $\phi = (\theta, \sigma, \delta)$ is stable over time $t$, it can be estimated by maximum likelihood, or equivalently solving the estimating equations:

$$\hat{\phi} = \underset{\phi}{argmax} \sum_{t=1}^{n} \log f(y_t | \phi),$$

$$\sum_{t=1}^{n} s(y_t | \hat{\phi}) = 0,$$

Question: Is the assumption valid or do the $\phi_t$ vary over time?

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

This can be assessed using the empirical scores $s(y_t | \hat{\phi})$ as measures of model deviation.

# Scores

Score function has 3 components $(s_\theta, s_\sigma, s_\delta)$, with $\tilde{y} = \exp^{-\frac{y-\theta}{\sigma}}$

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

# Empirical Fluctuation Process

The empirical fluctuation process $efp(\cdot)$ captures systematic deviations from zero over time:

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

Functional central limit theorem (FCLT) for $efp(\cdot)$: $W^0$ converges to a 3-dimensional Brownian bridge:

$$efp(\cdot) \; \overset{d}{\to} \; W^0(\cdot)$$

# Test

$efp(\cdot)$ could be aggregated to test statistic in various ways.

Here: Employ Andrews' sup*LM* test

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

p-values can be computed from:

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

# Breakpoint Estimation

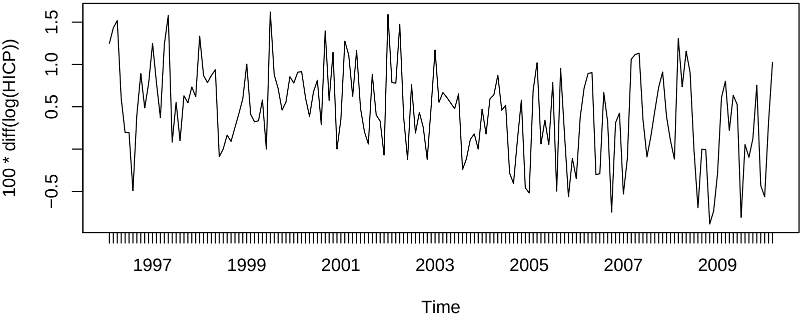
If instability detected, estimate $B$ breakpoints $\tau_1, ..., \tau_B$ via maximization of full segmented likelihood:

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

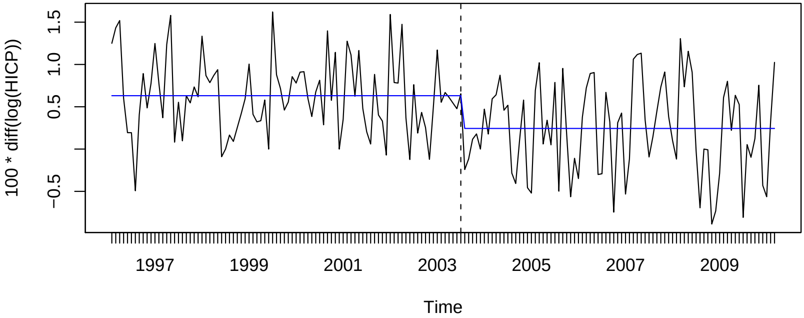
All parameters $\tau_1, \ldots, \tau_B, \phi^{(1)}, \ldots, \phi^{(B+1)}$ can be estimated jointly using dynamic programming.

Model selection: Select best $B$ via a modified BIC from fitted models for $B = 1, \ldots, 6$.

# Slovenia: Data

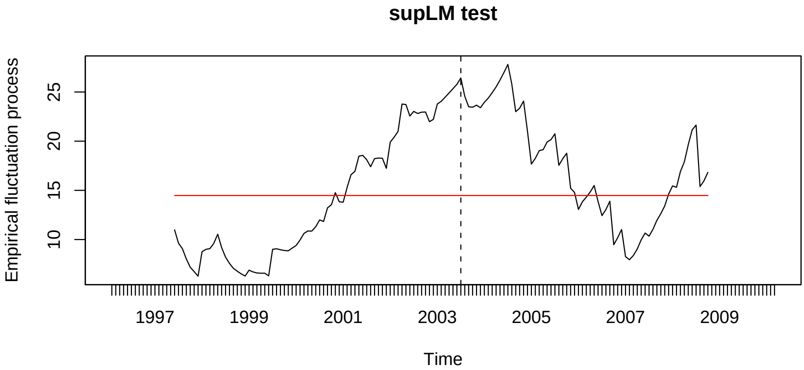


# Slovenia: Fitted Model

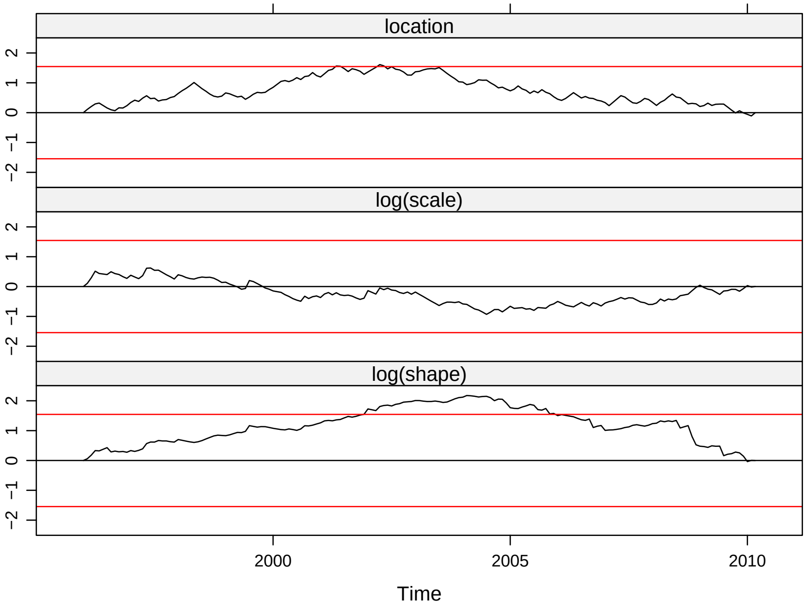



| Country | Segment | Mean | Variance | Skewness |
|---|---|---|---|---|
| Slovenia | Feb 1996–Jul 2003 | 0.631 | 0.211 | 0.588 |
| | Aug 2003–Mar 2010 | 0.244 | 0.344 | 0.143 |

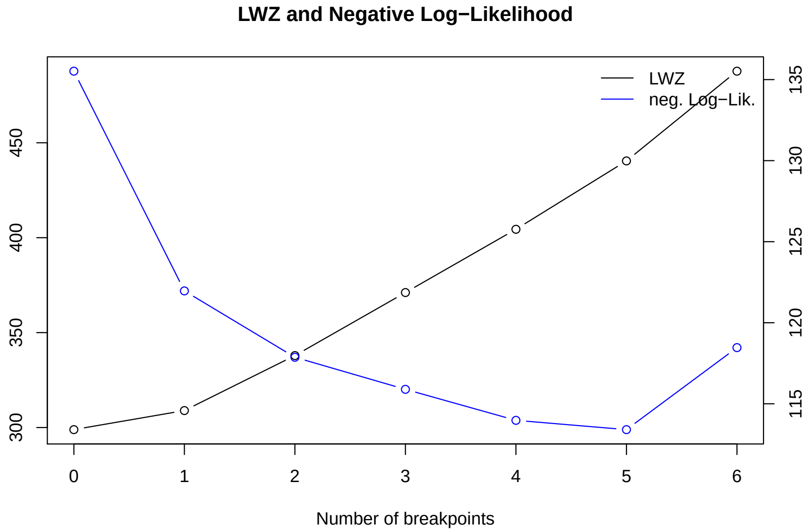
# Slovenia: Test



# Slovenia: Moment Changes



# Slovenia: Breakpoint Selection



# Slovenia: Fitted Model

Economic Interpretation:

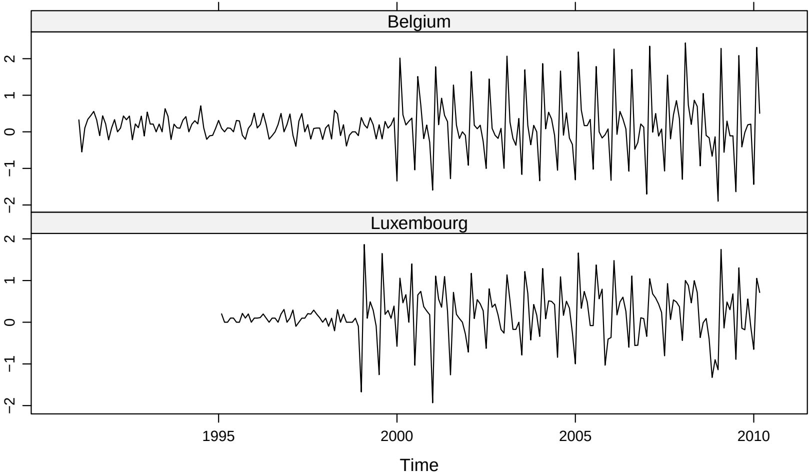
- had to reach Maastricht criteria
  - low inflation rate ($<$ 1.5 percentage points higher than average of 3 best performing)
  - deficit no higher than 3% of GDP
  - gross government debt $< 60\%$ of GDP
  - no devaluation in ERM II
- most reforms regarding financial sector introduced in 2003
- strong contraction in money supply (M1) starting in 2003
- from 2003 onwards much lower mean, but higher variance
- entered ERM II in June 2004; declared ready to join by ECB in May 2006

# Results

Some countries follow very similar patterns

- Eastern countries: Czech Republic, Estonia, Hungary, Poland and possibly Slovakia
- Belgium and Luxembourg
- Italy and Spain
- Ireland
- No change countries: Finland, Greece, Netherlands
- Further results

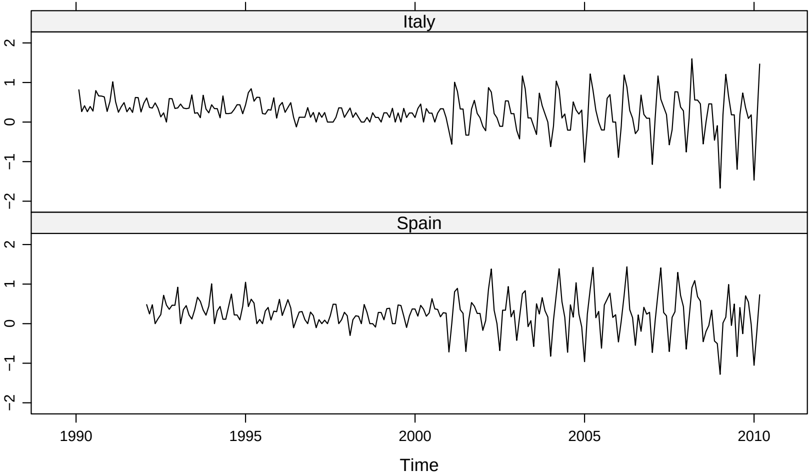
# Belgium and Luxembourg



# Belgium and Luxembourg

| Country | Segment | Mean | Variance | Skewness |
|---|---|---|---|---|
| Belgium | Feb 1991–Dec 1999 | 0.146 | 0.064 | $-0.037$ |
| | Jan 2000–Mar 2010 | 0.177 | 0.954 | 0.504 |
| Luxembourg | Feb 1995–Dec 1998 | 0.088 | 0.013 | 0.261 |
| | Jan 1999–Mar 2010 | 0.224 | 0.531 | $-0.484$ |

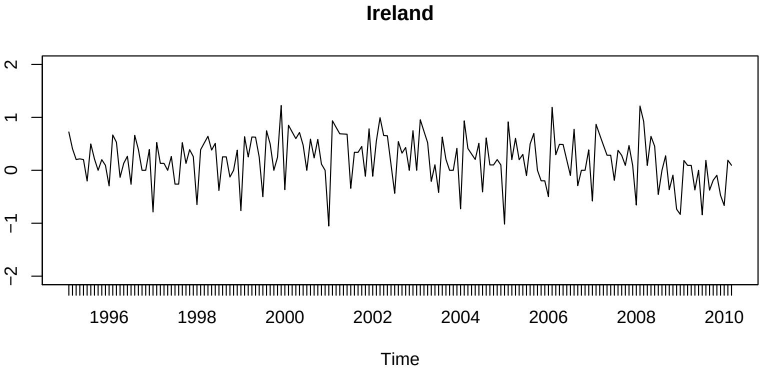
# Italy and Spain



# Italy and Spain

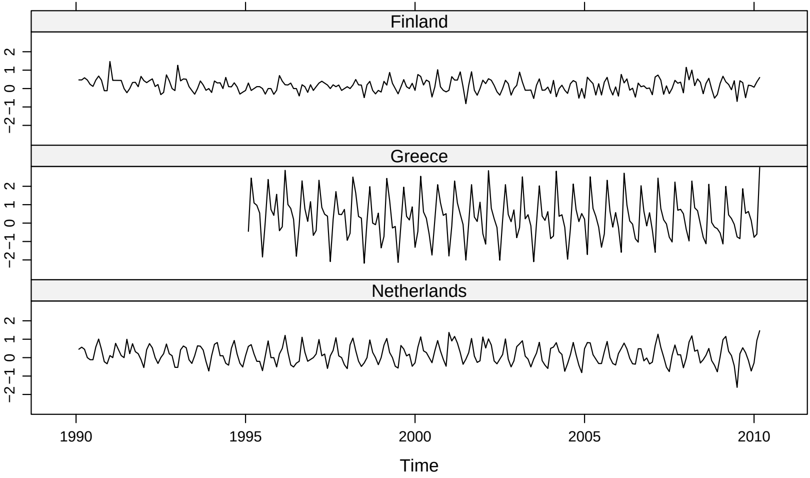
| Country | Segment | Mean | Variance | Skewness |
|---|---|---|---|---|
| Italy | Feb 1990–May 1996 | 0.414 | 0.041 | 0.963 |
| | Jun 1996–Dec 2000 | 0.168 | 0.020 | 0.726 |
| | Jan 2001–Mar 2010 | 0.182 | 0.321 | −0.261 |
| Spain | Feb 1992–May 1996 | 0.372 | 0.070 | 1.139 |
| | Jun 1996–Dec 2000 | 0.200 | 0.040 | 0.019 |
| | Jan 2001–Mar 2010 | 0.223 | 0.342 | −0.362 |

# Ireland




| Country | Segment | Mean | Variance | Skewness |
|---|---|---|---|---|
| Ireland | Feb 1995–Mar 2008 | 0.255 | 0.205 | −0.696 |
| | Apr 2008–Mar 2010 | −0.131 | 0.184 | −0.995 |

# No Change Countries



# No Change Countries

| Country | Segment | Mean | Variance | Skewness |
|---|---|---|---|---|
| Greece | Feb 1995–Mar 2010 | 0.323 | 1.480 | 0.431 |
| Netherlands | Feb 1990–Mar 2010 | 0.185 | 0.293 | 0.598 |
| Finland | Feb 1990–Mar 2010 | 0.165 | 0.132 | 0.280 |

# Conclusion

- Stabilizing Effect of EURO?
- Overall lowering in mean inflation rates
- Overall increase in volatility

# HICP

First step: local sub-index of a specific price collected item $R_{iy}^t$:

$$R_{iy}^t = \frac{(\prod_{j=1}^n p_{iyj}^t)^{1/n}}{(\prod_{j=1}^n p_{iyj}^0)^{1/n}}$$

Second step: sub-index for whole country $R_i^t$:

$$R_i^t = \sum_{y=1}^m R_{iy}^t G_y$$

$$R_h^{t,T} = R_h^{12,T-1} \left[ \frac{\sum_{i=1}^q w_i^T R_i^t / R_i^{12,T-1}}{\sum_{i=1}^q w_i^T} \right]$$

Third step: weighted average of all included individual subindexes:

$$HICP_t = \sum_{i=1}^n \gamma_i R_h^{t,T}$$

# GL: Skewness