Eurozone prices: a tale of convergence and divergence

Alfredo Garcia-Hiernaux[1] Maria T. Gonzalez-Perez [2] David E. Guerrero [3]

[1] Universidad Complutense de Madrid

[2] Banco de España

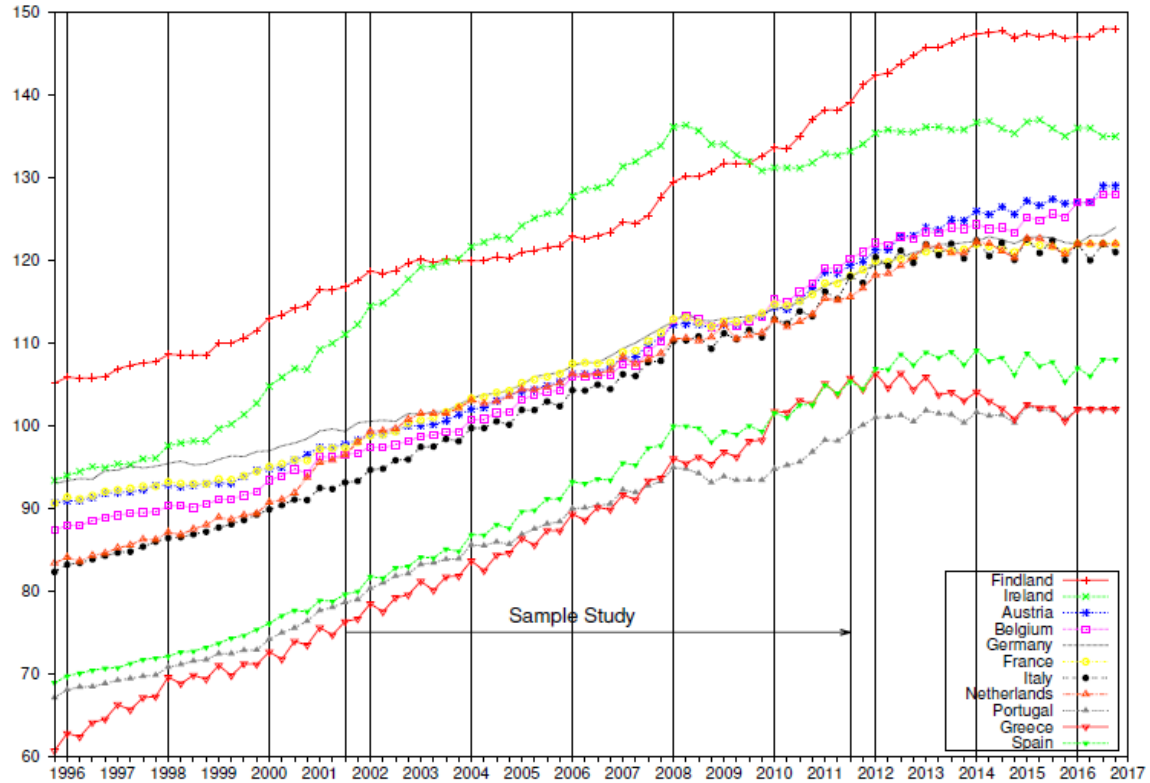
[3] CUNEF

XXV Meeting of the Central Bank Researchers Network
October 30, 2020

The views expressed in this paper are those of the author and do not necessarily represent those of the Bank of Spain.

QUARTERLY PRICE LEVEL SERIES

FIGURE: Price level series for EA-11: FI, IR, AU, BE, DE, FR, IT, NT, **PT, GR, ES**



EA-11: would it be convergence or divergence of prices and inflation since the EMU?

OUTLINE

- **Theoretical Background**:
  - Definitions: inflation + relative prices (PCM and PCV)
  - Methodology: dynamics of relative prices + hypothesis testing
- **Empirical exercise**:
  - HCPI for EA-11 from 2002-2011 (pre-Sovereign Debt crisis)
  - Conclude about PCM (absolute and relative) and PCV
- **Main Results**:
  - We cannot find evidence of price/inflation convergence for some countries.
  - Absolute PCM (P, π): FR/DE and IT/DE
  - Relative PCM (π): PT/DE, PT/FR, BE/IT, AU/IT, DE/ES, AU/ES, NT/ES, BE/GR
  - PCV only for IT/AU
- **This paper:**

  - We **provide a methodology based on the dynamics of relative prices to monitor the price level convergence dynamics** in a monetary union.

  - Our results **set the bases for a further study** (in progress) of PCM/PCV in the Eurozone **after 2012**.

Definitions: inflation

- $p_{i,t} = \ln P_{i,t}$, - $\pi_{i,t} = \Delta \ln P_{i,t} = p_{i,t} - p_{i,t-1}$

$\pi_{i,t}$ is I(0). Long-run rise in prices would be "steady" and "sustained"

- $\pi_t = \pi_t^* + \varepsilon_t$

Purely monetary phenomenon + driven by non-monetary shocks. No assump. (Shapiro, 2020)

- $\tau_{i,j,t} = \ln(P_{i,t}/P_{j,t}) = \tau_{i,j,t}$, - $\tau_{i,j,t} = \tau^*_{i,j,t} + \gamma_{i,j,t}$

$\tau_{ij,t}$ is I(0). Otherwise, P_i, P_j "would wander apart indefinitely" (Cecchetti et al., 2002)

Definition

The permanent inflation component π_t^* is the expected variation of the price level in the long run, where $\mathcal{F}_t$ denotes all information available at period t.

$$\pi_t^* = \lim_{k \to \infty} \mathbb{E}[\pi_{t+k} | \mathcal{F}_t]$$

Definition

The permanent relative price component $\tau^*_{i,j,t}$ for country i with respect to country j is the expected (log) relative price level in the long run, formally:

$$\tau^*_{i,j,t} = \lim_{k \to \infty} \mathbb{E}[\tau_{i,j,t+k} | \mathcal{F}_t]$$

DEFINITIONS: ASYMPTOTIC PRICE LEVEL CONVERGENCE IN MEAN

Asymptotic Price level Convergence in Mean

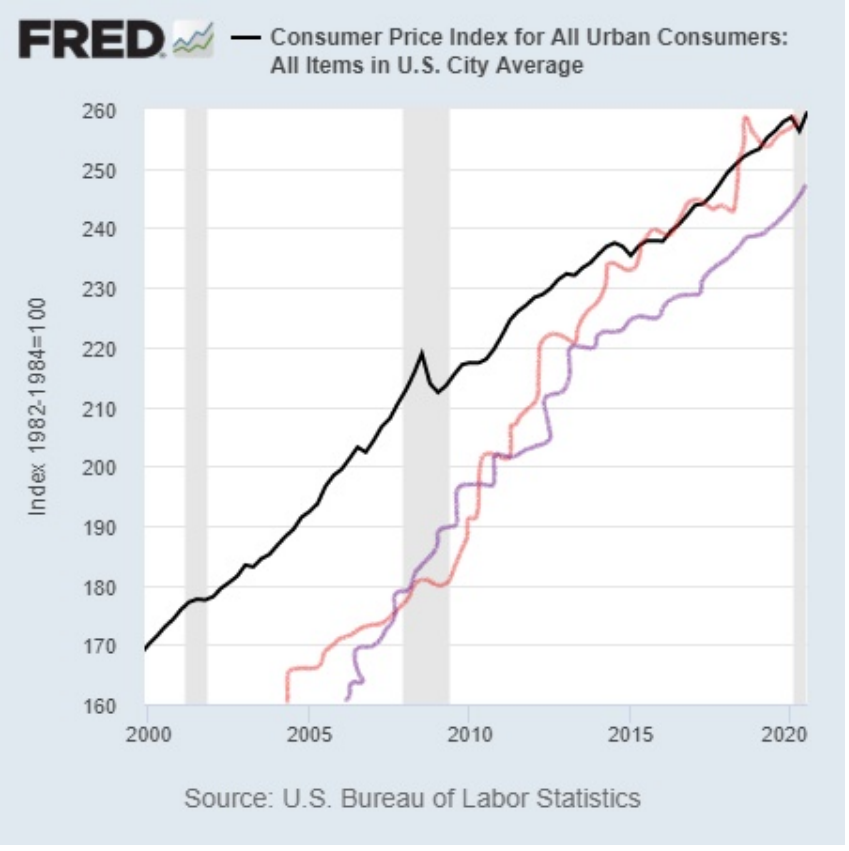
DEFINITION

For the asymptotic PCM, the price levels in countries i and j converge asymptotically if the permanent ratio component for country i with respect to country j is constant.

$$\lim_{k \to \infty} \mathbb{E}[\tau_{i,j,t+k} | \mathcal{F}_t] = \tau^*_{i,j}$$

- If PCM and $\tau^*_{i,j} = 0$, P_i *and* P_j *converge in an absolute sense (convergence as steady state)*

- If PCM and $\tau^*_{i,j} \neq 0$, *with* $c \in \{\mathbb{R} - 0\}$, P_i *and* P_j *converge in a relative sense (catching-up convergence)*



Definition: Asymptotic price level convergence in variance

Asymptotic Price level Convergence in Variance

- PCM holds for (P_i, P_j), with $i \neq j$. - The variance of the (stationary) log-ratio of nominal prices must tend to a constant (zero).

Definition

If nominal prices P_i and P_j are I(1), the inflation rates π_i, π_j stationary, and PCM is fulfilled, then PCV holds and the price levels in countries i and j converge asymptotically if

$$\lim_{k \to \infty} \mathbb{E}[(\tau_{i,j,t+k} - \tau^*_{i,j})^2 | \mathcal{F}_t] = \nu^*_{i,j} \geq 0$$

holds for all t and with probability 1, where $\nu^*_{i,j}$ is a constant that represents the asymptotic expected variance of the relative prices.

DEFINITION: THE DYNAMICS OF LOG-RATIO OF PRICES ($\tau_{i,j}$)

Model:

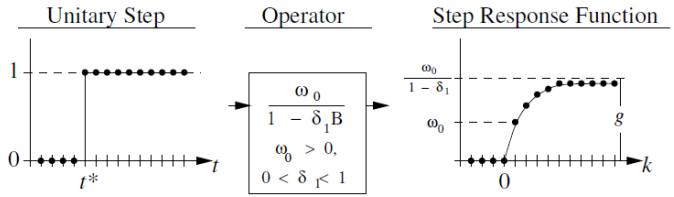
$$\tau_{i,j,t} = \overbrace{(\mu_{i,j} + C_{i,j,t})}^{D_{i,j,t}} + \overbrace{(\phi_{i,j,p}^{-1}(B)\theta_{i,j,q}(B)a_{i,j,t})}^{S_{i,j,t}}, \quad a_{i,j} \sim N(0, \sigma_{ij}) \quad \forall i,j; i \neq j$$

- Transient deterministic component to *measures the convergence process*, subject to $\tau_{i,j}$ is I(0):

$$C_{i,j,t} = \frac{\omega_s(B)}{\omega_r(B)}\psi_t^{t^*} = \nu(B)\psi_t^{t^*} = \sum_{k=1}^{\infty} \nu_k \psi_t^{t^*} B^k$$

- the steady-state gain (*total effect*) $g := \sum_{k=0}^{\infty} \nu_k = \nu(1) < 0$
- the mean lag of responses (*speed of convergence, curvature*): $l := \left. \frac{\nu'(B)}{\nu(B)} \right|_{B=1}$

FIGURE: Example of convergence path for: $r = 1$ and $s = 0$, so $\nu(B) = \omega_0/(1 - \rho_1 B)$, subject to $\omega_0 > 0$ and $0 < \rho_1 < 1$.



HYPOTHESIS TESTING

Hypothesis testing for PCM:

$$\tau_{ijt} = \overbrace{\mu_{ij} + C_{ijt}}^{D_{ijt}} + \phi_{ijp}^{-1}(B)\theta_{ijq}(B)a_{ijt}, \quad a_{ij} \sim N(0, \sigma_{ij}) \quad \forall i, j; i \neq j$$

$$C_{ijt} = \sum_{k=1}^{\infty} \nu_k \psi_t^{t^*} B^k$$

Hypothesis testing for PCM: P_i, P_j are CI(1,-1)

If $\tau_{i,j}$ is stationary $\rightarrow$ PCM: H(1)

If $D_{ij} = 0$ or $D_{ij} \neq 0 \rightarrow$ absolute or relative PCM: H(2)

Hypothesis testing for PCV: if PCM

If PCM and residuals are homoskedastic + downtrend SDI (standard deviation of innovation) evolution $\rightarrow$ PCV: H(3) (Breush and Pagan, 1979)

EMPIRICAL RESULTS: P_i DYNAMICS

Data: quaterly price level (from HCPI) for EA-11, from 2002-2011. Source: Eurostat.
The statistical model: P_i are I(1) with an AR(1) or an AR(2) stochastic component, constant μ_i and a seasonal component. So π_i is I(0) and: $\pi^*_{it} = \lim_{k\to\infty} \mathbb{E}[\pi_{it+k}|\mathcal{F}_t] = \mu_i$ (Mean).

TABLE: Estimated univariate price models (Quartely Prices in Log Differences)

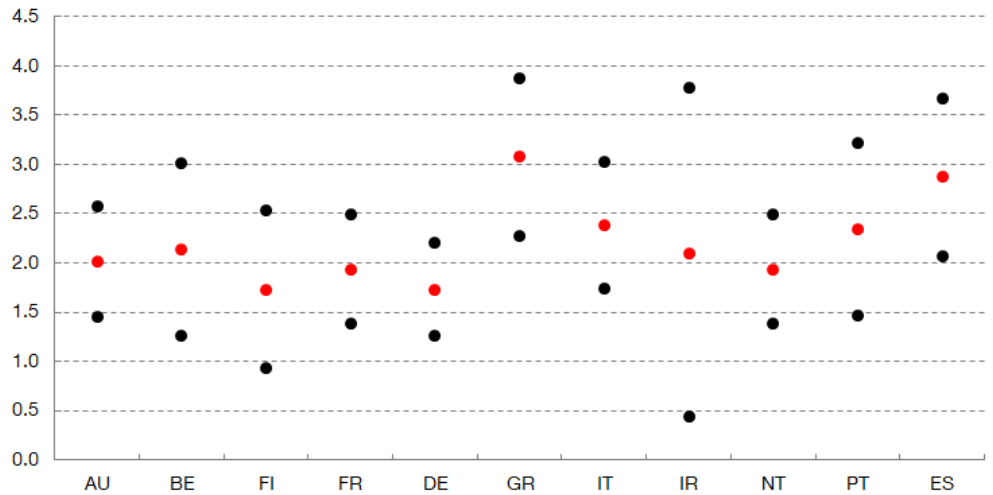
Variable (Mnemonics)	AR(1) $\hat{\phi}_{11}$ (s.e.)	AR(2) $\hat{\phi}_{12}$ (s.e.)	AR(2) $\hat{\phi}_{12}$ (s.e)	Mean (s.e.) (%)	Resid. Std.Dev. (%)	ACF$^{(1)}$ $Q_{(9)}$	SF$^{(2)}$ $H_0 : \phi_{11} = 1$	GLR$^{(3)}$ $H_0 : \theta = 1$
Austria	0.26	–	–	0.50	0.35	14.8	14.8**	0.0
(AU)	(0.14)			(0.07)				
Belgium	0.43	–	–	0.53	0.42	14.5	11.5**	0.0
(BE)	(0.14)			(0.11)				
Findland	0.38	–	–	0.43	0.38	16.7	11.7**	0.2
(FI)	(0.14)			(0.10)				
France	0.31	–	–	0.48	0.31	16.4	14.6**	0.0
(FR)	(0.14)			(0.07)				
Germany	0.24	–	–	0.43	0.31	8.3	17.2**	0.0
(DE)	(0.15)			(0.06)				
Greece	0.34	–	–	0.76	0.45	15.3	13.2**	0.0
(GR)	(0.14)			(0.10)				
Italy	0.44	-0.47	0.41	0.59	0.32	11.7	7.7**	0.0
(IT)	(0.20)	(0.20)	(0.18)	(0.08)				
Ireland	0.73	–	–	0.52	0.39	18.6	2.2**	0.2
(IR)	(0.10)			(0.21)				
Netherlands	–	0.54	-0.67	0.48	0.34	15.1	5.8**	0.0
(NT)		(0.16)	(0.13)	(0.07)				
Portugal	0.38	–	–	0.58	0.58	5.3	12.8**	0.0
(PT)	(0.18)			(0.11)				
Spain	0.35	–	–	0.71	0.45	6.8	13.4**	0.1
(ES)	(0.15)			(0.10)				

Notes: (1) Q is the Ljung and Box (1978) statistic for the autocorrelation function (ACF). H_0 is that there is no autocorrelation in the first nine lags. (2) SF: Shin and Fuller (1998) statistic tests whether an AR(1) operator is nonstationary. We estimate an alternative ARIMA(3,0,1) model and test the null hypothesis. (3) GLR: Generalized Likelihood Ratio (GLR) test of Davis, Chen and Duismuir (1995) for the null hypothesis of noninvertibility of an MA(1) operator, if a second difference and a MA(1) operator to control over-differentiation are added

* Rejects the null hypothesis at the 10% level, ** Rejects the null hypothesis at the 5% level.

EMPIRICAL RESULTS: INFLATION RATE (π_i^*)

FIGURE: Annual (permanent) inflation rates by country (π_i^*) and 95% confidence intervals (2001-2011)



- Significant differences in inflation volatility across some countries (CI widths), as the case of IR.
- On average, inflation reached values below 2% inflation in this time, with the exception of Greece and Spain (low initial price levels), who reported higher values, at 95% confidence. However, **is there convergence in prices/inflation over this period? How did we ended in 2011 with respect to the initial point? PCM, PCV**

Empirical Results: hypothesis testing

(A) $\tau_{i,j}$ is stationary

- Testing **Relative PCM** by pairs. H(1): τ_{ij} is stationary (SF Unit Root test, if red we reject H_0 : non-stationarity at 95% (**) and 90% (*) confidence level.)

	DE	AU	BE	FI	FR	GR	IR	IT	NT	PT	ES
DE	–	0.0	0.0	0.0	1.8**	4.7**	0.4	1.8**	0.0	1.8**	4.1**
AU	0.0	–	5.5**	0.0	0.3	2.2**	0.4	3.8**	0.0	0.0	2.0**
BE	0.0	5.5**	X	0.1	0.0	2.5**	0.0	1.3*	0.0	0.0	0.0
FI	0.0	0.0	0.1	–	0.0	0.5	0.0	0.0	0.0	0.3	0.0
FR	1.8**	0.3	0.0	0.0	–	4.8**	0.1	2.6**	2.9**	2.7**	1.5*
GR	4.7**	2.2**	2.5**	0.5	4.8**	X	2.5**	4.1**	4.8**	0.8	1.3*
IR	0.4	0.4	0.1	0.0	0.1	2.5**	–	0.0	0.0	0.0	0.0
IT	1.8**	3.8**	1.3*	0.0	2.6**	4.1**	0.0	–	9.5**	0.9	2.0**
NT	0.0	0.0	0.0	0.0	2.9**	4.8**	0.0	9.5**	–	1.4*	3.8**
PT	1.8**	0.0	0.0	0.3	2.7**	0.8	0.0	0.9	1.4*	–	1.9**
ES	4.1**	2.0**	0.0	0.0	1.5*	1.3*	0.0	2.0**	3.8**	1.9**	–

Interpretation: DE (FR) numerarie, *relative PCM* no rejected with: FR, GR, IT, PT, ES (DE, GR, IT, PT, ES, NT)

EMPIRICAL RESULTS: HYPOTHESIS TESTING

(B) Test for the **stability of the convergence operator** in C_{ijt} ($H_0 : \rho_1 = 1$ vs. $H_0 : \rho_1 < 1$) only for those relative prices with PCM (transition-stationary)

	DE	AU	BE	FI	FR	**GR**	IR	IT	NT	**PT**	**ES**
DE	–	–	–	–	3.4**	0.0	–	1.7**	–	4.6**	8.8**
AU	–	–	0.0	–	–	0.0	–	4.5**	–	–	6.9**
BE	–	0.0	–	–	–	2.2**	–	2.7**	–	–	–
FI	–	–	–	–	–	–	–	–	–	–	–
FR	3.4**	–	–	–	–	0.0	–	0.0	0.0	2.5**	0.0
GR	0.0	0.0	2.2**	–	0.0	–	0.0	0.0	0.0	–	0.0
IR	–	–	–	–	–	0.0	–	–	–	–	–
IT	1.7**	4.5**	2.7**	–	0.0	0.0	–	–	0.0	–	0.0
NT	–	–	–	–	0.0	0.0	–	0.0	–	0.6	4.5**
PT	4.6**	–	–	–	2.5**	–	–	–	0.6	–	0.0
ES	8.8**	6.9**	–	–	0.0	0.0	–	0.0	4.5**	0.0	–

Interpretation: DE (FR) numerarie, there is an evidence of a stable convergence path (reject H_0 in favor of H_1) with FR, IT, PT, ES (DE, PT) during this period of time. *We **continue the tests on PCM and PCV** for these pairs*.

EMPIRICAL RESULTS: HYPOTHESIS TESTING

(C) Testing for **absolute PCM** ($H_0 : \tau^*_{ij} = g_{ij} + \mu_{ij} = 0$ vs $H_1 : \tau^*_{ij} \neq 0$). t-student and LR.

Panel A: Long Run Gap Estimation Results and t-student test for convergence in mean[1]

	DE	AU	BE	FI	FR	GR	IR	IT	NT	PT	ES
DE	–	–	–	–	-0.00	–	–	-0.30	–	-17.40**	-10.10**
AU	–	–	–	–	–	–	–	-1.20**	–	–	-8.30**
BE	–	–	–	–	–	-8.40**	–	-1.70**	–	–	–
FI	–	–	–	–	–	–	–	–	–	–	–
FR	0.00	–	–	–	–	–	–	–	–	-17.90**	–
GR	–	–	8.40**	–	–	–	–	–	–	–	–
IR	–	–	–	–	–	–	–	–	–	–	–
IT	0.30	1.20**	1.70**	–	–	–	–	–	–	–	–
NT	–	–	–	–	–	–	–	–	–	–	-8.90**
PT	17.40**	–	–	–	17.90**	–	–	–	–	–	–
ES	10.10**	8.30**	–	–	–	–	–	–	8.90**	–	–

Notes: (1) The Tau test is a student-t test of Asymptotic Price Convergence in Mean, where $H_0 : \tau^*_{ij} = g_{ij} + \mu_{ij} = 0$ is that the long run gap between nominal prices is zero. Only the long-run gap estimation is presented when convergence is accepted, otherwise (–) no evidence of convergence was found. * (**)Rejects the null hypothesis at the 10% (5%) level.

- Evidence of **absolute PCM** only between **FR and DE** (in line with economic theory) and **DE and IT** in this period of time. *Evidence of steady-state convergence in prices and inflation for FR and IT with respect to DE.*
- The **rest of country-pairs** show **relative PCM**. *Evidence of catching-up convergence.*

EMPIRICAL RESULTS: CONVERGENCE SPEED ESTIMATION

(D) Convergence speed (to the new equilibrium) $\hat{l} := \left. \frac{\nu^{`}(B)}{\nu(B)} \right|_{B=1}$

Panel B: Convergence Speed Estimation Results and t-student test for significance[3]

	DE	AU	BE	FI	FR	**GR**	IR	IT	NT	**PT**	**ES**
DE	–	–	–	–	5.90**	–	–	25.00*	–	5.60**	18.80**
AU	–	–	–	–	–	–	–	13.80**	–	–	27.40**
BE	–	–	–	–	–	33.50**	–	2.40**	–	–	–
FI	–	–	–	–	–	–	–	–	–	–	–
FR	5.90**	–	–	–	–	–	–	–	–	8.30**	–
GR	–	–	33.50**	–	–	–	–	–	–	–	–
IR	–	–	–	–	–	–	–	–	–	–	–
IT	25.00**	13.80**	2.40**	–	–	–	–	–	–	–	–
NT	–	–	–	–	–	–	–	–	–	–	11.50**
PT	5.60**	–	–	–	8.30**	–	–	–	–	–	–
ES	18.80**	27.40**	–	–	–	–	–	–	11.50**	–	–

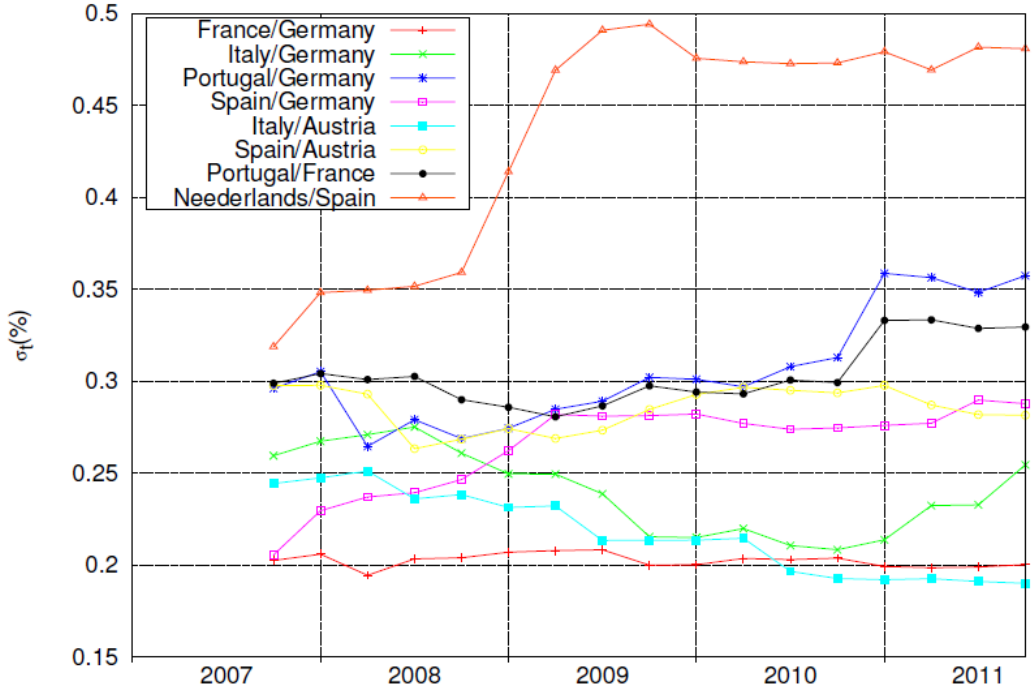
- Absolute PCM: FR/DE 1/2-reached it in 1.5 years, IT/DE in 6.25 years.
- Relative PCM (n= 11Y) with stable convergence operator. 1/2 of the time necessary to reach the new equilibrium.

  DE: PT/DE ($\approx$ 1.5Y)
  FR: PT/FR ($\approx$ 2Y)
  IT: BE/IT ($\approx$ 0.5Y), AU/IT ($\approx$ 4Y).
  ES: DE/ES ($\approx$ 5Y), AU/ES ($\approx$ 7Y), NT/ES ($\approx$ 3Y)
  GR: BE/GR ($\approx$ 8.5Y)

EMPIRICAL RESULTS: HYPOTHESIS TESTING

(E) Testing for **PCV**. Only those with PCM (τ_{ijt} stationary)

- a_{ij} is heteroskedastic: necessary but no sufficient condition for $\lim_{k\to\infty} \sigma_{at+k} = 0$
- MA(25) for τ_{ij} standard error (downward/upward trend). $\downarrow \sigma_a$ for IT/AU (PCV)



	DE	AU	BE	FI	FR	GR	IR	IT	NT	PT	ES
DE	–	–	–	–	1.2	–	–	0.5	–	1.3	2.3
AU	–	–	–	–	–	–	–	5.3**	–	–	1.3
BE	–	–	–	–	–	2.3	–	9.3**	–	–	–
FI	–	–	–	–	–	–	–	–	–	–	–
FR	1.2	–	–	–	–	–	–	–	–	1.7	–
GR	–	–	2.3	–	–	–	–	–	–	–	–
IR	–	–	–	–	–	–	–	–	–	–	–
IT	0.5	5.3**	9.3**	–	–	–	–	–	–	–	–
NT	–	–	–	–	–	–	–	–	–	–	3.6*
PT	1.3	–	–	–	1.7	–	–	–	–	–	–
ES	2.3	1.3	–	–	–	–	–	–	3.6*	–	–

Notes: (1) Breusch-Pagan test is a Likelihood Ratio test of Asymptotic Price Convergence in Variance, where H_0 is homoscedasticity. If the null hypothesis is rejected, there is conditional heteroscedasticity, with variance decreasing (increasing) with time starting at t^*.
*(**)Rejects the null hypothesis at the 10% (5%) level.

Concluding remarks

This paper:

- Proposes a methodology based on (i) the decomposition of log-ratio of prices in permanent (D_{ijt}) and transient (S_{ijt}) components, and (ii) hypothesis testing on the model parameters.
- The methodology allows estimate (i) (permanent) inflation per each country, (ii) test PCM (absolute and relative), (iii) speed of convergence when this hold, and (iv) PCV.

Main results: 2001-2011

1. Inflation around 2%, above 2% for ES and GR
2. Absolute PCM (convergence in P and π): FR/DE, IT/DE
3. Relative PCM (convergence in π): PT/DE, PT/FR, BE/IT, AU/IT, DE/ES, AU/ES, NT/ES, BE/GR
4. Relative PCM and PCV for IT/AU

We find lack of price level convergence for some EMU countries from 2001-11, underscoring a "convergence cost" paid by countries with lower price level, that does not tend toward zero in the absence of convergence.

Our results advise using this methodology to monitoring relative and absolute price level convergence and study the monetary policy efficiency in the long run. Understand the heterogeneous impact of a coordinated monetary policy in a monetary union, and improve the policy design.

Future work (in progress)

Robustness checks and future research (in progress):

(I) Sample size is not long enough. We are updating the sample to include until 2019.

(II) There is probably a convergence in tradable goods and services, but the prices of non-tradable goods and services either do not converge, or converge more slowly. Our analysis reflects a combination of both.

(III) More complex transition paths.

Thank you!