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Barbara Meller  
Dieter Nautz

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# The Impact of the European Monetary Union on Inflation Persistence in the Euro Area\*

Barbara Meller<sup>†</sup>                      Dieter Nautz<sup>‡</sup>  
*Goethe University Frankfurt*      *Free University Berlin*

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## Abstract

This paper uses the European Monetary Union (EMU) as a natural experiment to investigate whether more effective monetary policy reduces the persistence of inflation. Taking into account the fractional integration of inflation, we confirm that inflation dynamics differed considerably across Euro area countries before the start of EMU. Since 1999, however, results obtained from panel estimation indicate that the degree of long run inflation persistence has converged. In line with theoretical predictions, we find that the persistence of inflation has significantly decreased in the Euro area probably as a result of the more effective monetary policy of the ECB.

**Keywords:** Monetary Policy Effectiveness and Inflation Persistence; Panel Test for Fractional Integration; Change in Inflation Persistence

**JEL classification:** C22, C23, E31

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<sup>†</sup>Goethe University Frankfurt, Gruenewaldplatz 1, 60323 Frankfurt am Main, Germany. E-mail: meller@finance.uni-frankfurt.de.

<sup>‡</sup>Free University Berlin, Institute for Statistics and Econometrics, Boltzmannstr. 20, 14195 Berlin, Germany. E-mail: dieter.nautz@fu-berlin.de.

# 1 Introduction

The analysis of inflation persistence has received increasing attention among economists. Central banks analyze the degree of inflation persistence in order to improve inflation forecasts and to assess the dynamic response of inflation to shocks. In particular, if the degree of inflation persistence is high, then shocks to inflation have long-lived effects which could impede the controllability of inflation. Therefore, in accordance with the predictions of New-Keynesian DSGE models, reduced inflation persistence might be the result of better monetary policy and an anchoring of inflation expectations.<sup>1</sup>

While there is a widespread belief that monetary policy effectiveness has increased over the last decades,<sup>2</sup> the empirical evidence on changes in inflation persistence has been rather elusive, see e.g. Mishkin (2007). For many countries, including the United States, detecting significant breaks in inflation persistence is complicated by the fact that monetary policy has changed only gradually and the delimitation of different policy regimes is not clear. By contrast, the introduction of the Euro and the common monetary policy of the European Central Bank (ECB) led to an obvious change in the monetary policy regime and to a marked improvement of monetary policy for many Euro area countries. Therefore, this paper uses the European Monetary Union (EMU) as a natural experiment to investigate whether more effective monetary policy reduces the persistence of inflation.

Our empirical approach differs from earlier contributions in two main aspects. First, in contrast to the bulk of empirical work on inflation persistence in the Euro area, we use country-specific and not synthetic Euro area inflation rates for the pre-EMU period. If monetary policy affects the persistence of inflation, using synthetic Euro area inflation seems inappropriate. It ignores that monetary policy and thus inflation persistence had been very different across member countries before the monetary union.

The second aspect in which our paper differs from most studies con-

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<sup>1</sup>For a discussion of the different sources of inflation persistence and its implications for monetary policy within the framework of a New Keynesian DSGE model, see e.g. Altissimo et al. (2006). This paper also gives an excellent survey of earlier evidence on inflation persistence in the Euro area.

<sup>2</sup>For example, Blinder et al. (2008) show that the communication strategies of central banks have improved considerably since the early 1980s.

cerns the measure used to establish a change in inflation persistence. In the major part of the growing literature on inflation persistence, inflation is regressed on several of its own lags and the sum of the coefficients of lagged inflation is used as a measure of persistence. Changes in persistence are investigated by rolling regressions or time-varying coefficients. However, even modest changes in methodology - such as lengthening of the sample period or correcting for small-sample bias - can alter both the magnitude and the statistical significance of the estimated decline in persistence. In fact, the conclusion that the sum of lagged coefficients of Euro area inflation has declined is still under debate, compare e.g. O'Reilly and Whelan (2005) and Beechey and Österholm (2009). According to Kumar and Okimoto (2007) and Gadea and Mayoral (2006), this intuitive way of measuring persistence becomes problematic if the time series is fractionally integrated.

Following Granger (1980), the fractional integration of inflation rates was established by e.g. Hassler and Wolters (1995) and Baillie et al. (1996). Yet, Kumar and Okimoto (2007) have been the first who established a *change* in U.S. inflation persistence using fractional integration techniques. There have been no empirical studies on a possible change in the degree of fractional integration of Euro area inflation since the EMU. In order to fill this gap, we investigate whether the degree of fractional integration of inflation rates in Euro area countries has actually declined since the start of the European Monetary Union as a result of the new, probably more effective monetary policy of the ECB.

For the pre-EMU period, sample size is not an issue and the order of fractional integration can be estimated for each member country separately. However, standard methods of fractional integration are not applicable during the EMU period simply because the Euro was introduced only ten years ago. In order to obtain an efficient estimate despite the short time period, we use the panel estimator advocated by Robinson (1995). Efficiency gains in the panel estimation are largest if one can impose the restriction that all time series have the same order of integration. While this restriction may appear to be implausible in many applications, a common degree of inflation persistence across countries of a monetary union seems to be a rather natural assumption as long as inflation persistence is predominantly driven

by the effectiveness of the common monetary policy. Panel estimation of the degree of fractional integration has not yet been widely applied and we are one of the pioneers to exploit this technique. As a consequence, we perform Monte Carlo simulations to ensure the reliability and robustness of our empirical results.

To assess the impact of the European Monetary Union on inflation persistence, we compare the country-specific orders of fractional integration estimated over the pre-EMU period to the common order of integration of Euro area wide inflation during the EMU period. Our results indicate that Euro area countries significantly gained by joining the EMU in terms of reduced inflation persistence. The order of fractional integration in the pre-EMU period was significantly positive in each country and was on average 0.32. By contrast, the common degree of long run inflation persistence in the Euro area is virtually zero since the common monetary policy of the ECB has been in place.

The remainder of the paper is organized as follows. In the next section, we estimate inflation persistence for each of the founding member countries over the pre-EMU period and reconcile our results with those of the earlier literature. In section 3, we briefly review the fractional integration panel estimator which we use to estimate Euro area inflation persistence over the EMU period. Conclusions are drawn in section 4.

## **2 Inflation Persistence in the pre-EMU Period**

### **2.1 Fractional Integration as Measure of Persistence**

Since Hassler and Wolters (1995), inflation has been recognized as a textbook example of a fractionally integrated time series. Fractional integration can appear in inflation rates after aggregating individual prices from firms that face different costs of adjusting their prices, see Gadea and Mayoral (2006). In this case, standard persistence measures like the sum of autoregressive coefficients could be misleading since they cannot discriminate between different degrees of long run persistence.

In this paper, we therefore follow e.g. Kumar and Okimoto (2007) and model inflation as a fractionally integrated time series. The fractionally

integrated process  $y_t$  is defined as

$$(1 - L)^d y_t = x_t, \quad t = 1, \dots, T, \quad (1)$$

where  $y_t$  is a purely stochastic process without deterministic components,  $L$  is the lag operator and the fractional differences  $(1 - L)^d$  are given by binomial expansion. If  $x_t$  is a stationary and invertible autoregressive moving-average [ARMA] process, then  $y_t$  is called an ARFIMA process, fractionally integrated of order  $d$ . The process is stationary as long as  $d < 0.5$ , but it displays long memory for  $d > 0$ . Long memory implies a form of serial dependence and persistence that cannot be captured by traditional ARMA processes. The autocorrelation function  $\rho_y(h)$  of a fractionally integrated process behaves as follows with lag  $h$  being large:

$$\rho_y(h) \sim \rho h^{2d-1}.$$

Note that  $\rho_y(h) \rightarrow 0$  as long as  $d < 0.5$ , but for  $d > 0$  the rate of convergence is so slow that serial correlation coefficients are not summable.

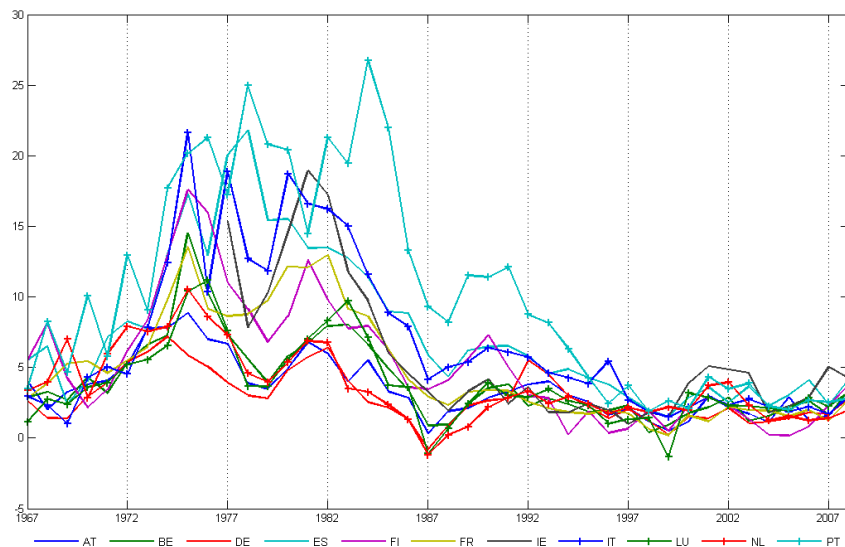
The effect of the *long memory parameter*  $d$  on persistence can be further illustrated by expanding the ARMA polynomials to obtain the moving average representation in terms of shocks  $\varepsilon_t$ :

$$y_t = (1 - L)^{-d} x_t = \sum_{j=0}^{t-1} c_j \varepsilon_{t-j}, \quad \text{with } c_j \sim c j^{d-1},$$

where  $\varepsilon_s = 0$  for  $s \leq 0$ . The higher the order of fractional integration, the longer it takes for a shock to die out.

## 2.2 Data

Our empirical analysis employs seasonally adjusted monthly CPI data provided by the OECD for the following ten founding members of the Euro area: Austria (AT), Belgium (BE), Germany (DE), Spain (ES), Finland (FI), France (FR), Italy (IT), Luxembourg (LU), Netherlands (NL) and Portugal (PT). Ireland has to be omitted in the pre-EMU sample, because monthly CPI data for Ireland is only available since 1997. The pre-EMU sample starts in 1966 due to data availability and ends 1998 which gives us



**Figure 1.** Annual inflation rates of EMU founding countries

395 observations for each country. Inflation in country  $g$  is defined as

$$\pi_{gt} = \log(CPI_{gt}) - \log(CPI_{gt-1}).$$

Figure 1 shows the time series of all country-specific inflation rates before and after the foundation of the EMU in 1999. For most of the countries, the *level* of inflation is clearly higher before the introduction of the Euro than afterwards. It is less obvious, however, whether the common monetary policy of the ECB also contributed to a decrease of inflation *persistence*.

### 2.3 Estimating Inflation Persistence in the pre-EMU Period

Before the European Monetary Union, each Euro area country had its own monetary policy and thus, a country-specific degree of inflation persistence. For the pre-EMU period, we therefore estimate the order of fractional integration of inflation for each country separately. Specifically, we apply the exact local Whittle estimator introduced by Shimotsu and Phillips (2005) which is consistent and asymptotically normally distributed for all values of  $d$ .

The estimated order of fractional integration can be spuriously high if

shifts in the mean of the time series are ignored. Therefore, our estimate of the long memory parameter  $d$  controls for shifts in mean as proposed by Hsu (2005).

Table 1 presents the estimated order of fractional integration of pre-EMU rates of inflation in Euro area countries under various assumptions about the number of mean shifts. Even when mean shifts are accounted for, there is strong evidence for all countries that the rate of inflation exhibits long memory ( $d > 0$ ) in the pre-EMU period. As expected, increasing the number of possible mean shifts decreases the estimated order of integration.

The significance of a potential mean shift is established using the test statistic (HR) proposed by Hidalgo and Robinson (1996).<sup>3</sup> With the exception of Italy, the HR test typically indicates a single significant mean shift. In Belgium and the Netherlands, the test finds two mean shifts but the impact of the second shift on the estimated  $d$  is only small. Using different bandwidth in the estimation of  $d$  only mildly affects the ranking of the countries according to their estimated degree of inflation persistence.<sup>4</sup>

In Table 1, we highlighted the estimates corresponding to the number of mean shifts suggested by the HR test. Referring to these estimates, the orders of fractional integration vary between 0.13 (NL) and 0.54 (IT, FR) with partly non-overlapping confidence intervals. The remarkable differences in the estimated long memory parameter across Euro area countries clearly indicate that it would have been inappropriate to assume a homogeneous degree of inflation persistence before the common monetary policy of the ECB had been implemented.

How does the estimated pre-EMU inflation persistence relate to the perceived effectiveness of monetary policy? Comparing simple indicators of monetary policy effectiveness, like e.g. the long-run average of inflation, with

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<sup>3</sup>Note that the asymptotic normal distribution of the HR test statistic is not valid in our application, because the break point is not exogenously given but found by a grid search. This search adds more uncertainty to the test statistic and might render its distribution flatter than under normality. Consequently, a break point that is found to be significant at a 10% level under the assumption of normality might indeed not be significant. Assuming normality, we make sure that we do not miss a significant mean shift but acknowledge that we might allow for insignificant mean shifts.

<sup>4</sup>A table reporting the order of integration using different values of the bandwidth together with the ranking of the countries according to their estimated degree of inflation persistence is available on request.



**Table 1.** The Order of Fractional Integration of the Rate of Inflation in the pre-EMU Period: The Role of Mean Shifts

	AT	BE	DE	ES	FI	FR	IT	LU	NL	PT
<i>no mean shift</i>										
$\hat{d}$	0.24	0.47	0.36	0.36	0.41	0.57	<b>0.54</b>	0.44	0.32	0.20
	[0.12,0.34]	[0.35,0.57]	[0.24,0.47]	[0.24,0.46]	[0.29,0.51]	[0.45,0.67]	[0.25,0.64]	[0.42,0.55]	[0.32,0.42]	[0.20,0.30]
<i>one mean shift</i>										
$\hat{d}$	<b>0.14</b>	0.42	<b>0.32</b>	<b>0.30</b>	<b>0.37</b>	<b>0.54</b>	0.51	<b>0.39</b>	0.18	<b>0.14</b>
	[0.02,0.26]	[0.30,0.54]	[0.20,0.44]	[0.18,0.42]	[0.25,0.49]	[0.42,0.66]	[0.39,0.63]	[0.27,0.51]	[0.06,0.30]	[0.02,0.26]
shift	1984:2	1985:3	1982:10	1986:1	1982:5	1982:4	1973:10	1985:11	1982:7	1985:3
<i>two mean shifts</i>										
$\hat{d}$	0.08	<b>0.35</b>	0.24	0.11	0.3	0.45	0.52	0.31	<b>0.13</b>	-0.06
	[-0.04,0.20]	[0.23,0.47]	[0.12,0.36]	[-0.01,0.23]	[0.18,0.42]	[0.33,0.57]	[0.40,0.64]	[0.19,0.43]	[0.01,0.25]	[-0.18,0.06]
shift 1	1984:2	1985:3	1982:10	1983:12	1982:5	1982:4	1973:10	1984:2	1982:6	1985:3
shift 2	1971:3	1973:9	1970:11	1973:2	1973:3	1973:3	1974:9	1973:9	1970:11	1973:3

Notes: The estimates of fractional integration accounting for mean shifts,  $\hat{d}$ , are based on a bandwidth  $m = T^{0.70} = 65$ . Alternative choices of  $m \in \{T^{0.60}, T^{0.65}, T^{0.70}, T^{0.75}\}$  had neither an important impact on the estimated order of integration nor the timing and the significance of the mean shifts. 95% confidence intervals of  $\hat{d}$  are shown in brackets. The estimates of  $d$  accounting for the appropriate number of mean shifts are highlighted. We account for a mean shift if the shift is significant at a 10% significance level.

the country-specific estimate of the order of fractional integration would confirm that there is a tendency of low-inflation countries to exhibit low inflation persistence. Yet, there are some notable exceptions: in particular, the long memory parameter of Portugal seems surprisingly low.

## 2.4 Review of the Empirical Literature

Let us now compare our empirical findings to previous studies relying on fractional integration when analyzing inflation persistence in the pre-EMU period. We are aware of three papers that consider the complete set of the EMU founding countries. Most contributions restrict their attention to the United States or the G7 countries. Table 2 reports the estimates found in the empirical literature. The first columns of the Table indicate that estimates may differ across different papers for various reasons. In particular, some studies use different sample periods, different estimators or bandwidths, some allow for mean shifts and some do not.

In spite of all these differences, Table 2 suggests the following conclusions. First, in line with our results for the pre-EMU period, all papers provide clear evidence in favor of long memory in the rate of inflation for all countries under consideration. Second, the estimated order of fractional integration across countries typically range between 0.1 and 0.6.<sup>5</sup> Third, the ranking of countries in terms of inflation persistence is very similar across studies. For example, in line with the reputation of the Bundesbank's monetary policy, inflation persistence in Germany was lower than in Italy and France. Fourth, the estimates of Baum et al. (1999) (BBC) and Conrad and Karanasos (2005) (CK) confirm that the relation between monetary policy and inflation persistence may be masked by other features of the economy. For example, in accordance with our results, BBC find that inflation persistence in Germany had been larger than in Portugal which seems to contradict the common view on the relative effectiveness of monetary policy in these countries. This indicates that cross-country comparisons of inflation persistence must take into account that monetary policy is not the only source of inflation persistence, see Altissimo et al. (2006).

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<sup>5</sup>The only exception is Gadea and Mayoral (2006) who use quarterly data and, thus, less observations in their analysis.

**Table 2.** Previous Studies on European Inflation Persistence using Fractional Integration

Author(s)	Sample period	m	Shift	Method	AT	BE	DE	ES	FI	FR	IT	LU	NL	PT
KO	1960:5-1975:4	$T^{0.75}$	0	LW			0.33			0.43	0.51			
	1988:5-2003:4	$T^{0.75}$	0	LW			0.02			0.14	0.45			
	1974:5-1989:4	$T^{0.75}$	0	LW			0.36			0.54	0.46			
HW	1969:1-1992:12	$T^{0.66}$	0	P			0.41			0.60	0.60			
BBC	1971:1-1995:12	$T^{0.69}$	0	LW	0.21	0.51	0.43	0.35	0.36	0.55	0.50	0.36	0.35	0.32
Hsu	1957:1-1998:12	$T^{0.78}$	1	LW			0.19			0.42	0.47			
		$T^{0.78}$	2	LW			0.09			0.18	0.31			
CK	1962:1-2004:1		0	A-G		0.21	0.20	0.18	0.19	0.31	0.35		0.20	0.14
	1980:1-2004:1		0	A-G		0.15	0.21	0.38	0.14	0.19	0.29		0.13	0.22
GM	1957:1- 2003:4		0	P	0.78	0.83	0.94	0.90	0.74	0.75	1.19	0.74	0.86	0.80
			0	A	0.82	0.87	0.83	1.07	0.67	0.68	0.66	0.83	0.79	1.14
BCT	1947:1-1990:9		0	A-G			0.18			0.45	0.45			
This paper	1966:1-1998:12	$T^{0.70}$	0-2	LW	0.14	0.35	0.32	0.30	0.37	0.54	0.54	0.39	0.13	0.14

Notes: We abbreviated Kumar and Okimoto (2007) by KO, Hassler and Wolters (1995) by HW, Baum et al. (1999) by BBC, Hsu (2005) by Hsu, Conrad and Karanasos (2005) by CK, Gadea and Mayoral (2006) by GM, Baillie et al. (1996) by BCT. The exact local Whittle estimator is abbreviated by LW, the log-periodogram estimator by P and an ARFIMA(-GARCH) model is abbreviated by A(-G). For more details on “this paper” see Tables 1.

### 3 Inflation Persistence in the EMU-Period

Before the 1990s, the economies of current Euro area countries differed to a great extent and in many aspects. Since the mid-nineties, Euro area countries converged not only in terms of the level of inflation. In accordance with the Maastricht treaty, convergence was further obtained with respect to e.g. fiscal policy, exchange rates, and long-term interest rates. Although there may be still room for improvement, compared to the pre-EMU period, the current degree of economic integration and harmonization in the Euro area is substantial. This suggests that also the persistence of inflation might have converged for Euro area countries. Therefore we may use the panel estimator of fractional integration introduced by Robinson (1995) to estimate the common order of fractional integration of Euro area inflation rates in the EMU period.

#### 3.1 Panel Estimator of Fractional Integration

The panel estimator of fractional integration was proposed by Robinson (1995). Despite its long availability, the study of Andersen et al. (2003) seems to be the only one implementing the panel estimator.<sup>6</sup> The rare use of the panel estimator is probably due to the fact that efficiency gains over individual time series regressions are large only if one can impose the restriction that all time series have the same order of integration. This restriction, however, might be overly strong in many applications.

In order to compute Robinson's panel estimator we first estimate the standard periodogram of each country  $g$ ,  $I_g(\lambda)$ , individually. The periodogram is evaluated at harmonic frequencies up to the bandwidth  $m$ . Then, the log periodogram of country  $g$ ,  $Y_{gk}^{(J)}$ , is the log of the sum of the periodogram evaluated at  $J$  adjacent harmonic frequencies:

$$Y_{gk}^{(J)} = \log \left\{ \sum_{j=1}^J I_g(\lambda_{k+j-J}) \right\}, \quad (2)$$

for  $k = l + J, l + 2J, \dots, m$  and  $\lambda_{k+j-J} = 2\pi(k + j - J)/T$  are the harmonic

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<sup>6</sup>Andersen et al. (2003) analyze the long memory behavior of realized return volatilities of assets.

frequencies.  $l$  is the trimming parameter and we follow the common practice to use  $l = 0$  in empirical work, compare e.g. Kumar and Okimoto (2007).

In a next step, the log periodogram regression is performed

$$Y_{gk}^{(J)} = c_g^{(J)} - d_g 2 \log \lambda_k + U_{gk}^{(J)}, \quad (3)$$

yielding OLS estimates of  $d_g$  for each country. Following Robinson (1995),

$$\sqrt{m} \left( \tilde{d}_g^{(J)} - d_g \right) \xrightarrow{d} N \left( 0, k_J \frac{1}{4} \right)$$

where  $\tilde{d}_g^{(J)}$  is the OLS estimate of regression (3) and  $k_1 = \pi^2/6 = 1.645$ ,  $k_2 = 1.289$ ,  $k_3 = 1.185, \dots, k_\infty = 1$ . Thus, using  $J > 1$  renders the estimation of  $d_g$  asymptotically more efficient. In finite samples, however, the appropriate choice of  $J$  is not obvious. In a final step, the panel estimate of  $d$  is obtained by the fixed effects estimator of the stacked log-periodogram regression (3) imposing the restriction that  $d$  is equal for all countries while  $c_g^{(J)}$  is country specific.

### 3.2 How to Choose $J$ and $m$ : A Monte Carlo Study

The parameter  $J$  governs the impact of adjacent harmonic frequencies on the estimated order of fractional integration. Although  $J > 1$  renders the estimations of  $d_g$  in (3) asymptotically more efficient,  $J = 1$  is typically used in empirical applications. In our panel estimation, we want to exploit the potential efficiency gains of  $J > 1$ . Since the optimal choice of  $J$  and its relation to the employed bandwidth is not well known in finite samples, we seek to shed more light on these issues by conducting a Monte Carlo simulation. To that end, we simulate 11 independent fractional white noise series of length 115 resembling our data sample. In line with the assumption imposed on the panel estimator, all series have the same long memory parameter  $d$ . We use 1000 iterations for each simulation and vary the common long memory parameter in the relevant range, i.e.  $d \in \{0, 0.1, 0.2, 0.3, 0.4, 0.49\}$ . The panel estimator is applied for  $J \in \{1, 2, 3, 4\}$  and various choices of the bandwidth  $m \in \{T^{0.60}, T^{0.65}, T^{0.70}, T^{0.75}\}$ . In order to account for the bias as well as the variance of the estimators, the evaluation of the estimator is based on the root mean squared error (RMSE) of the estimates.

Table 4 in the Appendix reports the results of the Monte Carlo exercise. For our application, the main results can be summarized as follows. For any value of  $J$ ,  $m$  or the true value of  $d$ , the RMSEs are small and differ only at the second decimal digit. This indicates that the estimation of  $d$  is only mildly affected by those parameters. For a particular choice of  $m$ , the smallest RMSE is obtained by choosing  $J = 1$  or  $J = 2$ . Generally, the larger the true value of  $d$ , the better the performance of the estimator when  $J = 1$  relative to  $J = 2$ . In particular, the smallest RMSE in case that  $d_0$  is between 0.00 and 0.30 is obtained by choosing  $J = 2$  and  $m = T^{0.75}$ .

### 3.3 Estimating Inflation Persistence in the EMU-Period

Let us now apply Robinson's (1995) panel estimator to investigate inflation persistence in the EMU period. Following the pre-EMU analysis, we use monthly, seasonally adjusted OECD data of CPI indices of the 11 EMU founding countries, see Section 2.1. Due to improved data availability, the EMU sample also contains data from Ireland. The EMU sample runs from 1999.01 until 2008.07, implying that the panel estimation is based on  $11 \times 115$  observations.

In Table 3, we present the results of the panel estimation of Euro area inflation persistence, measured by its order of fractional integration. In accordance with our Monte Carlo simulation, the empirical results differ only slightly with respect to the choice of the bandwidth and the parameter  $J$  in equation (2). In contrast to pre-EMU inflation, the estimated order of integration of Euro area inflation is only small and not significantly different from zero for almost all combinations of  $m$  and  $J$ . Table 3 provides strong evidence that inflation persistence has decreased since 1999 for all Euro area countries. Our results suggest that the decrease in inflation persistence has been particular strong for France and Italy. Yet, there has also been a remarkable decrease in the persistence of German inflation. Following our Monte Carlo study on the impact of  $J$  and  $m$ , we use  $J = 2$  and  $m = T^{0.75}$  and therefore estimate that the common order of integration of the 11 Euro area countries is 0.05.

The panel estimator assumes that the order of integration of inflation is the same across the 11 Euro area countries in the EMU period. In order

**Table 3.** The Common Order of Fractional Integration of Euro Area Inflation in the EMU Period: Role of  $J$  and  $m$

$m, J$	1	2	3	4
$T^{0.60}$	0.13	0.07	0.06	0.15
	[0.01, 0.25]	[-0.06, 0.20]	[-0.04, 0.16]	[0.05, 0.25]
$T^{0.65}$	0.06	0.03	0.07	0.05
	[-0.07, 0.20]	[-0.08, 0.14]	[-0.01, 0.15]	[-0.06, 0.15]
$T^{0.70}$	0.08	0.08	0.09	0.09
	[-0.02, 0.19]	[-0.01, 0.17]	[0.02, 0.17]	[0.00, 0.18]
$T^{0.75}$	0.07	<b>0.05</b>	0.06	0.06
	[-0.03, 0.17]	[-0.03, 0.13]	[-0.01, 0.13]	[-0.02, 0.13]

Notes: The table presents the fractional integration panel estimator,  $\tilde{d}$ , of all EMU founding members from 1999:1-2008:7.  $\tilde{d}$  was estimated for different values of the bandwidth,  $m$ , and different values of the parameter  $J$  of equation (2). The 95% confidence interval is shown in brackets. The most appropriate choice of  $m$  and  $J$ , according to our Monte Carlo study, is highlighted.

to test this assumption, we compute the Wald statistic for the equality of  $\tilde{d}_g$  for all  $g$ , using  $J = 2$  and  $m = T^{0.75}$ , see Robinson (1995). We do not reject the hypothesis of a common  $d$  at the 10%-significance level (p-value: 0.32). Note that the panel estimation of  $d$  assumes the absence of fractional cointegration, see Andersen et al. (2003). However, in our application fractional cointegration is not an issue simply because our results show that inflation rates of Euro area countries are  $I(0)$  over the EMU period.

## 4 Concluding Remarks

While there is no doubt that changes in inflation persistence should have a decisive impact on the conduct of monetary policy, the repercussions of monetary policy on inflation persistence are less clear. On the one hand, there are several contributions which find that inflation persistence has decreased in recent years, probably as a result of more effective monetary policy, see e.g. Kumar and Okimoto (2007). On the other hand, there are studies, including e.g. Pivetta and Reis (2007), O'Reilly and Whelan (2005) and Gadea and Mayoral (2006), who find only little evidence of changes in

inflation persistence for various countries.

Typically, determining a break date of inflation persistence is difficult because monetary policy often changes only gradually hampering a clear delimitation of different policy regimes with different degrees of inflation persistence. By contrast, the adoption of the common monetary policy of the European Central Bank (ECB) has led to a clear-cut change in monetary policy for the bulk of Euro area countries. This paper investigated the relationship between monetary policy and inflation persistence by analyzing the potential change in inflation persistence in the Euro area due to the European Monetary Union.

Following e.g. Kumar and Okimoto (2007) and Gadea and Mayoral (2006), we modeled inflation rates as fractionally integrated  $I(d)$  processes and determined persistence by the long memory parameter  $d$ . In accordance with the empirical literature, we found that inflation exhibits long memory ( $0 < d < 1$ ) in all Euro area countries in the pre-EMU period. In the pre-EMU period, countries with more credible central banks tend to have less persistent rates of inflation. However, our results also revealed that cross-country comparisons must take into account that monetary policy may not be the only source of inflation persistence, see Altissimo et al. (2006).

For the analysis of inflation persistence in the EMU period, we proposed the application of the panel estimator introduced by Robinson (1995). Our results show that inflation persistence has significantly decreased in most of the Euro area countries. The decline in long run inflation persistence has been particularly strong for France and Italy, but there has also been a remarkable decrease in the persistence of inflation in Germany. In particular, post-EMU inflation does not exhibit long memory anymore, i.e. the common long memory parameter  $d$  is not significantly different from zero. This finding is robust with respect to implementation details of the panel estimator. Taking the European Monetary Union as a natural experiment for a clear-cut change in the monetary policy regime, this paper shows that more effective monetary policy is able to reduce the persistence of inflation.

The current paper not only evaluates the monetary policy of the ECB over the last ten years. Since the degree of inflation inertia is one of the most crucial parameters affecting the performance of monetary policy, our findings



may also have important implications for current monetary policy. Recent theoretical contributions discuss how monetary policy should be designed when the degree of inflation persistence is unknown. Following e.g. Walsh (2005), the worst-case scenario arises when the central bank chooses its policy assuming that inflation is very persistent when it is not. In fact, underestimating inflation persistence may be an optimal policy response, see Amano (2007) and Leitimo (2007). Therefore, our empirical results strongly suggest that the monetary policy of the ECB should act assuming that the persistence of euro area inflation is low.

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## Appendix

**Table 4.** RMSE( $\tilde{d}$ ) in Monte Carlo Study: role of  $m$ ,  $J$  and  $d_0$

$m, J$	1	2	3	4	1	2	3	4
	$d_0 = 0.00$				$d_0 = 0.10$			
$T^{0.60}$	0.061	<b>0.059</b>	0.064	0.075	<b>0.059</b>	0.062	0.069	0.085
$T^{0.65}$	0.050	<b>0.050</b>	0.053	0.053	<b>0.051</b>	0.052	0.059	0.060
$T^{0.70}$	0.045	<b>0.043</b>	0.046	0.048	0.043	<b>0.041</b>	0.046	0.050
$T^{0.75}$	0.038	<b>0.037</b>	0.038	0.040	0.038	<b>0.036</b>	0.039	0.043
	$d_0 = 0.20$				$d_0 = 0.30$			
$T^{0.60}$	<b>0.062</b>	0.065	0.081	0.109	<b>0.060</b>	0.071	0.098	0.143
$T^{0.65}$	<b>0.052</b>	0.054	0.068	0.074	<b>0.052</b>	0.061	0.088	0.103
$T^{0.70}$	<b>0.044</b>	0.045	0.058	0.068	<b>0.043</b>	0.050	0.071	0.091
$T^{0.75}$	0.041	<b>0.039</b>	0.045	0.055	0.040	<b>0.040</b>	0.052	0.070
	$d_0 = 0.40$				$d_0 = 0.49$			
$T^{0.60}$	<b>0.061</b>	0.086	0.129	0.190	<b>0.059</b>	0.100	0.160	0.241
$T^{0.65}$	<b>0.053</b>	0.071	0.114	0.139	<b>0.052</b>	0.082	0.138	0.173
$T^{0.70}$	<b>0.045</b>	0.057	0.091	0.121	<b>0.044</b>	0.063	0.109	0.149
$T^{0.75}$	<b>0.040</b>	0.041	0.064	0.090	<b>0.039</b>	0.047	0.080	0.116

Notes: The table reports the Root Mean Squared Error (RMSE) of  $\tilde{d}$  in the Monte Carlo simulation with 1000 replication. The simulated sample consists of 11 time-series of length 115 which are all integrated of order  $d_0$ . The RMSE for different values of  $d_0$ ,  $m$  and  $J$  are reported. Given certain values of  $m$  and  $d_0$  but different values of  $J$ , the RMSE is highlighted which is smallest.

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