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before and after the onset of
the Monetary Union

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WAGES AND PRICES IN EUROPE BEFORE AND AFTER THE ONSET OF THE MONETARY UNION

RICCARDO GIRARDI[°] AND PAOLO PARUOLO^{°‡}

ABSTRACT. This paper investigates possible structural changes induced by the Euro on the relations among wages, prices and unemployment for the five major European economies. The dynamic adjustment and the level relations are found to be different across subperiods as well as across countries. During the European Monetary Union (EMU) period, it is found that the four major economies within the EMU present a level Phillips Curve with similar coefficients, albeit within different specifications. On the contrary, during the same period the UK does not present a detectable level Phillips Curve. During the EMU period, for all countries including the UK, deviations from reference values are found to influence unemployment. Only for Germany and Spain, instead, we find evidence that deviations from reference values influence inflation dynamics. We also find a decrease in macroeconomic volatility for all European nations, with the exception of France.

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1. INTRODUCTION

The formation of the European Monetary Union (EMU) was anticipated to impact labor markets. Several forces were predicted to induce higher flexibility of wages under the EMU: the near impossibility of competitive devaluations, the increase of the number of (potential) workers, the increased competition and level of activity in the goods markets¹. All this would contribute to the a more efficient wage-price dynamics, which were predicted to imply faster returns of inflation and unemployment to their reference or target levels. These changes could be embodied – at least in part – in a flatter level Phillips Curve, and in a dynamic adjustment of inflation and of labor markets towards it. A decade after the onset of the EMU, understanding to which degree reality has met these predictions appears of interest, both for economic theory and policy; this is the broad objective of the present paper.

Several studies have documented the flattening of the US Phillips Curve in the last 15 years, see the contributions in Galì and Gertler (2009). A flatter Phillips Curve has traditionally been associated either with the structural effect of globalization or with the success of monetary policy in stabilizing actual and expected inflation, see e.g. Gaiotti (2010). The first goal of this paper is to investigate if flatter Phillips Curves exist also for European countries in recent years and if this can be ascribed to the EMU and not to globalization.

The EMU was also predicted to eventually contribute to the goal of price stability, which is usually associated with the moderation of the volatility of macroeconomic time series, as for the case of the ‘great moderation’ in the US, see Stock and Watson (2003). A second goal of the present paper is to measure if a similar effect can be found on data from EMU countries.

Finally, a third and final objective of the paper is to compare the adjustment of unemployment, inflation and unit labor cost before and after the onset of the EMU. More efficient labor markets are usually expected to react in a faster way. The question of if and how fast the unemployment rate reacts to inflation dynamics – and hence to monetary policy – is of obvious critical concern regarding the real effects of the common EMU monetary policy. Moreover, the adjustment of inflation to a level Phillips curve is associated with the effectiveness of monetary policy in bringing actual inflation in line with expected inflation.

In order to address these research questions, we consider macroeconomic time-series data for the five major European economies: France, Germany, Italy, Spain and the United Kingdom. The first four countries are members of the EMU, while the UK is not; the inclusion of the UK serves as a control for factors other than the participation in the EMU.

For each of these countries, we estimate a reduced form model of unit labor cost, unemployment, price markup and inflation, on two separate sample periods. The type of reduced-form model allows to estimate relationships in levels of the variables, irrespective of the sample

¹See Alesina and Giavazzi (2010) Chapter 5, for an ex-post estimation of the effect of EMU on trade and Blanchard and Giavazzi (2003) on the interactions between product- and labor-markets deregulations. In the face of higher competition, firms within the EMU were expected to re-gain competitiveness by restructuring and/or adjusting their cost structure on the labor side; this would impact on national wage bargaining mechanisms and deliver higher wage flexibility. The single currency was expected to facilitate labor mobility; also thanks to increased trade, see Andersen et al. (2000), wages would tend to converge. This observation also implied a decrease in the bargaining power of workers unions, which would also result in higher wage flexibility.

degree of persistence, without making use of pre-filtering and de-trending, which can have perverse effects, see e.g. Ferroni (2011). When we do not find a relation between inflation and unemployment or unit labor cost with the expected signs, we say that no level Phillips Curve can be found for a specific country.

The first sample period covers the years before the EMU, while the second sample period begins with the onset of the EMU and it is terminated before the beginning of the Great Recession in 2008. The latter was induced by international factors external to European labor markets, whose effects would hence be confounded with the ones brought about by the adoption of the Euro. By comparing results for each country for the two sample periods, we are able to measure changes controlling for the particular institutional structure of labor markets in each major European economy.

Empirical results can be summarized as follows. First of all, we find evidence of a level Phillips Curve in all countries which participate in the EMU during the EMU period; this is not always the case for the same countries in the pre-EMU period. This contrasts with the absence of a Phillips Curve for the UK during the EMU period; the UK presents a Phillips Curve only in the EMU period. The absence of a Phillips Curve for the UK in the EMU period may be due to an evolving adaptation of the UK economy to the different international environment, and/or it could reflect the impact of recent liberalizations in the UK labor market.² Because the UK was subject to the same globalization trends as the rest of the selected countries, we conclude that the presence of (rather homogeneous) level Phillips curves for the EMU countries can be ascribed to the introduction of the common currency.

We find that the appropriate measure of marginal cost in the Phillips Curve is both country- and period-specific. In some instances the unemployment rate *or* unit labor cost play the role of summary statistic for marginal cost; in other cases we find that *both* contribute to an overall index of marginal cost, especially in recent years. For Germany, the Phillips Curve appears flatter in the EMU period than before it, albeit within a different specification. Comparing estimates of the Phillips Curve across EMU countries during the EMU period, we find that the slopes are rather similar, possibly with the exception of Italy, which has a higher slope. These results give some support to the predicted effects of the EMU, albeit with some heterogeneity across EMU countries. For the countries which present a Phillips Curve in both subperiods, namely Germany, France and Italy, it is not possible to distinguish if this change in the slope of the Phillips Curve has been caused by globalization or by the introduction of the Euro.

Secondly, we find that the volatility of inflation and unemployment is smaller in the EMU period for all countries, including the UK, with the exception of France. Hence in terms of macro volatility, there appears to be a generic beneficial effect of the EMU – and/or of the concomitant international conditions in the EMU period – for the whole European Union.

²The UK was one of three countries that granted free movement of workers to accession nationals following the enlargement of the European Union in May 2004; this resulted in a large, rapid and concentrated migration inflow of workers into the UK labor market, see Lemos and Portes (2008) and reference therein. This episode may have altered the relationship between the aggregate unemployment rate and inflation. Lemos and Portes (2008) report regression results on monthly growth rates of unemployed and wages, and conclude that there is little evidence in favor of effects of the migration. No evidence is however given for the levels of the series.

Thirdly we find a more significant response of unemployment to deviations from the level reference values in the EMU period, with the exception of France. For France we find that unemployment does not appear to adjust to deviations from reference values. By comparison, the responses of unemployment in the pre-EMU period are usually insignificant, with the only exception of Spain. This evidence shows that there are real effects of monetary policy within the EMU.

The response of inflation to deviations from the reference values in the EMU period is significant only for Germany and Spain, while for France, Italy and the UK inflation appears not to adjust to deviations from steady states. Because deviations of inflation from reference values is one of the determinants of a standard Taylor monetary policy rule, this finding suggests that monetary policy is (potentially) effective in delivering inflation targeting only for Germany and Spain and not in the other EMU countries.

Since the determinants of the reference values for inflation – based on the level Phillips curve – involve (composite) measures of marginal cost, this evidence also challenges the presumption that policies aimed at improving competitiveness of French, Italian and English labor markets will result in an improved control of inflation dynamics. Unit labor cost is found also not to react to deviations of inflation from reference values for Germany, France and Italy in the EMU period. This may be due to an empirical adjustment of competitiveness over longer horizons.

Further investigations on these issues may help appreciate their economic policy implications more thoroughly; due to space limitations, we decided to leave them to future research.

The paper is organized as follows. The rest of the introduction discusses how the present paper is related to the literature. Section 2 presents the economic framework, Section 3 describes the data, Section 4 reports empirical evidence and Section 5 concludes. Appendix A reports derivations of the steady state relations, while Appendix B contains a description of the data-sources.

1.1. Relation with the literature. The high level of unemployment in continental Europe and its persistence in the 1990s has been widely documented, see e.g. see Blanchard (1998) and references therein. Several labor markets reforms have been advocated as necessary in order to reduce unemployment in the Europe, see Honkapohja and Westermann (2009). The efficacy of these measures rests on the relation of wages and prices with unemployment.

The interaction of wage- and price-dynamics is important for inflation prediction, see e.g. Altissimo et al. (2006), and hence for monetary policy. Labor market rigidities are key factors in New Keynesian Phillips Curve (NKPC) models, see e.g. Chapter 6 in Galì (2008), Galì et al. (2001) and Blanchard and Galì (2007). The counter-cyclical of real wages predicted by Keynes' General Theory is still a contentious empirical issue, see e.g. Rothemberg and Woodford (1999), Mankiw (2001) and Messina et al. (2009).

Recent macroeconomic time-series analyses on European wages include Arpaia and Pichelmann (2007), Schreiber and Wolters (2007) and Lawless and Whelan (2011); these studies were produced when too few observations from the EMU period existed, and hence they could not

distinguish between the pre-EMU and EMU periods.³ Other papers investigated wage- and price-rigidities in survey data on European countries, see Altissimo et al. (2006) and Druant et al. (2009).

The choice of macroeconomic data at country level is dictated by the specificity and heterogeneity of European labor markets, see e.g. Pinchelman (2003), Laylard et al. (2005), Werding (2006), Druant et al. (2009). Blanchard (1998), Blanchard and Katz (1999) documented a medium-term decline of the wage share and persistent increase in unemployment rates in continental Europe for the period 1980-1998, which is unparalleled in anglo-saxon countries. The heterogeneity of these labor markets suggests an empirical macroeconomic analysis at the national level, given that an European aggregate may well confound or hide medium term equilibria present at the national level.

The econometric tools we employ allow for nonstationarity, as recently increasingly assumed in macro modelling, see Huh and Jang (2007) and Woodford (2008) *inter alia*, who allow inflation to be stationary in first differences. We find support of this hypothesis for both sample periods and all countries. Schreiber and Wolters (2007) state that “no other accepted model [other than that of an integrated process] for the highly persistent behavior of unemployment and inflation in continental Europe exists”(page 357).⁴

Schreiber and Wolters (2007) observe that, given the high persistence of variables such as unemployment, a constant steady-state equilibrium involving the levels of the variables corresponds to the presence of a cointegration relation. This approach corresponds to ‘Strategy A’ in Fukač and Pagan (2010) (page 61) for handling permanent components. Cointegration techniques have been used in the empirical literature on wages and prices e.g. in Gruen et al. (1999), Petursson and Slok (2001) and Schreiber and Wolters (2007). Our analysis provides a comparison of the dynamics of wages and prices in the pre-EMU and EMU periods across the major European economies, which is not found elsewhere.

³Arpaia and Pichelmann (2007) analyzed yearly wages, productivity and unemployment (but not prices) from 1980 to 2005 for European countries. Schreiber and Wolters (2007) analyzed quarterly German prices and unemployment from 1977 to 2002. Lawless and Whelan (2011) analyzed Euro-Area aggregate wages and inflation up to 2005; they also report evidence from a panel of yearly data on different sectors. Time-series evidence on wages and prices in the pre-EMU period is provided by several papers: Marcellino and Mizon (2001) discuss the case of Italy; Galí et al. (2001) report estimates of Phillips Curves for Europe prior to 1999. Other recent time series studies considered wage data, like Messina et al. (2009), who estimated the degree of real wages counter-cyclicity across OECD countries using quarterly data up to 2004; they found evidence of heterogeneity. However they do not include prices as a separate time series and made no attempt to estimate stable level relations.

⁴Empirically, real wages, relative prices and unemployment have been found to be well-described by difference-stationary processes, or I(1). The observation that the unemployment rate u_t is a bounded time series has often been employed to discard a priori the possibility that the unemployment rate could be described empirically as an I(1) series. However, consider $u_t^* := \ln(u_t/(1 - u_t))$ and a linear approximation to the logit function $u_t^* \approx a + bu_t$ over the historical range of values for u_t . u_t^* is unbounded and could well be I(1); if this was the case, one would expect also u_t to be empirically close to I(1), if the linear approximation $u_t^* \approx a + bu_t$ is accurate, which is the case for the historical range of values of u_t . In the application we have hence decided to include u_t directly in place of u_t^* to facilitate the interpretation of the coefficients.

2. ECONOMIC FRAMEWORK

In this section we discuss the steady-state implications of the New Keynesian (NK) model in Blanchard and Galì (2007), henceforth BG. This model is taken here as reference for the relations among wages, prices and unemployment. The BG model features staggered-prices à la Calvo as well as real-wage rigidities; these are some of the key features of NK models at whatever level of sophistication. It assumes a production function with a non-produced, exogenous input that we take to represent imports, hence accounting for the openness of European economies. Prices are set by monopolistic firms in the goods market which optimize profits, while households set wages in the labor market optimizing their utility.

We derive the steady-state of inflation, unit labor costs and unemployment by suppressing the dynamics of growth rates in the model, obtaining linear relations involving levels of these variables. These level relations correspond to cointegrating relations if the data are found to be I(1), as in our empirical analysis. Because the focus of this paper is empirical, we report only the steady-state implications of the BG model, and refer to the original source and to Appendix A for details.

2.1. Wages and prices. The hybrid NKPC curve is obtained in BG assuming real wage rigidities of the following form, see their eq. (15):

$$\tilde{w}_t = \gamma \tilde{w}_{t-1} + \theta mrs_t,$$

where mrs_t is the marginal rate of substitution between work and leisure, and \tilde{w}_t is the real wage. In the following we let $w_t := \tilde{w}_t - y_t + n_t$ be unit labor cost, where $y_t - n_t$ is log productivity. BG assume $\theta = 1 - \gamma$; here we assume that this is not the case, in order to obtain a steady state that is compatible with the empirical finding that unit labor cost is I(1).

The real wage rigidities above imply a dynamic equation for unit labor cost w_t ; the resulting NKPC, eq. (12) in Appendix A, reads

$$\pi_t = \psi_0 + \psi_1 \pi_{t-1} + \psi_2 \pi_{t+1}^e - \psi_3 u_t + \psi_4 v_t + \eta_{\pi t}^*, \quad (1)$$

where ψ_i are non-negative functions of the model parameters, π_t is CPI inflation, π_{t+1}^e is the expectation of π_{t+1} formulated at time t , u_t is the unemployment rate, v_t is the price of a non-produced, exogenous production input, and $\eta_{\pi t}^*$ is a term containing growth rates and an expectational error. The NKPC in (1) includes u_t as the indicator for marginal costs. Galì and Gertler (1999), Galì et al. (2001), Galì et al. (2005) suggested to use unit labor cost w_t as a measure of marginal cost; see also Neiss and Nelson (2002). In the empirical analysis we include both u_t and w_t .

2.2. Steady state. We derive the steady state of the wage-price system in Appendix A, in terms of π_t and w_t . The steady state, see eq. (13) and (14) in Appendix A, is given by

$$\pi_t = \gamma_0 - \gamma_1 u_t + \gamma_2 v_t + \eta_{\pi t} \quad (2)$$

$$w_t = \gamma_3 - \gamma_4 u_t + \gamma_5 v_t + \eta_{wt} \quad (3)$$

where $\eta_{\pi t}$ and $\eta_{w t}$ are deviations from steady states, which include growth rates and expectational errors. These deviations from steady states correspond to statistically stationary processes when the original variables π_t and w_t are integrated of order 1 or 0.

Note that the system (2)-(3) is identified, as it corresponds to the steady-state solution of the model of π_t and w_t in terms of unemployment u_t and the price of the non-produced factor input price v_t .

2.3. Import prices. We associate v_t with the relative price of imports, $p_{M,t} - p_{y,t}$, $v_t := p_{M,t} - p_{y,t}$, where $p_{y,t}$ is the log of GDP deflator and $p_{M,t}$ is the log of prices of imported goods; hence the parameter γ_2 measures the pass-through of foreign (relative) prices to internal inflation. As customary in many macro-models, see e.g. Galí (2010), the CPI price index is assumed to be a weighted average of producers' prices and import prices, i.e. $p_{c,t} = (1 - \mu)p_{y,t} + \mu p_{M,t}$, where μ measures the degree of openness of the economy. By these assumptions one has

$$v_t := p_{M,t} - p_{y,t} = \frac{1}{\mu} (p_{c,t} - p_{y,t}), \quad (4)$$

which is used to replace v_t with $(p_{c,t} - p_{y,t})/\mu$ in the system (2)-(3) above, absorbing $1/\mu$ in coefficients γ_2 and γ_5 .

Remark that the price wedge $p_{c,t} - p_{y,t}$ is a measure of firms' price markup over cost. In a number of papers, Banerjee and Russell have proposed to model the markup as a function of inflation as well as of productions costs, see Russell and Banerjee (2008), Banerjee and Russell (2005) and references therein. Here we consider this possibility when coefficients cannot be interpreted in terms of the relations (2)-(3).

3. DATA

We consider data on 5 countries: Germany (DEU), Spain (ESP), France (FRA), United Kingdom (GBR), Italy (ITA). For each country, we consider an index of unit labor cost, denoted as w_t , the unemployment rate, u_t , the consumer price index, $p_{c,t}$, the GDP price deflator, $p_{y,t}$. The data vector contains the following 4 variables: $X_t = (w_t, u_t, p_{c,t} - p_{y,t}, \pi_t)'$, where $\pi_t := p_{c,t} - p_{c,t-1}$. Data were downloaded from the OECD website, see Appendix B for details on the construction of the data.

In particular, because only an index of earnings is available, the variable w_t was constructed as the log of the ratio of an index W_t° of total compensation and of an index of productivity $P_{r,t}$. This means that w_t is measured up to a location transformation.

We define the pre-EMU sample as the period from 1985Q3 to 1998Q4, while the EMU sample includes observations from 1999Q1 to 2007Q4. We chose 1985Q3 as starting period in coincidence with the Plaza agreement of September 22, 1985 which affected the stability of currency markets. We selected 2007Q4 as the end date of the sample, in order to exclude the beginning of the Great Recession.

The data are plotted in Fig. 1 in levels and in Fig. 2 in first differences, over an extended time period from 1980 to 2009. Levels of the variables appear non-stationary, while first differences are possibly mean-reverting. Recall that X_t is said to be I(1) if at least one of

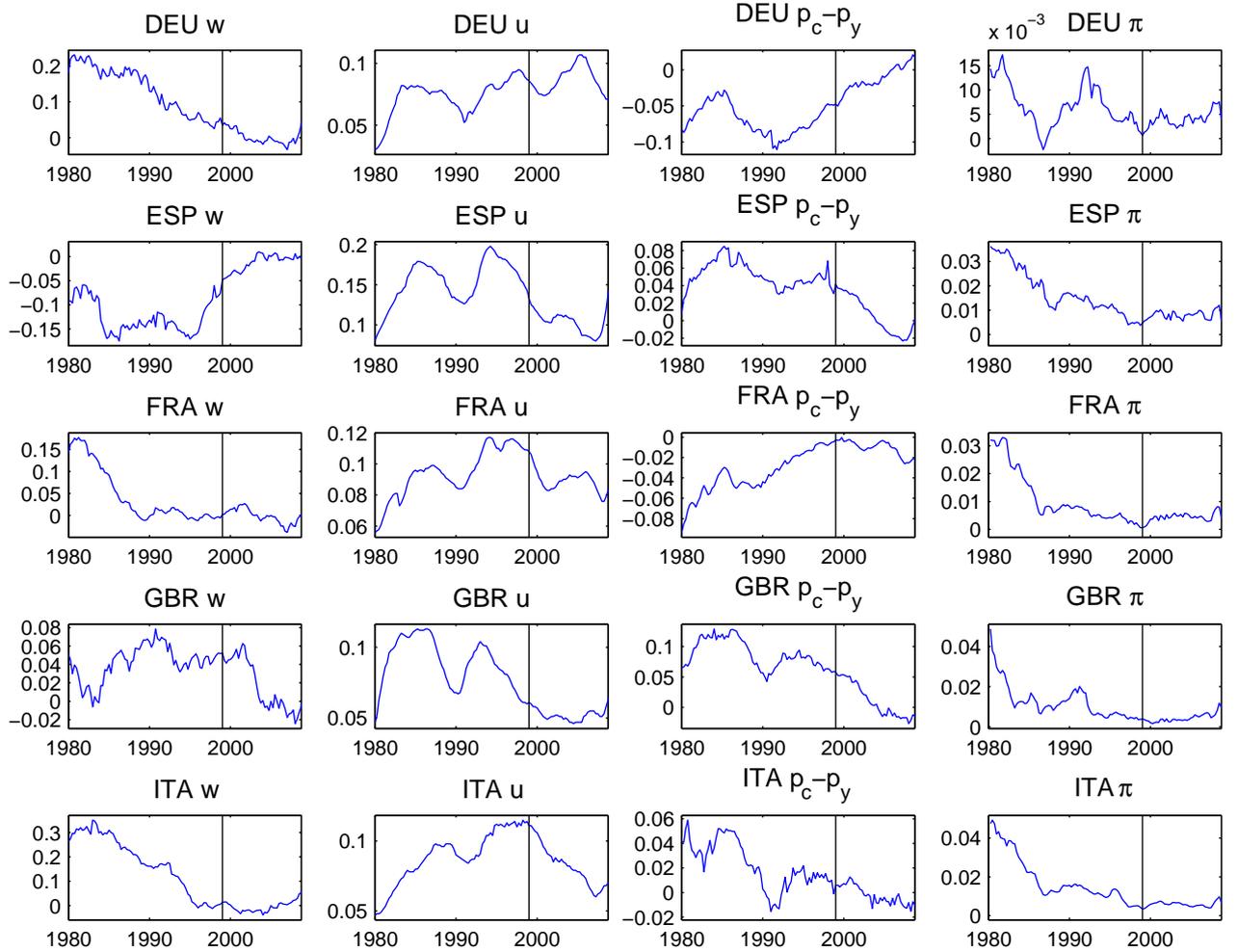


FIGURE 1. Data in levels 1988-2009. Vertical line corresponds to 1999Q1.

the variables contained in X_t is difference-stationary; visual inspection hence suggests that the data are $I(1)$.

4. EMPIRICAL EVIDENCE

For each sample, we specify a (possibly cointegrated) VAR model as in Johansen (1996) and Juselius (2006), of the type

$$\Delta X_t = \alpha \beta' X_{t-1}^* + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Phi D_t + \varepsilon_t, \quad (5)$$

where $D_t := (1, D_{1t}, D_{2t}, D_{3t})'$ contains the constant and three de-measured seasonal dummies, $X_{t-1}^* := (X_{t-1}', t)'$, and ε_t are i.i.d. $N(0, \Omega)$, Ω positive definite. The coefficients in (5) are allowed to take different values in the pre-EMU and EMU samples. Here we use the standard notation $\Delta := (1 - L)$ where L is the lag operator.

Note that (5) allows for the presence of a linear trend in X_t ; this augments the deterministic component implied by the economic reference model. The linear trend proxies for long-run trends not captured by the observed data. One can test ex-post if such linear trends are indeed not necessary.

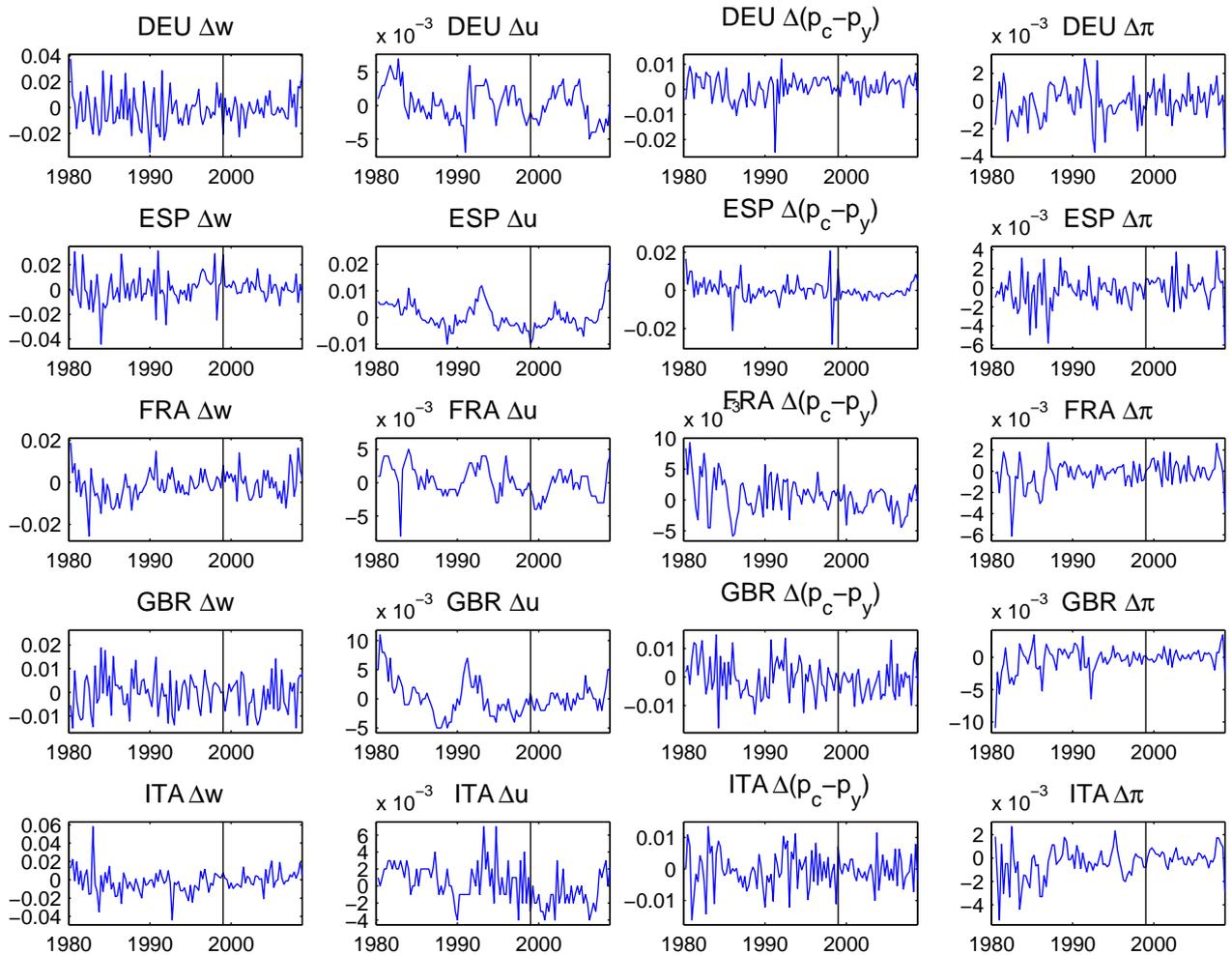


FIGURE 2. Data in first differences 1988-2009. Vertical line corresponds to 1999Q1.

The lag length k was selected on the basis of Hannan and Quinn (HQ) information criterion, using the pre-EMU sample. HQ selected $k = 2$ for all countries except DEU, for which HQ indicated $k = 1$. For uniformity we set $k = 2$ for all countries; the lag-length was fixed at 2 also in EMU sample.

4.1. Number of level relations. We tests for cointegrating ranks via the ‘trace test’ $LR(r|p)$. This gives evidence on the order of integration of the process ($I(1)$ or $I(0)$), as well as on the number of common trends in the system, which equals $4 - r$. Because X_t appears to be $I(1)$, the linear system (2), (3) implies a cointegration rank r at least equal to 2. Table 1 reports the results, in the form of p -values associated with $LR(r|p)$ tests. In the lower panel of the Table, we report the implied selection of cointegration rank, indicated as r_i with $i = 1, 2$ for the two samples.⁵

⁵The p -values in Table 1 were computed on the basis of a Γ approximation to the distribution of the discretised limit functional, see Doornik (1998) and Boswijk and Doornik (2004), where the discretised sample-size was set equal to the effective sample size. This corresponds to applying the factor a in formula (4) of Johansen (2002), which is the part of his Bartlett correction that does not depend on parameters.

		DEU	ESP	FRA	GBR	ITA
	r_1	Pre-EMU sample, 1985Q3-1998Q4				
	0	0.009*	0.010*	0.000*	0.002*	0.002*
	1	0.110	0.637	0.003*	0.092	0.033*
	2	0.402	0.692	0.265	0.112	0.369
	3	0.525	0.727	0.457	0.170	0.504
	r_2	EMU sample, 1999Q1-2007Q4				
	0	0.001*	0.000*	0.000*	0.011*	0.000*
	1	0.054	0.009*	0.071	0.369	0.066
	2	0.200	0.085	0.230	0.785	0.138
	3	0.374	0.122	0.237	0.798	0.401
Implied selection of cointegration ranks						
Pre-EMU	r_1	1	1	2	1	2
EMU	r_2	1	2	1	1	1

TABLE 1. p -values of cointegration rank tests $LR(r|p)$ and implied selection of cointegration ranks. Upper panel: p -values computed on the basis of a Γ approximation to the distribution of the discretised limit functional with number of steps equal to effective sample size. *: significant at 5% level. Lower panel: selected cointegration ranks at 5% significance level.

	DEU	ESP	FRA	GBR	ITA
Pre-EMU	0.69	0.88	0.71	0.77	0.86
EMU	0.92	0.77	0.83	0.71	0.82

TABLE 2. Largest modulus of estimated stationary roots, when fixing the cointegration ranks at the values selected in Table 1.

We find the cointegration rank to be in the majority of cases equal to 1, and hence only a single level relation from the the reduced-form system (2)-(3) can be identified. This single level relation may be either one of the equations (2)-(3) or a linear combination of the two. This lack of identifyability of one of the two relations may reflect a gradual adjustment process started at the beginning of the EMU, which is approximated statistically by an integrated process.

The selected cointegration rank does not change between the pre-EMU and the EMU periods for Germany and the UK; for France and Italy the cointegration rank decreased from 2 to 1 and for Spain it has increased from 1 to 2. Remark that the selected cointegration rank is rather sensitive to the choice of significance level: at 10% significance level, the selected cointegration ranks in the EMU period would be equal to 2 also for Germany, France and Italy. This would leave the UK as the only country with cointegration rank equal to 1. The cointegration ranks were then fixed in subsequent analysis at the values reported in Table 1; the resulting model is indicated as model \mathcal{M} .

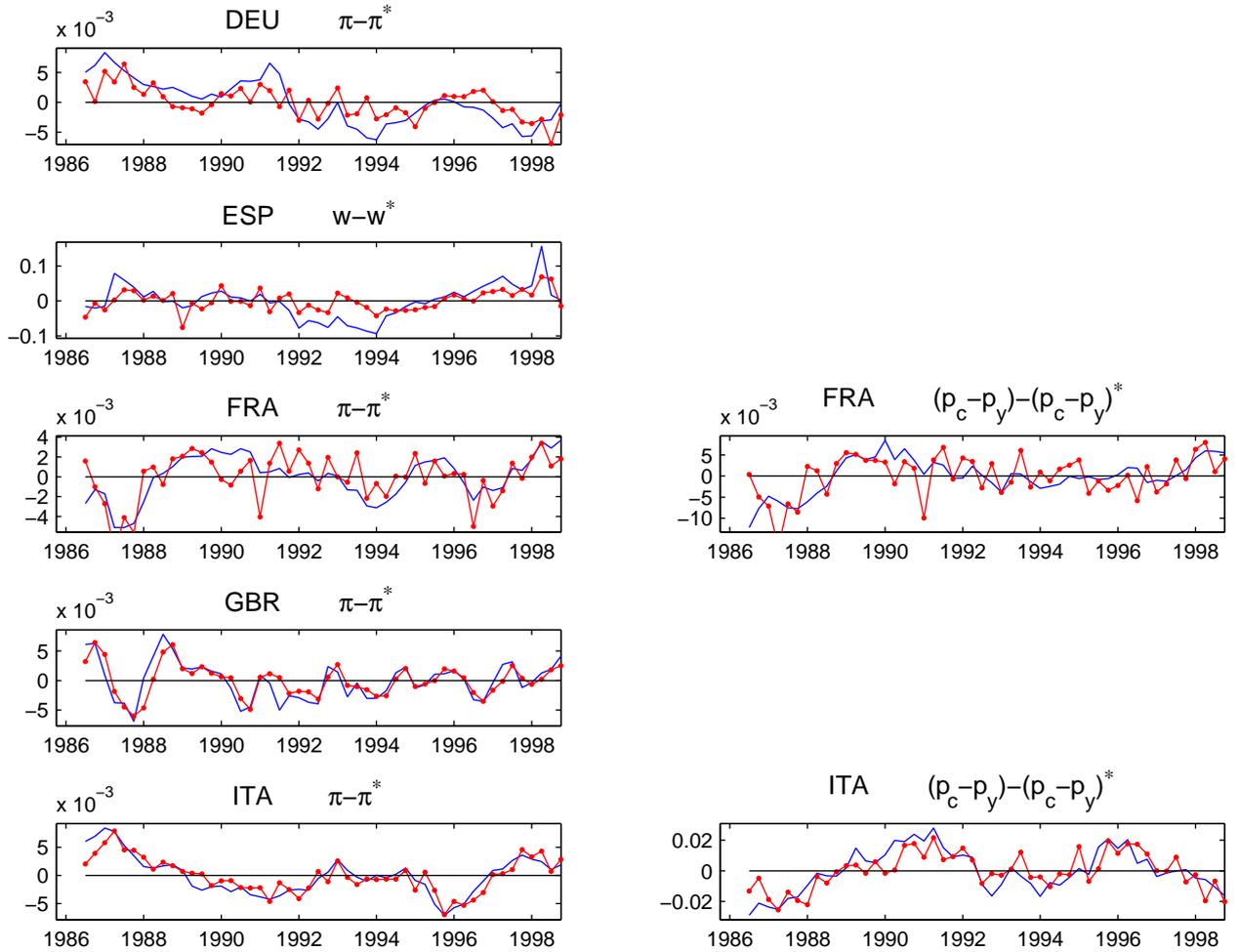


FIGURE 3. Cointegration relation in pre-EMU sample.

The degree of persistence of the estimated VAR system can be measured globally with the modulus of the largest autoregressive root (different from 1), when the cointegration rank is fixed at the estimated values in Table 1. These are reported in Table 2; they were computed as the largest moduli of the eigenvalues of the companion matrix, excluding eigenvalues equal to 1. One can see that, in all systems, there is a large degree of persistence. Comparing degrees of persistence between the pre-EMU and the EMU periods, one finds that it has increased with the EMU especially for Germany and France, which had comparably lower persistence than the remaining countries before the EMU. This higher persistence appears to be the price paid by these EMU countries for the single monetary policy.

4.2. Estimates of level relations. Within model \mathcal{M} , we identified the cointegration parameters in β^* along the lines of the economic framework of Section 2. The interpretation of the β coefficients is also coupled with the one of the adjustment coefficients α ; in this subsection

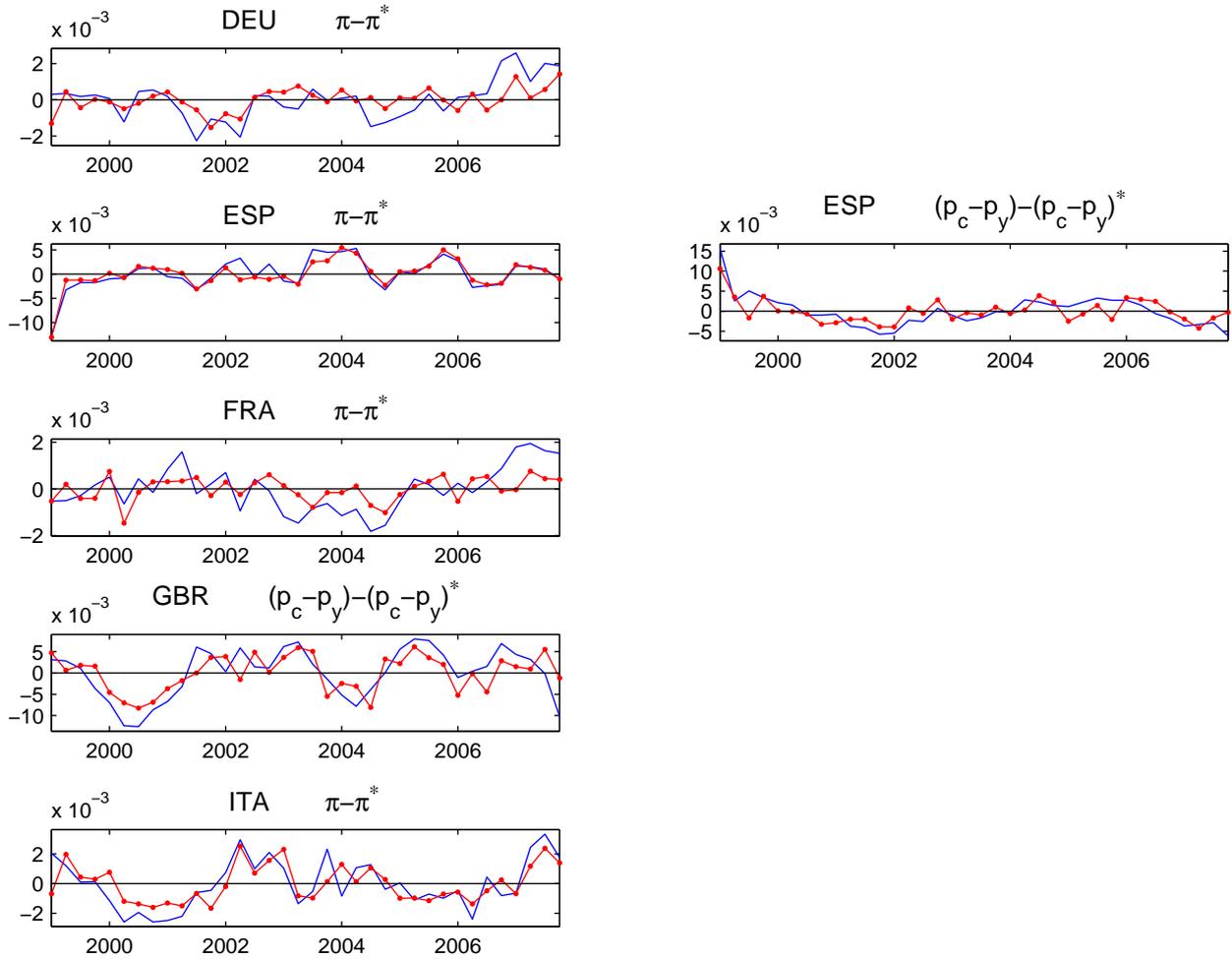


FIGURE 4. Cointegration relation in EMU sample.

we present both. The α coefficients provide information on one-step-ahead Granger-causality and forecast analysis.⁶

When the cointegration rank is equal to 1, we interpret the resulting level relation as a linear combination of the two equations in system (2)-(3). If the coefficient of π_t is significant, we normalize estimates setting the coefficient to π_t equal to -1 , and we interpret the linear combination as a relation of the type $\pi_t = \pi_t^* - \eta_{\pi t}^*$, where π_t^* is the reference value and $\eta_{\pi t}^*$ is the stationary error $\eta_{\pi t}^* := \widehat{\beta}^{*I} X_t^*$.

Insignificant coefficients are next set to zero and the resulting specification is tested jointly against model \mathcal{M} , using the more conservative significance level of 1%; this choice reflects a greater protection of the economic hypotheses used in the identification of the level relations. The restrictions are maintained if the test does not reject. When the sign of the coefficients does not match economic expectations, or the coefficient of π_t is insignificant, we normalize

⁶The corresponding long-run and interim forecast analysis can be addressed as in Omtzigt and Paruolo (2005) and Fanelli and Paruolo (2010). In this paper we restrict attention to the α coefficients and the one-step-ahead analysis for reasons of simplicity, and leave the long-run and interim analysis to further research.

the relation on unit labor cost w_t and, in case this does not work, on the markup $p_{c,t} - p_{y,t}$, following the interpretation laid out in Section 2.

When the selected cointegration rank is equal to 2, we identify the system as in (2)-(3). When this does not give the expected signs in the two relations, we identify a Phillips Curve and a markup relation, as explained in Section 2. Also in this case, insignificant coefficients are set to 0, and β is re-estimated under these restrictions, provided they were not jointly rejected at 1% level. Similarly to the case of a single cointegrating relation, the cointegrating relations are here denoted as $\pi_t = \pi_t^* - \eta_{\pi t}^*$, $w_t = w_t^* - \eta_{wt}^*$ or $p_{c,t} - p_{y,t} = (p_{c,t} - p_{y,t})^* - \eta_{pt}^*$, where η_t^* indicates one of the elements of the vector $\eta_t^* := \widehat{\beta}^{*'} X_t$.

Table 3 reports the estimated β coefficients. First of all, we note that different countries present different relations linking the variables in X_t . This signals a potential pitfall of analyzing aggregated Euro-area data, and the presence of heterogeneous country-specific effects of monetary policy. Moreover, we find the trend coefficients usually significant; these linear trends probably proxy for some unmeasured relevant variables.

The graphs of the cointegrating relations are depicted in Fig. 3 and 4. Each graphs includes the time-series plot of $\eta_t^* := \beta^{*'} X_t^*$ as a solid line, along with $\beta^{*'} R_t^*$, as a dotted-solid line, where R_t^* is the residual of X_t^* regressed on ΔX_{t-i} , $i = 1, \dots, k-1$ and D_t . Marked differences in the persistence of the two series are an indication of the presence of I(2) variables in the system. In both subperiods, there does not appear to be marked differences in the persistence, hence implying that the systems do not include I(2) variables.

One can observe an increase in the persistence of these plots when passing from the pre-EMU to the EMU sample. This feature is in line with the results in Table 2, and it may reflect a more time-consuming transmission mechanism of the single monetary policy within the EMU. Because the system does not include an interest rate variable, we are not in the position to analyse these effects more accurately; these issues are left to future research.

One common feature of the estimated adjustments during the EMU period is the lack of Granger-causality from deviations from level Phillips Curves $\pi_t - \pi_t^*$ to unit labor cost for Germany, France and Italy. The predicted higher flexibility of wages under EMU can only be found for the case of Spain, which present significant adjustment of unit labor cost. This may be explained by the fact that adjustment in unit labor costs may take longer time-horizons to materialise.

We next analyse the level relations and the adjustment coefficients country by country.

4.2.1. *Germany.* In the pre-EMU period, we find a standard Phillips Curve with unemployment as an index of marginal cost. The estimate of the slope equals -0.32 , in line with Schreiber and Wolters (2007) who report a slope equal to -0.5 for a sample period ending in 2003.⁷

⁷It is not simple to compare this estimate of the slope with a US analogue, because most specifications use unit labor cost w_t as a measure of marginal cost, see Galí et al. (2005). In order to substitute unit labor cost w_t with the unemployment rate u_t , one would need to substitute a level relation between w_t and u_t of the type given in (3). This relation is however found not to hold empirically for Germany in both sample periods.

country & period	w_t	u_t	$p_{c,t} - p_{y,t}$	π_t	$t/100$
DEU pre-EMU		-0.32***		-1	
EMU	0.05***	-0.09***	0.06**	-1	0.02***
ESP pre-EMU	-1	-1.89***	6.10***		0.44***
EMU	0.29***	-0.29***		-1	-0.07***
			-1		-0.21***
FRA pre-EMU	-0.12***	-0.24***		-1	
			-1		0.12***
EMU	-0.05***	-0.23***	0.15***	-1	0.00*
GBR pre-EMU	0.36***			-1	-0.01**
EMU	0.47***		-1	4.29***	-0.18***
ITA pre-EMU		-0.30***	0.16***	-1	
	-0.46***		-1		-0.29***
EMU		-0.55***	-0.34***	-1	-0.09***

TABLE 3. Estimates of the cointegration parameter β_j^* , $j = 1$ (pre-EMU sample), $j = 2$ (EMU sample). *: significant at 0.05 level; **: significant at 0.01 level; ***: significant at 0.001 level.

country & period	Δw_t	Δu_t	$\Delta(p_{c,t} - p_{y,t})$	$\Delta\pi_t$
DEU pre-EMU	0.20	0.11	-0.65**	0.24***
EMU	3.11	-0.91*	-1.16	0.69***
ESP pre-EMU	0.02	-0.02*	-0.09***	-0.01
EMU	-1.87***	0.18	-0.50***	0.13
	-0.25	-0.46***	0.24*	0.22**
FRA pre-EMU	0.53	0.41*	-0.70**	0.27**
	0.06	-0.22**	0.46***	-0.07
EMU	-0.03	0.06	-1.57**	0.43
GBR pre-EMU	-1.42***	-0.01	-0.97***	0.17**
EMU	-0.57*	0.11**	0.10	0.00
ITA pre-EMU	0.86	0.04	-0.67*	0.20***
	0.34**	-0.05	-0.03	0.04***
EMU	0.18	0.99***	0.08	0.05

TABLE 4. Estimates of the adjustment coefficients α_j , $j = 1$ (pre-EMU sample), $j = 2$ (EMU sample). *: significant at 0.05 level; **: significant at 0.01 level; ***: significant at 0.001 level.

For the EMU period, unit labor cost and the price wedge are also found to be significant variables in the Phillips Curve, hence signalling that in the EMU period the German economy has increased its links to foreign variables. Recall that foreign variables include also other European nations; this is hence in line with the expectation of the effects of the Euro.

The signs of the coefficients adhere to expectations; both w and u contribute to a single index of marginal cost, with opposite coefficients. Their effects are thus combined. The coefficients of u_t is reduced to 1/3 of the value before the EMU, although the slopes are not strictly comparable, due to the presence also of unit labor cost as an additional determinant of marginal cost in the EMU period.

The analysis of the α coefficients for Germany reveals that in the pre-EMU period, deviations $\pi_t - \pi_t^*$ Granger-cause the price wedge and inflation in one-step-ahead forecast, but not unemployment. One may describe this situation by saying that adjustment took place only in nominal variables, and that no real effects of $\pi_t - \pi_t^*$ can be detected. Because $\pi_t - \pi_t^*$ is one of the determinants of a Taylor monetary policy rule, one can infer that there is no detectable real effects of monetary policy in the period before the EMU.

In the EMU period, instead, one finds that both inflation and unemployment are Granger-caused by $\pi_t - \pi_t^*$, where the reference values now incorporate the additional influence of import prices and of unit labor cost. This signals a greater link from nominal to real variables in the EMU period, in line with the expected increased efficiency of the transmissions of monetary policy signals during the EMU. Note that this response is not necessarily faster, because of the increased degree of persistence signaled in Table 2. What has changed is that the adjustment of unemployment is statistically significant in the EMU period. The fact that $\pi_t - \pi_t^*$ Granger-causes inflation is a sign of the effectiveness of monetary policy in bringing actual inflation in line with expected inflation, at least for Germany.

4.2.2. *Spain.* Spain presents a cointegration rank of 1 in the pre-EMU and of 2 in the EMU periods. In the pre-EMU period, the coefficient of π_t was not significant and it was hence restricted to 0. The resulting equation was then normalized as (3); the coefficients estimates were found to have the expected signs.

In the EMU period, Spain presents a Phillips Curve similar to the one of Germany. Both w_t and u_t contribute to a single index of marginal cost, with opposite coefficients; their effects are hence combined. The coefficient of the price wedge in the Phillips Curve has been normalized to 0 because the second relation has been identified as a markup equation. The second level relation consists simply of the price wedge $p_{c,t} - p_{y,t}$ being stationary around a linear trend with negative slope. This signifies the steady decline of Spanish markups in the EMU period, possibly reflecting a decreased inflation risk.

The α adjustment coefficients show that unit labor costs and the price wedge appear to adjust to $\pi_t - \pi_t^*$, while unemployment, the price wedge and inflation react to $(p_{c,t} - p_{y,t}) - (p_{c,t}^* - p_{y,t}^*)$. This observed adjustment behavior is more complicated than the simple one-equation standard interpretation of the Phillips Curve, where one would expect $\pi_t - \pi_t^*$ to primarily Granger-cause inflation. It also signals a steady adjustment process of inflation and unemployment to European standards during the first decade of the EMU through the trend-stationary markup deviations $(p_{c,t} - p_{y,t}) - (p_{c,t}^* - p_{y,t}^*)$.

4.2.3. *France.* France presents a cointegration rank of 2 in the pre-EMU period and of 1 in the EMU period. Despite a cointegration rank of 2 in the pre-EMU period, the system cannot be identified as the reduced form (2)-(3), because of wrong signs of the estimated coefficients once

normalised. We hence identified the first relation as a Phillips Curve and the second one as a markup relation. Both relations are similar to the one found for Spain in the EMU period, except that the trend coefficient in the markup is positive, implying an increase in the markup, and a negative coefficient of w_t in the Phillips Curve, which implies that the coefficient of w_t decreases the effect of the one on u_t ; their effects hence partially cancel out in the aggregate index of marginal cost.

In the analysis of the α coefficients in the pre-EMU period, both $\pi_t - \pi_t^*$ and $(p_{c,t} - p_{y,t}) - (p_{c,t}^* - p_{y,t}^*)$ influence unemployment and the price wedge, while only $\pi_t - \pi_t^*$ affects inflation. This latter effect is in line with the standard single-equation formulations of the Phillips Curve.

In the EMU period a single cointegration relation is found, which is normalized as a Phillips Curve. The resulting coefficient estimates are very similar to the Phillips Curve in the pre-EMU period. The level Phillips curve in the EMU period however also contains effects from foreign variables via the price wedge, which has a significant coefficient.

The analysis of the α coefficients shows the absence of Granger-causality from $\pi_t - \pi_t^*$ to inflation; this challenges standard expectations for the Phillips Curve. Unlike for Germany and Spain, moreover, there is no evidence of Granger-causality from $\pi_t - \pi_t^*$ to unemployment. This suggests that monetary policy has no direct (one-step) effects through $\pi_t - \pi_t^*$ to inflation and unemployment. One finds that deviations $\pi_t - \pi_t^*$ affect the price wedge, signaling that adjustment takes place at the level of the markup of prices.

This finding appears to accord with the view that monetary policy is not geared towards (and is not effective in) inflation targeting for France. Moreover it challenges the view that policies aimed at improving competitiveness of French labor markets will result in an improved control of inflation dynamics.

4.2.4. *Italy.* Also Italy presents a cointegration rank of 2 in the pre-EMU period and of 1 in the EMU period. In the pre-EMU period, the two relations have been normalized similarly to France as a Phillips Curve and a markup relation. The Phillips Curve has a slope coefficient to u_t similar to the one of France and Germany, albeit w_t does not contribute to the index of marginal cost, unlike for France. The Phillips Curve also includes a price-wedge effect of the expected sign. The sign of w_t in the markup relation is, instead of the wrong sign; this variable is possibly picking up a slow adjustment of the price wedge in preparation for the EMU. The analysis of the α coefficients reveals that deviations $\pi_t - \pi_t^*$ mostly affect inflation and the price wedge, while $(p_{c,t} - p_{y,t}) - (p_{c,t}^* - p_{y,t}^*)$ influences unit labor cost and inflation.

In the EMU period, Italy presents a single cointegrating relation, normalized as a Phillips Curve. The coefficient of unit labor cost is insignificant, and it is hence normalized to 0. The slope coefficient for Italy (of u_t) is higher in absolute value than for the other nations within the EMU, and higher than the slope for Italy in the pre-EMU period.

The analysis of the α coefficients shows that monetary policy has no direct (one-step) effects through $\pi_t - \pi_t^*$ to inflation; this challenges standard expectations for the Phillips Curve. One finds instead that deviations $\pi_t - \pi_t^*$ mostly affect unemployment, signaling that adjustment takes place in real terms.

This finding appears to accord with the view that monetary policy is not geared towards (and is not effective in) inflation targeting for Italy. Moreover it challenges the view that policies aimed at improving competitiveness of Italian labor markets will result in an improved control of inflation dynamics.

4.2.5. *United Kingdom.* It is interesting to compare the above findings for countries within the EMU with the case of the UK. In both periods the UK presents cointegration rank equal to 1. In the pre-EMU period, the relation is normalized as a Phillips Curve, with a single significant index of marginal cost, given by unit labor cost w_t . Deviations from this Phillips Curve have significant effects on all variables except unemployment. Granger-causality from $\pi_t - \pi_t^*$ to inflation is in line with expectations on the Phillips Curve.

In the EMU period, however, the single relation is not found to conform to a level Phillips Curve, because the coefficient of π_t is insignificant, and it is hence set to 0. The resulting relation is normalized as a markup equation, with a positive coefficient of unit labor cost and of inflation.

The comparison of the UK with the other EMU countries show that a level Phillips Curve cannot be found only for the UK. This may be due to an evolving adaptation of the UK economy to the different international environment, and/or it could reflect the impact of recent liberalizations in the UK labor market. Alternatively – or complementarily – this may be the effect of non-participation of the UK in the EMU.

The deviations $(p_{c,t} - p_{y,t}) - (p_{c,t}^* - p_{y,t}^*)$ are found to have significant effects on unemployment and unit labor cost. Hence one finds that adjustment to foreign prices shocks takes place in the UK labor markets, both in terms of employment and competitiveness.

4.3. **Macroeconomic volatility.** All countries within the EMU generally experienced a decline in volatility between the pre-EMU period and the EMU period; the variance ratios are reported in Table 5. This decline is more pronounced for DEU, ESP and ITA, where the factor of reduction is around 2. FRA experienced no such decline. Over the same periods, the UK presents instead a substantial constancy of volatility in unit labor cost and the price wedge, and a decline in volatility of unemployment and inflation.

The evidence points to a reduced volatility for many EMU countries in the EMU period for the price wedge, wages and unemployment, as predicted by the proponents of the EMU. The UK appears to have participated in this reduction of volatility. France appears to be an exception to this rule. There has been a concomitant reduction of volatility in inflation for Germany, Spain, the UK and Italy but not for France. Hence the EMU and concomitant international factor appear to have had a beneficial effect on the macroeconomic volatility of all European countries, including the UK, with the exception of France.

5. CONCLUSIONS

In this paper we have investigated the dynamics and volatility of wages and prices before and after the onset of the EMU. All EMU countries present a level Phillips Curve in the EMU period, with similar coefficients, albeit within different specifications. The UK does not present a detectable level Phillips Curve in the EMU period. This appears in line with the anticipated

country & period	$(\Omega_1)_{11} / (\Omega_2)_{11}$	$(\Omega_1)_{22} / (\Omega_2)_{22}$	$(\Omega_1)_{33} / (\Omega_2)_{33}$	$(\Omega_1)_{44} / (\Omega_2)_{44}$
DEU pre-EMU	1.276	0.033	0.191	0.013
EMU	0.363	0.017	0.082	0.005
ratio	3.514	1.890	2.330	2.520
ESP pre-EMU	1.093	0.060	0.303	0.021
EMU	0.189	0.032	0.020	0.014
ratio	5.791	1.897	14.824	1.467
FRA pre-EMU	0.159	0.013	0.026	0.006
EMU	0.222	0.011	0.022	0.007
ratio	0.715	1.167	1.193	0.821
GBR pre-EMU	0.345	0.022	0.223	0.015
EMU	0.426	0.011	0.186	0.005
ratio	0.809	1.954	1.200	3.189
ITA pre-EMU	0.754	0.039	0.190	0.005
EMU	0.455	0.011	0.110	0.002
ratio	1.657	3.533	1.737	2.573

TABLE 5. Estimate of error variances in $\text{diag } \Omega_j$ multiplied by 10^4 in the pre-EMU and EMU periods; $\varepsilon_t := (\varepsilon_{1t}, \dots, \varepsilon_{4t})'$ is ordered conformably with $X_t := (w_t, u_t, p_{ct} - p_{yt}, \pi_t)$.

benefits of the EMU rather than of globalization, which has influenced both continental Europe and the UK.

The EMU appears to have had the effect of bringing the EMU countries more in line with one another; their Phillips Curves appear more similar in the EMU period than before it, albeit implying a relatively higher level of extrinsic persistence.

The dynamic adjustments are different between the pre-EMU and the EMU periods and across countries. During the EMU period, for all countries, including the UK, we find that deviations from reference values influence unemployment. This signals the presence of real effects for the single monetary policy. Only for Germany and Spain deviations from the level Phillips Curve are found to Granger-cause inflation as predicted by single-equation Phillips Curve theory, while for the other EMU countries adjustment takes place either on markups or in unemployment.

We also find a decrease in macroeconomic volatility for all countries that have joined the EMU with the exception of France. The UK also experiences a similar decline. This shows that the EMU and concomitant international factor appear to have had a beneficial effect on the whole of Europe.

Many areas of investigation related to the present work appear worth of further investigation. For instance, one could analyse long-run responses to deviations from reference values of the level Phillips Curves, using the tools proposed in Omtzigt and Paruolo (2005). Moreover one could measure the speed of adjustment to long-run values by analysing interim responses as proposed by Fanelli and Paruolo (2010). These analyses may offer further insights on the

medium-run responses of prices and labor markets to the common monetary policy of the Eurozone. This is left to future research.

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A. APPENDIX A: ECONOMIC MODEL

In this Appendix we give details on the derivation of the steady-state for inflation, unemployment and wages. We use the notation of BG, with the addition of time subscripts, except for the real wage, indicated here as \tilde{w}_t in order to avoid confusion with unit labor cost (i.e. real wages in efficiency units), which is indicated here as $w_t := \tilde{w}_t - y_t + n_t$. In this appendix we take the following basic equations on page 56 in BG, Appendix A:

$$mc_t = \tilde{w}_t - mpn_t \quad (6)$$

$$\tilde{w}_t = \gamma\tilde{w}_{t-1} + \theta mrs_t \quad (7)$$

$$\pi_t = \beta\pi_{t+1}^e + \lambda(mc_t + \mu^p) \quad (8)$$

Eq. (7) is a modification of eq (15) in BG, where BG assume $\theta = 1 - \gamma$; here we assume that this not the case, in order to obtain a steady state that is compatible with the empirical finding that w_t and π_t are I(1).

A.1. Wage dynamics. By section 1 in BG, one has $mrs_t = y_t - \phi n_t + \xi$ and by the first equation in section 6.2 in BG, one has $\tilde{w}_t = y_t - \phi n_{s,t} + \xi$. This implies that $\tilde{w}_t - mrs_t = \phi u_t$ where $u_t := n_{s,t} - n_t$ is the rate of involuntary unemployment. Substituting $\tilde{w}_t = mrs_t + \phi u_t$

into (7) one finds $mrs_t + \phi u_t = \gamma \tilde{w}_{t-1} + \theta mrs_t$, which can be solved for mrs_t , yielding $mrs_t = \frac{\gamma}{1-\theta} \tilde{w}_{t-1} - \frac{\phi}{1-\theta} u_t$. Substituting back into (7), one finds

$$\tilde{w}_t = \frac{\gamma}{1-\theta} \tilde{w}_{t-1} - \frac{\theta \phi}{1-\theta} u_t \quad (9)$$

From $\tilde{w}_t - y_t + n_t = \tilde{w}_t - \alpha(\tilde{w}_t - v_t + \log(\alpha/(1-\alpha)))$, which follows from $y_t - n_t = \alpha(m_t - n_t)$ and $m_t - n_t = w_t - v_t + \log(\alpha/(1-\alpha))$, see 3 lines before (A2) in BG, one finds

$$w_t = (1-\alpha) \tilde{w}_t + \alpha v_t + \alpha \log((1-\alpha)/\alpha).$$

Solving for \tilde{w}_t and setting $k := \alpha \log((1-\alpha)/\alpha)$, one finds $\tilde{w}_t = (w_t - \alpha v_t - k) / (1-\alpha)$, which can be substituted back into (9). One finds $\frac{1}{1-\alpha} (w_t - \alpha v_t - k) = \frac{1}{1-\theta} \gamma \left(\frac{1}{1-\alpha} (w_{t-1} - \alpha v_{t-1} - k) \right) - \frac{\theta \phi}{1-\theta} u_t$ which yields the dynamic equation

$$w_t = \phi_0 k + \phi_1 w_{t-1} + \phi_2 v_t - \phi_3 v_{t-1} - \phi_4 u_t. \quad (10)$$

with $\phi_0 := \frac{1-\theta-\gamma}{1-\theta} k$, $\phi_1 := \frac{\gamma}{1-\theta}$, $\phi_2 := \frac{\alpha}{1-\theta}$, $\phi_3 := \frac{\alpha\gamma}{1-\theta}$, $\phi_4 := \frac{(1-\alpha)\theta\phi}{1-\theta}$.

A.2. NKPC and steady state for π . By eq. (A1) in BG one has $\pi_t = \beta \pi_{t+1}^e + \lambda(w_t - a)$ with $a := \log(1-\alpha) - \mu^p$. Hence

$$w_t = a + \frac{1}{\lambda} (\pi_t - \beta \pi_{t+1}^e) \quad (11)$$

Rewriting (10) as $w_t = \phi_0 + \phi_1 w_{t-1} + b_t$ with $b_t := \phi_2 v_t - \phi_3 v_{t-1} - \phi_4 u_t$, and substituting into it from (11) for t and $t-1$, one finds

$$a + \frac{1}{\lambda} (\pi_t - \beta \pi_{t+1}^e) = \phi_0 + \phi_1 \left(a + \frac{1}{\lambda} (\pi_{t-1} - \beta (\pi_t + \zeta_t)) \right) + b_t$$

where ζ_t is an expectation error $\pi_t^e - \pi_t =: \zeta_t$; this implies

$$\pi_t = \psi_0 + \psi_1 \pi_{t-1} + \psi_2 \pi_{t+1}^e + \frac{\lambda}{1 + \phi_1 \beta} b_t - \frac{\phi_1 \beta}{1 + \phi_1 \beta} \zeta_t.$$

where $\psi_0 := \frac{\lambda(\phi_0 + (\phi_1 - 1)a)}{1 + \phi_1 \beta}$, $\psi_1 := \frac{\phi_1}{1 + \phi_1 \beta}$, $\psi_2 := \frac{\beta}{1 + \phi_1 \beta}$. Substituting $b_t = (\phi_2 - \phi_3) v_t - \phi_4 u_t + \phi_3 \Delta v_t$ one finds

$$\pi_t = \psi_0 + \psi_1 \pi_{t-1} + \psi_2 \pi_{t+1}^e - \psi_3 u_t + \psi_4 v_t + \eta_{\pi t}^*, \quad (12)$$

with $\psi_3 := \frac{\lambda}{1 + \phi_1 \beta} \phi_4$, $\psi_4 := \frac{\alpha \lambda (1 - \theta - \gamma)}{(1 + \phi_1 \beta)(1 - \theta)}$. Note that the error $\eta_{\pi t}^* := \frac{\lambda}{1 + \phi_1 \beta} \phi_3 \Delta v_t - \frac{\phi_1 \beta}{1 + \phi_1 \beta} \zeta_t$ is a stationary error if v_t is I(1) and if the expectation error ζ_t is I(0). Eq. (12) gives the hybrid NKPC in eq. (1). The steady state can be readily obtained as

$$\pi_t = \gamma_0 - \gamma_1 u_t + \gamma_2 v_t + \eta_{\pi t} \quad (13)$$

where $\gamma_0 := (1 - \psi_1 - \psi_2)^{-1} \psi_0$, $\gamma_1 := (1 - \psi_1 - \psi_2)^{-1} \psi_3$, $\gamma_2 := (1 - \psi_1 - \psi_2)^{-1} \psi_4$ and $\eta_{\pi t} := -\psi_1 \Delta \pi_t + \psi_2 (\pi_{t+1}^e - \pi_t) + \eta_{\pi t}^* / (1 - \psi_1 - \psi_2) = (\psi_2 - \psi_1) \Delta \pi_t + \psi_2 \zeta_{t+1} + \eta_{\pi t}^* / (1 - \psi_1 - \psi_2)$. The term $\eta_{\pi t}$ is equal to 0 in steady state and it is a stationary error if v_t, π_t are I(1) and the expectation errors are I(0).

A.3. Steady state for w . Replacing w_{t-1} with $w_t - \Delta w_t$ and v_{t-1} with $v_t - \Delta v_t$ in (10) one finds

$$w_t = k - \frac{(1-\alpha)\theta\phi}{1-\theta-\gamma}u_t + \alpha v_t + \eta_{wt}$$

where $\eta_{wt} := \frac{\alpha\gamma}{1-\theta-\gamma}\Delta v_{t-1} - \frac{\gamma}{1-\theta-\gamma}\Delta w_{t-1}$ is equal to 0 in the steady state of the model, and it is stationary if w_t and v_t are I(1) processes. We write this as

$$w_t = \gamma_3 - \gamma_4 u_t + \gamma_5 v_t + \eta_{wt} \quad (14)$$

where $\gamma_3 := k$, $\gamma_4 := \frac{(1-\alpha)\theta\phi}{1-\theta-\gamma}$, $\gamma_5 := \alpha$.

B. APPENDIX B: DATA SOURCES

Data were downloaded in March 2010 from <http://stats.oecd.org/> accessing the following OECD datasets: Main Economic Indicators, Quarterly National Account and Labor Statistics databases. The series were downloaded with start date 1980.Q1 whenever possible. Data definition was as follows:

- $w_t := w_t^\circ - pr_t$, with $w_t^\circ := \log W_t^\circ$, where $W_t^\circ := W_t^\dagger / W_{t_0}^\dagger$ and t_0 corresponds to 2005Q1 and $W_t^\dagger := E_t H_t$.
- E_t : index, s.a., average total earnings paid per employed person per hour, including overtime pay and regularly recurring cash supplements.
- H_t : hours worked. H_t was obtained from the temporal disaggregation of the annual data using the Fernandez methodology as implemented in Proietti (2006), using quarterly employment as an indicator series. The estimates are obtained as the expected value of the unobserved quarterly series given the observed annual data and the quarterly indicator, assuming a linear regression model with RW errors.

Missing data for DEU 1983-1990 have been reconstructed using the yearly time series DS-071602 provided by Eurostat

(<http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes>), which gives the average number of actual weekly hours of work, both full-time and part-time occupation.

- $pr_t := \log P_{r,t}$ where $P_{r,t} = P_{r,t}^\dagger / P_{r,t_0}^\dagger$, $P_{r,t}^\dagger := G_t / EI_t$. $G_t := GDP_t / GDP_{t_0}$, $EI_t := EMP_t / EMP_{t_0}$ where t_0 corresponds to 2005Q1.
- GDP_t : Gross domestic product - expenditure approach; current prices, levels, quarterly s.a.
- EMP_t : Employees, all persons, s.a. For DEU, the time series was back-reconstructed previous to the German unification by assuming that there was no change in Employees between 1990Q4 and 1991Q1.
- u_t : Harmonized Unemployment Rate (HUR), all persons, s.a. Missing data for DEU before 1991 was reconstructed on the basis of the non-harmonized unemployment rate, all persons, s.a.
- $p_{c,t} := MA_4(\log CPI_t)$. Data on CPI was downloaded from 1979Q1 to perform the transformation; CPI_t is Consumer prices, all items, Index, 2005=100. $MA_4 := \frac{1}{4}(1 + L + L^2 + L^3)$, is a moving average of order 4.

- $p_{y,t} := \log P_{y,t}$ where $P_{y,t}$ is GDP, total, implicit price deflator, edition (vintage) Feb. 2010. Missing data for ITA 1979-1980 and ESP 1979-1994 was taken or reconstructed from the GDP implicit price deflator, edition (vintage) Jan. 2003.