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Inflation and business cycle convergence in the euro area: Empirical analysis using an unobserved component model

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Abstract

The optimum currency area literature highlights that large inflation differentials can undermine a monetary union. In the euro area, inflation rates diverged after the creation of the single currency, and started to converge again after mid 2002. Another point suggested by the literature is that business cycles are an important determinant of inflation differences across countries. Against this background, we assess the convergence of inflation rates and business cycles in the euro area and study the relationship between them. The analysis is done using unobserved component model estimated with the Kalman filter. In general, from 1980 to 2008, inflation rates and business cycles have become more aligned in the euro area. It is found that output gap is better than unit labour costs as an indicator of business cycle when studying convergence. We also conclude that inflation rates have converged faster than output gaps. When looking at the causality between the convergence of these two variables, it is found that the destabilising impact of inflation divergence is limited.

Keywords: Inflation, convergence, Kalman filter, business cycle.

JEL classifications: E31, C32.

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1 Introduction

As stressed by the optimum currency area literature, large inflation differentials can undermine the success of a monetary union. Moreover, since one of the main drivers of inflation is the business cycle, convergence in inflation rates should be related with convergence in business cycles. The study of the relationship between these two convergence processes is the main goal of this paper. Specifically, we want to analyse if divergence (convergence) in inflation rates after the introduction of the euro can be explained by divergence (convergence) in business cycles.

Since the creation of the European Exchange Rate Mechanism (ERM) in 1979, there is evidence that monetary policy convergence in the euro area has been accompanied by inflation convergence. However, some inflation divergence after the introduction of the euro has been observed (Lane, 2006; Busetti et al., 2007) . Such a phenomenon can also be seen in Figure 1. Associated with the nominal convergence demanded by the Maastricht Criteria, the cross section standard deviation of inflation rates in the euro area decreased to 0.6% in September 1999. [1] Subsequently, the standard deviation increased until it reached 1.2% in mid 2002. After this peak, the downward tendency in inflation dispersion restarted, and in March 2007 the lowest level ever observed of 0.47% was achieved. In the first years of the euro (1999-2002), the countries with highest inflation rates were Greece, Ireland, the Netherlands, Portugal and Spain.

From the above analysis, we observe that after the launch of the euro, inflation differentials have initially increased. Some possible explanations can be advanced for such phenomenon. Firstly, inflation divergence may be due to equilibrating mechanisms. It is generally accepted that long-run relative price levels across countries depend on relative productivity or income levels. Therefore, since economic and monetary integration may lead to convergence of relative productivity and income, poor countries in an union will have temporarily higher inflation rates. This is known as the Balassa-Samuelson effect, which will be more important in a long-run horizon. Inflation differentials can also replace nominal exchange rate adjustments, since countries with low inflation gain external competitiveness (Lane, 2006).

[1] In the empirical results of this paper, euro area refers only to 12 countries, the original 11 plus Greece.

Besides equilibrating mechanisms, other explanation for inflation differentials rely on the fact that the baskets of goods and services used to measure CPI inflation differ from country to country. However, these differences have played a small role since the creation of the euro (ECB, 2003; Honohan and Lane, 2003).

The euro may also produce inflation differentials with destabilizing macroeconomic consequences. The nominal convergence between countries before the creation of the euro meant a bigger decline in real interest rates in peripheral countries. This implied a faster growth of credit, house prices, aggregate demand, and therefore inflation for those countries. This one-off expansionary shock dissipated over time as higher inflation led to the real appreciation of the currency.

A more recurrent situation in a monetary union is the existence of temporary asymmetric shocks. For example, with short-run supply rigidities, demand shocks create transitory inflation. Without a national monetary policy, the ability to deal with these shocks is limited. Inflation differentials cannot be corrected by a currency depreciation of high-inflation countries. In the case of deflationary shocks, countries may use expansionary fiscal policy to try to solve the problem, but this can lead to a violation of the Stability and Growth Pact with negative effects on the euro area financial markets (Honohan and Lane, 2003).

The ability to deal with asymmetric shocks will be even more limited if shocks are persistent. If the labour market is not perfectly flexible, with current rather than future inflation determining wages growth, higher inflation today may lead to higher wage growth, starting an upward spiral of wage growth and inflation.

Indeed, Vines et al. (2006) show that when inflation is significantly persistent, countries in a monetary union maybe subject to large and long cycles after asymmetric shocks. In their model, fiscal policy can have an important role in reducing inflation differences between countries.

In addition, in a monetary union, higher than average inflation rates produce lower than average real interest rates, which may lead to both excessive debt accumulation and property prices growth, with the subsequent painful adjustment process. This can then exacerbate the differences in business cycles among European countries, widening inflation differentials even more, in a cycle of divergence (Honohan and Lane, 2003; Dullien and Fritshe, 2008).

There are however two stabilising mechanisms empirically relevant in the euro area (Hofmann and Remsperger, 2005). Firstly, GDP growth in one country has positive output spillover effects on other countries, reducing inflation differentials. Naturally, small countries will have a limited impact on other countries. Secondly, the real exchange rate acts as a correcting mechanism: countries with higher than average inflation rates, will face a real appreciation that reduces demand and inflationary pressures. Even though this correction occurs at a gradual pace, the effect accumulates over time, since external competitiveness depends on relative price levels.

Let us highlight the most innovative features of this paper and our contributions to the literature. The analysis of the convergence of business cycles using the Kalman filter, as proposed by Hall et al. (1997), is new in the literature. Also, the real Unit Labour Cost (ULC) as an indicator of business cycle has been largely ignored in the convergence literature, even though this indicator is important in the New Keynesian approach to inflation. [2] In addition, the joint analysis of the convergence processes of inflation and business cycles with Hall et al.'s (1997) model has two novelties. First, we compare the rates at which the (unobserved) convergence of inflation and business cycles evolve over time. Second, we analyse the two-way causality between inflation and business cycles convergence.

Our results indicate that, from 1980 to 2008, inflation differentials in the euro area have converged in expectation. However, there was some temporary divergence after the creation of the euro, especially for Greece, Ireland, the Netherlands, Portugal and Spain. The business cycles of euro area countries have also become more aligned. Such phenomenon is much more clear when the output gap is used than when the real or nominal ULC are used. A further finding is that inflation rates have converged faster than output gaps. When looking at the causality between the two, on one hand, output gap convergence tends to have a positive effect on inflation convergence. On the other hand, a cumulative inflation convergence tends to have a positive effect on a country' business cycle.

The remainder of the paper is organised as follows. In Section 2 the main concepts of convergence are revised. Next, in Section 3 we analyse the convergence of inflation over the

[2] In the New Keynesian Phillips Curve the inflation's driver is the marginal cost, which can be measured using the labour income share, also called real unit labour costs.

period 1980-2008, using the Kalman filter to test whether the variance of the unobserved convergence component decreased over time. In Section 4 we apply the same methodology to study the convergence of business cycles. The comparison of convergence rates of inflation and output gap is done in Section 5. Section 6 comprises the study of the causality between inflation and output gap convergence. Finally, Section 7 concludes the study.

2 Convergence measurement's methodology

There are many ways of measuring convergence of economic variables and it is difficult to agree on a satisfactory measure of economic convergence (Hall et al., 1997). Hall et al. (1997) refer to three definitions of convergence: pointwise, in expectations and in probability. The most appealing definition is convergence in expectations, which occurs when the limit of the expected value of the scaled difference between two series goes to a constant:

$$\lim_{t \to \infty} E\left(X_t - \theta Y_t\right) = \alpha.$$

This definition allows the difference between the two series to be random in the limit. This is an adequate feature to measure the convergence of economic time series, because they are usually measured with error, and thus the variance of its difference will not go to zero asymptotically, as demanded by the concept of convergence in probability.

It is easy to see that if two series are stationary, then they have converged in expectation. However, typically the discussion of convergence occurs in the context of non-stationary series. Here, it is possible to have at least three situations. Firstly, if the difference $z_t = X_t - \theta Y_t$ is non-stationary as t goes to infinite, then there is no convergence by any of the previous definitions, since the variance of z_t will not go to zero asymptotically and there is no long-run mean to which series converge. Secondly, if X_t and Y_t are non stationary but cointegrated (and the cointegration residuals are I(0)), then they have converged in expectation but not necessarily in probability. Many studies have used the concept of cointegration between series and the stationarity of the difference of two series to assess inflation convergence (For example Holmes, 2002; Busetti et al., 2007; Gregoriou et al., 2007). Thirdly, it is possible that two series are non-stationary and non-cointegrated for the entire sample, but they convergence at the end of the sample. This occurs when, after an initial period of non-stationary behaviour, the difference between variables becomes stationary due to changes in the economic environment. This means that cointegration is not a necessary condition for convergence. As Hall et al. (1997) highlight, convergence is defined as a limiting case, while cointegration is a concept that applies to the entire sample.

Alternatively, Hall et al. (1997) propose a more appealing way to measure convergence; which makes use of time-varying parameters and allows for convergence to take place gradually, as the series generating process evolves towards stationarity. Therefore, this methodology deals adequately with structural breaks in convergence processes. The proposed model is then:

$$\begin{aligned}
X_t - \theta Y_t &= \alpha_t + \varepsilon_t && (1)\\
\alpha_t &= \alpha_{t-1} + \upsilon_t && (2)\\
\varepsilon_t &\sim N(0, \sigma^2)\\
\upsilon_t &\sim N(0, \Omega_t)\\
\Omega_t &= \phi\Omega_{t-1}, \text{with } \Omega_o \text{ given,}
\end{aligned}$$

where ε_t is a random error that accounts for measurement errors. The model's central element is the unobserved component α_t, which measures the convergence between series, and depends on an error term υ_t. The initial variance of υ_t is given by Ω_o. If the variance of υ_t converges to zero ($\phi < 1$), then α_t will evolve to a non-stochastic constant, and convergence in expectation is guaranteed. A formal test involves the null hypothesis of no convergence $H_o : \phi = 1$. If the null is rejected and the variance of ε_t goes to zero, then it occurs also convergence in probability. This framework encompasses the evaluation of convergence based on cointegration. Indeed, an estimate of $\Omega_o = 0$ for I(1) series means that they are cointegrated. Finally, this model is in the state-space form, with equation (1) as the measurement or observation equation and equation (2) as the state or transition equation. The Kalman filter has to be applied to the state-space form equations, where α_t is the state variable. Firstly, this filter provides "optimal" forecasts of the unobserved component α_t. [3] Then, these forecasts are

[3] They are optimal in the sense that they minimize the Mean Squared Error.

used to generate series of one-step-ahead prediction errors and their variances, which contain unknown parameters to be estimated. Finally, using those series of errors and variances, standard maximum likelihood techniques can be used to estimate the unknown parameters.

The described model decomposes the difference between two series in two components: a permanent component, α_t, which we interpret as a measure of convergence, and an error ε_t, which is a transitory component. What the Kalman filter actually does is to determine which part of the change in the dependent variable, $X_t - \theta Y_t$, can be attributed to each one of these components.

We use the model proposed by Hall et al. (1997) in two innovative ways. First, we test for each country if output gap and inflation converge at the same rate. To answer that, we estimate the following model for each country:

$$\begin{aligned}
difx_t^i &= \alpha_t^x + \varepsilon_t^x && (3)\\
dif\pi_t^i &= \alpha_t^\pi + \varepsilon_t^\pi && (4)\\
\alpha_t^x &= \alpha_{t-1}^x + \upsilon_t^x\\
\alpha_t^\pi &= \alpha_{t-1}^\pi + \upsilon_t^\pi\\
\varepsilon_t^x &\sim N(0,\sigma_x^2);\ \varepsilon_t^\pi \sim N(0,\sigma_\pi^2)\\
\upsilon_t^x &\sim N(0,\Omega_t^x); \upsilon_t^\pi \sim N(0,\Omega_t^\pi)\\
\Omega_t^\pi &= \phi\Omega_{t-1}^\pi, \Omega_o^\pi \text{ given.}\\
\Omega_t^x &= (\phi\cdot\phi^z)\,\Omega_{t-1}^x, \Omega_t^x = \Omega_o^\pi\cdot\Omega_o^z \text{ given.}
\end{aligned}$$

where $difx_t^i = x_t^i -\ x_t^{eur}$, with x_t^i being the output gap of country i and x_t^{eur} the output gap of euro area. Also $dif\pi_t^i = \pi_t^i - \pi_t^{eur}$, with π_t^i as the inflation rate of country i and π_t^{eur} as the inflation rate of euro area. Equations (3) and (4) are estimated simultaneously. And the rates of convergence of the unobserved component' variance and the initial variance are allowed to be different for inflation and output gap, being the purpose to compare the rates of convergence of these two variables. If we do not reject $H_o : \phi^z = 1$, the two convergence processes occur at the same rate, $\Omega_t/\Omega_{t-1} = \phi$. These processes will be even more similar if the initial variance of the state variables also coincide, *i.e.*, if we do not reject $H_o : \Omega_o^z = 1$.

The second extension of Hall et al. (1997)'s model consist in assessing the two-way causality between the convergence processes of inflation and business cycles, using the state variable α_t as convergence indicator. In order to study that, two changes have been made to the model comprising equations (3) and (4). First, we assume that the last period state variable of output gap may affect the current state variable of inflation (equation (8)). And since the causality can be bidirectional, it was also assumed that the last period state variable of inflation may influence the current state variable of output gap (equation (7)). That leads to the following model, where all equations are estimated simultaneously for each country i:

$$
\begin{aligned}
difx_t^i &= \alpha_t^x + \varepsilon_t^x && (5)\\
dif\pi_t^i &= \alpha_t^\pi + \varepsilon_t^\pi && (6)\\
\alpha_t^x &= \gamma_{gg}\alpha_{t-1}^x + \gamma_{ig}\alpha_{t-1}^\pi + \upsilon_t^x && (7)\\
\alpha_t^\pi &= \gamma_{ii}\alpha_{t-1}^\pi + \gamma_{gi}\alpha_{t-1}^x + \upsilon_t^\pi && (8)\\
\varepsilon_t^x &\sim N(0,\sigma_x^2);\ \varepsilon_t^\pi \sim N(0,\sigma_\pi^2)\\
\upsilon_t^x &\sim N(0,\Omega_t^x)\\
\Omega_t^x &= \phi^x\Omega_{t-1}^x, \Omega_o^x \text{ given.}\\
\upsilon_t^\pi &\sim N(0,\Omega_t^\pi)\\
\Omega_t^\pi &= \phi^\pi\Omega_{t-1}^\pi, \Omega_o^\pi \text{ given.}
\end{aligned}
$$

Some comments are necessary regarding parameters γ. Firstly, we allowed γ_{gg} and γ_{ii} to be different from 1 to ensure model's stability. Furthermore, when one of the series converges and the other does not, only some values for γ make sense. If the output gap converges and inflation does not converge, then $\gamma_{ig} = 0$. Otherwise, in the limit there was a non stationary component in output gap. Likewise, $\gamma_{gi} = 0$ if the output gap does not converges and inflation converges. Finally, if both series converge, γ_{ig} and γ_{gi} may or may not be different from zero.

In the next sections, we apply the above models to the convergence of inflation and business cycles in the euro area for the period 1980-2008.

3 Convergence of inflation rates

Let us start with the study of inflation convergence from 1980 to 2008. A relatively large period is analysed to put the evolution of inflation rates during the euro period in an historical context. The focus is on the convergence of each country towards the euro average, analysing the difference between inflation rate of each country and the euro average: $\pi_{i,t} - \pi_{eur,t}$, where $\pi_{i,t}$ is the inflation rate of country i in period t, and $\pi_{eur,t}$ is the euro area inflation rate. [4] When available, we used the quarterly *harmonized* CPI from Eurostat after removing the seasonality, otherwise the non harmonized CPI from OECD Main Economic Indicators was used. For euro area seasonally adjusted data was obtained from ECB.

The interest is to see whether inflation differences evolve gradually towards stationarity, as outlined in the model composed by equations (1) and (2). Under the null hypothesis $\phi = 1$, model (1) is non-stationary and ϕ is in the boundary of the likelihood space. [5] So, under the null the test statistic follows a non-standard distribution. Using Monte Carlo simulations, Hall et al. (1997) suggest that ϕ is asymptotically normally distributed and that the standard errors are underestimated by a factor which varies between 1.65 and 2.0. [6]

Looking at Table 1, the null of non convergence is not rejected for Austria, Germany and the Netherlands. In the former two cases the z-statistics is higher than 1.8, but in the latter case it is smaller than 1 indicating a clear non-rejection of the null. The reason why the null is not rejected for that countries may be related with the fact that, unlike for the other countries, for these three there is not a clear reduction in inflation's volatility (Figures 2). Indeed, inflation rates of these countries were already relatively more stable in the beginning of the sample and their average inflation differentials were among the lowest ones. In addition, the null hypothesis that the variance of the state variable was zero in the first period or in the last period for each of the three countries is not rejected (fifth and sixth columns of Table 1, respectively). In other words, these countries already had a very high degree of convergence in 1980Q1, and for that reason the test does not identifies clearly further convergence afterwards.

[4] $\pi_{i,t}$ and $\pi_{eur,t}$: quarterly inflation rate annualized: $(1+\inf quarterly)^4 - 1$, where $\inf quarterly = p_t/p_{t-1} - 1$, with p_t as the CPI.

[5] Note that with $\phi > 1$ the model is explosive.

[6] The *z-statistics*'s critical value at 5% significance for rejecting the null hypothesis (using a one-sided test: $H_0 : \phi = 1$ vs $H_1 : \phi < 1$) should be (in absolute value) between 2.71 (=1.65*1.645) and 3.29 (=2*1.645).

In addition, notice that in 2008Q4 the variance of the state variable converged to zero for the other countries as well (sixth column of Table 1). In summary, in the period 1980-2008, there is evidence of inflation convergence in the euro area.

However, what we have just stated, does not mean that sub-periods of divergence did not exist. In fact, Becker and Hall (2009) show that inflation co-movement was smaller after the creation of the euro than before. Such divergence can be identified in our approach, for each country, when the unobserved convergence variable, α_t, is significantly different from zero. An estimate of that variable can be obtained using its filtered value, and the root mean squared error (RMSE) can be used to assess if that estimate is statistically different from zero. [7] From Figures 2 and Table 2 it can be observed an increase in positive divergence (in the sense that the state variable stays significantly above zero for a certain number of periods) in some quarters after 1998 for Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. In line with this finding, Busetti et al. (2007) identify Portugal, Greece, Ireland and Spain as a group where inflation differentials were stable after 1998, but with inflation rates relatively higher than the average. Notice that for these countries the divergence may have been associated with the significant reduction in the real interest rate that accompanied the nominal convergence to the euro. In contrast for Austria, Finland, France and Germany there are periods of negative divergence with the euro average. But for all countries, except Austria, France, Luxembourg and Spain, the divergence is reversed latter in the sample. For that four countries the indicator of convergence (the final filtered value of the state variable α_t) is statistically different from zero in the last period of the sample (seventh column of Table 1). While for Austria and France the differential to the euro average is negative, for Luxembourg and Spain is positive. Also, for Luxembourg the indicator of divergence is half the one of Spain, and the divergence occurred for a shorter period. This seems to indicate that only for Spain it may exist concerns regarding its long-run external competitiveness. In conclusion, inflation divergence was in general temporary in nature, not putting in danger the long-run stability of the euro area.

[7] The filtered value of α_t is computed as follows. Firstly, it is obtained the one-step ahead forecast for period t using information until $t-1$. The filtered state of α_t corresponds to the update of this forecast using information up to t.

4 Convergence of business cycles

Given that there is a strong relationship between business cycles and inflation, our hypothesis is that inflation convergence in the euro area has been accompanied by convergence in business cycles. However, there are different indicators to measure the business cycle. While traditionally output gap has been used to measure economic fluctuations, the New Keynesian approach argues that the correct driver of inflation is the real ULC. In order to study business cycles' convergence, we will use those two indicators, beginning with the real ULC.

4.1 Convergence of real ULC

In the literature, some attention has been given to wages and productivity in explaining inflation divergence. For example, the ECB Inflation Persistence Network concluded that the most important source of inflation differentials in the euro area was a "sustainable differential in wage growth and narrower differences in productivity growth" (ECB, 2003).

In our paper we analyse the convergence of wages and productivity by looking at real ULC. This variable has the advantage of combining average wages (w_t) and labour productivity (pr_t). Indeed, real ULC (s_t) can be written in logs as: $s_t = ulc_t - pd_t = w_t - pr_t - pd_t$, where ulc_t is the nominal ULC and pd_t the GDP deflator. Notice that nominal ULC is given by $w_t - pr_t$.

There is some previous work by Dullien and Fritsche (2008) on the convergence of growth rates of nominal ULCs in the EMU using annual data, between 1960 and 2007. These authors do not reject the hypothesis of convergence for all EMU countries on two grounds. Firstly, nominal ULC growth differentials towards the average are stationary. Secondly, there is cointegration between ULC growth rates of individual countries and the rest of the EMU. There is also no evidence of structural break in the convergence of nominal ULC growth rates caused by the introduction of the euro.

Using Panel Analysis of Nonstationarity in the Idiosyncratic and Common components (PANIC), Fritsche and Kuzin (2007) are more pessimistic regarding nominal ULC growth convergence in the euro area. They found that it is difficult to identify a common factor, with idiosyncratic factors explaining the majority of the variance. Besides that, countries respond to the common factor in very different ways, and it is possible to identify two groups of countries. One is the "hard currency" club, composed of Austria, Belgium, Germany, Luxembourg and the Netherlands. The other group includes Finland, Greece, Ireland, Portugal and Spain, which share common movement due to their catching-up processes. Finally, note that Fritsche and Kuzin (2007) and Dullien and Fritsche (2008) by using nominal ULC, ignore that if an increase in labour costs is accompanied by an increase in labour productivity, it may not affect inflation. This is the reason why in our paper real ULC is used as a measure of business cycles.

Our initial focus is on the the convergence tests applied to the difference between the log of real ULC of each country and the euro average. The real ULC was obtained dividing the nominal ULC by the GDP deflator, with both indexes with base 100 in 2005. Both the seasonally adjusted nominal ULC for the entire economy and the seasonally adjusted GDP deflator were obtained from OECD. [8] Since data are expressed in indices, it is not expected convergence towards the same level of real ULC. But if two countries converge, we expect to observe their real ULCs moving together, implying that real ULC differentials fluctuate around a constant (not necessarily zero). However, it is possible to admit that in the beginning of the convergence process the co-movement of real ULC between a high inflation country and euro area will be small. A high inflation country aiming to reduce inflation rate to the euro area level has to undergo an initial period of strong reduction in real ULC. This will naturally imply initial divergence between the two series. But once inflation has converged (as has occurred in euro area countries), it is expected that real ULCs will basically grow at the same rate in both countries. This justifies the use of the unobserved convergence component approach based on the Kalman filter, which is able to detect ongoing convergence.

The graphs of real ULC differentials do not show a clear pattern of convergence (Figure 3). Confirming this, the formal test shows convergence at 5% significance only for Austria, Finland, France and Greece (Table 4).

From the real ULC's graphs of the four countries for which the test identified convergence, we observe that the convergence process is not yet finished. To formally confirm this

[8] The nominal ULC series excludes also the irregular movements in the underlying series. Moreover, since for Portugal the ULC of the entire economy was not available, we used the ULC of the business sector.

conclusion, a Wald test can be performed to analyse if the state variable residual's variance, $var(v_t)$, is zero in the last quarter of the sample: $H_0 : \Omega_{2008Q4} = 0$. [9] For the four countries where convergence was detected, this test rejects the null, confirming the incompleteness of the convergence process (Table 3). In fact, the variance of the state variable residual has been decreasing, but it was not yet zero in 2008Q4. This means that the real ULC differentials still have a non-stationary behaviour, with convergence in expectation not yet achieved, but in the limit the variance will go to zero.

Since there is weak evidence of real ULC, we analyze next the convergence of the growth of nominal ULC. Our results show convergence (at 5% level of significance) only for Belgium, Italy, the Netherlands and Spain (Table 5). [10] This supports the results of Fritsche and Kuzin (2007).

In conclusion, convergence in inflation was achieved despite a rather incomplete convergence on real and nominal ULC. This casts doubts over the ability of both real and nominal ULC to explain inflation convergence. Therefore, in the next section we analyse output gaps' convergence, expecting to found better evidence of business cycles convergence.

4.2 Convergence of output gaps

In this section, we study the convergence of output gaps in the euro area by analysing the difference between the output gap of each country and the euro area output gap. This indicator measures the synchronisation of business cycles, but it is not expected that its variance will go exactly to zero, because output gap is measured with some error. Instead, it is sensible to assume that as business cycles become more synchronised, the variance of output gaps' difference decreases. [11]

The several studies on the evolution of output gap correlation in the euro area have not reached an unanimous conclusion (De Haan et al, 2008). Our analysis will assess if,

[9] It is worth making one note regarding this test. As a Wald test is asymptotically equivalent to a likelihood ratio test, the null is testing more than if the variance is zero in the last period. Indeed, it is testing whether it exists a full path of convergence leading to a zero variance in the last period.

[10] Notice that for the growth rates of the nominal ULC we are not really interested in studying if there is convergence in expectation, because that is already ensured, as that variables are stationary. Instead, our main goal is to understand how the variance of that variables evolves over time. As a result, we can use the standard critical value 1.675 for a one-sided test at 5% significance.

[11] Once more, we are not interested in studying if there is convergence in expectation, because that is already ensured, as output gaps are stationary variables.

despite possible short periods of convergence/divergence, for the full period there is convergence/divergence of output gaps.

The output gap was calculated as the difference between the log of output and the log of output's trend. To obtain the output's trend we used the HP filter, with lambda fixed at 1600. The real GDP data was obtained from OECD, except for Portugal were data is from IMF. Using these data, it is obtained that for all countries except Ireland, the variance of output gap' differentials has decreased in a statistically significant way between 1980 and 2008 (Table 6). [12] Notice that the result for Ireland is strongly affected by the steep decrease in output gap that occurred in 2008.

The convergence in business cycles in the euro area is probably explained by the deepening of trade and monetary integrations. Particularly, the adoption in 1979 of a system of fixed exchange rates and the subsequent creation of a single currency implied convergence of policies that may have led to greater conformity in the business cycles. Artis and Zhang (1997, 1999) defend that this has occurred during the European Exchange Rate Mechanism.

The convergence rates vary from -1.09% per quarter for Luxembourg to -3.69% per quarter for the Netherlands (Table 6). [13] In addition, it is possible to identify some interesting patterns. On one hand, there is a group of countries with smaller rates of convergence: Austria, Belgium, France and Luxembourg. Probably, the output gap of these countries was already highly synchronised with euro area in 1980. On the other hand, we have the Southern countries: Greece, Italy, Portugal and Spain. These countries that in 1980 were less linked to the euro area business cycle have converged at higher rates. Also Finland that had strong trade links with the former Soviet Union, has had a quick convergence towards the euro area business cycle.

In general, since 1980, business cycles of euro area countries have become more aligned. This was expected due to the increasing economic and monetary integration occurred in the euro area.

[12] In this test we use the standard critical values to test $H_0 : \phi = 1$, because the difference of output gaps is stationary even if H_0 is not rejected.

[13] The convergence rate is $\Omega_t/\Omega_{t-1} - 1 = \phi - 1$.

5 Comparing the convergence processes of inflation and output gap

From what was seen above, there is strong evidence of convergence in inflation rates. On the business cycle side, there is also robust evidence of convergence between output gaps. In this context, one interesting question is whether both processes occurred at the same rate. To answer that, we estimated the model composed by equations (4) and (3).

For Finland and Germany the convergence processes of inflation and output gap occurred at the same rate, since we do not reject $H_o : \phi^z = 1$ (Tables 7). [14] Naturally, also for Ireland and the Netherlands the processes were different because the non-convergence hypothesis was not rejected for one of the variables. For the remaining eight countries the processes were also distinct, with the convergence of inflation occurring at a faster rate than the convergence of output gap: on average 6.9% per quarter faster. The same occurs for Finland and Germany, but the difference in the convergence dynamics of the two variables was not statistically significant. The reason for a faster convergence of inflation than output gap, may be found in the Maastrich criteria that stressed the importance of nominal convergence.

It is worth mentioning that the comparison between the rates of convergence of inflation and output gap does not clarify if there was causality between the two processes. For instance, the two processes may have occurred at the same rate because other factors are implying a common rate of convergence. Therefore, in the next section we study if there is in fact causality between both processes of convergence.

6 Causality between the convergence of inflation and output gap

There are many reasons why the convergence of inflation and the convergence of output gap may influence each other. On one hand, when a country's output gap is higher than the average output gap, there is pressure for its inflation to be also higher than the average. On the other hand, inflation's convergence may affect output gap's convergence, even though the

[14] We use a two-sided test because both $\phi^z < 1$ and $\phi^z > 1$ are plausible alternative hypothesis.

direction of the impact is unclear. It is true that if a country's inflation (and output gap) is growing faster than the average that leads to a loss of competitiveness, which may reduce output gap and lead to *convergence* of this variable. But on the contrary, high inflation leads to *lower* real interest rates, which will increase aggregate demand and lead to output gap divergence. Which of these effects is the dominant one has to be determined empirically.

There exist already papers linking output gap and inflation differentials. Using annual data, Rogers (2002), Honohan and Lane (2003), Honohan and Lane (2004) and Angeloni and Ehrmann (2006) conclude for the significance of output gap in explaining inflation differences in the euro area. However, Honohan and Lane (2004) with quarterly data conclude for the insignificance of output gap. Our work contributes to this literature estimating with quarterly data a new model to assess convergence - the unobserved component model composed by (5) and (6) - that allows a two-way causality between inflation and the business cycle.

As expected from the discussion above, our results (see Table 8) show that the effect of output gap convergence on inflation convergence is positive for all countries except for France and Italy, but is never statistically significant except for Finland, the Netherlands and Portugal (the latter at 10%). On the other hand, the sign of the effect of inflation convergence on output gap convergence is always positive, except for Belgium, Italy and Spain, but is never statistically significant.

So far, our evidence shows that the causality between the two convergence processes is statistically weak. However, it is well known that the impact of inflation differentials has a cumulative effect on the cyclical position, because price differences undermine external competitive position in a permanent way. Therefore, we analyse next the *cumulative* effect of inflation convergence on output gap convergence. For that, we use the percentage difference of CPIs instead of the difference of inflation rates and we obtain more significant results than before (Table 9). An increase in the distance of output gap to the euro average increases CPIs differentials for all countries (except Spain), and this relation is statistically significant for Austria, Finland, France, Germany, Ireland, Netherlands and Portugal. [15] The reverse causality also exists: when CPI is above the euro average, output gap differences tend to decrease. This relation is statistically significant for some countries: Austria, Finland, Italy

[15] For Austria, Germany and Portugal the significance is at a 10% level.

and the Netherlands. For Ireland and Spain the effect is also negative but not statistically significant. Belgium is the only country for which CPI divergence has a positive and statistically significant effect on output gap divergence. For France, Germany, Greece, Luxembourg and Portugal that effect is also positive but not statistically significant. One explanation for the non statistical significance of such effect for some countries may lay on the fact that the two effects of inflation convergence on output gap convergence described above tend to compensate each other. In sum, these results show that inflation differentials tend to have a non statistically significant effect on output gap divergence or tend to reduce it. This limits the destabilizing effects of inflation differentials.

7 Conclusion

In this paper we had two major concerns: assess convergence of inflation rates and business cycles in the euro area and study the relationship between these convergence processes.

We started by studying the convergence of inflation, real ULC, nominal ULC and output gap towards the euro average. From 1980 to 2008, inflation differentials in the euro area have converged in expectation, despite the emergence of some temporary divergence after the introduction of the euro. This transitory diverging dynamic was more significant for the Netherlands, Greece, Ireland, Portugal and Spain. For the latter four countries, it can be argued that the identified inflation divergence was one factor contributing to the 2011 sovereign debt crisis, in the sense that has weakened the countries' economic growth.

Business cycles of euro area countries have also became more aligned between 1980 and 2008, and that was clearer when using the output gap to measure them. This indicates that when studying inflation convergence, the output gap is a better indicator of the business cycle than the real ULC.

For countries where convergence of output gap and inflation was identified, convergence of inflation occurred at a faster rate than convergence of output gap. Looking at the causality between the two phenomena, an increase in output gap divergence leads to cumulative divergence in CPI for a considerable number of countries. Therefore the increase in economic and monetary integration expected to occur with the euro probably will lead to further convergence of inflation, since it will mean a further alignment of business cycles. In the opposite direction, a cumulative increase in inflation divergence tends to depress some countries business cycles. As a result, the destabilising impact of inflation divergence is more limited.

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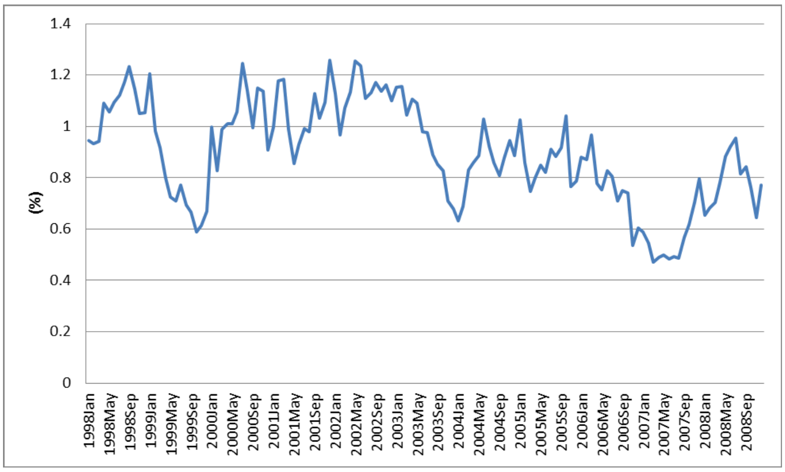

Figure 1: Cross section standard deviation of inflation rates after 1998. Note: annual inflation rates based on CPIs: $(p_t/p_{t-12} - 1) \cdot 100$. For each quarter, the standard deviation for the group of 12 countries was obtained.

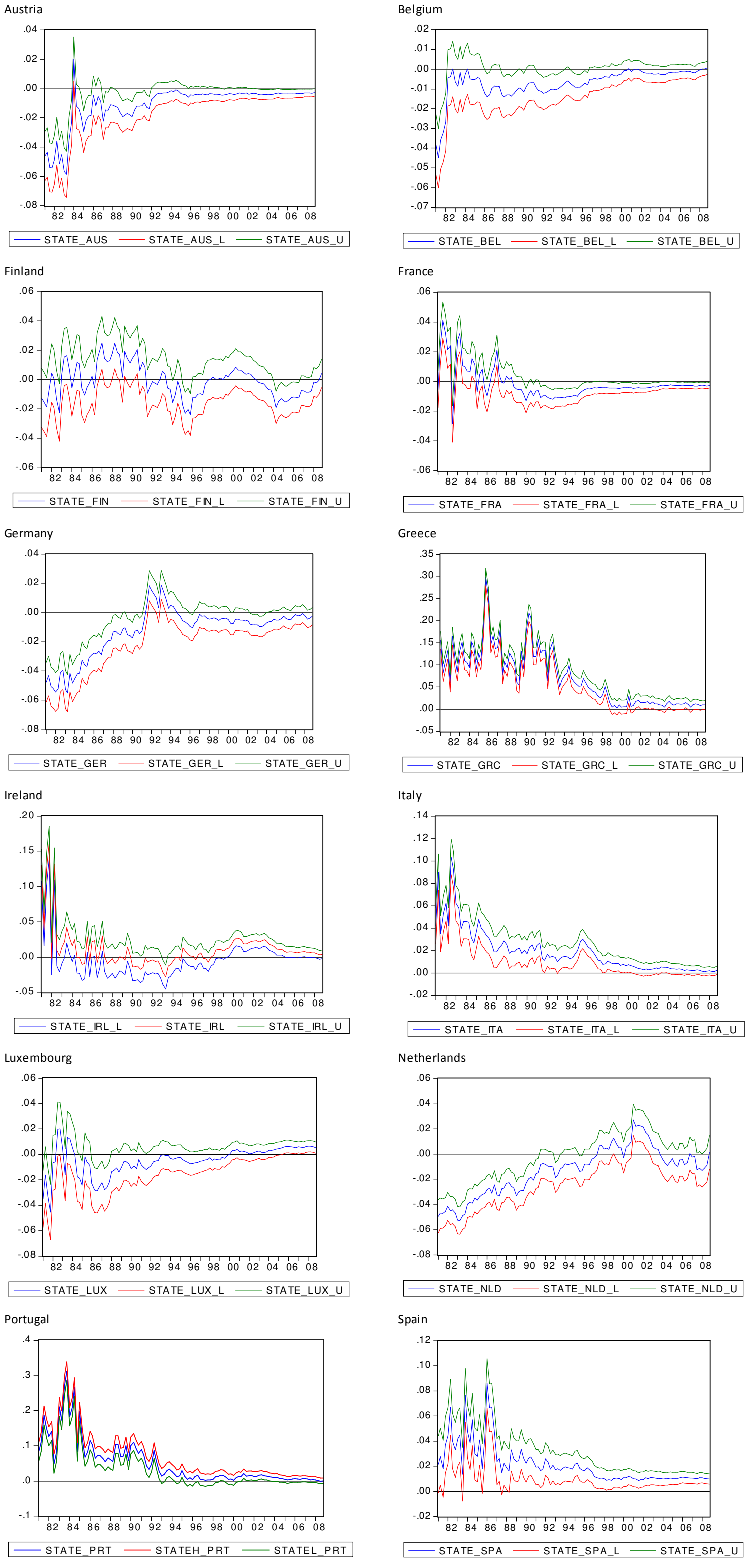

Figure 2: Inflation's differentials towards euro area, filtered state variable, 1980Q1-2008Q4. Note: "state" is the filtered state variable, and "stateh" and "statel" are, respectively, the upper and lower limit of the 95% significance interval. Countries legend: AUT - Austria, BEL - Belgium, FIN - Finland, FRA - France, GER - Germany, GRC - Greece, IRL - Ireland, ITA - Italy, LUX - Luxembourg, NLD - The Netherlands, PRT - Portugal,and SPA - Spain.

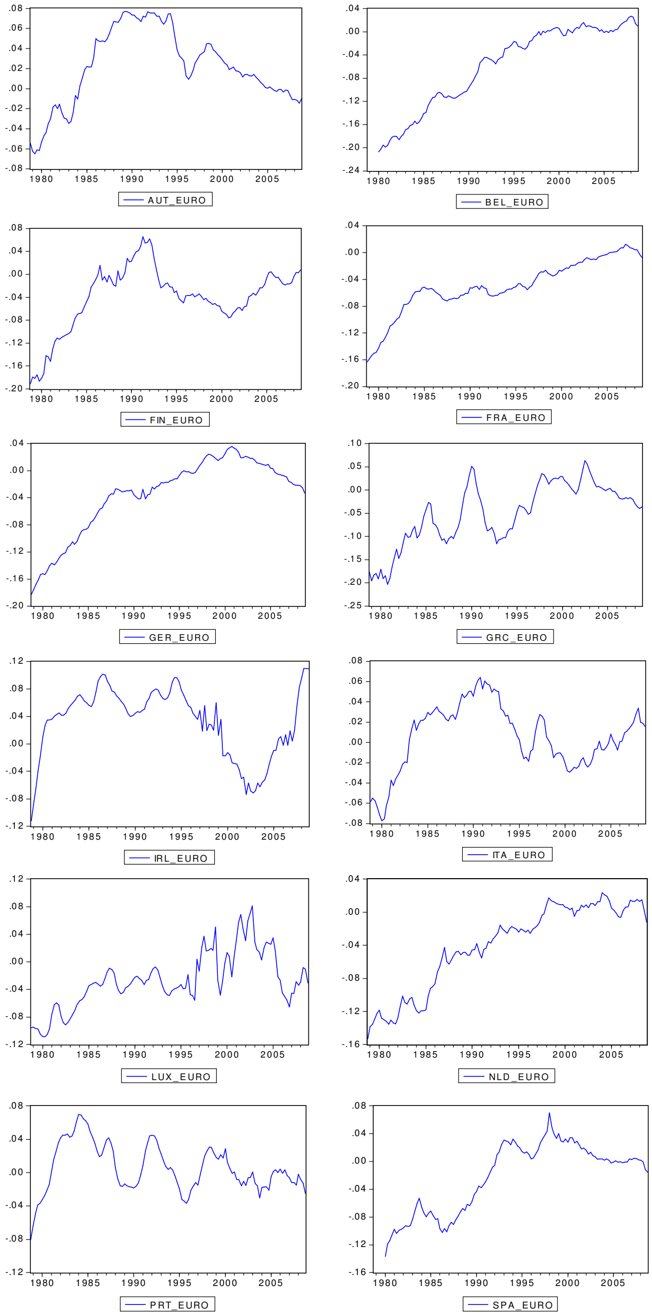

Figure 3: Log difference between the real ULC of each country and the euro area.

Table 1: Measuring inflation convergence towards euro area with time-varying parameters. Estimation with the Kalman Filter, 1980Q1-2008Q4

	Var(ε_t)	ϕ	$\phi-1$	Ω_{80Q1}	Ω_{08Q4}	$\alpha_{09Q1\|08Q4}$
Austria:						
coeff.	8E-05***	0.8900*	-0.1099	0.0008	1.31E-09	-0.0026**
s.e. /RMSE	1.13E-05	0.0392		0.0006	5.8E-09	0.0012
z stat.	7.0796	-2.8035		1.4151	0.2258	-2.0921
Log likelih.	340.23					
Belgium						
coeff.	0.0001***	0.9274**	-0.0725	9.74E-05**	1.69E-08	0.0005
s.e. /RMSE	1.2E-05	0.0193		5.74E-05	3.56E-08	0.0016
z stat.	8.3333	-3.7533		1.6968	0.4747	0.3448
Log likelih.	339.2969					
France						
coeff.	4.08E-05***	0.8858***	-0.0662	0.0012**	1.09E-09	-0.0026***
s.e. /RMSE	6.69E-06	0.0235		0.0006	2.96E-09	0.0009
z stat.	6.0986	-4.8485		2.0261	0.3682	-2.6805
Log likelih.	367.1511					
Finland						
coeff.	0.0001***	0.9634***	-0.0365	0.0002**	3.8E-06	0.0041
s.e. /RMSE	2.75E-05	0.0075		0.0001	3.08E-06	0.0051
z stat.	5.2727	-4.8358		2.2080	1.2337	0.7929
Log likelih.	300.1584					
Germany						
coeff.	7.16E-05***	0.9613	-0.0386	9.18E-05	9.9E-07	-0.0024
s.e. /RMSE	8.31E-06	0.0207		8.8E-05	1.58E-07	0.0030
z stat.	8.6161	-1.8623		1.0431	0.6265	-0.7852
Log likelih.	346.3500					
Greece						
coeff.	0.0001***	0.9388***	-0.0611	0.0141**	1E-05	0.0092
s.e. /RMSE	2.78E-05	0.0098		0.0061	8.26E-06	0.0062
z stat.	3.5971	-6.2280		2.3100	1.2106	1.4918
Log likelih.	237.7761					
Ireland						
coeff.	0.0001***	0.9204***	-0.0795	0.0058***	4.25E-07	0.0038
s.e. /RMSE	2.69E-05	0.0084		0.0014	3.96E-07	0.0032
z stat.	4.9814	-9.4265		3.9276	1.0732	1.2050
Log likelih.	275.9299					
Italy						
coeff.	7.09E-05***	0.9191***	-0.0808	0.0010***	6.33E-08	0.0024
s.e. /RMSE	1.11E-05	0.0100		0.0003	6.52E-08	0.0018
z stat.	6.3873	-8.0491		2.6096	0.9708	1.3041
Log likelih.	333.5419					
Luxembourg						
coeff.	0.0001***	0.9173***	-0.0826	0.0005	2.64E-08	0.0053**
s.e. /RMSE	2.75E-05	0.0185		0.0004	4.93E-08	0.0021
z stat.	6.0000	-4.4478		1.2321	0.5354	2.4823
Log likelih.	304.3132					
Netherlands						
coeff.	0.0001***	1.0095	0.0095	9.01E-06	2.68E-05	0.0012
s.e. /RMSE	2E-05	0.0156		1.07E-05	2.3E-05	0.0084
z stat.	5.9000	0.6084		0.8420	1.1652	0.1520
Log likelih.	321.8492					
Portugal						
coeff.	0.0001***	0.9167***	-0.0833	0.0169***	7.7E-07	0.0005
s.e. /RMSE	4.2E-05	0.0112		0.0060	8.73E-07	0.0039
z stat.	4.3333	-7.4375		2.8095	0.8820	0.1333
Log likelih.	244.1434					
Spain						
coeff.	0.0001***	0.9030**	-0.0969	0.0019	1.59E-08	0.0098***
s.e. /RMSE	2.8E-05	0.0274		0.0013	4.55E-08	0.0019
z stat.	5.0000	-3.5373		1.4433	0.3494	4.9433
Log likelih.	301.7576					

Notes: The z-statistics are for the null of each respective coefficient equal to zero, except for ϕ where the null is $\phi = 1$. *** - Reject the null at 1% significance level, ** - at 5%, and * - at 10%. The significance refers to one-sided tests, except for $\alpha_{09Q1|08Q4}$ where it refers to two-sided test. For the significance of the null hypothesis $\phi = 1$ see footnote 7. For the final one-step ahead values of the state variable, we present the corresponding RMSE

Table 2: Quarters of statistically significant divergence in inflation after the creation of the euro

Country	Average of the state variable in the diverging period	No. of quarters of divergence	Quarters of divergence
Austria	-0.3626	26	1999Q2-Q3, 2002Q1, 2003Q1-2004Q4, 2005Q2-2008Q4
Finland	-1.3792	11	2004Q1-2006Q3
France	-0.3395	39	1999Q1-2004Q3, 2005Q1-2008Q4
Germany	-0.8477	8	2002Q2-2004Q1
Greece	1.7277	11	2000Q4, 2001Q3-2002Q4, 2003Q2, 2005Q1, 2006Q3-Q4
Ireland	1.8260	25	1999Q3-2005Q1, 2006Q4-2007Q1
Italy	0.6662	7	1999Q1-1999Q3, 2000Q1-Q2, 2003Q2, 2003Q4
Luxembourg	0.5869	14	2005Q3-2008Q4
Netherlands	2.0184	8	1999Q1, 2001Q1-2002Q3
Portugal	1.5478	12	1999Q1, 2001Q1-2003Q3
Spain	1.0407	40	1999Q1-2008Q4

Note: Inflation differentials are statistically different from zero when in absolute value are larger than $2 \times RMSE$

Table 3: Testing if the variance of the convergence variable for the real ULC is zero in 2008Q4

Country	Test statistic	p-value
Austria	11.3067	0.0008
Finland	13.1068	0.0003
France	20.5439	0.0000
Greece	10.1554	0.0014

Note: Wald test with the null hypothesis $H_0 : \Omega_{2008Q4} = 0$ is performed for the countries for which it was obtained convergence in Table 4. The test statistics has a Chi-square distribution under the null.

Table 4: Measuring real ULC convergence towards euro area with time-varying parameters. Estimation with the Kalman Filter, 1980Q1-2008Q4

	coeff.	s.e.		coeff.	s.e.
Austria:			**Ireland**		
ϕ	0.9783***	0.0044	ϕ	1.0270***	0.0029
Ω_{80Q1}	7.6E-05***	2.0E-05	Ω_{80Q1}	2.87E-05***	5.53E-06
Belgium			**Italy**		
ϕ	0.9950	0.0045	ϕ	0.9943	0.0035
Ω_{80Q1}	3.2E-05***	9E-05	Ω_{80Q1}	6.12E-05***	1.37E-05
Finland			**Luxembourg**		
ϕ	0.9803***	0.0040	ϕ	1.0265***	0.0032
Ω_{80Q1}	0.00022***	5.81E-05	Ω_{80Q1}	4.6E-05***	9.73E-06
France			**Netherlands**		
ϕ	0.9875**	0.0031	ϕ	0.9935	0.0029
Ω_{80Q1}	2.4E-05***	1.2E-05	Ω_{80Q1}	5.21E-05***	1.17E-05
Germany			**Portugal**		
ϕ	0.9897*	0.0037	ϕ	0.9968	0.0052
Ω_{80Q1}	3.09E-05***	7.95E-06	Ω_{80Q1}	7.37E-05***	2.57E-05
Greece			**Spain**		
ϕ	0.9786**	0.0052	ϕ	0.9896	0.0046
Ω_{80Q1}	0.00053***	0.00019	Ω_{80Q1}	7.86E-05***	2.67E-05

Notes: The z-statistics are for the null hypothesis $\phi = 1$ or $\Omega_{80Q1} = 0$. *** - Reject the null at 1% significance level, ** - at 5%, and * - at 10%. The significance refers to one-sided tests. For the significance of the null hypothesis $\phi = 1$ see footnote 7. Initially, we assumed $Var\left(\varepsilon_t\right) \neq 0$, but this variance was not significantly different from zero. Therefore, results presented here assume $Var\left(\varepsilon_t\right) = 0$.

Table 5: Measuring nominal ULC convergence towards euro area with time-varying parameters. Estimation with the Kalman Filter, 1980Q1-2008Q4

	coeff.	s.e.		coeff.	s.e.
Austria:			**Ireland**		
ϕ	0.9905*	0.0057	ϕ	0.9979	0.0045
Ω_{80Q1}	1.18E-05***	4.13E-06	Ω_{80Q1}	1.81E-05***	5.45E-06
Belgium			**Italy**		
ϕ	0.9912**	0.0024	ϕ	0.9936***	0.0026
Ω_{80Q1}	7.28E-06***	9.84E-07	Ω_{80Q1}	2.34E-05***	3.63E-06
Finland			**Luxembourg**		
ϕ	0.9942*	0.0039	ϕ	0.9998	0.0069
Ω_{80Q1}	1.03E-06***	2.75E-06	Ω_{80Q1}	1.96E-05**	1.03E-05
France			**Netherlands**		
ϕ	1.0030	0.0037	ϕ	0.9925**	0.0039
Ω_{80Q1}	1.74E-06***	4.43E-07	Ω_{80Q1}	5.84E-06***	1.6E-06
Germany			**Portugal**		
ϕ	0.9988	0.0057	ϕ	1.0128**	0.0058
Ω_{80Q1}	2.37E-06***	8.09E-07	Ω_{80Q1}	8.05E-06***	2.08E-06
Greece			**Spain**		
ϕ	1.0058*	0.0043	ϕ	0.9897***	0.0016
Ω_{80Q1}	2.3E-05***	7.47E-06	Ω_{80Q1}	7.17E-06***	5.92E-07

Notes: The z-statistics are for the null hypothesis $\phi = 1$ or $\Omega_{80Q1} = 0$. *** - Reject the null at 1% significance level, ** - at 5%, and * - at 10%. The significance refers to one-sided tests. For the significance of the null hypothesis $\phi = 1$ we used standard critical values. Initially, we assumed $Var(\varepsilon_t) \neq 0$, but this variance was not significantly different from zero. Therefore, results presented here assume $Var(\varepsilon_t) = 0$.

Table 6: Measuring output gap convergence towards euro area with time-varying parameters. Estimation with the Kalman Filter, 1980Q1-2008Q4

	$Var(\varepsilon_t)$	ϕ	$\phi - 1$	Ω_{80Q1}
Austria:				
coeff.	2.14E-16	0.9860***	-0.0139	4.85E-05***
s.e. /RMSE	2.63E-06	0.003		1.14E-05
Belgium				
coeff.	6.28E-06***	0.9851**	-0.0148	2.54E-05***
s.e. /RMSE	2.13E-06	0.0073		9.92E-06
France				
coeff.	6.63E-08	0.9914***	-0.0085	1.88E-05***
s.e. /RMSE	1.03E-06	0.0030		5.03E-06
Finland				
coeff.	7.35E-06	0.9687***	-0.0312	0.00046***
s.e. /RMSE	5.96E-06	0.0062		0.00013
Germany				
coeff.	1.67E-15	0.9793***	-0.0206	6.7E-05***
s.e. /RMSE	1.64E-06	0.0051		1.41E-05
Greece				
coeff.	1.15E-17	0.9642***	-0.03575	0.0025***
s.e. /RMSE	5E-08	0.0033		0.0005
Ireland				
coeff.	2.46E-19	1.0220***	0.0220	2.66E-05***
s.e. /RMSE	1.70E-06	0.0029		5.93E-06
Italy				
coeff.	7.92E-07	0.9771***	-0.0228	5.37E-05***
s.e. /RMSE	1.17E-06	0.0073		1.91E-05
Luxembourg				
coeff.	6.44E-05*	0.9890**	-0.0109	0.00068***
s.e. /RMSE	4.28E-05	0.0044		0.00011
Netherlands				
coeff.	7.81E-06***	0.9630***	-0.0369	0.00031***
s.e. /RMSE	3.1E-06	0.0064		0.00010
Portugal				
coeff.	3.15E-05***	0.9762***	-0.0237	0.00018***
s.e. /RMSE	7.9E-06	0.0061		0.00007
Spain				
coeff.	1.26E-05***	0.9665**	-0.0334	5.16E-05*
s.e. /RMSE	1.87E-06	0.0143		3.24E-05

Note: The z-statistics are for the null of each respective coefficient equal to zero, except for ϕ where the null is $\phi = 1$. *** - Reject the null at 1% significance level, ** - at 5%, and * - at 10%. The significance refers to one-sided tests. Standard critical values were used for the test regarding ϕ.

Table 7: Testing the equality of the convergence processes of inflation and output gap. Estimation with the Kalman Filter, 1980Q1-2008Q4

	coeff.	s.e.		coeff.	s.e.
Austria:			**Greece**		
ϕ^z	1.1099**	0.0481	ϕ^z	1.0271***	0.0119
Ω^z_{80Q1}	0.0534***	0.0445	Ω^z_{80Q1}	0.1848***	0.1007
$(1-\phi^\pi)-(1-\phi^x)$	-0.0976		$(1-\phi^\pi)-(1-\phi^x)$	-0.025	
Belgium			**Italy**		
ϕ^z	1.0649***	0.0204	ϕ^z	1.064***	0.0126
Ω^z_{80Q1}	0.2146***	0.1515	Ω^z_{80Q1}	0.047***	0.022
$(1-\phi^\pi)-(1-\phi^x)$	-0.0619		$(1-\phi^\pi)-(1-\phi^x)$	-0.059	
Finland			**Luxembourg**		
ϕ^z	1.0031	0.0222	ϕ^z	1.077***	0.022
Ω^z_{80Q1}	1.1307	0.6312	Ω^z_{80Q1}	1.272	1.056
$(1-\phi^\pi)-(1-\phi^x)$	-0.0030		$(1-\phi^\pi)-(1-\phi^x)$	-0.071	
France			**Portugal**		
ϕ^z	1.120***	0.027	ϕ^z	1.068***	0.014
Ω^z_{80Q1}	0.013***	0.007	Ω^z_{80Q1}	0.010***	0.0053
$(1-\phi^\pi)-(1-\phi^x)$	-0.106		$(1-\phi^\pi)-(1-\phi^x)$	-0.062	
Germany			**Spain**		
ϕ^z	1.0148	0.017	ϕ^z	1.077**	0.0323
Ω^z_{80Q1}	0.812	0.687	Ω^z_{80Q1}	0.018***	0.018
$(1-\phi^\pi)-(1-\phi^x)$	-0.0143		$(1-\phi^\pi)-(1-\phi^x)$	-0.070	

Note: These coefficients result from the estimation of the unobserved component model composed by (4) and (3). To save space, only two coefficients are presented. The z-statistics are for the null of each coefficient equal to one.*** - Reject the null at 1% significance level, ** - at 5%, and * - at 10%. Significance levels are for two-sided tests and based on standard critical values.

Table 8: Causality between convergence of inflation and output gap. Estimation with the Kalman Filter, 1980Q1-2008Q4

	coeff.	s.e.	z stat.		coeff.	s.e.	z stat.
Austria:				**Ireland**			
γ_{gi}	0.0602	0.0754	0.7987	γ_{gi}	0.0467	0.0573	0.8149
γ_{ig}	0.0001	0.0001	1.3965	γ_{ig}	6.30E-05	4.59E-05	1.3724
Belgium				**Italy**			
γ_{gi}	0.1058	0.0898	1.1783	γ_{gi}	-0.0502	0.0508	-0.9883
γ_{ig}	-1.08E-05	1.03E-05	-1.0508	γ_{ig}	-9.09E-06	1.31E-05	-0.6954
Finland				**Luxembourg**			
γ_{gi}	0.2568**	0.1047	2.4514	γ_{gi}	0.0147	0.0297	0.4953
γ_{ig}	4.05E-05	4.70E-05	0.8624	γ_{ig}	9.72E-06	5.69E-05	0.1708
France				**Netherlands**			
γ_{gi}	-0.0239	0.0713	-0.3361	γ_{gi}	0.1990***	0.0736	2.7037
γ_{ig}	1.72E-05	1.42E-05	1.2087	γ_{ig}	0.0002	0.0001	1.4056
Germany				**Portugal**			
γ_{gi}	0.0889	0.0984	0.9037	γ_{gi}	0.1530*	0.0892	1.7155
γ_{ig}	2.72E-05	2.10E-05	1.2961	γ_{ig}	2.39E-05	2.79E-05	0.8552
Greece				**Spain**			
γ_{gi}	0.0477	0.0991	0.4809	γ_{gi}	0.1290	0.0867	1.4881
γ_{ig}	3.21E-05	4.72E-05	0.6807	γ_{ig}	-1.46E-05	1.74E-05	-0.8366

Note: These coefficients result from the estimation of the unobserved component model composed by (5) and (6). To save space, only two coefficients are presented. The z-statistics are for the null of each individual coefficient equal to zero. *** - Reject the null at 1% significance level, ** - at 5%, and * - at 10%. Significance levels are for two-sided tests and based on standard critical values.

Table 9: Causality between convergence of CPI and output gap. Estimation with the Kalman Filter, 1980Q1-2008Q4

	coeff.	s.e.	z stat.		coeff.	s.e.	z stat.
Austria:				**Ireland**			
γ_{gi}	0.0900*	0.0491	1.8297	γ_{gi}	0.0078***	7.71E-05	102.1373
γ_{ig}	-0.0009***	2.60E-05	-34.6175	γ_{ig}	-0.0108	0.0079	-1.3620
Belgium				**Italy**			
γ_{gi}	0.0360	0.0684	0.5261	γ_{gi}	0.0125	0.0620	0.2018
γ_{ig}	0.0009***	2.09E-06	463.4060	γ_{ig}	-0.0010***	0.0001	-6.1782
Finland				**Luxembourg**			
γ_{gi}	0.0746***	0.0206	3.6224	γ_{gi}	0.0106	0.0136	0.7825
γ_{ig}	-0.0162***	0.0007	-20.5568	γ_{ig}	0.0010	0.0489	0.0210
France				**Netherlands**			
γ_{gi}	0.0263***	0.0019	13.3666	γ_{gi}	0.1421**	0.0557	2.5480
γ_{ig}	0.0015	0.0017	0.9002	γ_{ig}	-0.0101***	0.0010	-9.8890
Germany				**Portugal**			
γ_{gi}	0.1015*	0.0581	1.7467	γ_{gi}	0.1530*	0.0892	1.7155
γ_{ig}	0.0010	0.0029	0.3539	γ_{ig}	2.39E-05	2.79E-05	0.8552
Greece				**Spain**			
γ_{gi}	0.0006	0.0473	0.0143	γ_{gi}	-0.0056	0.0680	-0.0824
γ_{ig}	2.72E-05	0.0031	0.0085	γ_{ig}	-0.0016	0.0033	-0.4852

Note: These coefficients result from the estimation of the unobserved component model composed by (5) and (6) using the difference of CPIs instead of the difference of inflation rates. To save space, only two coefficients are presented. The z-statistics are for the null of each individual coefficient equal to zero.*** - Reject the null at 1% significance level, ** - at 5%, and * - at 10%. Significance levels are for two-sided tests and based on standard critical values.