Working Paper

5/2007

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Inflation Differentials and Business Cycle Fluctuations in the European Monetary Union

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March 8, 2007

Abstract

The high degree of persistence in the national inflation differentials of the majority of EMU Member States observed since the introduction of the euro has raised serious concerns among researchers and policy-makers alike. In this paper I review the main theoretical arguments which explain their existence within a monetary union and, by means of econometric methods, analyze their dynamic behavior prior and after the introduction of the euro. Furthermore I investigate, through single-equation GMM and panel TSLS estimations, the empirical evidence for different degrees of correlation between the country-specific business cycles fluctuations and the arise of national inflation differentials with respect to the euro area average.

Keywords: Inflation differentials, convergence and stationary tests, GMM estimation, Phillips Curve.

JEL CLASSIFICATION SYSTEM: C23, C33, E31, E32

*I would like to thank Rudolf Zwiener, Peter Hohfeld, Katja Rietzler and Peter Flaschel for valuable comments and suggestions. Financial support by the Hans-Böckler Foundation is gratefully acknowledged.

1 Introduction

With the culmination of the monetary unification process by the Member States of the European Monetary Union (EMU) represented by the abolition of their national currencies and the adoption of the euro, the degree of wage and price flexibility at the national level became particularly important for the macroeconomic stability of the participating economies as well as for the EMU as a whole. Indeed, in the absence of country-specific nominal exchange rates and monetary policy conduction implied by a monetary unification, the country-specific wage and price developments are likely to gain a much more important role as macroeconomic adjustment mechanisms to internal and external imbalances through their effect on the real exchange rates and therefore on the competitiveness of the different economies. Their ability to fulfill this function, nevertheless, depends in a significant manner on their degree of persistence and therefore on their capability to react in a quick and sufficient manner to those shocks.

In this light, the high degree of persistence of most of the national inflation rate differentials of the EMU Member States observed in the years posterior to the introduction of the euro has raised serious concerns among researchers and policy makers alike: Because the differences in the national inflation rates seem not to be caused by accordant developments in the productivity in those economies, the relative competitiveness of the member countries might suffer from significant shifts in the medium run, with serious consequences for the future developments of output and employment.

The main purpose of this paper is to analyze the dynamic behavior of the national inflation rates in the euro area and the linkage between their dispersion and persistence to the country-specific business cycles prior and after the monetary unification from both the theoretical and the empirical point of view. This study is organized as follows. In section 2 I briefly overview the main theoretical explanations for the existence of inflation differentials in a common currency area, with special focus on the EMU. In section 3 the process of convergence of the national inflation rates prior to the introduction of the euro as well as their dynamic behavior after that date is analyzed by econometric convergence and stationary tests. Structural inflation adjustment equations as well as inflation differential equations for selected EMU countries are estimated and discussed in section 4, in order to find structural explanations for the observed persistent inflation differentials in the EMU. Section 5 concludes.

2 Inflation Differentials within Monetary Unions: Main Causes and Consequences

In the new macroeconomic environment resulting from a monetary unification and the related disappearance of the country-specific nominal exchange rates, other macroeconomic characteristics such as the mobility of the production factors and the degree of wage and price flexibility obtain an even more important role as macroeconomic adjustment mechanisms to asymmetric shocks at the national level.[1]

The empirical evidence concerning the mobility of the factors of production in the European Monetary Union is twofold: While the factor capital is found to have become highly mobile across the EMU members, the degree of labor mobility in the EMU has remained much lower, primarily due to the language and cultural barriers among the EMU Member States. Concerning these countries, De Grauwe and Vanhaverbeke (1993, p.124) find that , "at the national level, there is almost no labor mobility but significantly more exchange rate variability". These findings are in line with Meltzer (1986), whereafter in a monetary union as the EMU[2] more of the adjustment to asymmetric shocks will take the form of real exchange rate changes than of labor mobility.

In the absence of the country-specific nominal exchange rate channel, effective adjustments of the real exchange rate to macroeconomic internal or external imbalances at the national level can only take place through wage and price adjustments. In a monetary union with low labor mobility as the EMU, thus, "inflation differentials are [...] the product of an equilibrating adjustment process within a monetary

[1] According to the Optimum Currency Areas (OCA) theory developed after the work by Mundell (1961), McKinnon (1963) and Kenen (1969), a high mobility of the factors of production, and especially of labor, is a central pre-condition for countries to be adequate candidates for a common currency area. Only in a currency union with high interregional factor mobility, asymmetric shocks do not represent a threat for the internal stability of the former because the regional labor markets are able to absorb these shocks in a quick and efficient manner by reorganizing the distribution of the labor force within the regions. In such a case, the currency union's central monetary authorities are thus able to focus on the currency union's external balance, once the internal balance was assured by the high interregional labor mobility.

[2] Since the EMU is the focus of this study I will not stick throughout this paper to the differentiated definition of a monetary and a currency union, after which a monetary union characterizes a single market with a common currency, while a currency union does not involve the existence of a single market, i.e. it does not rule out the existence of trade barriers, tariffs, etc. between the currency union members (obviously, the trade effects in a monetary union will be higher than in a currency union), but I will use both terms interchangeably.

union and, as such, are not only unavoidable, but also desirable."[3] Now, while the full equality of the inflation rates of monetary union members is indeed an undesirable situation which would hinder the individual adjustment of the different economies to asymmetric shocks, a similar dynamic behavior of the national inflation rates is desirable due to a variety of aspects: In the first place, similar national inflation rates imply also similar real interest rates, and therefore more uniform monetary policy impulses across the monetary union. In the second place, similar inflation rates imply stable bilateral real exchange rates among the monetary union's members, and therefore also a balanced competitiveness development among them. Furthermore, similar inflation rates are likely to lead to similar inflationary expectations in the member countries, making for the central bank the control of inflation at a currency area wide level easier. On the contrary, if the national inflation rates persistently differ from each other and subsequently the national inflation differentials are upwardly or downwardly biased from the monetary union's average level, an unstable macroeconomic development of the monetary union members might occur, as it will be discussed in the next sections.

At this point it should be stressed that the entrance in a monetary union implies for the joining countries a radical regime change in their macroeconomic environment for a variety of reasons which go way beyond the loss of an independent monetary policy to react to exogenous shocks and the disappearance of the country-specific nominal exchange rates: With the entrance in a monetary union, macroeconomic patterns such as the wage bargaining processes or the inflationary expectations formation of a country valid before it joined the monetary union are likely to change after the adoption of the new common currency, in the sense of the Lucas's (1976) Critique. Additionally, due to the reduction of the nominal exchange rate risk and of the transaction costs resulting from the monetary unification, to the subsequent higher economic integration and international trade among the monetary union members as well as to the higher regional production specialization "countries that enter a currency union are likely to experience dramatically different business cycles as before."

In the following section I briefly review the main structural and cyclical factors which, at least theoretically, could explain the existence of inflation rate differentials

[3]ECB (2005, p.61). See ECB (2003) and Fritsche, Logeay, Lommatzsch, Rietzler, Stephan and Zwiener (2005) for an extensive discussion of the main causes for inflation differentials in the European Monetary Union.

(and their persistence) in a monetary union,[4] and discuss the possible consequences of the existence of persistent inflation differentials for the macroeconomic behavior of monetary union members.

2.1 Structural Factors

Tradable and Non-Tradable Goods Price Level Convergence: Due to the important process of real convergence and the high economic integration resulting from the monetary unification, many observers have interpreted the persistent inflation differentials among the EMU member countries mainly as a consequence of the Balassa-Samuelson (BS) effect[5] resulting from the catching-up process of low to high income EMU members.

In the Balassa-Samuelson framework, the production structure of the economies can be clearly differentiated between tradable and non-tradable goods, and labor is assumed to be perfectly mobile within a country across these two sectors. Under conditions of perfect competition, profit maximization in both sectors implies

$$p^{\mathrm{T}} f'_{\mathrm{T}}(L) = w = p^{\mathrm{N}} f'_{\mathrm{N}}(L) \tag{1}$$

where p^{T} and p^{N} denote the price of tradable and non-tradable goods and $f'_{\mathrm{T}}(L)$ and $f'_{\mathrm{N}}(L)$ denote the marginal product of labor in the tradable and non-tradable goods sectors. Expressing eq.(1) in growth rates delivers

$$\pi^{\mathrm{T}} + \alpha^{\mathrm{T}} = \pi^{\mathrm{N}} + \alpha^{\mathrm{N}} \tag{2}$$

where α^{T} and α^{N} denote the growth rate of labor productivity in the tradables and non-tradables production sector, respectively. Under the assumption of perfect goods market integration across the countries of a monetary union and the absence of arbitrage possibilities, the inflation rate of the tradable goods is the same across the member countries, so that

$$\pi_i^{\mathrm{T}} = \pi^{\mathrm{T}} \quad i = 1, \dots N.$$

[4] Here I do not focus on additional methodological issues concerning the composition of basket of goods of the Harmonized Consumer Price Index (HCPI) since, as discussed in Alberola (2000, p.60), the differences in the weights of the goods in the representative basket of the EMU members, while containing some information, are not fundamental for the explanation of the extent and persistence of inflation differentials in the euro area.

[5] Balassa (1964) and Samuelson (1964).

This, nevertheless, does not necessarily hold for the inflation rate of the non-tradable goods in the different economies. If the aggregate price level can be expressed as a Cobb-Douglas function of both tradable and non-tradable goods, the aggregate inflation rate in country i can be expressed as

$$\pi_i = (1-\gamma)\pi_i^{\mathrm{T}} + \gamma\pi_i^{\mathrm{N}} = \pi_i^{\mathrm{T}} + \gamma(\alpha_i^{\mathrm{T}} - \alpha_i^{\mathrm{N}}).$$

Since the production of tradable goods is usually more capital intensive and therefore gains more from technological process than the non-tradable goods production, a higher growth rate of labor productivity in the first production sector is to be expected. When labor productivity grows in the tradable goods sector, wages in that sector can rise without leading to an increase in the price tradable goods. Nevertheless, due to the assumed intersectoral labor mobility, the nominal wage in the non-tradable sector is likely to increase to the same extent, despite of the lower productivity growth in that sector. The result is an increase in the non-tradable goods prices and therefore also in the general price level.

For the inflation differentials between two countries i and j, or between country's i inflation rate π_i and the monetary union's average π_{MU}, it follows

$$\pi_i - \pi_{MU} = \gamma(\alpha_i^{\mathrm{T}} - \alpha_i^{\mathrm{N}} + \alpha_{MU}^{\mathrm{T}} - \alpha_{MU}^{\mathrm{N}}), \tag{3}$$

implying that the difference between the national and the monetary union's average inflation rates arise from the sector and country differences in productivity. According to eq.(3), the existence of inflation differentials is caused solely by different structural factors concerning the production schemes between two countries, or alternatively, by the differences between their economic development.

Despite of its apparent high explanatory power for the existence of inflation rate differentials in a monetary union, the Balassa-Samuelson model exhibits nevertheless a variety of conceptual and empirical shortcomings. At the conceptual level, in the first place, situations are possible where a catching up effect might take place with productivity growth equally high in both the tradable and non-tradable sectors. In this case the explaining content of the BS model would vanish, since the catching up effect would occur without exerting any pressure on the aggregate price levels. In the second place, the differentiation of the production structure of an economy between a tradable and a non-tradable goods sector is in the actual world almost impossible, due to the high integration of goods at all stages of the production process. In the third place, the BS model assumes constant production elasticities in both sectors, while in reality they are likely to be endogenously determined. Additionally, on empirical grounds, the econometric studies by Alberola (2000), Sinn and Reutter (2000), Ortega (2003) and Lommatzsch and Tober (2004) find that the Balassa-Samuelson effect is not able to explain the inflation differentials in the euro area due to the size and persistence of the latter, since "it appears that the actual [inflation differentials] between groups of countries have been significantly larger than what the BS model would imply."[6]

Exchange Rate Pass-Through: The extent of the exchange rate pass-through on the aggregate domestic price levels of the different countries and therefore on the inflation differentials between them depends on the degree of openness of their economies and on their production profile, i.e. on their dependence on foreign intermediate and energy goods. Obviously, the influence of external factors on the price level varies with the measure of the price level which is used: Concerning producer prices and the GDP deflator, these are affected by external effects only to the extent up to which foreign intermediate goods are used in the production of domestic final goods. If on the contrary the consumer price index (CPI) is analyzed, as done in the majority of empirical studies on inflation dispersion such as Busetti, Forni, Harvey and Venditti (2006), nominal exchange rate fluctuations affect the development of the CPI additionally through the share of foreign goods in the consumer basket. Inflation dispersion measures based on the national CPI will thus be biased by the import price dimension, since the CPI depends to a higher extent on exogenous, foreign shocks (through the role of the import prices) than the GDP deflator or the producer price index. In this regard ECB (2003, p.18) finds that "import prices tend to account for the inflation differentials of most countries with a relatively high degree of openness and/or dependency [with the Netherlands being a notably exception]".

Degree of Inflation Persistence: As discussed for example in ECB (2003), while the existence of national inflation rate differentials across the EMU Member States is inevitable and even more, desirable as an adjustment mechanism to asymmetric, country-specific shocks, a high degree of persistence of these inflation differentials above or below the monetary union's average might, through its cumulative effect, lead to significant shifts in the relative competitiveness positions of the monetary union's members. Indeed, while persistent inflation rate differentials arising from

[6] ECB (2003, p.34). See also De Grauwe (1996), Alberola and Tyrväinen (1998), De Grauwe and Skudelny (2000) and for similar findings.

corresponding differences in the productivity levels of the respective countries might not be a source of macroeconomic instability but rather an expression of the catch-up mechanism of less developed to more developed economies, persistent inflation rate differentials arising solely from the persistence in the price setting behavior by firms might represent a danger for the medium run sustainability of the currency area.

As it will be shown below, the degree of inflation persistence within the member economies is likely to explain an important share of the inflation differentials within a currency union: When nominal wages and prices are sticky and react only in a delayed and slow manner to exogenous shocks, differences in the inflation rates of the member countries of a monetary union might be of greater magnitude and longer duration as in the case where wages and prices are flexible and the degree of inflation persistence is low. As stated in ECB (2005, p.63), "since the late 1980s there has been evidence of an ongoing increase in the cyclical synchronization of euro area countries. [. . .] At the same time, inflation differentials in the euro area appear to be very persistent, in the sense that many countries have systematically maintained either a positive or a negative inflation gap against the euro area average since the introduction of the euro".[7]

2.2 Business Cycle Related Factors

Business Cycle Synchronization and Country-Specific Shocks: Besides the structural factors discussed above, a main determinant of the inflation rate of a country is its actual position within its business cycle, that is the extent of the actual excess aggregate demand: While a high excess aggregate demand is likely to lead, due to capacity constraints and the eventual price-setting power of the firms, to an increase in the growth rate of the price level, with a low excess aggregate demand the growth rate of the price level is likely to fall, due to the reluctance from side of the firms to carry the burden of storage costs in case of overproduction. In a monetary union consisting of different countries, differences between the actual position of the different economies within their respective business cycles are likely

[7]A further possible explanation for the different degree of inflation differentials persistence in the U.S. and the euro area could be delivered by the empirical findings of Flaschel and Krolzig (2006) and Proaño, Flaschel, Ernst and Semmler (2006): Thereafter the degree of wage and price flexibility to labor and goods market pressures, respectively, is higher in the U.S. than in the euro area. This could explain why, compared to the inflation rate differentials across U.S. regions, the inflation differentials in the euro area feature a much higher degree of persistence.

to explain to an important extent the existence of inflation differentials among them.

The characteristics of the national business cycles are in turn likely to be affected by the monetary unification of the participating countries to a significant extent. Nevertheless, both at the theoretical and the empirical level, there is still no consensus on whether countries within a monetary union are likely to have *more* or *less* national business cycles. On the one hand, according to Kenen (1969), Eichengreen (1990), Krugman (1993) and Krugman and Venables (1996), a higher economic integration is likely to increase the degree of regional production specialization in the monetary union countries, and therefore the disparity in the regional economic development in the presence of high interregional labor mobility and asymmetric, industry-specific shocks, reducing the correlation between their business cycles, whereas, as Frankel and Rose (1998, p.1014) state, "Increased trade results in greater specialization if most trade is inter-industry. [...] If much trade is *within* rather than between industries, these specialization effects may be small."[8] On the other hand, after Frankel and Rose (1998) and Rose and Engel (2002), more international trade is likely to result in more highly correlated business cycles. Rose and Engel (2002, p.1084) show, by regressing the pairwise correlations of detrended real GDP between the euro area countries on a variety of macroeconomic variables as well as currency union dummies, that "countries that are members of a common currency union tend to have more highly synchronized business cycles; the correlation is perhaps .1 higher on average for currency union members than for non-members. [Nevertheless,] while economically and statistically significant, the size of this effect is small in an absolute sense." The European Commision (2004, p.29), in turn, shows, by calculating the output gap correlation among EMU members, other European countries and the U.S., that "cyclical synchronization has tended to be much higher between euro-area Member States than between the euro area and other EU-countries (EU-3) or the USA."

Besides of the influence of the regular business cycles fluctuations on the inflation gaps between the different countries, the occurrence of asymmetric, country-specific shocks is also likely to affect, at least temporarily, the relative dynamic behavior of the national price levels in a monetary union, due to the increased adjustment role of respective wages and prices in the absence of the country-specific nominal exchange rate.

[8]According to Deroose, Langedijk and Roeger (2004, p.8), "depending on the definition, intra-industry trade is about twice as important within the euro area than inter-industry trade".

In both cases, the resulting dynamic behavior of wages and prices is likely to affect the country's level of economic activity through a variety of channels, being the real interest rate and the competitiveness channels the most important ones. Now, while the competitiveness channel is likely to act in a stabilizing manner (high inflation rates caused by an excessive aggregate demand lead to a real appreciation of the prices of the domestic goods and a subsequent loss of competitiveness which in turn, through a reduction of the net exports, cools down the level of economic activity), the real interest channel is likely to operate in the opposite direction: Thereafter high inflation rates caused again by an overheating economic activity lower the real interest rate, boosting furthermore aggregate investment and therefore aggregate demand.

Asymmetric Monetary Impulses: With a single monetary policy effective for all monetary union members, the existence of different national inflation rates implies different real interest rates in the respective economies and therefore also different monetary policy impulses across the monetary union members.[9] In such a macroeconomic environment, the extent up to which the participating countries are indeed affected by asymmetric, country-specific shocks, and therefore the extent up to which their business cycles are correlated – and in a more updated sense the degree of synchronization – with each other, is a key feature for the effectiveness and adequateness of monetary policy in a monetary union.[10]

Indeed, since in a monetary union with a single Central Bank a common, one-size-fits-all monetary policy oriented at the macroeconomic conditions (economic activity and price stability) of the whole monetary union, might not be sufficient to guarantee price stability and a high employment level in the individual economies. Because the national inflation rates enter only in a weighted manner in the aggregate currency area indicator, the Taylor (1993) principle – which demands the monetary policy reaction to overact against inflation to be sufficiently effective – might, at least theoretically, not be fulfilled: A relative small country in a monetary union which is relatively close in its economic structure, might persistently achieve an above average

[9] See e.g. European Commision (2004, p.32).

[10] As already discussed above and recognized by Mundell (1961), if factor (and specially labor) mobility is not high between the monetary union countries, the existence of asymmetric (country- or region-specific) shocks will complicate in a significant manner the conduction of monetary policy by the central authorities. Only if regions (or countries) are normally exposed to similar exogenous shocks and therefore share similar business cycles, the single monetary policy will bring advantages to all monetary union participants.

economic activity through higher-than-average inflation – and therefore through lower-than-average real interest rates –, due to the low weight of its national inflation rates in the monetary unions average.[11] Due to this, the relative strength of the competitiveness and the real interest rate channels is even quite important for the medium run macroeconomic performance of countries within a monetary union.

Besides the operative role of monetary policy pursuing price stability at the monetary union's level, the central monetary authorities also set a medium term nominal anchor through its influence on the expectations of the economic agents and therefore also on the wage bargaining processes which take place at the national level in the MU countries. Indeed, in the medium run, the inflationary expectations in the member countries of a monetary union will, in theory, converge to the currency area wide inflation rate targeted by the central monetary authorities, given that they possess enough credibility by the economic agents within the monetary union.[12]

3 Inflation Differentials in EMU: Convergence and Stationarity Analysis

The convergence of the national inflation rates – and therefore the reduction of the national inflation rate differentials – to a similar (and low) level was considered by the EMU architects a prerequisite for the monetary unification and a necessary condition for the future sustainability of the EMU: Indeed, one of the convergence criteria for joining the European Monetary Union established by the Maastricht Treaty 1992 was the "the achievement of a high degree of price stability; this will be apparent from rate of inflation which is close to that of, at most, the three best performing Member States in terms of price stability".[13]

[11] The asymmetrical distribution of burdens and benefits of joining a monetary union for large and small open economies was denoted by Tavlas (1994) as a "problem of inconsistency", see Mongelli (2002, p.12).

[12] An extrapolation of this line of thought would lead to the conclusion that under the assumption of increasingly synchronized national business cycles and homogeneous inflationary expectations of the economic agents across the monetary union, the dispersion of the actual price inflation rates should decrease over time, since the national inflation rate differentials would behave in a similar manner across the monetary union.

[13] The convergence criteria are established in article 121 § 1 and in protocol 21 of the Treaty on European Union (url: http://europa.eu.int/en/record/mt/top.html). The other convergence criteria established therein are

- "the sustainability of the government financial position; this will be apparent from having

In line with the Maastricht criteria of nominal convergence, during the years previous to Stage Three of EMU (the culmination of the monetary unification process with the introduction of the euro), a significant process of convergence of the national inflation rates to a similar low level (and therefore also a significant reduction in their dispersion) could be observed in all eleven candidate countries, as shown in figures 1 and 2.[14] As it can be observed in figure 1, the standard deviation of inflation rate

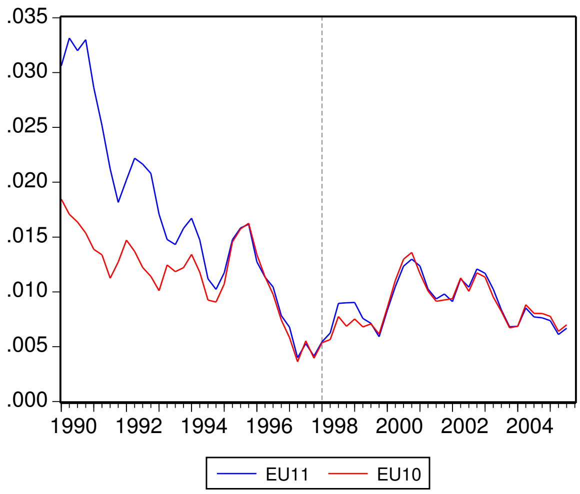

Figure 1: Inflation Differentials: Unweighted Standard Deviation of EU-12, EU-11 (EU-12 less Greece) and EU-10 (EU-11 less Portugal)

differentials among the EU-12 group fell from 0.03 in 1991 to 0.01 in 1999, at the time of the introduction of the euro. Now, while a reduction in the dispersion of the inflation differentials might reduce eventual asymmetric effects of the common one-size-fits-all monetary policy of the ECB across the EMU members as discussed in the

achieved a government budgetary position without a deficit that is excessive as determined in accordance with Article 104c(6);

- the observance of the normal fluctuation margins provided for by the Exchange Rate Mechanism of the European Monetary System, for at least two years, without devaluing against the currency of any other Member State;
- the durability of convergence achieved by the Member State and of its participation in the Exchange Rate Mechanism of the European Monetary System being reflected in the long-term interest rate levels."

[14]Throughout this analysis we will focus on the EU-11 group and will leave Greece aside due to the widely-known lack of reliability of the Greek macroeconomic data prior to its joining to EMU.

previous section, this measure does not tell much about the individual development in the respective countries, and more importantly, it does not deliver much insight in the consequences for the differentials in the national price *levels* resulting from the inflation rate differentials. Indeed, as discussed in De Grauwe (1996), the criterion of convergence of the inflation rates, as postulated by the Maastricht Treaty, might not be appropriate to ensure the future sustainability of a monetary union as the EMU, since a "convergence in yearly inflation rates can hide increasing divergences of trends in price levels, when the same countries have small but consistently higher inflation rates than other countries."[15] Not the convergence but the non-persistence of a one-sided divergence is what is determining for a balanced medium run macroeconomic development of the member countries of a monetary union as a group. As stated before, different countries may have from time to time inflation rates different from the currency union's average as a result of the national adjustment to asymmetric shocks; Nevertheless, as discussed before, when these differentials are persistently positive or negative, they might lead to ongoing shifts in the relative competitiveness position of the member countries.

Figure 2 shows the dynamic path of the national inflation differentials with respect to the EMU average for selected Member States: As it can be observed there, the national inflation rates have been persistently above or below the EMU average not only at EMU Stage II (what could be attributed to a wage and price rigidity which could have slowed down the nominal convergence process), but, more problematically, also after the official introduction of the euro (EMU Stage III) in January 1999. This pattern is also observable if the gaps between the national inflation rates and the levels determined by the Maastricht convergence criterion, that is, the average of the three lowest inflation rates of the EMU Member States, are taken into account, as shown in figure 3.

In order to provide a graphical notion of the cumulative effects of persistently above or below average inflation rates for the relative medium run competitiveness of the EMU members, we show in figure 4 the cumulated inflation and nominal unit labor costs differentials of selected EMU member countries. As it is clearly observable there, while the significant persistence of these two macroeconomic indicators also *after* the monetary unification 1999 has lead to a clear significant enhancing in the competitiveness of Germany and Austria, it has lead to the opposite result in Spain, Ireland and the Netherlands.

[15] In section 3.3 we address this issue by means of half-lives analysis of the national inflation differentials.

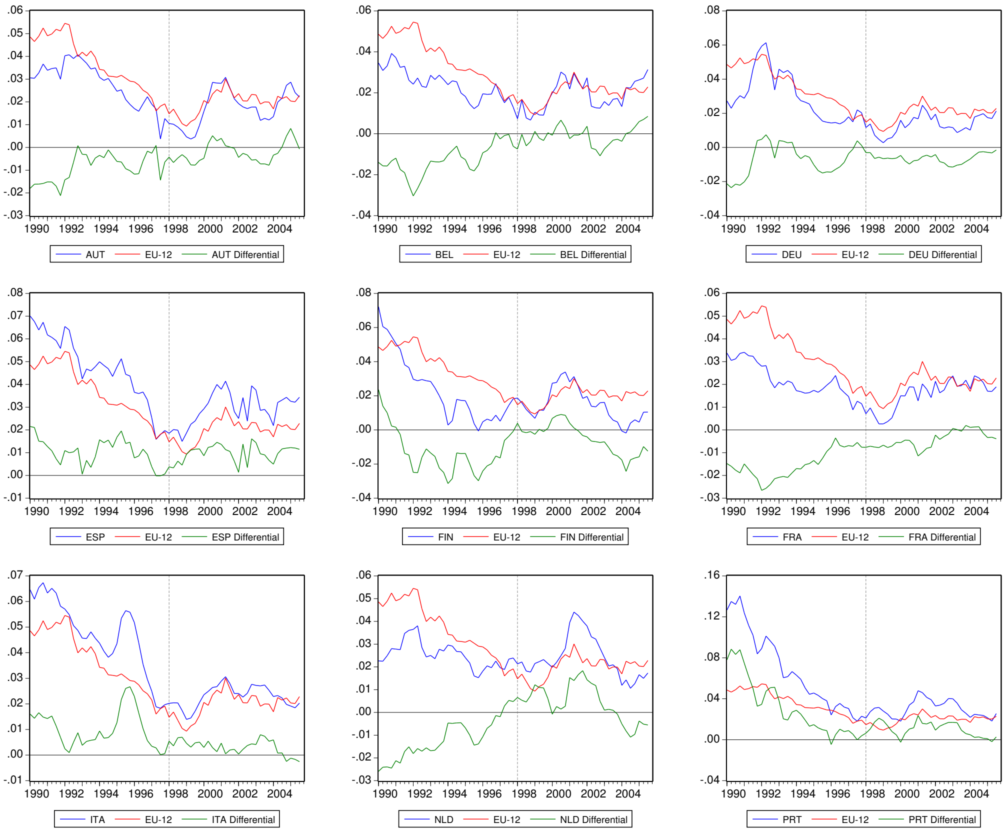

Figure 2: Inflation Differentials (to EMU Average) of selected EMU Countries

Whether this development has been caused by the drop out of punishing mechanisms for countries not fulfilling the Maastricht criteria after their joining to EMU, and the resulting "non cooperative" behavior of some EMU countries after 1999 or contrarily it has been the result of other structural problems such as a high degree of nominal rigidities, or whether it is only the reflection of the macroeconomic adjustment mechanisms acting in a monetary union, is an issue which will be approached in section 4.

In the analysis of this section, on the contrary, we investigate the possible $\beta-$convergence of the national inflation rate differentials to the EMU average.[16] In Barro and Sala-i Martin (1991) and Barro and Sala-i Martin (1992)'s terms, β convergence is present if different cross-sectional time series show a mean revert-

[16]The concepts of β- and the σ convergence date back on Barro and Sala-i Martin's (1991) analysis on cross country economic growth convergence.

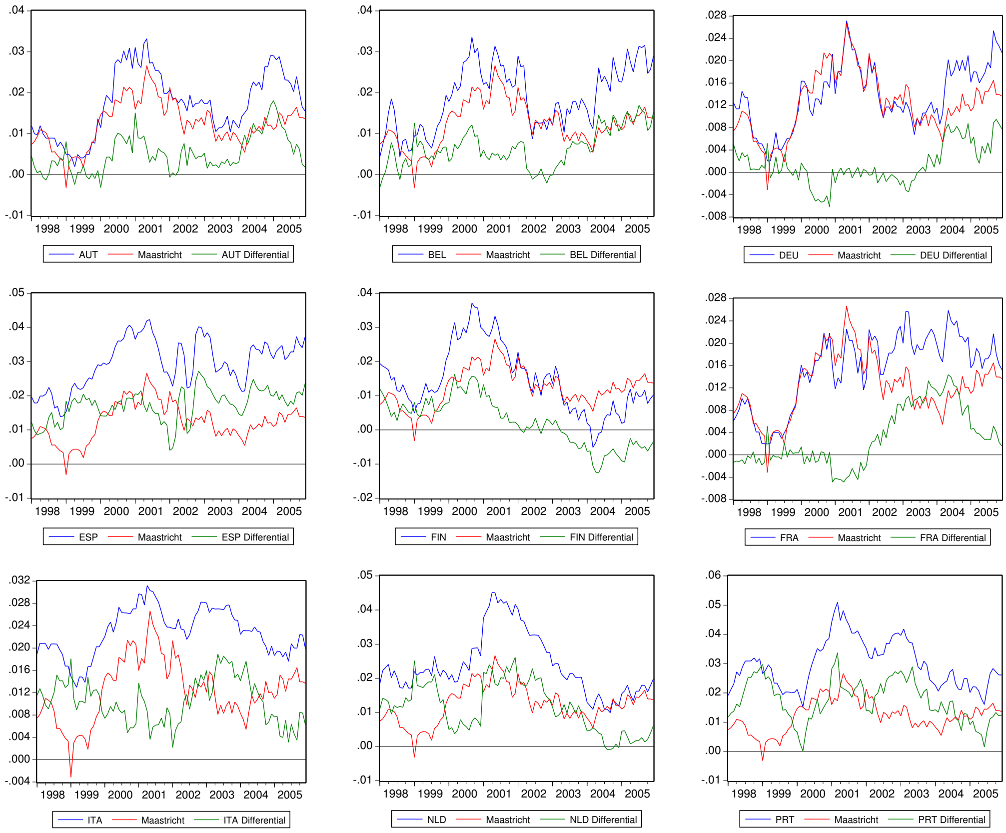

Figure 3: Inflation Differentials (to Maastricht Convergence Criterion)

ing behavior to a common level . σ convergence, the other convergence criterion, concerns on the contrary the reduction of the overall dispersion of the time series.

Following previous empirical analyses on inflation differentials as Mentz and Sebastian (2003), Beck and Weber (2005) and Busetti et al. (2006), we use unit root and stationary tests to investigate the dynamic behavior of the national CPI inflation rate diffentials (to the EMU average) prior to and after the monetary unification. Nevertheless, our approach differs from these studies in a variety of aspects: While Mentz and Sebastian (2003) employ the Johansen procedure to test for possible cointegrating relationships between the *levels* of the national inflation rates, I focus on the eventual process of convergence and stationary of the national inflation differentials to the euro area average – obviously, the presence of a cointegrating relationship between the levels of the national inflation rates, as investigated in Mentz and Sebastian (2003) would imply a stationary difference between them –. Busetti

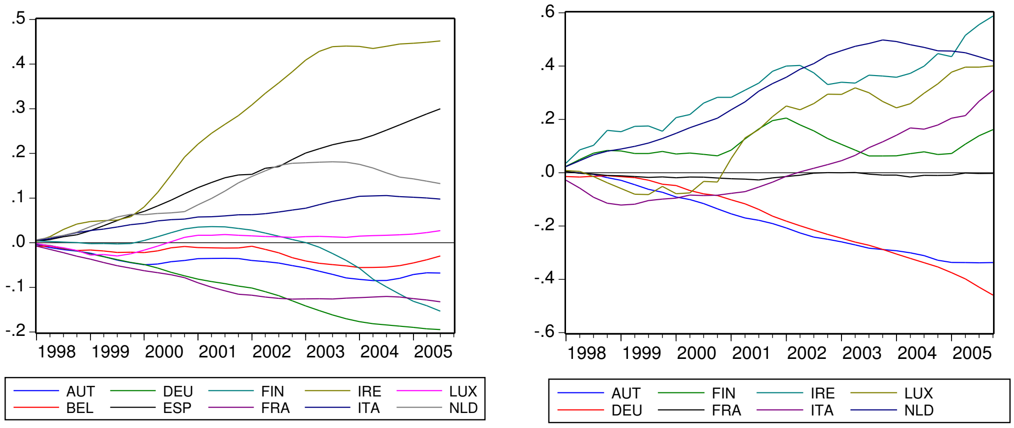

Figure 4: Cumulated Inflation and Nominal Unit Labor Costs Differentials of selected EMU countries

et al. (2006) also follow a similar strategy by performing unit root and stationarity tests on the bilateral inflation differentials of all EMU countries: Indeed, as discussed in Harvey and Carvalho (2002), while the Augmented Dickey-Fuller (ADF) or the Phillips-Perron unit root tests as are adequate to test whether two time series tend to *converge* to a similar level after being hit by an exogenous shock, stationarity tests as for example proposed in Kwiatkowsky, Phillips, Schmidt and Shin (1992), are suitable to test whether those series *have converged*, that is if they tend to remain at similar levels after a similar shock.

The strategy goes as follows: For the sub-period prior to the creation of the EMU (EMU Stage II), univariate unit root tests on the national inflation differentials are performed in order to check for statistical evidence on the convergence process. For the subperiod after the monetary unification (EMU Stage III), stationary tests on the same time series are calculated. This separate hypothesis testing on the two subperiods makes particularly sense due to the regime change discussed by Frankel and Rose (1998), whereafter the behavior of the economic agents can change so significantly due to the monetary unification that previous valid parameters are likely to lose explanatory power for the macroeconomic developments after the monetary unification.

The data set used in this section stems from the OECD Main Economic Indicators database. In order to have a representative sample size, monthly data of the national Consumer Price Indices is used (nevertheless, since monthly data is not available for Ireland, we do not include this country in our analysis).[17] The national inflation rate $\pi_{i,t}$ is measured as the annual percentage change in the CPI, the deviation of country's i national inflation rate from the euro area's aggregate inflation rate at time t is denoted $\varphi_{i,t} = \pi_{i,t} - \pi_t^{mu}$.[18]

3.1 Univariate Convergence and Stationarity Tests

The simplest univariate representation of the Data Generating Process (DGP) of the national inflation differentials is an AR(1) process

$$\varphi_{i,t} = \rho\varphi_{i,t-1} + \alpha + \delta t + \epsilon_{i,t}, \tag{4}$$

where α denotes a time-invariant drift term and t represents a linear time trend. The reformulation of eq.(4) as an AR(p) process in error-correction form which additionally incorporates lagged differences of $\varphi_{i,t}$ in order to control for eventual serial correlation, delivers

$$\Delta\varphi_{i,t} = \phi\varphi_{i,t-1} + \sum_{j=1}^{p_i} \gamma_{i,j}\Delta\varphi_{i,t-j} + \alpha^* + \delta^* t + \epsilon_{i,t}, \tag{5}$$

with $\phi = \rho - 1$, $\alpha^* = (1-\rho)\alpha$ and $\delta^* = (1-\rho)\delta$, which is the equation normally used by standard Augmented Dickey-Fuller (ADF) unit root tests.[19] Hereby the null hypothesis $H_0 : \rho = 1$ is tested against $H_1 : \rho < 1$.[20] It should be easily observable that for $\rho < 1$, a mean reverting behavior in the levels of the inflation rate differentials would be observed. The specific value of ρ, furthermore, provides some information about the speed of convergence of the analyzed time series.

An important question arises in this respect when the analysis concerns specifically inflation differentials, namely whether a constant should be included or not

[17] The use of the Harmonized Consumer Price Indices (HCPI) – available only from 1995 – would, despite of being the "more correct" variable, have reduced significantly the number of available observations and therefore also the explanatory power of the performed unit root tests.

[18] The analysis of the inflation rate *differentials* with respect to the euro area average instead of the simple *levels* controls additionally for cross-section dependence, see Beck and Weber (2005, p.7).

[19] To check for the robustness of the ADF test results, we perform also Phillips-Perron unit root tests, which correct in a different, non-parametric manner as the ADF tests for serial correlation. Those statistics are reported in the appendix of this paper.

[20] As stated before, Mentz and Sebastian (2003) follow an alternative though equivalent strategy: using the Johansen procedure, they test for cointegrating relationships between the levels (not the differentials) of national inflation rates. Obviously, in presence of cointegration between the inflation rate levels, the differentials between them would be stationary.

in eq.(5). Busetti et al. (2006) state that when testing for inflation differentials, the focus should be on absolute convergence, with the consequence that no constant should be included in the test. In our view, such specification strategy is likely to bias the test results, since a certain behavior of the time series, namely relative convergence, is a priori factored out. Especially concerning the observed persistence in the national inflation rates, the (eventual) value of the constant could also contain some information about their degree of persistence. Due to this reason we believe that a constant should be included when testing for unit root in a first stage and only be excluded from a new computation in the second stage if it is statistically insignificant under the normal distribution.

With respect to the inclusion of a deterministic linear (!) time trend in (5), it should be clear that its statistical significance in eq.(5) would imply trend-stationary for the inflation rate differential, because $\delta^* > 0$ also implies that $\rho < 0$, since $\delta^* = (1-\rho)\delta)$. A trend-stationary inflation differential of country i implies that a) from the beginning it will diverge upwards or downwards the euro area average if the national inflation rate lied close to the monetary union's average or b) after having reached the currency area average at a certain point, it would diverge (upwards or downwards) again, depending on whether at the starting point country i's inflation differential was below or above the currency area average. These two implications would speak against the inclusion of a linear time trend in the convergence tests equations. Nevertheless, due to the regime change caused by the monetary unification discussed in Frankel and Rose (1998), such outcomes might not occur, since the linear time trend might lose validity for the dynamics of the inflation rate gaps due to the possible change in the behavior of the economic agents.

Concerning the second subperiod, I use the Kwiatkowsky et al. (1992) (KPSS) test to check for the stationary of the national inflation rate gaps after the introduction of the euro. The main difference between the KPSS test and the unit root tests discussed in the previous section is the definition of the null hypothesis: While in the first mentioned tests the null is the existence of a unit root, in the KPSS under the null the analyzed time series is stationary. To test for this hypothesis, Kwiatkowsky et al. (1992) use the residuals of the OLS regression of the analyzed series y_t on the set of exogenous variables X_t,

$$\varphi_t = X_t'\delta + u_t \tag{6}$$

where X_t can consist of a constant or a constant and a deterministic time trend. Under the null of the KPSS test, y_t is assumed to be level or trend stationary.

Now, for my analysis of national inflation rate differentials, not only the eventual stationarity of the time series, but also the *level* around which these time series can be considered to be stationary is important: a stationarity around a nonzero level would imply a persistence in the inflation rate differentials, and therefore a sustained gain or loss of relative competitiveness towards the other Member States, depending whether the nonzero level is below or above zero. As it will be discussed below, such a dynamic behavior of the national inflation differentials in the EMU will be confirmed for many countries by my econometric estimation results.

Table 1: National Annual Inflation Rate Differentials (to EMU average): Univariate ADF Unit Root Tests

	Subsample: 1990:1 - 1997:12						1998:1 - 2005:12	
	No Intercept		With Intercept				No Intercept	
Country	ϕ	p-val*	ϕ	p-val*	const.	t-stat	ϕ	p-val*
AUT	-.0544	.0544	-.1333	.0788	-.0010	.0557	-.0770	.0981
BEL	-.0164	.3063	-.0545	.4977	-.0006	.2110	-.1062	.0827
DEU	-.0366	.0688	-.0387	.5327	-3.8E-5	.8977	-.0206	.3366
ESP	-.0437	.0566	-.1110	.2232	.0008	.1473	-.0050	.6062
FIN	-.0313	.1115	-.0834	.0344	-.0013	.0082	-.0218	.3336
FRA	-.0082	.3939	-.0224	.8256	-.0002	.6118	-.0266	.3046
ITA	-.0264	.1332	-.0442	.5729	.0002	.4885	-.0569	.1568
LUX	-.0233	.2326	-.0828	.4700	-.0008	.2085	-.1612	.0495
NLD	-.0256	.0778	-.0229	.7862	4.7E-5	.8985	-.0400	.1452
PRT	-.0217	.0499	-.0218	.6408	6.1E-6	.9933	-.0300	.1977

Note: * denotes MacKinnon (1996) one-sided p-values.

Table 1 contains a variety of interesting and somewhat concerning results. In the first place, concerning the univariate ADF unit root tests results,[21] we find in the first subsample from 1990:1-1997:12 a very differentiated picture of the absolute convergence process of the inflation differentials among the EMU countries. Indeed, when the ADF tests are computed without the intercept, as proposed by Busetti et al. (2006), only for Portugal, the country with the most remarkable disinflation process besides Greece, the H_1 hypothesis of absolute convergence cannot be rejected at the 5% significance level. At the 10% level, this hypothesis cannot be rejected additionally for Austria, Germany, Spain and the Netherlands, and with some tol-

[21] Alternatively, we computed Phillips-Perron unit root tests with nearly the same results. These univariate and panel Phillips-Perron tests can be found in the appendix of this paper.

erance, Italy. If not absolute, but relative or conditional convergence is tested by including an intercept in the ADF tests, we find statistically significant coefficients also for Finland. For the remaining countries, Belgium, France and Luxembourg, we find a completely different dynamic behavior of their national inflation differentials: For these economies, the null of a non-convergent dynamic behavior of the national inflation differentials cannot be rejected at standard confidence levels, even when a linear trend is included (not reported in table 1).

In order to investigate the degree of persistence in the national inflation rate differentials we compute the half-lives with the empirical estimates of $\hat{\phi} = \hat{\rho} - 1$ according to

$$\tau_i = \frac{\ln(0.5)}{\ln(\hat{\rho}_i)}.$$

Table 2 shows the speed of convergence of the inflation differentials of the EMU

Table 2: Inflation Differentials to EMU Average: Computed Half Lives

Country	AUT	BEL	DEU	ESP	FIN	FRA	ITA	LUX	NLD	PRT
					Subsample: 1990:1 - 1997:12					
τ	12.39	41.91	18.58	15.51	21.79	84.18	25.90	25.90	26.72	31.59
					Subsample: 1998:1 - 2005:12					
τ	8.65	6.173	33.30	138.2	31.44	25.71	11.83	3.94	16.97	22.75

Member States: While during the 1990s the speed of convergence of the national inflation differentials was on average nearly two years, or 24 months (hereby we do not take into account Belgium, France and Luxembourg, the countries for which the null of a non-convergent behavior could not be rejected at standard confidence levels), in the second subsample posterior to the monetary unification (EMU Stage III) the average speed of convergence of the inflation gaps in the EMU was nearly eighteen months, or one and a half years. For comparison Beck and Weber (2005) calculate half-lives for the interregional inflation rate differentials in the U.S., Canada and Japan between six months and one year. The EMU thus, compared with these economies – the other monetary union comparable in size and economic characteristics –, seems to exhibit a much higher degree of persistence in its inflation rate differentials, which could, if this behavior remains unchanged in the following years, represent a problem for the conduction of monetary policy and the balanced macroeconomic development of the EMU Member States, as discussed before.

Respecting the stationarity of the inflation gaps in subperiod posterior to the monetary unification, we find that while the null hypothesis of stationary cannot be rejected for Austria, Belgium Germany, Spain, Luxembourg and Portugal, only for Belgium and Luxembourg we find statistical support for a stationarity of their inflation differentials *around the zero level.* For all other mentioned countries, we find that the respective inflation differentials are stationary around a *nonzero* level.

Table 3: National Annual Inflation Rate Differentials (to EMU average): KPSS Stationarity Tests.

Subsample: 1998:1 - 2005:12										
Country	AUT	BEL	DEU	ESP	FIN	FRA	ITA	LUX	NLD	PRT
LM-stat	.1711	.2509	.2288	.2351	.9628†	.7103†	.4635†	.1827	.6268†	.4017
const	-.0023	-.0008	-.0061	.0097	-.0052	-.0043	.0029	.0009	.0039	.0099
t-stat	.0000	.0893	.0000	.0000	.0030	.0000	.0000	.0809	.0000	.0000

Note:† denotes rejection at the 5% level according to Kwiatkowsky et al. (1992, Tab.1).

According to the KPSS test results shown in table 3, we can categorize the EMU countries in three subgroups[22] a below-average inflation group, an above-average inflation group, and a subgroup with non-stationary inflation behavior. In the first one, consisting of Austria, Belgium and Germany, the national inflation rate differentials are stationary around a below-average level. In the second subgroup, composed of Spain, Luxembourg and Portugal, the inflation rate differentials rather fluctuate around an above-average level. In the third subgroup, consisting of Finland, France, Italy, and the Netherlands, the null of stationary inflation rate differentials around a constant level can be rejected at the 5% level: all countries in this subgroup, even Italy and the Netherlands after showing pronouncedly positive inflation rate differentials between 1998 and 2003, show increasingly negative inflation rate differentials in the past three years.

Additionally, we computed stationarity tests for the national inflation differentials *to the Maastricht criteria consistent levels*, that is, to the average inflation of the three countries with the lowest inflation rates. Indeed, since other candidates to join EMU as Bulgaria and Romania still have to fulfill the Maastricht convergence criteria, it would be interesting to investigate whether the countries already members in EMU would still fulfill such criteria.We thus redefine the national inflation differentials not relative to the EMU average, but relative to the average of the three

[22]The categorization of ECB (2003, p.7) of the EMU countries in high and low inflation countries is in line with our results.

countries with the (at each period) highest price stability.

Table 4: National Annual Inflation Rate Differentials (to Maastricht Criterion): KPSS Stationarity Tests.

Sample: 1998:1 - 2005:12										
Country	AUT	BEL	DEU	ESP	FIN	FRA	ITA	LUX	NLD	PRT
LM-stat	.4829†	.5599†	.5494†	.5884†	1.006†	.7275†	.1219	.4169†	.5046†	.2155
const	.0051	.0066	.0001	.0172	.0022	.0031	.0104	.0084	.0114	.0173
t-stat	.0000	.0000	.0000	.0000	.0030	.0000	.0000	.0000	.0000	.0000

Note:† denotes rejection at the 5% level according to Kwiatkowsky et al. (1992, Tab.1).

Table 4 shows the results of the KPSS stationarity tests: As it can be observed, for nearly all countries the null hypothesis of stationary inflation differentials around the level consistent with the Maastricht criteria can be rejected. If the EMU countries where to enter the EMU now, nearly none of them would fulfill the convergence criteria of the Maastricht Treaty.

3.2 Multiple Series Convergence and Stationarity Tests

Besides investigating the dynamic behavior of the national inflation differentials through single equation tests, we use multiple series or panel tests. As discussed in Breitung and Pesaran (2005), the panel approach has additional advantages with respect to the univariate analysis of the previous section, since it allows to extract more information from the cross sectional dimension, if the analyzed time series are expected to exhibit a similar behavior. Additionally, this procedure allows to identify convergence "clubs" or subgroups, by the statistical test of a similar autoregressive term.[23]

We use two different types of panel unit root tests for our analysis: the multivariate versions of the ADF and Phillips-Perron tests (the latter reported in the appendix) as proposed by Maddala and Wu (1999) and by Choi (2001) and the Breitung (2000) test.

The Breitung (2000) test is a two-step procedure which is based on the following

[23]See e.g. Busetti et al. (2006).

equation

$$\Delta\varphi_{i,t} = \phi\varphi_{i,t-1} + \sum_{j=1}^{p_i} \beta_{i,j}\Delta\varphi_{i,t-j} + X'_{i,t}\delta + \epsilon_{i,t} \quad \text{with} \quad i = 1, 2, \ldots N,\ t = 1, 2, \ldots, T. \tag{7}$$

where $X'_{i,t}$ contains as exogenous terms an intercept and a linear trend. As it can be observed in eq.(7), the Breitung test allows for a different cross-sectional lag order, but assumes that the autoregressive coefficient (ϕ) is cross-sectionally equal, so that the null of a unit root process

$$H_0 : \phi = \phi_i = 0,\ \forall\ i.$$

is tested against $H_1 : \phi < 0$. In the first step of the Breitung procedure, $\varphi_{i,t}$ and $\Delta\varphi_{i,t}$ are regressed on the lagged terms $\Delta\varphi_{i,t-j}$ to correct for autocorrelation.

In the second step, the (standarized) residuals $\bar{\varphi}_{i,t}$ and $\Delta\bar{\varphi}_{i,t}$ are used to calculate the standarized proxies $\tilde{\varphi}_{i,t} = \bar{\varphi}_{i,t}/s_i$, which are transformed and (eventually) detrended according to[24]

$$\begin{aligned}
\Delta\varphi^*_{i,t} &= \sqrt{\frac{T-t}{T-t+1}}\left(\Delta\tilde{\varphi}^*_{i,t} - \frac{\Delta\tilde{\varphi}^*_{i,t+1} + \ldots + \Delta\tilde{\varphi}^*_{i,t+T}}{T-t}\right) \\
\varphi^*_{i,t-1} &= \tilde{\varphi}^*_{i,t-1} - c_{i,t},
\end{aligned}$$

where

$$c_{i,t} = \begin{cases} 0 & \text{if no intercept or trend} \\ \tilde{\varphi}_{i,t} & \text{with intercept, no trend} \\ \tilde{\varphi}_{i,1} - ((t-1)/T)\tilde{\varphi}_{i,t} & \text{with intercept and trend} \end{cases}$$

The autoregressive coefficient ϕ is then estimated by

$$\Delta\varphi^*_{i,t} = \phi\varphi^*_{i,t-1} + \nu_{i,t}.$$

Breitung (2000) shows that ϕ is asymptotically normal distributed.

By means of these panel convergence tests, as also done in previous studies as Beck and Weber (2005) and Busetti et al. (2006), we can confirm the results obtained by univariate unit root tests shown in table 1: As shown by the panel ADF tests in table 5, for the subgroup consisting of Austria, Germany, Spain, the Netherlands and Portugal, the null hypothesis of a *joint* process of absolute convergence cannot be rejected for the period prior to the introduction of the euro. Our strategy to identify this subgroup was as follows: Due to the definition of the null hypothesis in

[24]See Eviews 5 (2004, p.521).

Table 5: National Annual Inflation Rate Differentials (to EMU average): Panel ADF and Breitung Unit Root Tests

Subsample: 1990:1 - 1997:12						
	M-ADF				Breitung	
Group	Fisher-χ^2	p-val*	Choi-Z	p-val*	Br. t-stat	p-val*
EU10	43.58	.0017	-3.660	.0001	.1393	.5554
NCG1: EU10-PRT	37.59	.0044	-3.309	.0005	.2779	.6095
NCG2: NCG1-AUT	31.77	.0107	-2.943	.0016	.5563	.7110
NCG3: NCG2-ESP	26.02	.0257	-2.547	.0054	.7489	.7730
NCG4: NCG3-DEU	20.67	.0554	-2.145	.0159	.8968	.8151
NCG5: NCG4-NLD	15.56	.1128	-1.715	.0431	1.0566	.8547
NCG6: NCG5-FIN	11.17	.1918	-1.308	.0953	-.4835	.3144
EUCG1={AUT,DEU,ESP,NLD,PRT}	28.02	.0018	-3.460	.0003	-.953	.1703

* Probability values assuming asymptotic Chi-Square distribution.

the panel context (where under the null *all* series in the panel possess a unit root, common or individual), we dropped stepwise from the group of EMU members we analyzed the countries for which the null of a unit root (and therefore the hypothesis of non-convergence) could be rejected at standard significance level by means of the ADF unit root (with no intercept) test results of table 1. This stepwise procedure allowed us to identify the subgroup of *non-convergent* countries, and residually, also the subgroup of *convergent* countries. Hereby we oriented at the multivariate version of the ADF tests, primarily due to comparability of results of table 3 and 5. For comparison we show also the resulting statistics from the Breitung panel unit root tests. Nevertheless, since under the null of these panel tests all series have a *common* autoregressive term ϕ, these tests impose more restriction under the null than the multivariate versions of the ADF and Phillips-Perron tests.

In sum our findings confirm the test results of the above mentioned studies concerning the convergence of the national inflation differentials prior to the monetary unification and a somewhat divergence thereafter. Especially we do not find support for a hypothesis of stationary inflation rate differentials *around a zero mean*, since as Busetti et al. (2006, p.21) state, when applying a multivariate stability test on a 11-dimensional vector of all (pairwise) inflation differentials obtain that "the null hypothesis is clearly rejected when testing without an intercept term while it cannot be rejected [...] if an intercept is included. Thus, while inflation rates within the

EMU can be considered jointly stationary over the period 1998-2004, they appear to fluctuate around different means, forming two or possibly three convergence clubs."

Keeping in mind the cumulative effects which persistently above or below average inflation rates can have on the competitiveness of domestic products in the international markets of goods and services, this findings rise serious concerns on the adequacy of the Maastricht convergence criteria prior, and the absence of them at all after the entrance of future candidates for joining EMU. As discussed before, persistently above-(below-)average inflation rate levels are likely to affect the relative level of economic activity of the monetary union's member countries through the real interest and exchange rate channel, and might represent a threat for their medium run competitiveness if they are not supported by accordant productivity growth developments.

4 Structural Analysis on Inflation Differentials and Business Cycles Fluctuations in the EMU

In this section I investigate, by means of econometric methods, the sources of inflation rate differentials in the EMU before and after the introduction of the euro. Hereby we focus on the link between the dynamics of the relative price inflation and the relative country-specific level of economic activity to the euro area average.

The methodological approach of this section resembles the one of Honohan and Lane (2003), who investigated the existence of inflation differentials in the EMU using different price indices by means of pooled OLS and GMM estimation methods. Their main empirical findings concerning the main determinants of inflation differentials in EMU can be summarized as follows:

- The coefficient of the lagged price level, a proxy for the price level convergence within EMU, enters significantly and with the right sign in all specifications.
- The rate of change of the nominal effective exchange rate (a measure for the pass-through) influences significantly the inflation gaps calculated with all used price indices.
- The fiscal surpluses are found to be insignificant in all specifications with the exception of the inflation gap based on the private consumption deflator, where the fiscal surplus is found to be only marginally significant.

- The effect the output gap is positive and statistically significant for all inflation differentials but the one calculated with the import price index.

This study nevertheless differs from Honohan and Lane (2003) in that while they used a panel approach with fixed effects to find joint effects among the EMU countries, the focus here is to determine the country specific role of the national business cycles positions, import price inflation and real marginal costs developments for the inflation differentials.

4.1 Theoretical Foundations

Concerning the empirical study of inflation and more especifically, of the inflation differentials in the EMU, the majority of existing empirical investigations such as Angeloni and Ehrmann (2004), von Hagen and Hofmann (2004) and Hofmann and Remsperger (2005) use the hybrid New Keynesian Phillips Curve as the starting point of their econometric estimations. Indeed, during the last decade, New Keynesian style models have become the standard workhorse of structural macroeconomic analysis in the majority of academic and policy-maker circles. Set in an intertemporal utility maximizing framework, the type of models discussed in Roberts (1995), Rotemberg and Woodford (1997) and Galí and Gertler (1999) explain inflation as the result of a Calvo (1983) staggered price setting by monopolistic firms which, under the assumption that wages are perfectly flexible, reset their prices in an optimal manner when they obtain the opportunity to do so. Under this theoretical setting, the resulting adjustment equation for aggregate price inflation, known as the New Keynesian Phillips Curve,[25] is expressed as

$$\pi_t = y_t + E_t[\pi_{t+1}]. \tag{8}$$

where y_t denotes the output gap and $E_t[\pi_{t+1}]$ denotes the expected inflation at $t+1$ based on the information set available at t.

The New Keynesian Phillips Curve, as discussed for example in Mankiw (2001), Estrella and Fuhrer (2002), Rudd and Whelan (2005) and Blanchard and Galí (2005) has, despite of its solid microfoundations, two main empirical shortcomings: In the first place, it implies a negative relationship between the rate of change of inflation

[25]See Walsh (2003) for an extensive discussion of the theoretical derivation of the New Keynesian Phillips Curve.

and the output gap, while the opposite holds in the majority of countries. In the second place, eq.(8) explains inflation as only dependent on the actual output gap and on the future expected inflation, with past inflation being completely irrelevant for its actual level. Aggregate macroeconomic data shows, on the contrary, a high degree of inflation persistence not only in the U.S. but in the majority of industrialized countries. In order to account for the high degree of autocorrelation observable in aggregate inflation data, Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001) have proposed a *hybrid version* New Keynesian Phillips Curve:

$$\pi_t = \upsilon_t + E_t[\pi_{t+1}] + \pi_{t-1}, \tag{9}$$

where actual inflation does not depend only on future expected, but also on past inflation and additionally not the output gap y, but υ, the log deviation of the real marginal costs from their steady state value (the actual variable derived by the theoretical New Keynesian model) is included. Galí and Gertler (1999) justify their modification concerning the past inflation influence through the assumption of "rule of thumb"-led firms which, when unallowed to reset their prices optimally, increase them according to the last inflation rate.

Apart from the empirical caveats concerning the New Keynesian Phillips Curve, its very much essence concerning its perception of reality has been questioned in a a variety of recent papers as Erceg, Henderson and Levin (2000) and Blanchard and Galí (2005). The main argument which has been put on the table is that empirical evidence suggests that not prices, but actually nominal wages should be considered as sticky. The high autocorrelation of inflation, or in other words its significant persistence, is caused primarily by the sluggishness of the nominal unit labor costs (that is, nominal wages corrected from labor productivity) and not by the sluggishness of the price level *per se*. Based on this notion, Erceg et al. (2000) and Christiano, Eichenbaum and Evans (2005) have developed, again in an intertemporal utility maximizing framework, theoretical models with both staggered wages and prices, where nominal wages, staggered also in a Calvo (1983) manner, are set in a monopolistic manner by the households.[26]

We leave nevertheless these critical considerations on the New Keynesian approach aside in the empirical analysis of this section and proceed in a rather a-

[26] Alternatively to the New Keynesians, other researchers as Fair (2000), or Chiarella, Flaschel and Franke (2005) have modelled wage and price inflation dynamics through two separate Phillips Curves, for both price and nominal wage inflation, the latter with different measures of demand pressure – the labor market on nominal wages and the goods market on prices – and more elaborated expectation schemes.

theoretical way which does not constrain our specification to a specific theoretical approach, but rather include freely different variables which are presumed to explain actual inflation by these and other different schools of economic thought. More specifically, we include besides the expected future and past inflation also the log-deviation of the real marginal costs from their long run mean υ, the growth rate of the nominal unit labor costs π^{ulc}, or in other words, the nominal wage inflation rate corrected by the growth rate of labor productivity and π^m, the import price inflation since, as discussed by Goodhart and Hofmann (2005, p.762), "omitting oil prices, commodity prices or import prices from the empirical Phillips Curve may give rise to a downwards biased estimate of the output gap coefficient, which may explain Mehra's (2004) finding that the significance of the output gap can be restored when supply shocks are included in the empirical model." Indeed, as discussed in ECB (2005, p.63-64), the main contributors to the observed inflation differentials in the euro area have been internal factors such as national unit labor costs and gross operating surpluses, and in relatively more open economies as the Netherlands and Belgium, the import prices. The below average development of the unit labor costs in Germany and France since the introduction of the euro also explain the negative inflation gap of these two countries with respect to the euro area average.

Our general specification can be thus expressed as

$$\pi_t = c + \beta_y y_{t-1} + \beta_\upsilon \upsilon_{t-1} + \kappa_f E_t[\pi_{t+1}] + \sum_{j=1}^{J} \kappa_{b,j}\, \pi_{t-j} + \kappa_m \pi_t^m + \kappa_w \pi_t^{ulc} \quad (10)$$

In the same manner, we estimate the national inflation differentials according to

$$\varphi_t = c + \beta_y \tilde{y}_{t-1} + \beta_\upsilon \tilde{\upsilon}_{t-1} + \kappa_f E_t[\varphi_{t+1}] + \sum_{j=1}^{J} \kappa_{b,j}\, \varphi_{t-j} + \kappa_m \varphi_t^m + \kappa_w \varphi_t^{ulc} \quad (11)$$

where $\tilde{}$ denotes the deviation of real variables (output gap and real unit labor costs) from the euro area average, and φ denotes the gap of price inflation, import price inflation and the growth nominal unit labor costs with respect to the euro average.

4.2 Econometric Analysis

Since our main objective is to detect the principal differences in the inflation (and inflation differential) determination between the EMU countries, we perform as first individual estimations of these two variables by means of the GMM (Generalized

Method of Moments) methodology.[27] This estimation procedure, developed on the work by Hansen (1982), is basically an instrumental variables estimation procedure, which nevertheless does not rely on any assumption concerning the distribution of the estimation residuals but instead, as a minimum distance estimator, seeks to optimize a determined objective function. The GMM estimator of β is a vector $\hat{\beta}^{\text{GMM}}$ which solves the problem[28]

$$\hat{\beta}^{\text{GMM}} \equiv \arg\min_{\beta} \left[\sum_{i=1}^{N} Z_i'(y_i - X_i\beta) \right]' \hat{W} \left[\sum_{i=1}^{N} Z_i'(y_i - X_i\beta) \right]$$

where Z is the matrix of instrumental variables, X the matrix of explanatory variables, y the vector of explained variables and $\hat{W}$ a symmetric, positive semidefinite weighting matrix which particular form is to be chosen. For the estimations discussed below, we used a weighting matrix which allows the GMM estimates to be robust against possible heteroskedasticity as well as serial correlation (of any order and form) in the error terms. The parameter values were computed through simultaneous updating of the HAC (heteroskedasticity and autocorrelation consistent) weighting matrix and the matrix of parameters, whereas the parameter convergence criterion was set to 0.001.

The use of a instrumental variables estimator as GMM is also adequate since it allows to account for eventual regressor endogeneity, in the case that some of the explaining variables are not completely exogenous. Additionally, since among the explaining variables contained in our general specification there are also expected future variables, the use of an instrument set composed solely by lagged variables allows to approximate the expected values of those forward-looking variables on the basis of the information available at time t. In order to test for the validity of the overidentifying restrictions (since we have more instrumental variables as coefficients to be estimated) we calculate the J-statistics as proposed by Hansen (1982).

We performed our single-equation GMM estimations of the inflation rate and inflation differentials adjustment equations according to eqs.(10) and (11) for Germany (DEU), France (FRA), Spain (ESP), Italy (ITA) and the Netherlands (NLD) including alternatively different measures of aggregate demand pressure on inflation in the set of explaining variables: The cyclical components of the industrial production indices and the national GDPs at constant 1995 prices calculated by the asymmetric

[27]For a comprehensive discussion of the GMM methodology see Hayashi (2000) and Wooldridge (2001).

[28]See Wooldridge (2002, p.190).

band-pass filter of Christiano and Fitzgerald (2003) and by the Hodrick-Prescott Filter, the utilization rate of capacity and the output gap according to the OECD methodology (shown in figure 5). In the set of instrumental variables we included the four lags of price inflation, the respective measure of aggregate demand, import price inflation and the nominal unit labor costs inflation.

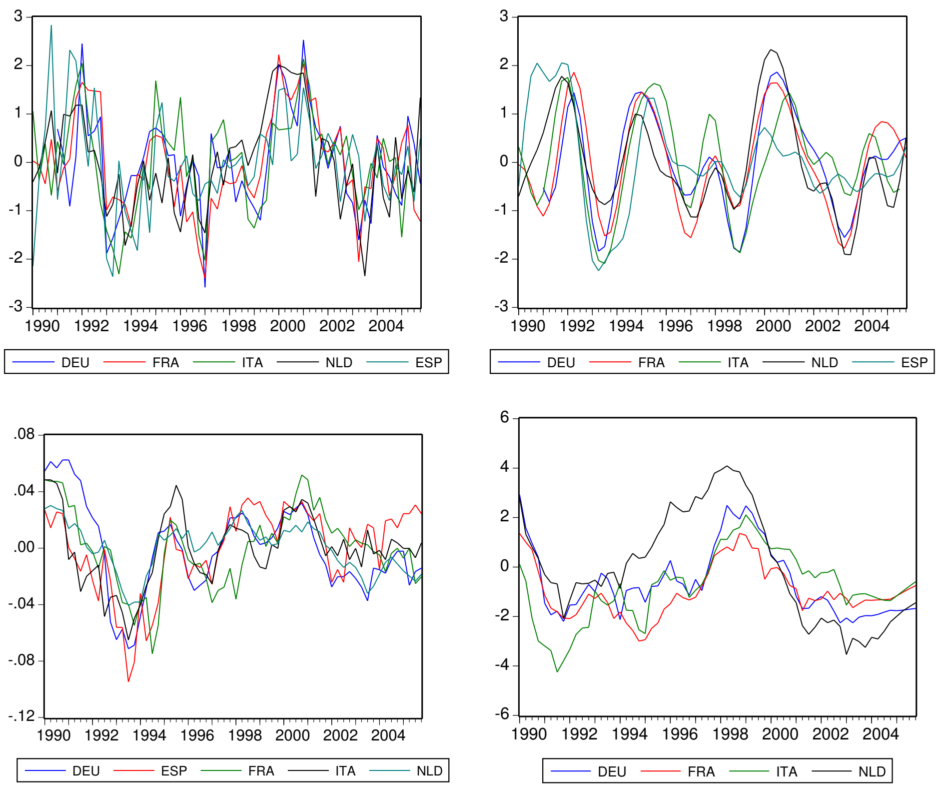

Figure 5: Measures of aggregate demand pressure: GDP at constant 1995 prices (Hodrick Prescott and asymmetric Christiano-Fitzgerald cyclical components), capacity utilization rate of the business sector and output gap (OECD series)

While the output gap series, calculated by the OECD, did not turn out to possess any explaining power for the analyzed economies, with the exception of France, the use of the cyclical components of the real GDP computed by the asymmetric Christiano-Fitzgerald methodology delivered results quite similar to the ones obtained with the more standard Hodrick Prescott filtered GDP series. Therefore we discuss here only two estimated equation for each country, obtained with the HP filtered GDPs and the capacity utilization rates as measures of the aggregate demand.

The obtained GMM parameter estimates are reported in table 6.

Table 6: Single-Equation GMM Estimation Results. Aggregate Demand Proxy: GDP at constant 1995 prices (HP Filter Cyclical Components)

Sample: 1990:1 - 2005:12											
	β_y	β_v	κ_f	$\kappa_{b,j}$	$\kappa_{b,4}$	κ_m	κ_w	const	$\bar{R}^2$	DW	J-stat
π_t^{DEU}	.0987 [.0000]	-	-	.1351 [.0000]	.7099 [.0000]	.0346 [.0000]	-	$-.0006$ [.0113]	.4383	1.955	.1567 []
φ_t^{DEU}	-	-	-	-	.8732 [.0000]	.0161 [.0000]	-	$-.0012$ [.0080]	.4172	1.420	.1642 [−]
π_t^{FRA}	.0580 [.0234]	.0353 [.0339]	-	-	.3689 [.0000]	.0313 [.0000]	-	.0028 [.0000]	.4832	1.871	.1147 [−]
φ_t^{FRA}	.2878 [.0002]	.0983 [.0000]	-	-	.5159 [.0000]	.0053 [.0000]	-	$-.0020$ [.0000]	.4488	2.079	.1716 [−]
π_t^{ITA}	.0741 [.0008]	.0106 [.0330]	.2484 [.0001]	.2281 [.0000]	.2904 [.0000]	.0037 [.0000]	-	.0017 [.0024]	.7044	2.021	.1322 [−]
φ_t^{ITA}	.4859 [.0000]	-	.3407 [.0102]	.3919 [.0001]		.0105 [.0029]	-	-	.1280	2.505	.4023 [−]
π_t^{ESP}	.0577 [.0000]	-	-	.6357 [.0000]	.3844 [.0000]	.0211 [.0000]	-	-	.4981	2.193	.1796 [−]
φ_t^{ESP}	.5121 [.0000]	-	-	.6298 [.0000]	.2916 [.0000]	.0065 [.0335]	-	-	.3876	2.199	.2021 [−]
π_t^{NLD}	.0738 [.0013]	-	.2431 [.0004]	-	.4775 [.0000]	.0090 [.0049]	.0090 [.0049]	.0565 [.0288]	.2945	2.212	.1786 [−]
φ_t^{NLD}	.5734 [.0000]	-	.3908 [.0004]	-	.2278 [.0006]	.0113 [.0000]	.0540 [.0000]	-	.3226	2.351	.1628 [−]

As it can be observed in table 6, the coefficient of aggregate demand pressure β_y — proxied in this specification by the Hodrick-Prescott filtered GDP at constant 1995 prices — enters significantly in both the inflation rate and the inflation differentials equation of all analyzed countries with exception of Germany, where it possess significant explanatory power only in the first equation. Respecting the extent of such influence on the national inflation differentials, table 6 shows that this is at largest in Italy and at lowest in France.

Concerning the coefficient of the real marginal costs, the first main determinant of aggregate price inflation in the New Keynesian Phillips Curve, in table 6 it is found to be statistically significant at standard confidence levels only in the inflation adjustment equations of France and Italy, and in the inflation differential equation of France. The second main determinant of inflation according to the New Keynesian approach, the expected future inflation, is found to possess a significant and similar explanatory power for the dynamics of the inflation and the inflation gaps of Italy and the Netherlands.

Lagged price inflation, as well as contemporaneous import price inflation, enter in a significant – and concerning the dimension of their estimated coefficients also in a quite similar – manner in the inflation adjustment equations of all five analyzed countries, and with the exception of Italy, also of all inflation rate differential equations. The sum of the coefficients of lagged inflation, often used as a persistence measure, is found to be the largest in Spain. Finally, respecting the growth rate of the nominal unit labor costs, these seem to account up to a certain degree the difference between the Dutch inflation rate and the euro area average, a result which is consistent with the empirical stylized facts discussed in ECB (2003).

Departing from these single-equation GMM estimation results, we focus now on the effect of the aggregate demand pressure on inflation before and after the introduction of the euro. Hereby we rely on the single-estimation results provided by table 6 and estimate by panel two-stage least squares (TSLS) a reduced form of eq.(10), where only lagged price inflation, contemporaneous import price inflation and the proxy for aggregate demand pressure enter as explanatory variables, not including the expected future inflation, which was found to be significant only in Italy and Spain, allows a certain consistency between our single-equation and panel estimation results.[29]

Due to the increased sample size which is obtained by a panel estimation procedure, we split our analyzed sample in a pre- and a post-euro subperiod, 1990:1-1997:4 and 1998:1-2005:4, respectively. According to the discussion of the previous section, we would expect an increased influence of the national business cycle position on the aggregate inflation after the monetary unification due to the disappearance of the country-specific nominal exchange rates. In order to increase the degrees of freedom of the panel estimation and due to the similarity of the estimated coefficients of the past CPI and present import price inflation reported in table 6, we restrict their coefficient in the panel estimation to be the same across countries and allow only β_y to be country-specific.

In both subsamples, the balanced panel contains 155 observations.[30] We present

[29] Angeloni and Ehrmann (2004), Hofmann and Remsperger (2005), Goodhart and Hofmann (2005), the first two concerning the inflation rates and not their differentials, found by fixed-effects panel estimation with euro area country data, that expected inflation enters significantly in inflation adjustment equations based on the hybrid New Keynesian Phillis Curve. Nevertheless, we would like to stress again that our estimated coefficients were obtained in a free GMM estimation without the use of constraints such as $\kappa_f + \kappa_{b,1} = 1$, as for example done in these mentioned studies.

[30] The four quarters of 1998 are included in both subsamples due to the fact that, while the euro officially was introduced at the beginning of 1998, it got into circulation among the public on January 1999.

in table 7 the estimation results for two specifications, I and II. In I we used the output gap (measured as the percent deviation of real GDP from the Hodrick-Prescott trend as in the previous section) at $t-1$, while in II the actual output gap value was used.

Table 7: Panel Two-Stage Least Squares Estimation Results. Aggregate Demand Proxy: GDP at constant 1995 prices (HP Filter Cyclical Components)

	Sample: 1990:1 - 1998:4						Sample: 1998:1 - 2005:4					
	I			II			I			II		
	coeff.	t-stat	p-val	coeff.	t-stat	p-val	coeff.	t-stat	p-val	coeff.	t-stat	p-val
const.	.0044	2.506	.0133	.0043	2.465	.0148	.0072	4.644	.0000	.0075	5.066	.0000
π_{t-1}	.1700	2.768	.0064	.1745	3.166	.0019	-	-	-	-	-	-
π_{t-4}	.5737	10.36	.0000	.5693	11.84	.0000	.5648	12.78	.0000	.5716	12.09	.0000
π_t^m	.0267	3.036	.0028	.0212	2.905	.0042	.0184	5.136	.0000	.0175	5.309	.0000
y_{t-j}^{DEU}	**.6405**	**1.919**	**.0569**	-.8628	-1.294	.1974	.1969	.9232	.3574	.1886	0.674	.5011
y_{t-j}^{ESP}	.1352	0.647	.5182	.3233	1.324	.1875	.0635	.1732	.8627	**.7126**	**1.977**	**.0499**
y_{t-j}^{FRA}	**.5101**	**2.895**	**.0044**	.1923	1.171	.2432	.1861	.6599	.5103	.1848	0.601	.5483
y_{t-j}^{ITA}	.2998	1.322	.1882	.6118	1.601	.1113	**.4377**	**2.755**	**.0066**	**.6641**	**4.565**	**.0000**
y_{t-j}^{NLD}	.2493	1.098	.2740	.1150	0.412	.6804	**.5088**	**2.224**	**.0276**	**.6048**	**2.089**	**.0384**
$\bar{R}^2$		.6063			.6095			.4158			.4218	
DW		2.055			2.130			2.063			2.073	

While the estimated coefficients of past CPI inflation and the actual import price inflation are quite stable across the four different estimations reported in table 7, a considerable variability concerning the coefficients of the country-specific aggregate demand proxies between the two specifications and also between the two analyzed subsamples can be observed in table 7. Indeed, in specification I, for the first subperiod we have positive, statistically significant and similar coefficients only for Germany and France. For the same subperiod, using not the past but the actual proxy for excessive aggregate demand (specification II), we find insignificant coefficients for all five analyzed countries at standard confidence levels.

Concerning the second subperiod, which comprises the monetary unification and the adoption of the euro, we find that the coefficient of aggregate demand turns out to be highly significant in specification I for Italy and the Netherlands, and also for Spain in specification II. Interestingly, the same coefficient for France and Germany loses significance with respect to the first subperiod.

How are these somewhat puzzling results to be interpreted? There are different possible explanations: As a first alternative, the German reunification (and the subsequent exceptional increase in the aggregate demand in Germany) might have influenced to a significant extent not only the German, but also the behavior of the price inflation rates of the other European countries, as Spain, Italy and the Netherlands during the first half of the 1990s. The monetary unification, as well as the slowdown of the German economy in recent years, might have dampened the effect of the German reunification, with the subsequent increase in the influence of the own business cycles observed in our estimations for Spain, Italy and the Netherlands in the second subperiod.

An alternative interpretation could be related with the pro-cyclicality of the fiscal deficits resulting from the present formulation of the Stability and Growth Pact (SGP). The main argument goes as follows: Due to the Stability and Growth Pact (SGP) criteria, the possibilities to conduct a counter-cyclical fiscal policy are restricted to a budgetary deficit limit of 3% of the national GDP, and a level of fiscal debt of 60% of GDP. This values, nevertheless, are no independent from the economic performance of the economy: As it is widely known, the budgetary positions are highly pro-cyclical, with increasing tax revenues (and decreasing social security expenses) in economic upswing phases and widening deficits in recessions. In pronounced recession phases, as for example in Germany since the middle 1990s, governments constraint by criteria as in the SGP, will increase indirect taxes in order to reduce their fiscal deficits, as for example is planned in Germany for 2007. Higher taxes, nevertheless, are likely to lead to general increases the aggregate price levels, contributing so to a counter-cyclical behavior of national inflation rates.

5 Concluding Remarks

In this paper I investigated the reasons for the existence and the dynamic behavior of the national inflation rates in the European Monetary Union from both the theoretical as well as from the empirical point of view. Among other things, I found statistical evidence for a persistent upward or downward bias of national inflation differentials of several EMU Member States. Taking into account that in a monetary union as the EMU the development of the national price levels is central for the homogeneity of the monetary policy impulses as well as for the international competitiveness of the monetary union member countries, the presence of inflation differentials persistently different from zero indeed raises some concerns about the future medium run macroeconomic development of the EMU members.

In order to identify the main determinants for the existence of inflation differentials in Germany, France, Italy, Spain and the Netherlands, I used a single-equation GMM methodology. The estimation results shed some interesting insights across the analyzed countries worth to be stressed: First, the effect of the relative business cycle position of the economy is statistically significant for both the inflation and inflation differentials in all countries but Germany, where this only holds for inflation. Second, the degree of persistence, measured by the coefficients of the lagged values of inflation, is significant and of similar extent in all analyzed countries for both inflation and inflation differentials estimations. Despite the fact that this result is to a significant degree only the reflection of the persistence in the *levels* of the inflation rate, the importance of lagged values, as one of the main explaining variables in the inflation rate differentials, raises some concerns with respect to the probable destabilizing effects that such a persistence might bring with in the medium run for the EMU Member States and also for the EMU as a whole.

Concerning the second main topic in our analysis, namely the role of the national business cycle positions for the respective inflation dynamics, I found a significant change of the significance of the business cycle position for the inflation determination prior and after the introduction of the euro: While its influence seems to have increased since the introduction of the euro in Italy, the Netherlands and Spain, the opposite seems to hold in Germany and France.

These results, nevertheless, are not definitive. The occurrence of extraordinary events such as the German reunification, as well as the simultaneous influence of contrarily acting effects and interplays might have weakened the accuracy of our econometric estimations. With the availability of larger data sets for the EMU Member States after the monetary unification, some of these open questions might be answered in the future.

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Appendix 1: Univariate and Panel Phillips-Perron Unit Root Tests

Table 8: National Annual Inflation Rate Differentials (to EMU average): Univariate Phillips-Perron Unit Root Tests

	Subsample: 1990:1 - 1997:12						1998:1 - 2005:12	
	No Intercept		With Intercept				No Intercept	
Country	ϕ	p-val*	ϕ	p-val*	const.	t-stat	ϕ	p-val*
AUT	-.0544	.0544	-.1333	.0705	-.0010	.0557	-.1082	.0913
BEL	-.0164	.3063	-.0545	.4976	-.0005	.2110	-.1502	.0494
DEU	-.0366	.0688	-.0387	.5251	-3.8E-5	.8977	-.0293	.3467
ESP	-.0369	.1016	-.0940	.3445	.0005	.1311	-.0182	.6087
FIN	-.0313	.1115	-.0834	.0361	-.0013	.0082	-.0218	.3387
FRA	-.0082	.3939	-.0323	.8142	-.0004	.3795	-.0372	.3134
ITA	-.0264	.1332	-.0442	.5650	.0004	.4885	-.0793	.1558
LUX	-.0228	.3209	-.1054	.3167	-.0012	.0609	-.3127	.0021
NLD	-.0256	.0778	-.0229	.7787	4.7E-5	.8985	-.0400	.1440
PRT	-.0217	.0499	-.0218	.6375	6.1E-6	.9933	-.0300	.1975

Note: * denotes MacKinnon (1996) one-sided p-values.

Table 9: National Annual Inflation Rate Differentials (to EMU average): Panel Phillips-Perron and Breitung Unit Root Tests

Subsample: 1990:1 - 1997:12						
	M-Phillips Perron				Breitung	
Group	Fisher-χ^2	p-val*	Choi-Z	p-val*	Br. t-stat	p-val*
EU10	42.10	.0027	-3.511	.0002	.1393	.5554
NCG1: EU10-PRT	36.58	.0059	-3.191	.0007	.2779	.6095
NCG2: NCG1-AUT	31.15	.0129	-2.853	.0022	.5563	.7110
NCG3: NCG2-ESP	26.30	.0237	-2.540	.0055	.7489	.7730
NCG4: NCG3-DEU	20.74	.0542	-2.116	.0172	.8968	.8151
NCG5: NCG4-NLD	15.32	.1206	-1.646	.0499	1.0566	.8547
NCG6: NCG5-FIN	10.69	.2195	-1.196c	.1158	-.4835	.3144
EUCG1={AUT,DEU,ESP,NLD,PRT}	26.77	.0028	-3.319	.0005	-.953	.1703

* Probability values assuming asymptotic Chi-Square distribution.

Appendix 2: Single-Equation GMM Estimation Results

Aggregate demand proxy: GDP at constant 1995 prices (HP cyclical components)

$$\pi_t^{\mathrm{DEU}} = \underset{[.011]}{-.0006} + \underset{[.0000]}{.0987}\, y_{t-1} + \underset{[.0000]}{.1351}\, \pi_{t-1} + \underset{[.0119]}{.0590}\, \pi_{t-2} + \underset{[.0000]}{.7099}\, \pi_{t-4} + \underset{[.0000]}{.0346}\, \pi_t^m$$

$$\bar{R}^2 = .4383 \qquad DW = 1.955 \qquad J\text{-stat} = .1567()$$

$$\varphi_t^{\mathrm{DEU}} = \underset{[.0809]}{-.0012} + \underset{[.0000]}{.8732}\, \tilde{\varphi}_{t-4} + \underset{[.0000]}{.0161}\, \varphi_t^m$$

$$\bar{R}^2 = .4172 \qquad DW = 1.420 \qquad J\text{-stat} = .1642()$$

$$\pi_t^{\mathrm{FRA}} = \underset{[.0000]}{.0028} + \underset{[.0234]}{.0580}\, y_{t-1} + \underset{[.0339]}{.0353}\, \upsilon_{t-1} + \underset{[.0000]}{.3689}\, \pi_{t-4} + \underset{[.0000]}{.0313}\, \pi_t^m$$

$$\bar{R}^2 = .4832 \qquad DW = 1.871 \qquad J\text{-stat} = .1147()$$

$$\varphi_t^{\mathrm{FRA}} = \underset{[.0000]}{-.0020} + \underset{[.0002]}{.2878}\, \tilde{y}_t + \underset{[.0000]}{.0983}\, \tilde{\upsilon}_{t-1} + \underset{[.0000]}{.5159}\, \varphi_{t-4} + \underset{[.0000]}{.0053}\, \varphi_{t-2}^m$$

$$\bar{R}^2 = .4488 \qquad DW = 2.079 \qquad J\text{-stat} = .1716()$$

$$\pi_t^{\mathrm{ITA}} = \underset{[.0024]}{.0017} + \underset{[.0008]}{.0741}\, y_t + \underset{[.0330]}{.0106}\, \upsilon_{t-1} + \underset{[.0001]}{.2484}\, \pi_{t+1} + \underset{[.0000]}{.2281}\, \pi_{t-1} + \underset{[.0000]}{.2904}\, \pi_{t-4} + \underset{[.0570]}{.0037}\, \pi_{t-1}^m$$

$$\bar{R}^2 = .7355 \qquad DW = 2.021 \qquad J\text{-stat} = .1322()$$

$$\varphi_t^{\mathrm{ITA}} = \underset{[.0139]}{.4859}\, \tilde{y}_{t-3} + \underset{[.0102]}{.3407}\, \varphi_{t+1} + \underset{[.0001]}{.3919}\, \varphi_{t-2} + \underset{[.0029]}{.0105}\, \varphi_{t-2}^m$$

$$\bar{R}^2 = .1280 \qquad DW = 2.5057 \qquad J\text{-stat} = .4023()$$

$$\pi_t^{\mathrm{ESP}} = \underset{[.0046]}{.0577}\, y_{t-1} + \underset{[.0000]}{.6357}\, \pi_{t-2} + \underset{[.0000]}{.3844}\, \pi_{t-4} + \underset{[.0000]}{.0211}\, \pi_t^m$$

$$\bar{R}^2 = .4981 \qquad DW = 2.193 \qquad J\text{-stat} = .1796()$$

$$\varphi_t^{\mathrm{ESP}} = \underset{[.0000]}{.5121}\, \tilde{y}_{t-2} + \underset{[.0000]}{.6298}\, \varphi_{t-2} + \underset{[.0000]}{.2916}\, \varphi_{t-4} + \underset{[.0335]}{.0065}\, \varphi_{t-2}^m$$

$$\bar{R}^2 = .3876 \qquad DW = 2.199 \qquad J\text{-stat} = .2021()$$

$$\pi_t^{\mathrm{NLD}} = \underset{[.0022]}{.0014} + \underset{[.0013]}{.0738}\, y_{t-1} + \underset{[.0004]}{.2431}\, \pi_{t+1} + \underset{[.0000]}{.4775}\, \pi_{t-4} + \underset{[.0049]}{.0090}\, \pi_{t-4}^m + \underset{[.0288]}{.0565}\, \pi_{t-2}^{ulc}$$

$$\bar{R}^2 = .2945 \qquad DW = 2.212 \qquad J\text{-stat} = .1786()$$

$$\varphi_t^{\mathrm{NLD}} = \underset{[.0000]}{.5734}\, \tilde{y}_{t-1} + \underset{[.0000]}{.3908}\, \varphi_{t+1} + \underset{[.0000]}{.2278}\, \varphi_{t-4} + \underset{[.0000]}{.0113}\, \varphi_{t-3}^m + \underset{[.0000]}{.0540}\, \varphi_{t-1}^{ulc}$$

$$\bar{R}^2 = .3226 \qquad DW = 2.351 \qquad J\text{-stat (p-val)} = .1628\ (.000)$$

Aggregate demand proxy: Capacity utilization rate

$$\pi_t^{\text{DEU}} = \underset{[.3206]}{-.0006} + \underset{[.0719]}{.0102}\, y_{t-4} + \underset{[.0044]}{.2223}\, \pi_{t-2} + \underset{[.0214]}{.1964}\, \pi_{t-4} + \underset{[.0000]}{.0318}\, \pi_t^m$$

$$\bar{R}^2 = .5018 \qquad DW = 1.812 \qquad J\text{-stat} = .1428$$

$$\varphi_t^{\text{DEU}} = \underset{[.5136]}{-.0004} + \underset{[.0704]}{.1467}\, \varphi_{t-2} + \underset{[.0003]}{.2731}\, \varphi_{t-4} + \underset{[.0165]}{.0094}\, \varphi_t^m$$

$$\bar{R}^2 = .4342 \qquad DW = 1.918 \qquad J\text{-stat} = .1586$$

$$\pi_t^{\text{FRA}} = \underset{[.0000]}{.0028} + \underset{[.0521]}{.0136}\, y_{t-1} + \underset{[.0111]}{.0427}\, \upsilon_{t-1} + \underset{[.0000]}{.3703}\, \pi_{t-4} + \underset{[.0000]}{.0233}\, \pi_{t-2}^m + \underset{[.1565]}{.0663}\, \pi_{t-1}^{ulc}$$

$$\bar{R}^2 = .5083 \qquad DW = 2.236 \qquad J\text{-stat} = \underset{[-]}{.1231}$$

$$\varphi_t^{\text{FRA}} = \underset{[.0024]}{-.0017} + \underset{[.0699]}{.0218}\, \tilde{y}_{t-1} + \underset{[.0098]}{.0518}\, \tilde{\upsilon}_{t-1} + \underset{[.0000]}{.6003}\, \varphi_{t-4} + \underset{[.0583]}{.0027}\, \varphi_t^m + \underset{[.0583]}{.0027}\, \varphi_t^{ulc}$$

$$\bar{R}^2 = .4741 \qquad DW = 2.137 \qquad J\text{-stat} = \underset{[-]}{.1633}$$

$$\pi_t^{\text{ITA}} = \underset{[.4167]}{-.0003} + \underset{[.0080]}{.0215}\, y_{t-1} + \underset{[.0001]}{.3033}\, \pi_{t+1} + \underset{[.0000]}{.3917}\, \pi_{t-1} + \underset{[.0000]}{.3288}\, \pi_{t-4} + \underset{[.0705]}{.0091}\, \pi_t^m$$

$$\bar{R}^2 = .8031 \qquad DW = 2.1261 \qquad J\text{-stat} = \underset{[-]}{.2081}$$

$$\varphi_t^{\text{ITA}} = \underset{[.5136]}{-.0004} + \underset{[.0000]}{.0875}\, \tilde{y}_{t-1} + \underset{[.0113]}{.1789}\, \varphi_{t-2} + \underset{[.0120]}{.1582}\, \varphi_{t-4} + \underset{[.0113]}{.0274}\, \varphi_t^m$$

$$\bar{R}^2 = .5361 \qquad DW = 1.7009 \qquad J\text{-stat} = .1267$$

$$\pi_t^{\text{ESP}} = \underset{[.0003]}{.0661}\, y_t + \underset{[.0000]}{.6132}\, \pi_{t-4} + \underset{[.0017]}{.0160}\, \pi_{t-4} + \underset{[.0017]}{.0160}\, \pi_{t-2}^m + \underset{[.0000]}{.2064}\, \pi_{t-3}^{ulc}$$

$$\bar{R}^2 = .3494 \qquad DW = 2.131 \qquad J\text{-stat} = \underset{[-]}{.1026}$$

$$\varphi_t^{\text{ESP}} = \underset{[.0000]}{-.0071} + \underset{[.0000]}{.2709}\, \tilde{y}_t + \underset{[.0003]}{.3115}\, \varphi_{t-2} + \underset{[.0000]}{.6882}\, \varphi_{t-4} + \underset{[.0057]}{.0109}\, \varphi_{t-1}^m + \underset{[.0000]}{.1602}\, \varphi_{t-2}^{ulc}$$

$$\bar{R}^2 = .3767 \qquad DW = 2.293 \qquad J\text{-stat} = \underset{[-]}{.1447}$$

$$\pi_t^{\text{NLD}} = \underset{[.0086]}{.0012} + \underset{[.0065]}{.0198}\, \upsilon_{t+1} + \underset{[.0988]}{.1866}\, \pi_{t+1} + \underset{[.0000]}{.3505}\, \pi_{t-4} + \underset{[.0085]}{.0165}\, \pi_t^m + \underset{[.0031]}{.1324}\, \pi_t^{ulc}$$

$$\bar{R}^2 = .2181 \qquad DW = 1.940 \qquad J\text{-stat} = \underset{[-]}{.1213}$$

$$\varphi_t^{\text{NLD}} = \underset{[.0019]}{-.0015} + \underset{[.0014]}{.3230}\, \varphi_{t+1} + \underset{[.0000]}{.3729}\, \varphi_{t-4} + \underset{[.0004]}{.0105}\, \varphi_4^m + \underset{[.0000]}{.1049}\, \varphi_4^{ulc}$$

$$\bar{R}^2 = .2943 \qquad DW = 2.385 \qquad J\text{-stat} = \underset{[-]}{.1252}$$

Publisher: Hans-Böckler-Stiftung, Hans-Böckler-Str. 39, 40476 Düsseldorf, Germany
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IMK Working Paper is an online publication series available at:
http://www.imk-boeckler.de

ISSN: 1861-2199

Hans Böckler Stiftung

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