# Determinants of inflation differentials in the euro area: Is the New Keynesian Phillips Curve enough?

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Abstract



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**Abstract**

In the euro area, inflation rates diverged after the creation of the single currency, and started to converge again after mid 2002. Against this background, this paper studies the determinants of inflation differentials in the euro area. We start by using the New Keynesian Phillips Curve (NKPC) to explain inflation differences for a panel of countries. It is found that expected inflation and exchange rate movements are important in causing diverging inflation dynamics, while lagged inflation and exchange rates dynamics are not. Moreover, the Incomplete Competition Model (ICM) adds explanatory power to the NKPC in describing inflation dynamics across countries. Not only the former model is not encompassed by the latter, but also the variables proposed by the ICM turn out as significant: the growth of nominal Unit Labour Cost and the long-run disequilibrium between prices and costs explain inflation differentials.

**Keywords:** Inflation, Business cycles, Convergence, New Keynesian Phillips Curve, Incomplete Competition Model

**JEL classifications:** C23, E12, E31, F41

# 1 Introduction

Since the creation of the European Exchange Rate Mechanism (ERM) in 1979, there is evidence that monetary and financial convergence in euro area has been accompanied by inflation convergence. However, some inflation divergence has emerged after the introduction of the euro (Lane, 2006; Busetti et al., 2006), as can also be observed in Figure 1. Due to the effort of nominal convergence before the creation of the euro, the cross section standard deviation of inflation rates in the euro area decreased to 0.6% in September 1999. [1] [2] Subsequently, inflation differentials increased until 1.2% in mid 2002. After these peak, inflation dispersion decreased again, and in March 2007 the lowest level ever observed of 0.47% was achieved. In euro first years (1999-2002), Greece, Ireland, the Netherlands, Portugal and Spain were the countries with highest inflation rates.

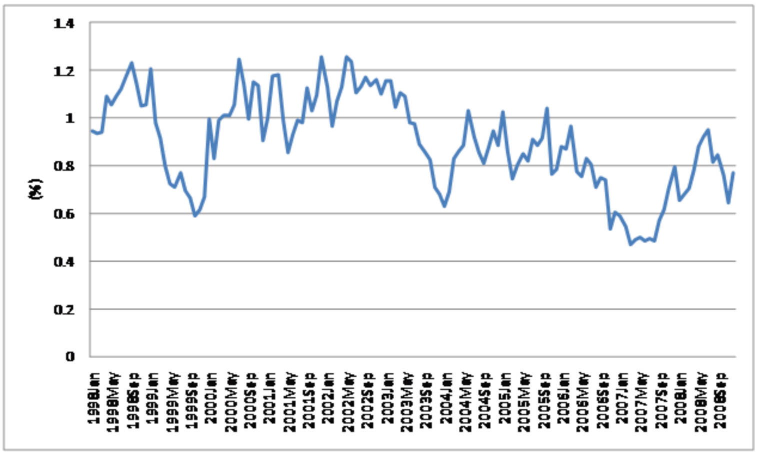


Figure 1: Cross section standard deviation of inflation rates after 1998

As highlighted by the Optimum Currency Area literature, large inflation differentials may undermine the success of a monetary union. In a monetary union, differences in inflation can be caused by temporary asymmetric shocks. For example, with short-run supply rigidities, demand shocks create transitory inflation. Without a national monetary policy, the ability to deal with these shocks is limited. Inflation differentials cannot be corrected by nominal

[1] In the empirical results of this paper, "euro area" refers only to 12 countries, the original 11 plus Greece: Austria, Belgium, Finland, France, Greece, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.

[2] Data: annual inflation rates based on CPIs: $(p_t/p_{t-12} - 1) \cdot 100$. For each quarter, the standard deviation for the group of 12 countries was obtained.

depreciation of high-inflation countries' currency. In case of deflationary shocks, countries may use expansionary fiscal policy to solve the problem. This can lead to a violation of the Stability and Growth Pact with negative effects on the euro area financial markets (Honohan and Lane, 2003).

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

Additionally, the creation of the euro may have produced inflation differentials with destabilizing macroeconomic consequences. Convergence to the euro meant a bigger decline in real interest rates in peripheral countries. This implied a faster growth of credit, house prices, aggregate demand, and therefore inflation. This one-off expansionary shock dissipated over time; namely because higher inflation led to real appreciation of currencies.

Apart from that initial impact, in a monetary union higher than average inflation rates produce lower than average real interest rates, which may lead to both excessive debt accumulation and property prices growth, with the subsequent painful adjustment process. This can then exacerbate the differences in business cycles among European countries, widening inflation differentials even more, in a cycle of divergence (Honohan and Lane, 2003; Dullien and Fritshe, 2008). Indeed, Vines et al. (2006) show in their theoretical model that when inflation is significantly persistent, countries in a monetary union maybe subject to large cycles after asymmetric shocks.

Inflation differentials are sometimes result of equilibrium mechanisms. Firstly, inflation divergence may be due to convergence on long-run relative price levels across countries. Inflation differences across countries can also replace nominal exchange rate adjustments, since countries with low levels of economic growth, inflation and wage growth gain external competitiveness (Lane, 2006).

There are also two stabilising mechanisms empirically relevant in the euro area (Hofmann and Remsperger, 2005). Firstly, GDP growth in one country has positive output spill-over effects on other countries, reducing inflation differentials. Secondly, the real exchange rate acts as a correcting mechanism: countries with higher than average inflation rates, will face a real appreciation that reduces demand and inflationary pressures.

Summing up, despite equilibrium and correcting mechanisms associated with inflation differentials, they are potentially dangerous for a monetary union. This constitutes the motivation for studying the determinants of inflation differences and the respective correcting mechanism in the euro area. Our study presents two distinctive features. Firstly, we test how inflation and exchange rate expectations affect inflation divergence. Expectations have been basically ignored despite their importance in explaining national inflation rates. Next, the New Keynesian framework is tested to see if it provides a complete description of inflation differentials, looking at the usefulness of the imperfect competition model. We are particularly concerned with the importance of both nominal Unit Labour Costs (ULC) growth and equilibrium conditions for prices on inflation dynamics. As a by-product of the analysis of convergence, we estimate the NKPC for the euro area using panel data. This is interesting, because there is little evidence on the NKPC using panel data.

Our empirical evidence shows that expectations of both inflation and exchange rates are statistically significant for inflation differences and their introduction changes the significance of other variables. Moreover, the only business cycle indicator relevant for explaining inflation divergence is labour cost growth. Also, the equilibrium conditions for prices suggested by the Incomplete Competition Model are important for explaining differences in inflation rates. Besides, the ICM model is not encompassed by the NKPC when explaining inflation differences. Lastly, our panel data evidence supports the NKPC for national inflation rates and the existence of the cost channel.

The remainder of the paper is organised as follows. In Section 2 we revise the main determinants of inflation differentials in the euro area. Section 3 estimates a model for inflation differentials using the New Keynesian Phillips Curve (NKPC). In Section 4 it is assessed if the ICM can explain better inflation differentials than the NKPC. Finally, Section 5 concludes.

## 2 Literature on the determinants of inflation differentials in the euro area

There are several possible determinants of inflation differentials in a monetary union like the euro area. Firstly, inflation differentials can be explained by differences in countries' business cycles. Such differences may emerge due to supply shocks (*e.g.* oil price) or domestic demand shocks. The latter shocks can arise due for instance to differences in fiscal policy, country-specific non-policy demand shocks (e.g. taste shocks), or asymmetric effects of common demand shocks. The latter shocks can be induced by monetary policy or exchange rate movements. In fact, the common policy interest rate may have different impacts on each country, due to differences in financial and economic structures (Hofmann and Remsperger, 2005). Also, the exchange rate's evolution can cause inflation differentials, even though countries share a common currency. That is so because differences in trade patterns may imply that national effective exchange rates respond differently to the evolution of the euro. In fact, the weight of imported consumption goods and inputs from outside the euro zone differs from country to country, as well as trading partners.

Notice that the effect of exchange rate on inflation occurs not only through aggregate demand, but also through its direct effect on import prices and inflation. A similar argument is valid for the nominal interest rate if the cost channel is relevant (Ravenna and Walsh, 2006). Interest rate affects directly inflation, due to its effect on total wage costs, and affects inflation indirectly because of its effect on output gap.

Asymmetric demand shocks may arise due to differences in consumption patterns. These differences also imply that the weight of each sub-index of goods in the HCPI differs across countries. As a result, symmetric changes in prices of goods across the monetary union, imply different inflation rates measured by the HICP. However, this effect did not play a relevant role in explaining inflation differentials in the euro area (Hofmann and Remsperger, 2005; ECB, 2003).

On the structural side, inflation differentials in a monetary union may arise due to price level convergence, which result from the convergence of both tradable and non-tradable prices (ECB, 2003; Hofmann and Remsperger, 2005). Tradable goods' prices convergence is originated by goods markets' integration, probably boosted by a single currency. In turn, real income convergence increased by the introduction of the euro, may also lead to convergence of non-tradable goods' prices, as explained by the Balassa-Samuelson effect.

Turning now to empirical models of determinants of inflation differences in the euro area, Honohan and Lane (2003) found that output gap, the change in nominal effective exchange rate (NEER) and price level convergence were significant in explaining inflation differentials in the euro area for the period 1998-2001. Looking at national inflation rates and not at inflation differentials, Hofmann and Remsperger (2005) find that real exchange rate may act as a correcting mechanism because of its direct effect on inflation. Countries with high inflation suffer a real appreciation of the currency that reduces directly inflation.

In line with Honohan and Lane (2003), Rogers (2002) conclude for the EMU-11, in the period 1997-2000, that CPI inflation differentials were fundamentally explained by the lagged price level, output gap and trade openness.[3] The price level had the expected negative coefficient and the two latter variables had positive coefficients. The lagged per capita GDP had also a negative effect on inflation differentials at a 10% level of significance. Regarding price level' significance, it was not robust enough to withstand more substantive analyses and most of inflation differences were accounted for factors other than convergence of prices.

Angeloni and Ehrmann (2006) included one more year of data than Honohan and Lane (2003) did, and taking into account data revisions, confirm that the exchange rate is a determinant of inflation differentials, but that its statistical significance is weak. In contrast, the significance of output gap and of the lagged price level increases in their estimates.

Honohan and Lane (2004) update their 2003 study with two more years of annual data, obtaining a sample covering the period 1999-2003. But they are not able to obtain their previous result of the significance of the change in NEER to explain CPI inflation differentials. However, output gap remains significant. It seems then that NEER is mainly affecting inflation through output gap. To make things even more complex, when using quarterly data for 1999Q1-2004Q1, they conclude that the *level* of NEER explains CPI inflation differentials, but that output gap does not explain. In the former variable's case, it is argued that in a monetary union national inflation rates act to correct misalignments in exchange rates: when

[3] It can be argued that the relevance of trade openness is associated with the exchange rate.

the euro is under-valued, the increase in inflation acts as a correction mechanism, reducing external competitiveness, especially for countries more exposed to extra-euro trade.

From the above discussion, it is clear that literature does not agree on the significance of output gap and NEER in explaining differences in inflation in the euro area. In order to contribute to the clarification of the relation between inflation and the business cycle, we will use real ULC in alternative to output gap. This variable is suggested by the New Keynesian literature as the correct driver of inflation. This literature also stresses that inflation is forward-looking, and there is a secondary role for lagged inflation. To assess the importance of lagged inflation is rather relevant because if inflation is sufficiently persistent, temporary demand and supply asymmetric shocks may cause persistent inflation differentials (Hofmann and Remsperger, 2005). Besides its contemporaneous value, we also use forward and lagged values of exchange rate to clarify the role of this variable on inflation differentials. The consideration of those last variables occurs because domestic prices may have a forward and backward component. The nominal interest rate may also play a direct role in inflation divergence if the cost channel is relevant.

Finally, fiscal deficits and real interest rate may also have contributed to inflation differentials, but probably their effect occurred essentially through the output gap. Along this line, Honohan and Lane (2003) found that, after controlling for output gap, fiscal positions did not have a statistically significant effect on inflation divergence in the euro area between 1999 and 2001.

## 3 Inflation differentials and the NKPC

In order to highlight the difference between factors influencing inflation and influencing inflation differentials, we start by explaining national inflation rates and then analyse inflation differentials. Then, the open economy NKPC is

$$\begin{aligned}\pi_{i,t} &= \gamma_f E_t \pi_{i,t+1} + \gamma_b \pi_{i,t-1} + \gamma_{mc} \widehat{mc}_{i,t} \\ &\quad + \gamma_e \Delta e_{i,t} + \gamma_{ef} E_t \Delta e_{i,t+1} + \gamma_{eb} \Delta e_{i,t-1}\end{aligned}$$

where $\pi_{i,t} = p_{i,t} - p_{i,t-1}$ is CPI inflation in $t$, $p_{i,t}$ the log of CPI, $\widehat{mc}_{i,t}$ is the marginal cost in percentage deviation from the steady-state, $mc_{i,t} - mc^{ss}$ (with both marginal costs defined in logs), and $\Delta e_{i,t}$ is the change in the log of the *nominal* effective exchange rate. The marginal cost is $mc_{i,t} = i_{i,t} + s_{i,t} - \log(\alpha_n)$, where $i_{i,t}$ is the log of the nominal interest rate of country $i$, $s_{i,t}$ the log of labour income share (or real marginal cost), and $\alpha_n$ is the labour share in the Cobb-Douglas production function.

Expectations of inflation affect current inflation because agents are forward-looking and prices are rigid. In addition, previous studies have shown (for example, Gali and Gertler, 1999; Gali et al., 2001) that a proportion of agents have backward-looking expectations, justifying the introduction of lagged inflation. The effect of business cycle in inflation is captured by labour share, which takes into account wages ($w_t$) and labour productivity ($pr_t$): $s_t = ulc_t - pd_t = w_t - pr_t - pd_t$. This Phillips Curve includes also open-economy variables in the spirit of Batini, Jackson and Nickell (2005), with the change in the nominal exchange rate translating the impact of import prices on CPI inflation. We expect that an appreciation of the euro, *i.e.*, an increase in $\Delta e_{i,t}$, has a negative impact on inflation ($\gamma_e < 0$). The expected and lagged values of exchange rate's change are introduced due to the assumption that expected and lagged domestic inflation affect present domestic inflation (Kara and Nelson, 2003). The lag and lead exchange rates coefficients are expected to be positive ($\gamma_{ef}$ and $\gamma_{eb} > 0$). Finally, the variable $i_{i,t}$ is present because it is assumed that the cost channel is present.

If marginal cost is not expressed in deviations from the steady-state, the last Phillips curve can be written as:

$$\begin{aligned} \pi_{i,t} \quad = \quad & \alpha + \gamma_f E_t \pi_{i,t+1} + \gamma_b \pi_{i,t-1} + \gamma_s s_{i,t} + \gamma_{in} i_{i,t} \\ & + \gamma_e \Delta e_{i,t} + \gamma_{ef} E_t \Delta e_{i,t+1} + \gamma_{eb} \Delta e_{i,t-1} + u_{i,t} \end{aligned} \tag{1}$$

with $\alpha = -\gamma_{mc} \left[ mc^{ss} + \log(\alpha_n) \right]$. Then, the constant includes the *common* steady-state marginal cost. It is also possible to define the Phillips curve using output gap, $x_{i,t}$, to measure the impact of business cycle on inflation. [4]

When estimating equation (1), data poolability was assumed, *i.e.*, that equation's coeffi-

[4]Rotemberg and Woodford (1997) conclude for $\widehat{mc}_{i,t} = x_{i,t}$ using sticky prices, complete nominal wages flexibility and absence of variable capital.

cients are the same for all countries. As highlighted by Bjornstad and Nymoen (2008), this assumption has the advantage of bringing efficiency gains. In the euro area, the assumption of poolability makes sense as countries in that area are relatively homogeneous, because they have been converging in nominal and real terms and share similar monetary and fiscal policy frameworks. The use of panel data with the poolability assumption is also sensible because inflation convergence is an aggregate phenomenon, involving simultaneously the dynamic evolution of a group of countries. In addition, with a panel there is no need to measure common factors explicitly (task that always involves some aggregation problems), since they can be captured by time dummies.

Turning now to the empirical explanation of inflation differentials, if equation (1) is valid for each country, it is also valid for the euro area as a whole. As a result, inflation differentials can be expressed as:

$$\begin{aligned} \pi_{i,t} &= \phi_t + \gamma_p pl_{i,t-1} + \gamma_f E_t \pi_{i,t+1} + \gamma_b \pi_{i,t-1} + \gamma_s s_{i,t} + \gamma_{in} i_{i,t} \\ & \gamma_s \Delta e_{i,t} + \gamma_{sf} E_t \Delta e_{i,t+1} + \gamma_{sb} \Delta e_{i,t-1} + u_{i,t} \end{aligned} \tag{2}$$

where time dummies, $\phi_t$, are a linear combination of euro area variables. Here,the price level $pl_{i,t-1}$ is introduced to capture the price convergence effect (Honohan and Lane, 2003). It is expected that countries with higher price levels experience lower inflation ($\gamma_p < 0$).

The model was estimated using a panel of 12 euro area countries; the original 11 founders and Greece. The panel comprises the period 1998Q1-2008Q4 and is unbalanced only when loans interest rate or the price of imports are used.[5] The estimation was done using Panel GMM because some variables are simultaneously determined (for example output gap and inflation); and also due to the presence of expectations. In order to estimate equation (1), expectations are replaced by observed values under the assumption of rational expectations. This assumption implies that agents' forecast errors are not correlated with information available at the time expectations are formed. As a result, we can obtain orthogonality conditions to apply GMM.

It is worth mentioning that we do not introduce country fixed effects for two reasons.

[5] Before 2003Q1 there were no data available on the interest rate for Luxembourg and before 2000Q1 there were no data available on imports price for Ireland (see data description in Section 7).

On one hand, inflation's expectations can accommodate differences in inflation rates that remain constant for the entire sample, without it being necessary to include a constant for such a purpose. On the other hand, introducing fixed effects with a lagged dependent variable produces bias in results.

The model can be expressed in a condensed way as

$$y_{it} = \mathbf{x}_{it}^{'}\boldsymbol{\beta} + u_{it},$$

with $\mathbf{x}_{it}^{'}(1 \times k) = \left[pl_{i,t-1}\ \pi_{i,t+1}\ \pi_{i,t-1}\ x_{i,t}\ i_{i,t}\ \Delta e_{i,t}\ \Delta e_{i,t+1}\ \Delta e_{i,t-1}\right]$ and $\boldsymbol{\beta}(k \times 1)$. As usual, it is assumed that observations are independent over $i$.

Staking the $T$ observations for the $i$th individual, we simplify the notation to

$$\mathbf{y}_i = \mathbf{X}_i\boldsymbol{\beta} + \mathbf{u}_i$$

where $\mathbf{y}_i$ and $\mathbf{u}_i$ are $T \times 1$ vectors and $\mathbf{X}_i$ is a $T \times k$ matrix.

Now, we assume that there is a matrix of instruments, $\mathbf{Z}_i$ $(T \times r)$, with $r > k$ , which satisfies $r$ moment conditions for each individual $i$:

$$E\left(\mathbf{Z}_i^{'}\mathbf{u}_i\right) = \mathbf{0}.$$

The GMM estimator looks to satisfy as close as possible these $r$ moment conditions, by minimising the quadratic form

$$J_N(\boldsymbol{\beta}) = \mathbf{g}(\boldsymbol{\beta})^{'}\mathbf{W}_N\mathbf{g}(\boldsymbol{\beta}) \tag{3}$$

with $\mathbf{g}(\boldsymbol{\beta}) = \sum_{i=1}^{N}\mathbf{Z}_i^{'}\mathbf{u}_i$ as the sample moment condition $(r \times 1)$ and $\mathbf{W}_N$ as the $r \times r$ weighting matrix.

We use the two step GMM with $\mathbf{W}_N = \widehat{\mathbf{S}}^{-1}$, where the matrix $r \times r$

$$\widehat{\mathbf{S}} = \frac{1}{N}\sum_{i=1}^{N}\mathbf{Z}_i^{'}\widehat{\mathbf{u}}_i\widehat{\mathbf{u}}_i^{'}\mathbf{Z}_i \tag{4}$$

is a consistent estimator for $\mathbf{S}$, the moment conditions' variance. With the sum being performed over individuals, the weighting matrix and standard deviations are robust to arbitrary serial correlation and time-varying variances of the errors (White period method). [6] The errors $\widehat{\mathbf{u}}_i$ are obtained in a first step with a consistent estimator for $\boldsymbol{\beta}$.

In GMM estimations the choice of good instruments is an important task. The convention in the literature is to use at least past information on the endogenous and forcing variables (Binder and Pesaran, 1995). In our case, we have to take into account that endogeneity is a potential problem for several variables. For example $\pi_{i,t+1}$, $x_{i,t}$, $\Delta e_{i,t+1}$ and $\Delta e_{i,t}$ can be seen as endogenous explanatory variables. Consequently, only lags of those variables can be used as instruments. A further reason for such a procedure is that information for period $t$ may not yet be available when agents form expectations. Therefore, we used as instruments two lags of inflation rate, a dummy variable, one lag of the change in exchange rate, output gap, interest rate and price level.[7] We added some additional instruments that proved to have a strong explanatory power in the first stage regression: CPI lagged two periods, one lag of the change in import prices and real exchange rate. [8]

One point worth testing when choosing instruments is their weakness, since weak instruments are common in forward-looking models with rational expectations (Mavroeidis, 2004). We performed such a test using the first stage regression of $t+1$ inflation on the instruments. Then, we retained the F-statistic of the joint significance of instruments. The same was done for the exchange rate in $t+1$. The rule of thumb is that if the F-statistic is larger than 10, the existence of weak instruments can be ruled out (Stock et al., 2002). In the regressions of Table 1, this rule of thumb is fulfilled for both exchange rate and inflation rate.

Since the models estimated here are overidentified (number of instruments $>$ number of regressors), the correlation between the error and instruments can be tested with the J-test. Applying this test in all of the following regressions indicates that instruments are not correlated with the error.

Before applying GMM as described above, it is necessary to transform equation (2) to

[6] The White estimator for $\widehat{\mathbf{S}}$ is based on the Panel Corrected Standard Error methodology (Beck and Katz, 1995; Eviews, 2007), where residuals are replaced by moment estimators of the unconditional variance.

[7] The dummy variable was introduced to accommodate the fact that retail interest rates were not harmonised before 2003Q1 (see Section 7).

[8] There are some small changes in instruments depending on the exact specification of the estimated equation. See notes to Table 1.

eliminate time dummies. That consists simply in subtracting the average of the model over individuals from the original model (Baltagi, 2008).

Next, estimation results are analyzed. Table 1, eq. (1), shows that we can replicate the traditional features of the Phillips curve. Coefficients of both lead and lag inflation are statistically different from zero, and their sum is less but not statistically different from one. Also, the forward component of inflation is larger than the backward component. Output gap has a positive but statistically insignificant effect on inflation. The cost channel is present, with the nominal interest rate having a positive and significant effect on inflation. [9] Lagoa (2010) suggests that the correct identification of the cost channel requires introducing the relative price of imports $(pi_{i,t} - pd_{i,t})$ on the Phillips Curve. Therefore, we introduced such variable, and even then the cost channel continues to be significant after 2002Q4, but becomes insignificant before this date (eq. (3), Table 1). [10]

Finally, the coefficients of the change in the NEER have the right signs and the coefficient associated with the lagged rate is statistically significant at 10%. If we replace the change in NEER by changes in Real Effective Exchange Rate or in import prices deflator, we do not obtain more significant results regarding these variables. [11]

It can be noticed that models' residuals are autocorrelated. This was expected since replacing variables' expectations by observed values induces a first order moving-average structure in the error term of the estimated model (Pesaran, 1987). To tackle this problem we use standard errors robust to heteroskedasticity and autocorrelation.

When real ULC is used in place of output gap, results remain identical, with real ULC not having also a statistically significant effect on inflation. It should be mentioned that the statistical insignificance of output gap or real ULC in the NKPC is not unusual in the literature. In Bjornstad and Nymoen (2008), which uses panel data, the real ULC has a negative sign and is not statistically significant. In a time series context, Bardsen et al. (2004) show that the significance of wage share in Gali et al. (2001) for the euro area is not

[9] The p-value of the null hypothesis of "no interest rate effect on inflation between 1998Q1-2002Q4" is 0.0346. So, at a 1% level of significance we do not reject the null hypothesis. This occurs, probably, because before 2003Q1 interest rate data are not fully harmonised across countries.

[10] Before 2003Q1 the interest rate is significant only at a 10% level. The p-value of the null hypothesis of "no interest rate effect on inflation between 1998Q1-2002Q4" is 0.0776.

[11] These results are available upon request from the authors.

Table 1: GMM estimation of the NKPC for a panel of 12 euro area countries.

| | Eq. (1) | Eq. (2) | Eq. (3) |
|---|---|---|---|
| $c$ | -0.00088 | -0.010 | -0.00033 |
| | (0.00057) | (0.023) | (0.00063) |
| $\pi_{i,t+1}$ | 0.83*** | 0.89*** | 0.68*** |
| | (0.014) | (0.098) | (0.111) |
| $\pi_{i,t-1}$ | 0.13* | 0.092 | 0.14** |
| | (0.073) | (0.070) | (0.068) |
| $x_{i,t}$ | 0.013 | - | 0.011 |
| | (0.014) | | (0.015) |
| $s_{i,t}$ | - | 0.0020 | - |
| | | 0.0050 | |
| $\Delta e_{i,t+1}$ | 0.057 | 0.044 | 0.059 |
| | (0.058) | (0.057) | (0.060) |
| $\Delta e_{i,t}$ | -0.045 | -0.017 | -0.057 |
| | (0.007) | (0.066) | (0.075) |
| $\Delta e_{i,t-1}$ | 0.051*** | 0.049*** | 0.049** |
| | (0.018) | (0.018) | (0.017) |
| $i_{i,t}$ | 0.00026** | 0.00022** | 0.00030** |
| | (0.00010) | (0.00010) | (0.00012) |
| $i_{i,t} \cdot D_t$ | -0.00014** | -0.00011* | -0.00020** |
| | (0.000065) | (0.000064) | (0.000088) |
| $pi_{i,t} - pd_{i,t}$ | - | - | 0.0084** |
| | | | (0.0034) |
| F-stat 1st stage reg.: | | | |
| $\pi_{i,t+1}$ | 11.72 | 11.53 | 12.37 |
| $\Delta e_{i,t+1}$ | 18.33 | 16.63 | 18.46 |
| J-statistic | 2.48 | 3.45 | 3.78 |
| | [0.28] | [0.32] | [0.15] |
| Q (2) stat. | 80.729 | 78.112 | 82.857 |
| | [0.00] | [0.00] | [0.00] |

Note: Panel GMM with period SUR weights and robust standard deviations. Instruments: Eq. (1): constant, $\pi_{i,t-1}$, $\pi_{i,t-2}$, $x_{i,t-1}$, $\Delta e_{i,t-1}$, $\Delta pi_{i,t-1}$, $q_{i,t-1}$, $i_{i,t-1}$, $pl_{i,t-1}$, $p_{i,t-2}$ and one dummy, $D_t$, that takes the value one for the period 1999Q1-2002Q4. Eq. (2): the same as eq. (1) plus $s_{i,t-1}$.Eq. (3): the same as eq. (1) plus $pi_{i,t-1} - pd_{i,t-1}$.

(...) contain standard errors robust to arbitrary serial correlation and time-varying variances of the errors.

[...] contain p-values. "***" means significance at 1%, "**" at 5%, and "*" at 10%.

$Q(2)$ is the Ljung-Box statistics to test zero autocorrelation in the residuals up to lag 2.

Table 2: Determinants of inflation differentials for a panel of 12 euro area countries. GMM estimation

| | Eq. (1) | Eq. (2) | Eq. (3) | Eq. (4) |
|---|---|---|---|---|
| $c$ | 0.00010<br>(0.00058) | 0.0068<br>(0.023) | 0.000090<br>(0.00050) | 0.000084<br>(0.00050) |
| $\pi_{i,t+1}$ | 0.96***<br>(0.13) | 0.96***<br>(0.10) | 0.86***<br>(0.13) | 0.86***<br>(0.13) |
| $\pi_{i,t-1}$ | -0.00062<br>(0.072) | -0.00030<br>(0.065) | 0.029<br>(0.073) | 0.030<br>(0.075) |
| $x_{i,t}$ | 0.0027<br>(0.037) | - | - | - |
| $s_{i,t}$ | - | -0.0014<br>(0.28) | - | - |
| $\Delta ulc_{i,t}$ | - | - | 0.082***<br>(0.031) | 0.080***<br>(0.030) |
| $\Delta e_{i,t+1}$ | 0.29<br>(0.20) | 0.26<br>(0.16) | 0.36**<br>(0.16) | 0.36**<br>(0.16) |
| $\Delta e_{i,t}$ | -0.33<br>(0.43) | -0.27<br>(0.27) | -0.43<br>(0.27) | -0.46*<br>(0.25) |
| $\Delta e_{i,t-1}$ | -0.015<br>(0.057) | -0.020<br>(0.053) | -0.016<br>(0.056) | - |
| $i_{i,t}$ | 0.000080<br>(0.000103) | 0.000066<br>(0.000061) | 0.00010<br>(0.000066) | 0.000099<br>(0.000067) |
| $pl_{i,t-1}$ | 0.00014<br>(0.0018) | -0.000084<br>(0.0014) | -0.00012<br>(0.0014) | 0.000025<br>(0.0014) |
| Time dummies | Yes | Yes | Yes | Yes |
| F-stat 1st stage reg.: | | | | |
| $\pi_{i,t+1}$ | 18.47 | 18.39 | 18.07 | 18.07 |
| $\Delta e_{i,t+1}$ | 114.20 | 111.96 | 111.60 | 111.60 |
| J-statistic | 2.87<br>[0.23] | 2.86<br>[0.41] | 2.91<br>[0.40] | 2.9<br>[0.57] |
| Q (2) stat. | 107.87<br>[0.00] | 111.13<br>[0.00] | 103.95<br>[0.00] | 104.33<br>[0.00] |

Notes: See notes to Table 1. Instruments: eq. (1): constant, $\pi_{i,t-2}$, $x_{i,t-1}$, $\Delta e_{i,t-1}$, $\Delta pi_{i,t-1}$, $q_{i,t-1}$, $i_{i,t-1}$, $pl_{i,t-1}$, $p_{i,t-2}$, $p_{i,t-3}$, $difp_{i,t-1}$ and time dummies . Eq. (2): the same as eq. (1) plus $s_{i,t-1}$. Eq. (3) and (4): the same as eq. (1) plus $\Delta ulc_{i,t-1}$.

robust enough to withstand small changes in the estimation methodology.

The fact that we are able to reproduce the basic characteristics of the Phillips curve found in estimations for individual countries constitutes evidence in favour of the poolability of the data.

Turning now to inflation differentials, results obtained from estimating equation (2) show that expected inflation is statistically significant and its coefficient is larger than in the equation for national inflation rates (Table 2, eq. (1)). In contrast, lagged inflation is not significant. Even though, exchange rate's coefficients are not statistically significant, coefficients of the exchange rate in $t$ and $t+1$ have the right signs. But the coefficient of the lagged change in exchange rate is wrongly signed, confirming that past dynamics do not seem to explain differences in inflation. In turn, output gap has a positive effect but it is not statistically significant. [12]

Finally, nominal national interest rate and the lagged price level are not statistically significant, with the latter variable having the wrong sign. Also, in Hofmann and Remsperger (2005), proxies of price level convergence are not significant in explaining national inflation rates. Likewise, in Rogers (2002), the lagged price level becomes insignificant in explaining inflation differences when the Arelano-Bond GMM estimator was used. The fact that such a variable is also not significant in our estimates probably means that in the euro area the level of price convergence was already high enough during the sample period. Indeed, Rogers (2007) shows that much of the price level convergence in Europe took place close to the completion of the Single Market in January 1993.

From the above results, we can conclude that lagged inflation rate and nominal interest rate play a role in explaining national inflation rates, but not in explaining inflation's differences across countries.

Notice that expectations play a central role in our results. If they are ignored, we obtain results similar to Honohan and Lane (2003), with output gap, the *level* of the real exchange rate and the lagged price level having a statistically significant impact on inflation differentials (see Table 3). The presence of the real exchange rate's level can be interpreted as national inflation rates acting to correct disequilibrium in that variable. Other possible interpretation is that with imported inputs in production, real exchange rate's level directly affects marginal cost (Kara and Nelson, 2003).

Returning to the regressions with expectations included, one intriguing result is the statistical insignificance of output gap. It can then be asked if by using an alternative measure of business cycle, more significant results can be obtained. Therefore, in place of output gap, we used real ULC, but this variable was also statistically insignificant (Table 2, eq. (2)).

In the context of business cycle effect on inflation, there is some preliminary empirical evidence showing that wage growth is associated with different inflation dynamics in the euro area (ECB, 2003). Also, Lown and Rich (1997) are able to effectively track inflation in the

[12] We also made an estimation (not shown) with the relative price of imports, $pi_{i,t} - pd_{i,t}$, which had a positive but insignificant coefficient.

Table 3: Determinants of inflation differentials ignoring expectations. GMM estimations for a panel of 12 euro area countries.

| | $c$ | $x_{i,t}$ | $e_{i,t}$ | $pl_{i,t-1}$ |
|---|---|---|---|---|
| Coeff. | 0.54*** | 0.11*** | -0.117*** | -0.031*** |
| s.e. | (0.18) | (0.04) | (0.039) | (0.0082) |
| Time dummies: | Yes | | | |
| J-statistic: | 2.59 [0.62] | Q (2) stat.: | 291.12 [0.00] | |

Notes: See notes to Table 1. Instruments: constant, $\pi_{i,t-1}$, $x_{i,t-1}$, $e_{i,t-1}$, $i_{i,t-1}$, $p_{i,t-2}$, $p_{i,t-3}$, $difp_{i,t-1}$ and time dummies.

1990's using a traditional Phillips curve augmented with nominal ULC growth. Following this suggestion, it was used nominal ULC growth instead of output gap or real ULC, and a positive and statistically significant coefficient was obtained for that variable (Table 1, eq. (3)). Other variables's coefficients have remained roughly the same as when output gap was used to explain inflation differences. We can then conclude that cyclical position affects inflation differentials if it affects the growth of nominal ULC.

In the last estimation, once more the lagged change in NEER has the wrong sign. If we remove it, the one period expected and current NEER become significant (Table 1, eq. (4)). As in Honohan and Lane (2003), a depreciation of the euro in $t$ tends to increase inflation differentials. This can be interpreted in the light of the fact that countries that have more imports from outside the euro area suffer higher imported inflation when exchange rate depreciates. Different velocities of exchange rate pass-through can also explain why movements in the euro have a temporary impact on inflation differentials (Honohan and Lane, 2003). However, exchange rate effect on inflation differentials will tend to decrease with time (Honohan and Lane, 2003). On one hand, the intra-eurozone trade will increase with the deepening of economic integration between member countries. On the other hand, as the importance of the euro increases in the world exchange rate market, more euro area imports will be priced in euros, thus weakening the direct impact of exchange rate fluctuations on consumer prices.

## 4 Inflation differentials, imperfect competition model and the NKPC

Given the empirical relevance of nominal ULC, let us look at the imperfect competition model (ICM) of inflation, which defines a role for nominal ULC. Here, we add the cost channel to the ICM presented by Bjornstad and Nymoen (2008). This model assumes that the price of domestically produced goods, $pd_t$, is set as a mark-up over nominal ULC and the nominal interest rate, and the mark-up depends on the relative price of domestic goods in terms of foreign goods, $pi_t$, (all variables are in logs):

$$pd_t = m_0 + m_1 (pi_t - pd_t) + i_t + ulc_t \tag{5}$$

, where $i_t$ is the *gross* nominal interest rate and $m_0$ is the steady-state mark-up. In equilibrium, there is a relationship between domestic prices on one hand, and ULC, nominal interest rate and import prices on the other hand. Nominal interest rate affects domestic prices because firms have to pay salaries in advance, *i.e.*, due to the cost channel.

With a constant share of imports in consumption, $1 - \gamma$, the CPI is by definition:

$$p_t \equiv \gamma pd_t + (1 - \gamma) pi_t. \tag{6}$$

If we solve (6) for $pd_t$ and replace the expression obtained in (5), we get after some manipulations:

$$p_t = \mu_0 + \mu_1(i_t + ulc_t) + (1 - \mu_1)pi_t,$$

with $\mu_0 = m_0\mu_1$ and $\mu_1 = \gamma/(1 + m_1)$. Since prices often are not in equilibrium, the model should be expressed in an equilibrium correction form, where:

$$\begin{aligned} \pi_t \quad = \quad & \mu_0\beta_1 + \alpha^f E\pi_{t+1} + \alpha^b \pi_{t-1} + \beta_1 (ulc_{t-1} + i_{t-1} - p_{t-1}) \\ & + \beta_2 (ulc_{t-1} + i_{t-1} - pi_{t-1}) + \beta_3 \Delta ulc_t + \beta_4 \Delta pi_t + \beta_5 \Delta i_t \end{aligned} \tag{7}$$

with all coefficients $\alpha$ and $\beta$ positive, except $\beta_2$ that is negative. [13] When the last period

[13] We do not test for cointegration regarding the two error correction terms due to the small time dimension

ULC plus nominal interest rate is higher than consumer price index, $ulc_{t-1} + i_{t-1} > p_{t-1}$, the disequilibrium is corrected with an increase in inflation in the *current* period. This occurs because ULC and nominal interest rate are excessively high compared with prices charged by firms. In turn, if in $t-1$ the ULC plus nominal interest rate is larger than imports price, $ulc_{t-1} + i_{t-1} > pi_{t-1}$, then in $t$ inflation decreases. [14] In the last equation, it was assumed that the dynamic part of the NKPC is valid: $\alpha^f$ and $\alpha^b$ are different from zero.

The open economy NKPC can be expressed in an error correction model of the price level, similar to (7). The initial equation is:

$$\pi_t = a^f E\pi_{t+1} + a^b \pi_{t-1} + b\widehat{mc}_t + cz_t, \tag{8}$$

where $\widehat{mc}_t = (s_t + i_t - \log(\alpha_n) - mc^{ss})$, $z_t$ is a vector containing open economy variables, as for example the change in real price of imports, $\Delta\left(pi_t - p_t\right)$; and $s_t$ is the wage share, defined as

$$s_t = ulc_t - pd_t. \tag{9}$$

Using (6), (8) and (9), after some manipulations, we obtain:

$$\begin{aligned}\pi_t &= \alpha + \frac{a^f}{1+\frac{b}{\gamma}} E\pi_{t+1} + \frac{a^b}{1+\frac{b}{\gamma}} \pi_{t-1} - \beta\left(p_{t-1} - \gamma ulc_{t-1} - (1-\gamma)\, pi_{t-1}\right) \\ &\quad + \beta\gamma\Delta ulc_t + \beta\left(1-\gamma\right)\Delta pi_t + \beta\gamma\Delta i_t + \psi z_t\end{aligned}$$

with $\alpha = -b\left(\log(\alpha_n) + mc^{ss}\right)$, $\beta = b/(\gamma + b)$ and $\psi = (c\gamma)/(\gamma + b)$. The last equation can be expressed as

$$\begin{aligned}\pi_t &= \alpha + \omega^f E\pi_{t+1} + \omega^b \pi_{t-1} + \beta_1\left(ulc_{t-1} + i_{t-1} - p_{t-1}\right) \\ &\quad + \beta_2\left(ulc_{t-1} + i_{t-1} - pi_{t-1}\right) \\ &\quad + \beta_3\Delta ulc_t + \beta_4\left(1-\gamma\right)\Delta pi_t + \beta_5\Delta i_t + \psi z_t.\end{aligned}$$

with $\omega^f = \frac{a^f}{1+\frac{b}{\gamma}}$ and $\omega^b = \frac{a^b}{1+\frac{b}{\gamma}}$, $\beta_1 = \beta$, $\beta_2 = -\beta\left(1-\gamma\right)$, $\beta_3 = \beta\gamma$, $\beta_4 = \beta\left(1-\gamma\right)$, and $\beta_5 = \beta\gamma$. This equation imposes three restrictions on the ICM: $H_0^a : \beta_1 + \beta_2 = \beta_3$, $H_0^b : \beta_4 =$

of the sample.

[14] Intuitively, in this situation imports price is low and the markup decreases, leading to a decrease in inflation.

Table 4: GMM estimation of the ICM for inflation differentials of 12 euro area countries, 1999Q1-2008Q4.

| | $c$ | $ulc_{i,t-1}+i_{i,t-1}-p_{i,t-1}$ | $ulc_{i,t-1}+i_{i,t-1}-pi_{i,t-1}$ | $\pi_{i,t+1}$ | $\pi_{i,t-1}$ |
|---|---|---|---|---|---|
| Coeff. | -0.00027 | 0.0084** | -0.0079** | 0.71*** | 0.063 |
| s.e. | (0.0013) | (0.0040) | (0.0040) | (0.13) | (0.070) |
| | $\Delta ulc_{i,t}$ | $\Delta pi_{i,t}$ | $\Delta i_{i,t}$ | $pl_{i,t-1}$ | Time dummies |
| Coeff. | 0.063** | 0.071* | 0.00095 | -0.00060 | Yes |
| s.e. | (0.025) | (0.041) | (0.00107) | (0.00064) | |
| F-stat 1st stage reg.: | 17.24 | J-stat. : | 6.63 | Q (2) stat.: | 108.11 |
| | | | [0.24] | | [0.00] |

Notes: See notes to Table 1. Instruments: constant, $\pi_{i,t-2}$, $x_{i,t-1}$, $q_{i,t-1}$, $i_{i,t-1}$, $\Delta i_{i,t-1}$, $p_{i,t-2}$, $p_{i,t-3}$, $difp_{i,t-1}$, $\Delta pi_{i,t-1}$, $ulc_{i,t-1}+i_{i,t-1}-p_{i,t-1}$, $ulc_{i,t-1}+i_{i,t-1}-pi_{i,t-1}$, $\Delta ulc_{i,t-1}$, $pl_{i,t-1}$ and time dummies.

$-\beta_2$, and $H_0^c : \beta_5 = \beta_3$. If $z_t$ includes the change in imports price, then $H_0^b$ is no longer an imposition arising from the NKPC. The significance of expected inflation is also fundamental for the validity of the NKPC.

In relation to national inflation rates, Bjornstad and Nymoen (2008) show with an annual panel of 20 OECD countries, from 1960 to 2004, that: (1) the NKPC is encompassed by the ICM model ($H_0^a$ is rejected), and (2) the expected rate of inflation serves as a replacement for the ICM specific equilibrium correction terms. In other words, when equilibrium terms are included, expected inflation's coefficient is not significant. This means that the omission of equilibrium correction terms creates an upwards bias in the estimate of $\alpha^f$, explaining why the lead coefficient of inflation is significant in many estimates of the Phillips curve. Also, for the UK, Bardsen, Jansen and Nymoen (2004) show that the introduction of two equilibrium correction terms, deviations from a long-run wage curve and an open economy price mark-up, makes forward inflation insignificant.

Based on the previous discussion, ICM is an alternative to the NKPC to explain inflation differentials. Therefore, in order to explain inflation differentials, we augmented the ICM in equation (7) with the lagged country's price level and estimated it using the same panel of countries as before. The null hypothesis $H_0^a$ is rejected, [15] meaning that the ICM model is not encompassed by the NKPC. In other words, it is better to use the ICM model than the NKPC, because the former is an unrestricted version of the latter. We can also see that the error correction variables are significant.

In addition, previous results obtained in this paper are confirmed: the relevance of expected inflation, the change in the nominal ULC, and imports price. We observe that, even though the coefficient of expected inflation decreases with the introduction of the error correction variables, it continues to be statistically significant. This confirms the importance of forward inflation in explaining differences in inflation dynamics. This result to a certain extent contradict Bjornstad and Nymoen (2008). Other point worth highlighting is that, even though the change in nominal interest rate does not has a significant effect on inflation differentials, its level is present on the equilibrium marginal cost, which has a significant impact on inflation.

The identified relevance of the nominal ULC for inflation differentials may create destabilising macroeconomic effects. Indeed, inflation differentials may lead to differences in wage growths that will have a further effect on inflation differentials. This feedback effect may not have a significant impact because, as suggested by Hofmann and Remsperger (2005), in the euro area there are mechanisms acting to correct inflation differentials.

## 5 Conclusion

This paper's major concern was to identify the determinants of inflation differences in the euro area. Firstly, for a panel of twelve euro area countries, the estimation of the NKPC with quarterly data for the period 1998Q1-2008Q4 produces results similar to other studies with time-series and panel data. Inflation has both forward- and backward-looking components, with the former being more important. Exchange rates also play a role in price changes, with lagged exchange rate having a statistically significant impact. While the cost channel is present, output gap or real ULC have a positive effect on inflation that however is not significant.

[15] P-value of 0.0063.

Regarding inflation differentials, we observe that expected inflation rate and exchange rate movements are important determinants of differences in inflation rates. In opposition, past dynamics of inflation and exchange rate do not play a very relevant role. The usual measures of business cycle, output gap and the real ULC, are not significant in causing differences in inflation dynamics. Similarly, the cost channel and price convergence are statistically irrelevant for inflation differentials. Finally, our results, indicate that there is not a direct correspondence between determinants of national inflation rates and determinants of inflation differentials.

It is worth mentioning that expected inflation plays a fundamental role in the results. When that variable was introduced, lagged price level and output gap lost their statistical significance. It seems then that these variables were significant only because they forecast inflation.

Furthermore, the growth of nominal ULC plays a significant role in explaining inflation differentials. This means that business cycle affects inflation differentials when it causes differences in wages evolution across countries. Inflation rates differences are also affected by the lagged disequilibrium in the long-run relationship proposed by the ICM, which involves domestic prices on the one hand, and the ULC, nominal interest rate and imports price, on the other hand. Furthermore, the introduction of the error correction terms proposed by the ICM reduce the coefficient of expected inflation but did not eliminate its statistical significance. Also, the ICM model is not encompassed by the NKPC when explaining inflation differences.

In terms of economic policy, our results show that expectations' management and the control of labour costs are fundamental to ensure a sucessfull inflation convergence process. The ECB should also take into account the impact of euro's evolution on inflation differentials. Given the relevance of labour costs, further work should be performed to assess the empirical relevance of a diverging inflationary cycle arising from the interaction between labour costs and inflation.

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# 7 Data Description

Data used is described below.

Quarterly inflation ($\log(p_{i,t}) - \log(p_{i,t-1})$) was measured using the seasonally adjusted harmonised CPI from Eurostat ($p_{i,t-1}$).

Difference of CPI indexes ($difp_{i,t}$): $log(p_{i,t}) - \log(p_{euro12,t})$. Harmonized CPI for euro area 12 ($p_{euro12,t}$) was obtained from Eurostat. Both indexes are seasonally adjusted and have value 100 in 2005.

The price level ($pl_{i,t}$), like in Honohan and Lane (2003), corresponds to the price level index of household final consumption expenditure from Eurostat. It was obtained as the purchasing power parity of consumption over current nominal exchange rate, with initial 12 members of euro area as a reference. The quarterly data was obtained interpolating the original annual data with local quadratic polynomial.

Real GDP seasonally adjusted was obtained from OECD Quarterly National Accounts and from International Financial Statistics of IMF (IFS/IMF) for Ireland, Luxembourg and

Portugal. The output gap ($x_{i,t}$) for each country was calculated as the difference between the log of output and the log of output's trend, with series starting in 1979Q1 or 1980Q1. To calculate the output's trend, we used the HP filter with lambda fixed at 1600.

Real ULC ($s_{i,t}$), or wage share, was obtained dividing the nominal ULC (2005=100) by the GDP deflator (2005=100).

Nominal unit labour costs ($ulc_t$) refer to the trend-cycle series for the entire economy obtained from Main Economic Indicators/OECD. Since for Portugal ULC for the entire economy were not available, we used ULC for the business sector.

GDP deflator ($pd_t$) seasonally adjusted was obtained from OECD National Accounts, except for Portugal, Ireland and Luxembourg, where data from IFS/IMF was used.

Nominal effective exchange rate ($e_{i,t}$) was obtained from IFS/IMF, base year 2005. This measure uses weights from the trade of manufactured goods. An increase in $e_{i,t}$ corresponds to an appreciation of the euro.

Real effective exchange rate ($q_{i,t}$) is based on relative Consumer Prices, 2005=100, and is from IFS/IMF.

Imports price ($pi_{i,t}$) seasonally adjusted are measured by imports price deflator from Quarterly National Accounts OECD (Imports of goods and services, 2005=100).

Retail interest rate ($i_t$): loans to corporations up to one year from Eurostat. Before 2003Q1, data is not harmonized. To accommodate this fact, we used a dummy for the period 1998Q1-2002Q4. Notice that before 2003Q1 there was no data available for Luxembourg, and for Finland before 2003Q1 we used the interest rate of loans to firms above one year.